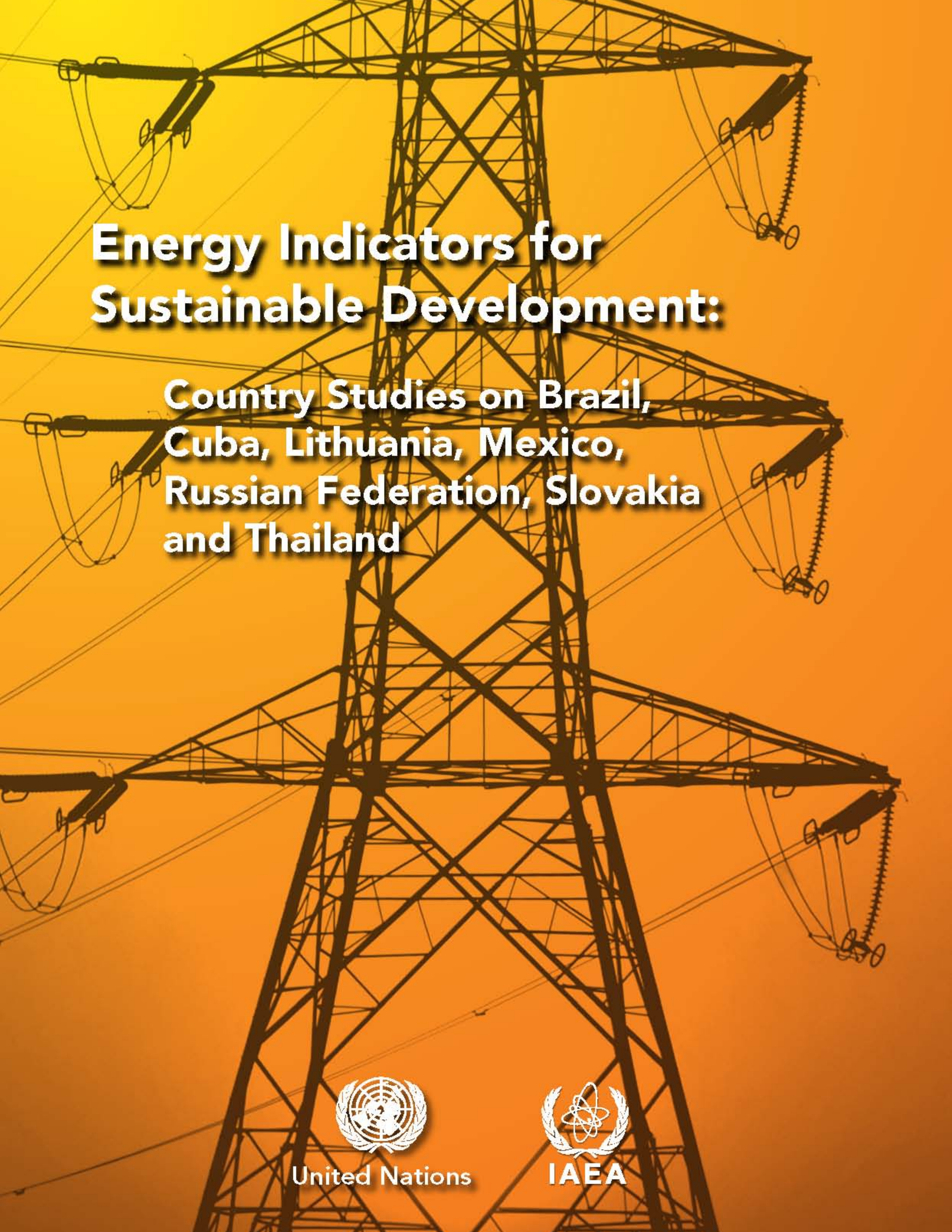

Energy Indicators for Sustainable Development:

Country Studies on Brazil, Cuba, Lithuania, Mexico, Russian Federation, Slovakia and Thailand

United Nations

IAEA

ENERGY INDICATORS FOR SUSTAINABLE DEVELOPMENT:

Country Studies on Brazil, Cuba, Lithuania
Mexico, Russian Federation, Slovakia and Thailand

INTERNATIONAL ATOMIC ENERGY AGENCY

UNITED NATIONS
DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS

FOREWORD

This publication presents seven national case studies from a coordinated research project on Indicators for Sustainable Energy Development conducted during the 2002-2005 time period. The project was led by the International Atomic Energy Agency (IAEA) in cooperation with the United Nations Department of Economic and Social Affairs (UNDESA). The case studies were developed by research organizations from Brazil, Cuba, Lithuania, Mexico, Russia, Slovakia and Thailand.

This publication is being issued just prior to the 15th session of the United Nations Commission on Sustainable Development for which energy for sustainable development is a major theme. The 15th session of the Commission will focus on policy decisions on practical measures and options to expedite implementation in selected clusters of energy issues. The application the energy indicator, especially their quantification, enables systematic monitoring of progress made towards the implementation of energy-related targets. This publication presents actual examples of how these indicators are developed at the national level, how they can be used to assess national energy systems and how they assist in reviewing the effectiveness of policies undertaken or planned.

Energy continues to pose a fundamental dilemma for achieving sustainable development goals - its use is necessary prerequisite for economic growth and social development while energy production and use are associated with adverse impacts on public health and the environment. Win-win situations specific to energy production and use do exist and national governments and institutions, and regional and international bodies have identified and promoted policies, initiatives and measures that encourage energy efficiency, alternative fuels, advanced and cleaner technologies that in one way or another result in foster economic activity with less energy per unit of output, increased access to affordable energy services and reduced environmental pollution Successes (and failures) have been measured in part by the use of energy indicators.

Energy indicators for sustainable development represent an important component in the national analysis and planning tool kit for achieving sustainable development. The indicators are intended to provide a flexible tool for analysts and decision makers at the national level to better understand their national situations and trends, the impacts of recent policies and the potential impacts of policy changes. The flexibility of this system of energy indicators permits specific adaptations to the national and local conditions and needs. As such, it is a versatile and powerful tool that can greatly assist countries by highlighting problems and constraints that may exist at the national level and by pointing to possible solutions as illustrated by the national case studies herein.

NOTE

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1. INTRODUCTION

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Energy poses a formidable challenge to those working to achieve sustainable development goals. We need to use energy to alleviate poverty, promote economic growth and foster social development. But as we consume more energy, stress is placed on the environment at the local, regional and transboundary levels. As we work together to safeguard the environment without slowing socio-economic development, we look for technological solutions, we look to change unsustainable patterns of consumption and production, and we seek the low-hanging fruit and the win-win solutions that provide the least costly ways of achieving sustainable development goals. Analytical tools, such as the energy indicators described in these case studies, can be helpful in finding the best solutions in a menu of available options, aimed at achieving these goals.

When the international community first made the commitment to sustainable development in 1992, at the Rio Conference on Environment and Development, there was an emphasis on environmental concerns. Though environmental concerns are still important, greater stress is now placed on the development side of the sustainable development equation. This is clearly reflected in the outcome of the World Summit on Sustainable Development (WSSD), held in Johannesburg in 2002.

Also, energy as an issue has received greater attention since the Rio Conference. At the ninth session of the United Nations Commission on Sustainable Development (CSD) held in 2001, key energy issues that contribute to achieving sustainable development goals were agreed upon. Since then, actions at the national level, as well as activities at regional and international levels, have been in line with these decisions. At WSSD the following year, further elaboration was made. The decisions embodied in the Johannesburg Plan of Implementation (JPOI) reflect a concern about entrenched poverty and the urgent need to achieve the Millennium Development Goals (MDGs) on poverty, as well as devote more emphasis to energy efficiency, renewable energy, advanced and cleaner technologies, and an enabling environment marked by a level playing field without market distortions. For the first time, the international community acknowledged that access to modern energy services for all is necessary for the alleviation of poverty. Reference to energy in the context of sustainable development was also made in the recently held United Nations 2005 Summit.[1] Follow-up on energy for sustainable development at the international level took place during the 14th session of the United Nations Commission on Sustainable Development held in 2006 and will continue during the 15th session of the Commission in 2007.

Amid this flurry of activity at the international level, individual countries are still faced with, and often grappling with, difficult decisions and trade-offs with regard to energy as they strive to achieve sustainable development. Current estimates indicate that 1.6 billion people are without access to electricity and that 2.4 billion people have no access to modern fuels. This means that approximately one third of the world's population live in the dark, eat uncooked or semi-cooked food and/or are exposed to hazardous indoor air pollution on a daily basis. Expanding energy access to this group of people is essential for alleviating poverty and, in fact, for achieving all of the MDGs. Improving energy access for the alleviation of poverty also means promoting small- and medium-scaled businesses, industrial development and better transportation networks in a general effort to improve socio-economic well-being. All of this will require greater energy use. To achieve these goals with minimal adverse effects on the environment is a basic goal of sustainable development.

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[1] The High-level Plenary Meeting of the 60th session of the General Assembly. United Nations, New York, 14-16 September 2005.

While there are no absolute answers and solutions vary by region, by country and even by locality, a common thread in reaching solutions is being able to ask and answer the right questions. The system of energy indicators and their implementation, discussed in the national case studies that follow, constitute a major step in this direction.[2]

These energy indicators were formulated in line with sustainable development goals and were designed to complement the indicators on sustainable development developed by the United Nations Commission on Sustainable Development. Work on developing indicators on sustainable development was undertaken in response to a call in Agenda 21 for harmonizing efforts, and the set has been tested, reviewed at the Commission's ninth session, and is currently being updated and modified based on national level feedback received.[3] While the indicators on sustainable development include some energy-specific indicators, the need for a more systematic approach for energy was noted by energy experts as this work progressed. There are other credible and viable indicator systems that focus on energy,[4] but those identified, discussed and applied in these case studies, are notable for their flexibility of use and their specific orientation towards sustainability dimensions, identified as economic, social and environmental. Countries can adapt these indicators to suit national energy characteristics and needs. In other words, the indicators are designed to fit real-life situations, rather than modifying or assuming away information that does not fit the model, as often occurs when applying statistical models and tools.

The effort that culminated in the development and refinement of these indicators was initiated by the International Atomic Energy Agency (IAEA) in cooperation with the International Energy Agency (IEA), the European Environmental Agency (EEA), EUROSTAT and the United Nations Department of Economic and Social Affairs (DESA). The indicators are identified and elaborated in the chapter entitled, Indicators for Sustainable Energy Development written by I.A. Vera, L.M. Langlois and H.H. Rogner. This chapter provides background on the rationale and need for energy indicators, and the ways and means of testing the indicators and encouraging their use. The chapter elaborates on the indicators themselves and illustrates their individual relevance to the economic, social and environmental dimensions of sustainable development; it also identifies their interrelationships and their credibility as a set or system for analyzing energy within the framework of sustainable development. Various activities undertaken by the IAEA as the indicators were developed, refined and tested with other international and regional agencies as well as experts in developing countries, are highlighted. This chapter provides an interesting and very useful introduction to the national case studies that follow.

The applications of the energy indicators in developing countries and countries with economies in transition are highlighted in the national case studies of Brazil, Cuba, Lithuania, Mexico, Russia, Slovakia and Thailand. Experts from these countries participated in the testing of the energy indicators, as part of the IAEA project. Thus, the case studies contained in this publication represent initial applications of the indicators, and are considered first steps in a hopefully more comprehensive and long-term utilization of the tool. Nevertheless, these cases highlight the flexibility and versatility of the indicators. They are used to assess energy situations and trends in countries with markedly different energy resources, dissimilar energy needs and wide variations in their economic systems and stages of development. Each application provides not only an example of the way in which the indicators can be used to support sustainable development measures and policies, but also an identification, and in some cases an analysis, of priorities and goals with regard to energy within the context of the broader sustainable development framework.

Brazil's energy mix is dominated by non-carbon emitting energy sources, notably hydroelectricity, used in the household and industrial sectors, and ethanol (from sugarcane), used in the transport sector. The Brazil case study written by R. Schaeffer, A. Salem Szklo, F. Monteiro Cima and G. Machado identifies a number of energy policy options on both demand and supply sides. On the demand side,

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[2] These indicators were recently updated and renamed as 'energy indicators for sustainable development.' See IAEA *et al*. (2005).

[3] For additional information, see United Nations (2001).

[4] See e.g., Schipper (1997), Howarth *et al* (1993), Schipper and Haas (1997), and Unander *et al.* (2004).

policy options for energy efficiency and end-use efficiency include reduction of energy intensity in the industrial sector, and transport efficiency; the chapter also discusses the potential impact of a fund to improve energy affordability for the poor. Supply side policy options for Brazil include: small-scale hydroelectric; wind power; solar photovoltaic; ethanol (as automotive fuel); sugarcane bagasse cogeneration; and natural gas-fired combined heat and power (CHP) plants. Moreover, the indicators highlight interlinkages among energy, economic, social and environmental data in a coherent way. The authors use time-series and cross-sectional data to support their analyses and assessments.

The recent history of Cuba, the largest Small Island Developing State, provides a rather unique case. After the dissolution in 1989 of Cuba's traditional trade agreements with the former Soviet Union, the country's favourable terms for importing crude oil and petroleum products ended. The adjustments that Cuba had to make in its energy policies are detailed in the chapter on Cuba written by D. Pérez, I. López and I. Berdellans. The authors use the indicators to evaluate the effectiveness of energy policies, including measures to reduce energy import dependence, increase the share of renewable energy resources in the total supply mix, and improve energy efficiency.

Lithuania provides an interesting illustration of a country faced with limited indigenous energy resources and an ageing nuclear power plant in an increasingly globalized economic environment. The Lithuanian case study by D. Streimikiene describes efforts at applying the ISED methodology to analyze energy trends and to set energy priorities and goals. These applications result in interesting policy recommendations for Lithuania, suggesting how to reduce energy intensity and increase end-use efficiency, as well as guaranteeing energy security and reaching a balance between affordability for the poor and end-use efficiency.

Mexico's evaluation of its energy priorities using the indicators is reported on by J. Medina-Ross, J. Mata-Sandoval and R. Lopez-Perez. In terms of the economy, energy represents an important contribution to Mexico's overall gross domestic product (GDP). The authors use the indicators to assess national energy priorities as articulated in Mexico's national plan of development. The article focuses especially on assessment of energy intensities, emissions levels, energy import dependency and the utilization of renewable sources. The authors also highlight the need for better data and statistical support to undertake a more extensive review.

The economy of the Russian Federation has undergone radical changes during the past decade, and its energy sector holds much promise for significant contributions to GDP. Russia's energy priorities, identified in the national energy strategy, are assessed by G. Aslanyan, S. Molodtsov and V. Iakobthcouk in the Russian chapter. Main energy priorities for Russia include: ensuring a stable supply for domestic needs and export; reducing energy intensity; increasing energy efficiency; reducing adverse environmental impacts associated with energy production and use; and ensuring energy affordability for the poor. The application of the indicators highlight the need for greater attention to environmental impacts and the needs of the poor, as well as necessary measures for the transport sector and for overcoming barriers impeding greater energy efficiency.

The Slovakian case study prepared by J. Balajka illustrates how the ISED system can be used to assess the country's energy system and to identify national energy priority areas. The trends resulting from energy policies implemented before the country's accession to the European Union in 2004 are analysed in detail. The ISED implementation results in interesting policy recommendations for Slovakia, suggesting how to improve energy pricing policies, reduce energy intensity and guarantee energy security.

The Thailand case study by J. Todoc, M. Todoc and T. Lefevre focuses on energy efficiency, affordability and accessibility, and the environmental dimensions of energy use. Data are available to analyze trends in the transport, manufacturing, commercial, household and residential sectors. The authors focus on energy use by the poor, noting that progress has been made in extending the electricity grid and encouraging more efficient cooking stoves. They also focus on the transport sector, which is the fastest growing sector in Thailand in terms of energy consumption.

While the application of the energy indicators, detailed in the national case studies contained in the following chapters, provides a snapshot view of the status of the energy sector in each country, more work is needed, in most countries, for a systematic and complete analysis. The indicators as a set have been modified and updated since these case studies were undertaken. It is hoped not only that these

preliminary tests provide useful information and lessons on each country, but also that they illustrate the usefulness of these indicators in highlighting problems, identifying barriers and pointing national policies and measures in the right direction. The 14th session of the United Nations Commission on Sustainable Development (CSD 14) provided a venue to highlight lessons learned, and we are optimistic that the international and regional work on energy indicators, as well as these national case studies, will provide valuable insights, lessons and a range of options for consideration.

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2. INDICATORS FOR SUSTAINABLE ENERGY DEVELOPMENT

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2.1. Introduction

The provision of adequate and reliable energy services at an affordable cost, in a secure and environmentally benign manner and in conformity with social and economic development needs, is an essential element of sustainable development. Energy is vital for eradicating poverty, improving human welfare and raising living standards (UNDP, *et al*. 2000). However, most current patterns of energy supply and use are considered unsustainable (UN, 2001). Many areas of the world have no reliable and secure energy supplies, and hence no energy services—which limits economic development. In other areas, environmental degradation from energy production and use inhibits sustainable development.

Adequate and affordable energy services have been critical to economic development and the transition from subsistence agricultural economies to modern industrial and service-oriented societies. Energy is central to improved social and economic well-being, and is indispensable for industrial and commercial wealth generation. But however essential it may be for development, energy is only a means to an end. The end is a sustainable economy and a clean environment, high living standards, prosperity and good health.

Key energy issues were discussed in 2001 at the ninth session of the Commission on Sustainable Development (CSD-9). In 2002, at the World Summit on Sustainable Development (WSSD) held in Johannesburg, South Africa (UN, 2002), the international community reaffirmed that access to energy is important to the Millennium Development Goal of halving, by 2015, the proportion of people living in poverty (UN, 2000). The WSSD agreed to facilitate access for the poor to reliable and affordable energy services in the context of broader national policies to foster sustainable development. The summit also called for changes in unsustainable patterns of energy production and use.

It is therefore important for policy makers to understand the implications and impacts of different energy programmes, alternative policies, strategies and plans in shaping development within their countries, and the feasibility of making development sustainable over time. Indicators, when properly analyzed and interpreted, can be useful tools for communicating data relating to energy and sustainable development issues to policy makers and to the public, and for promoting institutional dialogue. They provide a way to structure and clarify statistical data to give better insight into the factors that affect energy, environment, economics and social well-being, and how these might be influenced and trends improved. Indicators can also be used to monitor progress of past policies, and to provide a "reality check" on strategies for future sustainable development. This cannot be done, however, without critical analysis of the underlying causal and driving factors.

In response to decisions taken by the United Nations Commission on Sustainable Development (CSD) and to Chapter 40 of Agenda 21, United Nations Department of Economic and Social Affairs (UNDESA) began working in 1995 to produce an overall set of indicators for sustainable development (ISD). This effort concluded with a package of 58 ISD, of which only three were energy related – annual energy consumption per capita, intensity of energy use, and share of consumption of renewable energy resources (UNDESA, 2001). In order to complement the effort of the Commission on Sustainable Development and to provide a higher resolution on energy, the International Atomic

Energy Agency (IAEA) started a long-term programme addressing indicators for sustainable energy development (ISED) in 1999. This was done in cooperation with various other international organisations, including the International Energy Agency (IEA), UNDESA, and some Member States of the IAEA. The project was conceived to:

- Fill the need for a consistent set of energy indicators;
- Assist countries in energy and statistical capacity building necessary to promote energy sustainability; and
- Supplement the work on general indicators being undertaken by the UN Commission on Sustainable Development (CSD).

The project was developed in two phases. In the first phase (1999–2001), an original set of 41 ISED was identified, and the conceptual framework to classify and implement these indicators was developed. Major themes and sub-themes and systematic cross-linkages among indicators were defined to establish causality. The results of the first phase were presented at CSD-9 in April 2001 (IAEA/IEA, 2001). In 2002, the ISED/IAEA project was classified as a Partnership of the WSSD, and was officially registered as such with the CSD.

The second phase started in 2002, with a three-year coordinated research project to implement the original set of ISED in seven countries. The countries were selected on the basis of proposals submitted by experts from statistical and energy research organisations interested in the evaluation of their countries' energy policies in accordance with their sustainable development objectives. The research teams worked on the evaluation of their countries' statistical capabilities and on the implementation of the particular subsets of the ISED most relevant to their energy priorities. The relevant indicators were used to analyse current energy policies and potential future energy strategies. This implementation project concluded in 2005, with participating countries summarising findings and lessons learned. The resulting national case studies are summarized in this publication in the chapters that follow.

The emphasis of the indicators discussed in this document is on national self-examination rather than international benchmarking. The interpretation depends on the state of development of each country, the nature of its economy, its geography, the availability of indigenous energy resources, etc. Critical analysis of underlying conditions is therefore essential. Nonetheless, changes in the value of each indicator over time, properly analysed, can help to quantify progress toward selected development goals within a country.

The second phase also included a parallel effort, coordinated with other international organisations and agencies involved in the development of energy indicators, for further refining the original indicator set. The final set of energy indicators resulting from this effort, which builds on the cumulative experience of these agencies, was published in 2005 in a joint interagency report on methodologies and guidelines (IAEA *et al*., 2005).

The main criterion driving the selection and refinement process of the energy indicators was their ability to address the most important energy-related issues of interest to countries worldwide. Furthermore, the indicators were selected, defined and classified to help countries assess effective energy policies for action on sustainable development. They were devised as a help to guide the implementation of various actions urged at the WSSD, and in particular to:

- Integrate energy into socio-economic programmes;
- Combine more renewable energy, energy efficiency and advanced energy technologies to meet the growing need for energy services;
- Increase the share of renewable energy options;
- Reduce the flaring and venting of gas
- Establish domestic programmes on energy efficiency;
- Improve the functioning and transparency of information in energy markets;

- Reduce market distortions; and
- Assist developing countries in their domestic efforts to provide energy services to all sectors of their populations.

The selection criteria also included considerations about data availability (in particular in developing countries), and the feasibility of collecting additional data deemed essential to the establishment of important indicators.

2.2. Phase I: Project Definition

The Original Set of Indicators for Sustainable Energy Development (ISED)

The original ISED considered the economic, social, environmental and institutional dimensions of sustainable development. During the first phase of the ISED project, the IAEA, in cooperation with UNDESA, the IEA and a number of Member States, worked on the identification of important issues within each of these main dimensions of sustainable development, with the final objective of defining a set of energy indicators applicable worldwide and commensurate with the CSD approach.

2.2.1. Economic dimension

Economic ISED measure how the use and production patterns of energy, as well as the quality of energy services, affect progress in economic development, and how the status of the energy sector and its trends in a country might improve the chances for economic development to be sustainable in the long run. All sectors of an economy—residential, industrial, commercial, transport, service and agriculture—require energy. These energy services in turn foster economic and social development at the local level by raising productivity and facilitating local income generation. Availability of energy affects jobs, productivity and development. Electricity is the dominant form of modern energy for telecommunications, information technology, manufacturing and services. Therefore, main factors of indicators in the economic dimension include energy use, production and supply; energy supply efficiency and end-use energy intensity; energy pricing, taxation and subsidies; energy security; and energy diversity. A difficulty with economic ISED lies in their interpretation, and specifically in maintaining a clear focus on income generation trends in economic growth and natural resource exploitation.

2.2.2. Social dimension

ISED in the social dimension measure the impact that available energy services may have on social well-being. Availability of energy services have implications in terms of poverty, employment opportunities, education, community development and culture, demographic transition, indoor pollution and health, as well as gender- and age-related implications. Social ISED describe issues related to accessibility, affordability and disparity in energy supply and demand. In rich countries, modern energy services (lighting, heating, cooking, etc.) are almost universally available. The energy is clean, safe, reliable and affordable. In poor countries, up to six hours a day may be required to collect wood and dung for cooking and heating, and this task is usually done by women. In areas where coal, charcoal, paraffin or kerosene are commercially available, these fuels take up a large portion of the monthly household income. Inadequate equipment and ventilation often means that the burning of these fuels inside the house takes a toll on human health, contributing to disease (and even death) through air pollution and fires. A major difficulty in the development of social ISED is the lack of relevant or adequate data (especially time-series) in developing countries.

2.2.3. Environmental dimension

The production, distribution and use of energy create pressures on the environment in the household, workplace and city, and at the national, regional and global levels. Therefore, energy indicators are useful for evaluating impacts of energy systems in all these areas. Environmental ISED measure the impact of energy systems on the overall environment, and in particular the determination of positive or

negative trends in land, water (fresh and marine), and air quality. Such environmental impacts vary depending upon how energy is produced and used, and on related energy regulatory actions and pricing structures. Gaseous emissions and particulates from the burning of fossil fuels pollute the atmosphere and cause poor local air quality and regional acidification. Large hydropower dams flood land and may cause silting of rivers. Both the fossil and nuclear fuel cycles, as well as geothermal production, emit some radiation and generate wastes of different levels of toxicity. Wind turbines can spoil a pristine countryside. And gathering firewood may lead to deforestation and desertification. Principal issues related to the environmental dimension include global climate change, air pollution, water pollution, wastes, land degradation and deforestation.

2.2.4. Institutional dimension

Institutional indicators assess the availability and adequacy of the institutional framework necessary to support an effective and efficient energy system. Institutional indicators are useful for linking and addressing the response actions and policy measures designed to influence trends in the social, economic and environmental dimensions. For example, institutional indicators might help to measure not only the existence but also the effectiveness of a national sustainable energy development strategy or plan, energy statistical capacity and analytical capabilities, and the adequacy and effectiveness of investments in capacity building, education or research and development. Institutional indicators could also help to monitor progress towards appropriate and effective legislative, regulatory and enforcement measures to foster efficient energy systems.

Indicators in this dimension are the most difficult to define for two reasons. First, they tend to address issues that are, by nature, difficult to measure in quantitative terms. Many of these issues relate to the future, and need dynamic analysis based on projections of energy production, use and investment. Second, the variables measured by institutional indicators tend to be structural or policy responses to sustainable development needs.

In practice, the four dimensions are interrelated. Figure 2.1 is a simplified illustration of the interrelationship among these various sustainability dimensions of the energy system. The environmental state associated with the energy system is affected by driving forces originating from the economic and social dimensions. The social state of the energy system is, in turn, influenced by certain driving forces originating from the economic dimension. The institutional dimension can affect all the other three dimensions—social, economic and environmental—through corrective policies that influence the sustainability of the whole energy system.

The effort to identify and categorise ISED went through several iterations. A provisional list of ISED was discussed at an international workshop in 1999 (IAEA, 1999). The list was later subject to informal testing in fifteen countries by volunteer groups of energy system analysts. The list of ISED resulting from the first phase of the project is shown in Table 2.1. The indicators in bold were considered most significant from the point of view of sustainable energy development and were viewed as the core set of ISED.

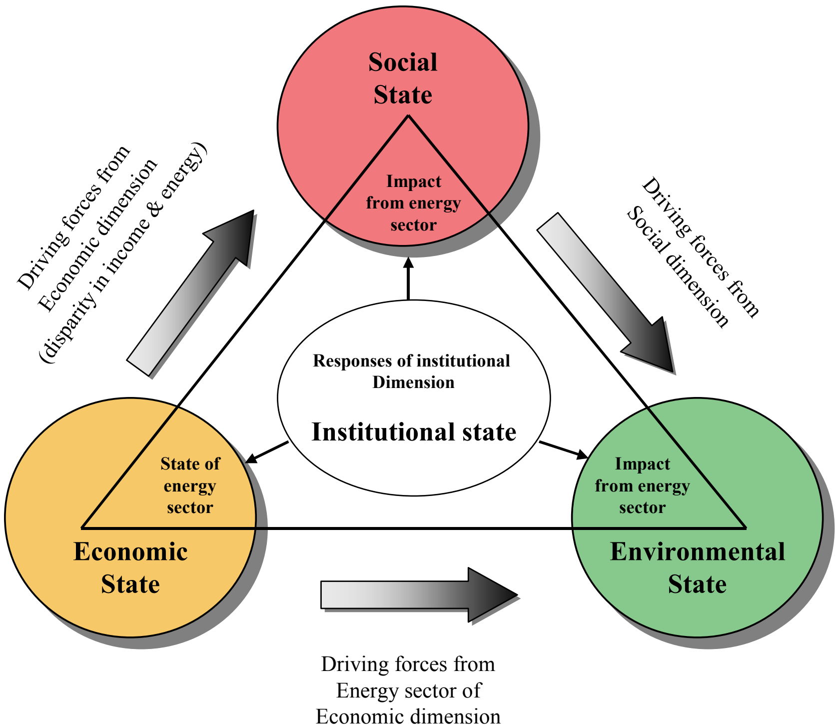

Figure 2. 1. Interrelationship among sustainability dimensions of the energy sector.
Source: IAEA/IEA (2001)
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TABLE 2.1. ORIGINAL SET OF INDICATORS FOR SUSTAINABLE ENERGY DEVELOPMENT (ISED)

1.	Population: total; urban
2.	GDP per capita
3.	**End-use energy prices with and without tax/subsidy**
4.	Shares of sectors in GDP value added
5.	Distance travelled per capita: total, by urban public transport mode
6.	Freight transport activity: total, by mode
7.	Floor area per capita
8.	Manufacturing value added by selected energy intensive industries
9.	**Energy intensity: manufacturing, transportation, agriculture, commercial & public services, residential sector**
10	Final energy intensity of selected energy intensive products
11.	**Energy mix: final energy, electricity generation, and primary energy supply**
12.	**Energy supply efficiency: fossil fuel efficiency for electricity generation**
13.	Status of deployment of pollution abatement technologies: extent of use, average performance
14.	**Energy use per unit of GDP**
15.	**Expenditure on energy sector: total investments, environmental control, hydrocarbon exploration & development, RD&D, net energy import expenses**
16.	**Energy use per capita**
17.	**Indigenous energy production**
18.	**Net energy import dependence**
19.	Income inequality
20.	**Ratio of daily disposable income/ private consumption per capita of 20% poorest population to the prices of electricity and major household fuels**
21.	**Fraction of disposal income spent on fuels (total population, 20% poorest)**
22.	**Fraction of households: heavily dependent on non-commercial energy; without electricity**
23.	**Quantities of air pollutant emissions (SO_2, NO_x, particulates, CO, VOC)**
24.	**Ambient concentration of pollutants in urban areas: SO_2, NO_x, suspended particulates, CO, ozone**
25.	Land area where acidification exceeds critical load

26.	**Quantities of greenhouse gas emissions**
27.	Radionuclides in atmospheric radioactive discharges
28.	Discharges into water basins: waste/storm water, radionuclides, oil into coastal waters
29.	**Generation of solid waste**
30.	**Accumulated quantity of solid wastes to be managed**
31.	**Generation of radioactive waste**
32.	**Quantity of accumulated radioactive wastes awaiting disposal**
33.	**Land area taken up by energy facilities and infrastructure**
34.	**Fatalities due to accidents with breakdown by fuel chains**
35.	**Fraction of technically exploitable capability of hydropower currently not in use**
36.	**Proven recoverable fossil fuel reserves**
37.	Life time of proven fossil fuel reserves
38.	Proven uranium reserves
39.	Life time of proven uranium reserves
40.	**Intensity of use of forest resources as fuelwood**
41.	Rate of deforestation

Source: IAEA/IEA, 2001.

These ISED were then categorised into a conceptual scheme for identifying cross-linkages among various indicators across all four dimensions of sustainable development (IAEA/IEA, 2001). The initial ISED framework was consonant with the driving force, state and response (DSR) framework devised by the CSD for the original ISD, even though the CSD later replaced its framework with a system of more tractable and more easily defined themes and sub-themes.

The driving force indicators were further split into two subcategories: direct and indirect driving forces. This allowed a distinction to be made between those factors having a direct influence on the state indicators and those that affect the state indicators indirectly by influencing one or more of the direct driving forces.

Table 2.2 classifies each of these 41 ISED either as an indirect or direct driving force, or a state indicator. There are fifteen indirect driving force indicators, fourteen direct driving force indicators and twelve state indicators. Again, the core ISED are shown in bold.

TABLE 2.2. ISED CLASSIFIED ACCORDING TO INDIRECT AND DIRECT DRIVING FORCES AND STATE

Indirect driving force	Direct driving force	State
1. Population: total; urban	**14. Energy use per unit of GDP**	**16. Energy use per capita**
2. GDP per capita	**15. Expenditure on energy sector: total investments, environmental control, hydrocarbon exploration & development, RD&D, net energy import expenses**	**17. Indigenous energy production**
3. End-use energy prices with and without tax/subsidy	**21. Fraction of disposal income spent on fuels (total population, 20% poorest)**	**18. Net energy import dependence**
4. Shares of sectors in GDP value added	**23. Quantities of air pollutant emissions (SO_2, NO_x, particulates, CO, VOC)**	22. Fraction of households: heavily dependent on non-commercial energy; without electricity
5. Distance traveled per capita: total, by urban public transport mode	**26. Quantities of greenhouse gas emissions**	24. Ambient concentration of pollutants in urban areas: SO_2, NO_x, suspended particulates, CO, ozone
6. Freight transport activity: total, by mode	27. Radionuclides in atmospheric radioactive discharges	25. Land area where acidification exceeds critical load
7. Floor area per capita	28. Discharges into water basins: waste/storm water, radionuclides, oil into coastal waters	**30. Accumulated quantity of solid wastes to be managed**
8.Manufacturing value added by selected energy intensive industries	**29.Generation of solid waste**	**32. Quantity of accumulated radioactive wastes awaiting**
9. Energy intensity: manufacturing, transportation, agriculture, commercial & public services, residential sector		
10. Final energy intensity of selected energy intensive products		

11. Energy mix: final energy, electricity generation, and primary energy supply **12. Energy supply efficiency: fossil fuel efficiency for electricity generation** 13. Status of deployment of pollution abatement technologies: extent of use, average performance 19. Income inequality **20. Ratio of daily disposable income/ private consumption per capita of 20% poorest population to the prices of electricity and major household fuels**	**31. Generation of radioactive waste** **33. Land area taken up by energy facilities and infrastructure** **35. Fraction of technically exploitable capability of hydropower currently not in use** **36. Proven recoverable fossil fuel reserves** 38. Proven uranium reserves **40. Intensity of use of forest resources as fuelwood**	**disposal** **34. Fatalities due to accidents with breakdown by fuel chains** 37. Life time of proven fossil fuel reserves 39. Life time of proven uranium reserves 41. Rate of deforestation

Source: IAEA/IEA, 2001.

2.3. Phase II: Project Implementation

The implementation of Phase II began in 2002, when IAEA started a three-year coordinated research project entitled descriptively as "Historical evolution of indicators of sustainable energy development and the use of this information for designing guidelines for future energy strategies in conformity with the objectives of sustainable development." The project was conducted with research organisations from Brazil, Cuba, Lithuania, Mexico, the Russian Federation, the Slovak Republic and Thailand. The main objective was to test and demonstrate the broad applicability of the original set of ISED, and to prepare country case studies summarising the experiences, lessons learned and problems encountered. Experts in each country were asked to implement the ISED in the context of their own national energy system. The ultimate goal of this activity was to explore, test and demonstrate the usefulness of the ISED for assessing specific policies and trends related to sustainable development.

Participating country teams were asked to perform the following specific tasks:

- Review the energy system in their country and summarise current status, main issues, trends, policies in place and future plans for expansion and improvement.
- Review the energy and environmental statistical capability of their country to determine its strengths and weaknesses, and the extent to which the ISED package could be incorporated.
- Select a number of energy-related priority areas or main issues for assessment with the ISED.
- Compile the necessary time series to develop the relevant ISED for assessing these specific priority areas.
- Implement the relevant ISED using time-series data to evaluate the current situation, past trends and expected future developments.
- Define additional indicators that may be unique to a particular country or required to assess priority areas.
- Assess the effectiveness of existing policies in achieving specific goals that move the country towards a more sustainable energy future.
- Formulate potential policies and strategies that could help further achieve the specified sustainable development goals with respect to energy and the environment, and assess the potential success of these response actions using the ISED framework.
- Provide a critique of the ISED, their ease of use, their applicability to current policy needs, their consonance with national statistical resources, and their utility as policy and energy system analysis tools.

Participants were asked to prepare reports addressing these tasks, and the rest of the chapters in this publication summarize the experiences, findings and lessons learned from the implementation of the ISED in the participating countries. Their findings and critiques also contributed to the further refinement of the ISED. It is therefore important to recognize that the country case studies included in later chapters were based upon the implementation of the original ISED set listed in Table 2.1, rather than the refined version discussed below.

2.4. Phase II: Refinement of Indicators

Energy Indicators for Sustainable Development (EISD)

The second phase of the IAEA energy indicators programme also included a parallel effort to further refine the original ISED set. This effort was conducted with other international organisations and agencies involved in the development of energy indicators, including UNDESA, the IEA, Eurostat and the European Environment Agency (EEA). The final set of energy indicators resulting from this effort builds upon the cumulative experience of these agencies and the inputs from the process of implementing the coordinated research project. It was published in 2005 in a joint interagency report on methodologies and guidelines (IAEA *et al*., 2005). Based on practicality, data availability and results from "learning by doing," the original set of 41 indicators was reduced to the 30 that constitute the current refined set of energy indicators. The original name "Indicators for sustainable energy development (ISED)" was then modified to "energy indicators for sustainable development (EISD)" to reflect the view held by many that "sustainable energy development" tends to refer only to renewable energy, rather than the broader spectrum of energy choices. This name change was considered necessary to avoid future misunderstandings in discussions relevant to energy and sustainable development.

A number of indicators were redefined and merged; others were classified as auxiliary indicators. Notably, indicators for the institutional dimension were dropped, having been found to be difficult to define quantitatively or to chart over time in a meaningful way. Since these indicators focus primarily on response actions, the assessment of the adequacy of these measures has been left to a qualitative discussion. Furthermore, although the original indicators followed the driving force/state/response framework, the report on methodologies and guidelines uses the main approach of themes and sub-themes currently used by the CSD.

The indicators in the EISD set are thus consistent with and supplementary to the CSD indicators as published by UNDESA in 2001 (UNDESA, 2001). Moreover, the 2005 interagency report reflects a consensus of leading experts on definitions, guidelines and methodologies. The 30 EISD are now classified according to the three major dimensions of sustainable development: social (four indicators), economic (sixteen indicators) and environmental (ten indicators). Each group is divided into themes and sub-themes. Table 2.3 lists the indicators of the EISD according to this scheme. The list also includes the basic components of each indicator. It is important to note that indicators can be classified in more than one dimension, theme or sub-theme, given the numerous interlinkages among these categories.

The 2005 interagency report provides background on the dimensions, themes and frameworks used to define the indicators. It also provides guidelines on how to select and use the indicators and discusses their limitations, pitfalls and constraints to ensure meaningful analysis and to avoid basic statistical misinterpretations. Finally, the report contains methodology sheets for each of the 30 EISD, designed to assist users in the elaboration, construction and implementation of the indicators. The methodology sheets include complete descriptions of the indicators, principal and alternative definitions, the components of each indicator, the units in which they are measured, instructions on how to construct them, data concerns, key data sources, and linkages to other indicators. The report is intended for specialists in energy and the environment, including statisticians, analysts, policy makers and academics—in particular those involved in the development of energy and environmental indicators relevant to sustainable development.

TABLE 2.3. LIST OF ENERGY INDICATORS FOR SUSTAINABLE DEVELOPMENT (EISD)

Social				
Theme	**Sub-theme**	**Energy indicator**		**Components**
Equity	Accessibility	SOC1	Share of households (or population) without electricity or commercial energy, or heavily dependent on non-commercial energy	-Households (or population) without electricity or commercial energy, or heavily dependent on non-commercial energy -Total number of households or population
	Affordability	SOC2	Share of household income spent on fuel and electricity	-Household income spent on fuel and electricity - Household income (total and poorest 20% of population)
	Disparities	SOC3	Household energy use for each income group and corresponding fuel mix	-Energy use per household for each income group (quintiles) -Household income for each income group (quintiles) -Corresponding fuel mix for each income group (quintiles)
Health	Safety	SOC4	Accident fatalities per energy produced by fuel chain	-Annual fatalities by fuel chain -Annual energy produced

Economic				
Theme	**Sub-theme**	**Energy indicator**		**Components**
Use and Production Patterns	Overall Use	ECO1	Energy use per capita	-Energy use (total primary energy supply, total final consumption and electricity use) -Total population
	Overall productivity	ECO2	Energy use per unit of GDP	-Energy use (total primary energy supply, total final consumption and electricity use) -GDP
	Supply efficiency	ECO3	Efficiency of energy conversion and distribution	-Losses in transformation systems including losses in electricity generation, transmission and distribution
	Production	ECO4	Reserves-to-production ratio	-Proven recoverable reserves -Total energy production
		ECO5	Resources-to-production ratio	-Total estimated resources -Total energy production
	End use	ECO6	Industrial energy intensities	-Energy use in industrial sector and by manufacturing branch -Corresponding value added
		ECO7	Agricultural energy intensities	-Energy use in agricultural sector -Corresponding value added
		ECO8	Service/ commercial energy intensities	-Energy use in service/ commercial sector -Corresponding value added
		ECO9	Household energy intensities	-Energy use in households and by key end use -Number of households, floor area, persons per household, appliance ownership
		ECO10	Transport energy intensities	-Energy use in passenger travel and freight sectors and by mode -Passenger-km travel and tonne-km freight and by mode

	Diversification (fuel mix)	ECO11	Fuel shares in energy and electricity	-Primary energy supply and final consumption, electricity generation and generating capacity by fuel type -Total primary energy supply, total final consumption, total electricity generation and total generating capacity
		ECO12	Non-carbon energy share in energy and electricity	-Primary supply, electricity generation and generating capacity by non-carbon energy -Total primary energy supply, total electricity generation and total generating capacity
		ECO13	Renewable energy share in energy and electricity	-Primary energy supply, final consumption and electricity generation and generating capacity by renewable energy -Total primary energy supply, total final consumption, total electricity generation and total generating capacity
	Prices	ECO14	End-use energy prices by fuel and by sector	-Energy prices (with and without tax/subsidy)
Security	Imports	ECO15	Net energy import dependency	-Energy imports -Total primary energy supply
	Strategic fuel stocks	ECO16	Stocks of critical fuels per corre-sponding fuel consumption	-Stocks of critical fuel (e.g. oil, gas, etc.) -Critical fuel consumption
Environmental				
Theme	**Sub-theme**	**Energy indicator**		**Components**
Atmosphere	Climate change	ENV1	GHG emissions from energy production and use per capita and per unit of GDP	-GHG emissions from energy production and use -Population and GDP
	Air quality	ENV2	Ambient concentrations of air pollutants in urban areas	-Concentrations of pollutants in air
		ENV3	Air pollutant emissions from energy systems	-Air pollutant emissions
Water	Water quality	ENV4	Contaminant discharges in liquid effluents from energy systems including oil discharges	-Contaminant discharges in liquid effluents
Land	Soil quality	ENV5	Soil area where acidi-fication exceeds critical load	-Affected soil area -Critical load
	Forest	ENV6	Rate of deforestation attributed to energy use	-Forest area at two different times -Biomass utilization
	Solid waste generation and management	ENV7	Ratio of solid waste generation to units of energy produced	-Amount of solid waste -Energy produced
		ENV8	Ratio of solid waste properly disposed of to total generated solid waste	-Amount of solid waste properly disposed of -Total amount of solid waste
		ENV9	Ratio of solid radioactive waste to units of energy produced	-Amount of radioactive waste (cumulative for a selected period of time) -Energy produced
		ENV10	Ratio of solid radioactive waste awaiting disposal to total generated solid radioactive waste	-Amount of radioactive waste awaiting disposal -Total volume of radioactive waste

Source: IAEA *et al*. (2005).

Clearly, the organisational framework of energy indicators has evolved somewhat from CSD-9 (April–May 2001) to the publication of the report on guidelines and methodologies in 2005. These changes, described above, reflect refinements based on experience in applying the indicators over the past five years. The basic approach and the analytical concept, however, have not changed. The shift from the driving force/state/response framework to the themes and sub-themes does not change the nature of the analysis, nor does it mean that causality and interrelationships among trends and factors are ignored. Such relationships are still the backbone of the indicator approach to sustainable development analysis. The adoption of the theme and sub-theme approach, and the emphasis on institutional changes as responses, make it easier, at least in theory, for policy makers to target policies to influence trends in a more sustainable direction, and to gauge the success of these policies over time.

As it has evolved, the EISD set is intended as a reference point or basis upon which users can develop their own specific indicators. Users do not have to implement the full set, but can select those indicators that are relevant; nor are users limited to the proposed EISD, but can create other indicators that are appropriate for their case.

2.5. Using EISD for analysis

Generating indicators is only a beginning. As a structure for critical analysis, the EISD can be used to relate sustainable development goals and strategies to economic, environmental, or social factors, and to policy analysis and monitoring. The IAEA has been using the EISD in three specific ways:

- To clarify statistical information;
- To monitor progress of past energy-related policies; and
- To provide a reality check on policy proposals.

In all three cases, indicators are being combined with energy system modelling. This marriage of indicators and scenario modelling is now a current analytical focus.

One of the first uses of the EISD was in the context of a partnership initiative, led by the IAEA and registered with the CSD, for developing country profiles on sustainable energy development. Started in 2002, this project now includes three participating countries—Brazil, Cuba and South Africa — along with the IAEA and UNDESA. The main objective is to marry scenario projections of national energy demand and supply and related policies with a statistical analysis of past and future trends in selected sustainable development priorities. This approach thus permits policy makers to gauge whether the energy system is evolving in a desirable direction and how appropriate corrections can be made. These country energy profiles comprise quantitative and qualitative assessments of energy demand, supply, domestic resources, technology and trade, and scenarios of energy sector evolution under different policy and technology assumptions. The analysis is structured to address the most important energy issues and national priorities in the context of the major dimensions of sustainable development (economic, social and environmental). Historical trends and current status are assessed using the EISD tool. Future developments are explored based on scenarios developed using as a starting point nationally defined sustainable development criteria and goals. The partnership initiative is thus an effective mechanism, at the national level, for evaluating the fulfilment of a country's Johannesburg Plan of Implementation. In 2006, the first study conducted under this partnership initiative on the Brazilian energy system was published (IAEA et al., 2006).

More recently, a regional project has been started by IAEA, involving fourteen countries in the Asia and Pacific region. Using the same approach as the national profiles, this project adds a regional dimension to the analysis. A spin-off benefit will be that the EISD framework will be integrated into the national statistical system of participating countries.

2.6. Conclusions

The IAEA has worked successfully in cooperation with national and international organisations to develop a worldwide set of recommended energy indicators for sustainable development. The ISED/EISD is an analytical tool designed for assessing energy systems and for measuring progress towards more sustainable energy futures. This tool is a starting point that can serve as a reference point for a more refined and complete set of energy indicators, for more coherent methodologies and guidelines for its implementation, and for the design of future scenarios.

The country case study presented in the chapters that follow illustrate the applicability and use of the ISED tool in the assessment of energy sectors and trends towards sustainable development at the national level. They also describe limitations and difficulties encountered in the implementation of the ISED analysis and in the interpretation of results.

Further development of energy indicators and their dissemination and implementation at the national and regional levels, as well as designing indicators for the assessment of advanced innovative technologies, are continuous efforts at the IAEA. It is hoped that this work will result in an expanded analytical tool useful to energy experts and other stakeholders.

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3. BRAZIL

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3.1. Introduction

This chapter represents Brazil's contribution to the Indicators for Sustainable Energy Development (ISED) programme coordinated by the International Atomic Energy Agency (IAEA). The ISED programme is designed to select particular subsets of sustainable development indicators most relevant to a country's energy priorities, and then to apply these indicators in analyses of current and potential future energy systems and policies.

This chapter presents the final report and follows the outline proposed for each county team included in the ISED project. The report is more analytical than previous progress reports prepared by Brazil, and includes some updated data. Moreover, it was developed in parallel with the study *Brazil: A Country Profile on Sustainable Energy Development* (IAEA, et al., 2006), which incorporated some of the indicators from the ISED project and supported some of the analysis undertaken in this study. Thus, it should be stressed that the coordination of this study coincides with the coordination of the Brazilian energy country profile study, and both were performed at the Federal University of Rio de Janeiro, in conjunction with the IAEA.

The rest of the chapter is organised into six major sections, as follows: (3.2) an overview of the Brazilian energy sector[1], (3.3) a review of the energy statistical data capability of the country, (3.4) the definition of major energy priority areas for the national context, (3.5) the implementation of the ISED framework for Brazil, (3.6) identification of response actions and energy policies in priority, and (3.7) the conclusions and recommendations of the report.

3.2. Overview of the Energy Sector[2]

This overview of the Brazilian energy sector discusses three principal topics. First, the Brazilian energy balance data indicators are presented and discussed. Second, selected indirect driving forces and states of the economic dimension of Brazilian sustainable energy development are then analysed. Finally, select driving forces and the states of other dimensions for sustainable energy development also are analysed.

It should be emphasized that the identification of each ISED Indicator used by the Brazilian Team is provided in the tables or charts. The selection of these indicators is discussed in Section 3.2, as well as the potential use of additional indicators to the original ISED set, whose aim is to provide information on specific features of the Brazilian energy system. Within this section, these additional indicators are identified by numbers and also by the label "additional".

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[1] The first section is based upon previously selected indicators, chosen according to the ISED methodology.

[2] Besides the update of some indicators and some analysis introduced by the Brazilian team, this section is based on two main sources: the first year- report of the ISED Project (Schaeffer et al., 2002) and Chapter 2 from the study *Brazil: a country profile on sustainable energy development*, written by Szklo and Cunha (IAEA et a., 2006).

3.2.1. Brazilian energy balance - general overview

During the previous two decades, Brazil's Energy Balance reflected considerable changes in the energy sector, economy and government policies (see Table 3.1) During the 1980s, the share of renewable energy sources in the Total Primary Energy Supply (TPES) increased owing to economic policies adopted during the 1970s, which promoted indigenous energy alternatives such as hydropower and biomass to replace oil imports. In addition, renewable replaced non-renewable biomass, due to the increased use of modern energy sources in the industrial sector (black liquor in the pulp and paper segment, for instance) and the urbanization of the country.[3]

TABLE 3.1. BRAZIL'S ENERGY BALANCE IN PJ – ISED #11

Domestic	1980	1985	1990	1995	2000	2001	2002
Coal and coal products	104	147	80	85	109	91	84
Gas	46	123	181	227	348	355	427
Oil and oil products	389	1,168	1,348	1,481	2,666	2,793	3,143
Hydropower	464	642	744	914	1,095	964	1,025
Nuclear	0	32	21	24	58	137	133
Biomass - Renewable	894	1,265	1,293	1,467	1,584	1,669	1,800
Biomass -non renewable	833	961	733	510	399	417	450
Total Domestic	2,730	4,340	4,401	4,709	6,259	6,427	7,061
Net Imports							
Coal and coal products	161	262	343	431	456	449	463
Gas	0	0	0	0	81	170	194
Oil and oil products	1,877	891	1,136	1,352	1,041	801	360
Electricity	-1	7	95	127	159	136	132
Biomass	0	0	31	65	2	3	0
Total Imports	2,037	1,160	1,606	1,976	1,740	1,559	1,149
Stock Variation							
Coal and coal products	-12	20	-9	0	2	18	-2
Oil and oil products	63	3	-80	106	-85	87	65
Biomass	6	-53	-4	0	40	9	4
Total Stock var.	57	-30	-93	105	-43	114	67
TPES (Domestic+Imp+Stck)							
Coal and coal products	253	430	415	517	568	559	544
Gas	46	123	181	227	429	525	621
Oil and oil products	2,329	2,062	2,404	2,939	3,623	3,681	3,568
Hydropower	464	642	744	914	1,095	964	1,025
Nuclear	0	32	21	24	58	137	133
Biomass	1,733	2,174	2,022	1,977	2,022	2,096	2,254
Electricity (imports)	-1	7	95	127	159	136	132
TOTAL TPES	4,824	5,471	5,882	6,725	7,954	8,097	8,276

Source: MME, 2003

[3] Please note that, throughout this report, the distinction between modern and traditional biomass sources proposed by Goldemberg and Coelho (2004) will be employed. According to these authors, "biomass produced in a sustainable way—the so-called modern biomass—excludes traditional uses of biomass such as fuelwood and includes electricity generation and heat production, as well as transportation fuels, from agricultural and forest residues and solid waste." On the other hand, ''traditional biomass'' is produced in an unsustainable way and it is used as a non-commercial source—usually with very low efficiencies for cooking in many countries".

Notes: The estimated fraction of combustible non-renewable biomass supplied in Brazil over the past two decades was based on Schechtman et al. (1999), ABRACAVE (2002), and Aquino (1999). However, the fragility of the primary data on this matter is still quite considerable, particularly owing to the historically significant use of fuelwood by the industrial sectors (to produce charcoal consumed largely by steel mills) and the residential sector (for cooking, particularly in rural areas).

TPES grew on average 2.5 % p. a. between 1980 and 2001, a rate slightly higher than the economic growth (2.0 % p. a.). For the same period, natural gas and hydropower increased steadily. The share of oil decreased in the first half of the 1980s, but since the oil counter shock in 1986, it has been recovering its market share; coal increased merely owing to the demand pull of the metallurgical sector; and biomass was pushed up through use of modern sources in the industrial sector and the transportation sector (ethanol-fuelled cars), and fuelwood substitution occurred mainly in the household sector (see Figure 3.1).

Actually, fuelwood as energy biomass in Brazil meets two main demands: small-scale decentralized use in the residential sector (an average of 32% of the domestic supply of fuelwood was channelled to meet these uses from 1980 through 2000)[4], and that of charcoal-burners.

On average, one half of the fuelwood used in the residential sector is gathered in the form of secondary growth such as scrubwood, twigs and branches (Schechtman et al., 1998), and consequently does not impose deforestation pressures (non-commercial woody biomass circuit)[5].

Fuelwood use in charcoal-burners (averaging out at 40% of the allocation of the fuelwood supply in Brazil from 1980 through 2000) is higher and more concentrated than that of the residential sector. In some areas, such as Amazonia, this contributes to deforestation pressures (Aquino, 1999). In other states, and for much of Brazil's steel industry output in Minas Gerais State, the use of energy-based biomass does not necessarily impose deforestation pressures, as much of the charcoal consumed is either renewable or produced from planted forests (ABRACAVE, 2002).

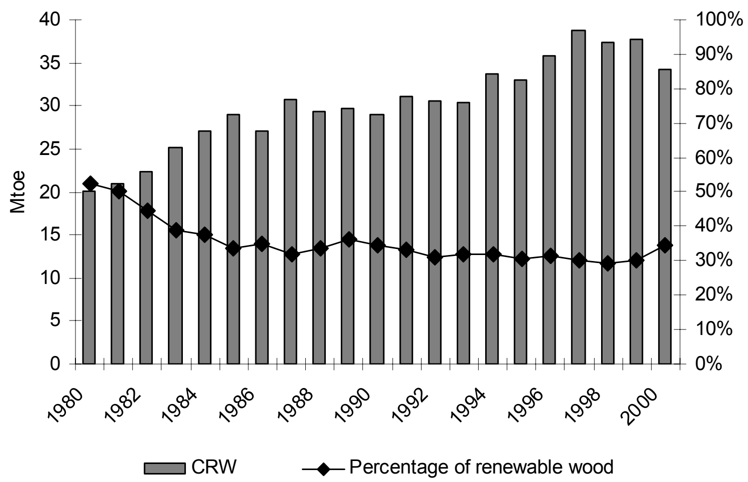

Figure 3.1. CRW indigenous production and percentage of renewable wood (1980-2000) –ISED # 17
Source: Based on MME (2001), Schechtman et al (1998), ABRACAVE (2002) and Aquino (1999).

Consequently, the use of biomass for energy purposes is not the main driving force behind the deforestation of native forests in Brazil (see Table 3.2), although it exists and therefore can be measured. Actually, in general terms, the expansion of commercial agriculture and cattle ranching − often fuelled by government incentives or by colonization and settlement policies − represents the main cause of deforestation, which is normally associated with predatory logging (Camargo, 2002). More recently, some specialists have also indicated the problem of export-oriented enterprises moving into the Amazon and Cerrado regions where they log, produce beef, and grow soybeans, all with detrimental impacts on the forests (Rodrigues, 2002).

4 As discussed in this document through the use of other ISED, these demands have been shrinking over the past two decades.

5 The exception to this rule is the urban sprawl around large towns and cities in Northern Brazil, where there is an established market for fuelwood and charcoal, in addition to easily-available wood from the Amazon Rainforest (Aquino, 1999).

TABLE 3.2. GROSS DEFORESTATION FROM 1978 TO AUGUST 2000 IN THE AMAZONIAN BIOMES[(1)] ISED #41

Years	Extent (km^2) [(2)]	Period	Mean rate 1 (km^2/year)	Mean rate 2 (%/year)
Jan/1978	152,200	77/88[(3)]	21,130	0.54
Apr/1988	377,500	88/89	17,860	0.48
Aug/1989	401,400	89/90	13,810	0.37
Aug/1990	415,200	90/91	11,130	0.30
Aug/1991	426,400	91/92	13,786	0.38
Aug/1992	440,186	92/94[(4)]	14,896	0.41
Aug/1994	469,978	94/95	29,059	0.80
Aug/1995	497,055	95/96	18,161	0.51
Aug/1996	517,069	96/97	13,227	0.37
Aug/1997	532,086	97/98	17,383	0.51
Aug/1998	551,782	98/99	17,259	0.49
Aug/1999	569,269	99/00	18,226	0.52
Aug/2000	587,727	00/01	15,787	

Source: INPE (2002)
Notes: (1) Relative to the area of remaining forest formations. The figures are related to all causes of deforestation in the Amazon. (2) Includes old deforestation. (3) Decade Mean. (4) Biennium Mean.

A final point related to the impact of non-renewable energy biomass on deforestation in Brazil is its considerable diversity of biomes. This makes it almost impossible to estimate an average value for the ratio between the energy content of non-renewable energy biomass consumed in Brazil, for which estimates exist[6], and the deforestation that this implies. Brazil has some 5.5 million km^2 of native forests, two-thirds of which are located in Amazonia and the remainder (in descending order) in the Cerrado savannas of the Center-West[7], the Atlantic Rainforest, the Caatinga scrublands and other associated ecosystems[8].

In addition to these natural forests, there are some 64,000 km^2 of tree plantations, used mainly to produce pulp and paper, charcoal, wood and rubber, located largely in Espírito Santo, Minas Gerais, Bahia, Paraná and São Paulo States (Schaeffer et al., 2002).

Still regarding the Brazilian Energy Balance, Brazil's energy dependence decreased over the last two decades, mostly owing to government programs on oil products substitution and national oil production expansion (Figure 3.2). The focus was on replacing imported oil because it is the most important energy source weighting the trade balance. Oil dependence decreased from 81% to 28% between 1980 and 2000. However, coal imports moved in the opposite direction, increasing mainly owing to the metallurgical industry needs, and a small fraction of total electricity began to be imported when the Itaipu bi-national power plant was started-up[9]. Natural gas imports were initiated in 1999.

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6 See Schechtman et al. (1998).

7 The *cerrado* savanna ecosystem occurs on the Central Brazilian Plateau (Planalto), as well as parts of Amazonia and the Northeast. These savannas consist largely of low-growing, widely-spaced trees with grassy ground cover. The *cerrado* savannas still lack adequate scientific surveys on the development of natural plant cover, and are today threatened by the expansion of agriculture growing grain crops for export.

8 The *caatinga* scrublands are rated as the only ecosystem that is exclusively Brazilian. Home to 932 known plant species, of which 380 are endemic, this heterogeneous biome also ranks among the ecosystems most altered by human activities.

9 In 1975, the bi-national Itaipu hydroelectric power plant began to be built, at the border between Brazil and Paraguay, in the south of the country. The plant was inaugurated in October 1984, while the final installation of 12,600 MW was completed in 1991 (the water intake of one single 715 MW Francis-turbine is 700 m^3/s, its weighted efficiency is 93.8%). Paraguay delivers to Brazil most of the power generated at 50 Hz (frequencies in Brazil and Paraguay are different, and Paraguay consumes less than 4% of the electricity generated by Itaipu). Thus, it was decided to build a composite transmission system, including an Extra High Voltage system (AC) for 6,300 MW (Brazilian part at 60 Hz, transmitted by 891 km at 750 kV) and a High Voltage system (DC) for about 6,000 MW of the 50 Hz part (imported from Paraguay, at ± 500 kV, and converted back into AC).

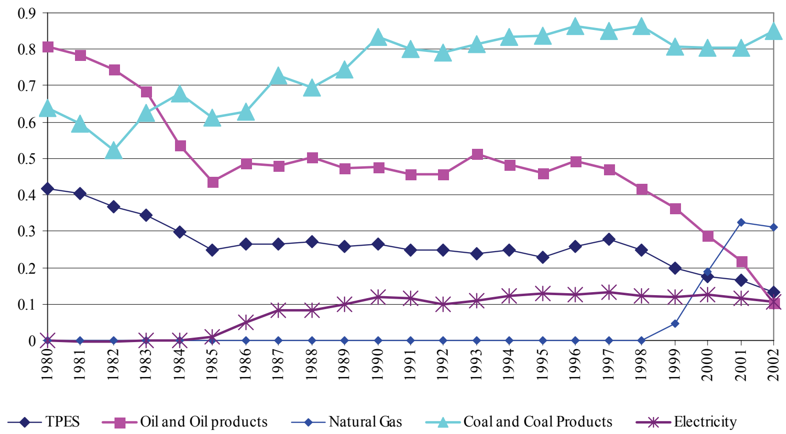

Figure 3.2. Energy net imports dependence ISED # 18
Source: MME (2003).
Note: The oil net imports used to calculate Brazil's dependence on oil include both imported crude and oil products (Schaeffer et al, 2002).

The Brazilian final energy use evolution shows the increase of non-renewable energy sources in the energy mix during the 1990s (see Table 3.3). The market share of electricity rose, but that of biomass remained the same. In addition, since the 1990s, charcoal has been replaced by coal or coke and neat ethanol by gasoline, although the proportion of anhydrous ethanol in the gasohol mixture remained roughly the same, hovering between 20 and 26% (MME, 2002a). In the case of natural gas, use is still low, given the infant stage of the industry. Nevertheless, growth of this energy source in Brazil's mix is expected in the near future, mostly by increasing its use in thermal-power plants and industrial heat generators. Some increase of natural gas household use is also expected in major cities of the Southeast. Figure 3.3 shows final energy use of the Brazilian economy by sector.

TABLE 3.3. FINAL ENERGY CONSUMPTION IN PJ – ISED # 11

Energy Sources	1980	1985	1990	1995	2000	2001	2002
Oil	2,131	1,898	2,241	2,747	3,352	3,331	3,291
Coal	184	315	303	394	439	426	451
Gas	30	65	102	130	215	255	320
Electricity	427	602	759	923	1,155	1,074	1,114
Fuelwood	1,147	1,085	893	919	1,024	1,113	1,203
Ethanol	88	242	329	389	270	253	262
Charcoal	179	259	257	206	201	184	193
				Sectors			
Industrial	1,583	1,710	1,806	2,138	2,561	2,574	2,723
Commercial & public	124	150	196	256	344	329	342
Transportation	1,116	1,192	1,441	1,807	1,983	2,000	2,028
Residential	879	777	758	760	866	843	866
Agriculture	243	255	253	297	305	323	337
Sub-total	3,945	4,084	4,454	5,258	6,059	6,069	6,296
Non energy / feedstocks	241	382	430	450	598	567	538
TOTAL	4,186	4,466	4,884	5,708	6,657	6,636	6,834

Source: MME, 2003.
Note: According to the authors' estimates, the renewable biomass fraction of the total biomass use increased from 56% in 1980 to around 80% in 2000.

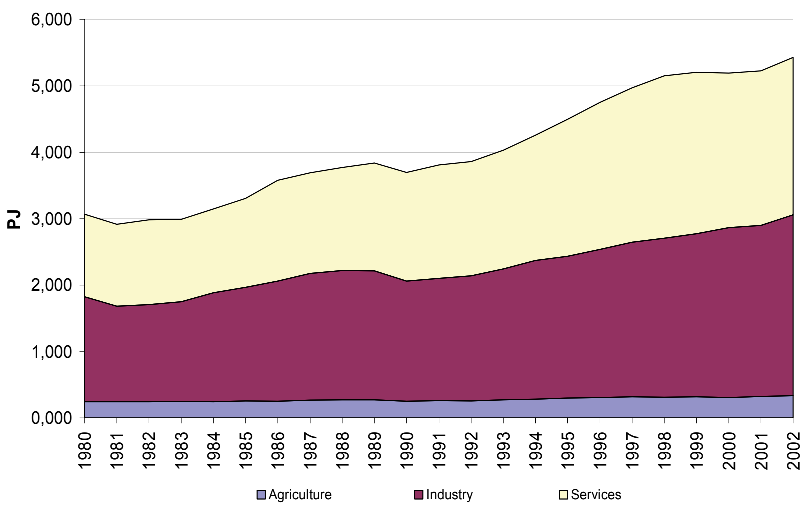

Figure 3.3. Final energy use of the Brazilian economy by sector –ISED #11
Source: MME (2003).

With regard to the sectoral analysis, the final energy consumption on the residential sector remained almost unchanged (average rate of -0.2%p.a.) between 1980 and 2001. The reduction of traditional biomass use was compensated by an increase in more efficient LPG and electricity use, due to the trend toward urbanization (see Figure 3.4, which derives from Indicator #1 of the ISED methodology).

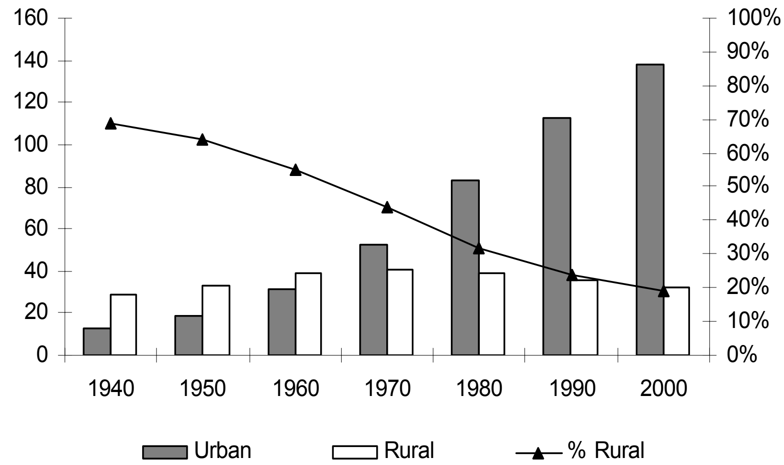

Figure 3.4. Population (million inhabitants) – ISED #1
Source: IPEADATA 2003.

In turn, the commercial and public sectors showed an average growth rate of 4.9% p.a., owing to the growing share of these sectors in the Brazilian GDP and their modernisation, which resulted in larger electricity consumers, such as big hospitals, hotels and shopping centres (Figure 3.5).[10]

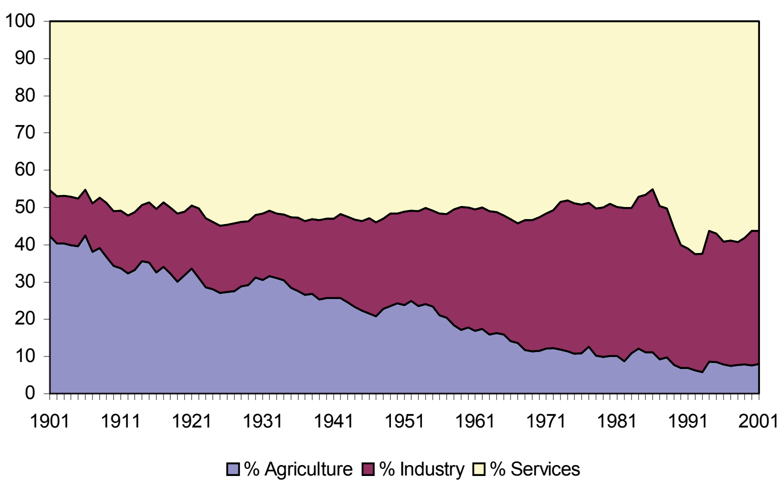

Figure 3.5. GDP's Share – ISED # 4
Source: IPEADATA, 2003.

The final energy consumption average growth rate of the transportation sector was also higher than that observed in the overall economy (respectively, 3.1% and 2.6% p.a.) between 1980 and 2001. This was due not only to activity effects (the increase of passenger and freight transportation), but also to the growth in road transport and the increased use of private cars in Brazil (see Table 3.4 and Table 3.5, which refer to Indicators #5 and Indicators #6 of the ISED methodology).

[10] See also section 3.4 containing the implementation of the ISED indicators for more information about the economic dimension and the direct and indirect driving forces of the Brazilian energy development.

TABLE 3.4. EVOLUTION OF TOTAL DISTANCE TRAVELLED BY PASSENGERS (PASSENGER ACTIVITY) IN BRAZIL – ISED #5

(pkm) (per capita)	Air	Rail	Road	Total
1980	78.60	114.26	3,374.33	3,567.19
1985	81.46	139.25	3,694.88	3,915.59
1990	102.76	123.09	4,115.03	4,340.88
1995	100.22	96.33	4,691.62	4,888.16
2000	121.10	n.a.	5,189.41	5,310.51

Source: GEIPOT, 2000

Notes: Passenger activity by aquatic mode of transportation is not included (not reported to GEIPOT). Rail includes subway and train. The same applies to passenger activity by rail in 2000. "n.a." means not available.

TABLE 3.5. EVOLUTION OF TOTAL FREIGHT TRANSPORT ACTIVITY PER CAPITA IN BRAZIL – ISED #6

(t.km) (per capita)	Air	Inland waters	Pipeline	Rail	Road	Total
1980	8.39	392.24	98.09	709.65	1,714.48	2,922.85
1985	9.91	577.72	131.50	741.83	1,686.08	3,147.06
1990	11.94	695.58	141.63	815.55	2,122.24	3,786.94
1995	12.28	444.04	151.61	858.15	2,383.45	3,849.54
2000	14.29	607.66	195.40	914.47	2,652.88	4,384.71

Source: GEIPOT, 2000

Notes: Inland water transportation includes coastal water transportation.

Also important in the transportation sector is the use of ethanol either as an additive to the gasoline or as the fuel for hydrated ethanol fuelled-cars. Automotive ethanol is specific and important within the context of energy used for automotive purposes in Brazil. There have been three ways of using ethanol produced from sugar-cane (since the introduction of the Alcohol Incentive Program in Brazil, known as PROALCOOL, during the mid-1970s): fuelling motors running only on alcohol in its hydrated form,[11] fuelling flex-fuel motors running on variable mixtures of hydrated alcohol and gasoline, and fuelling gasoline motors, as a gasoline additive, in its anhydrous form (at 99.6 GL [Gay Lussac]) in proportions that have varied over the past two decades, as shown by Figure 3.6.[12]

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[11] Ethanol has a number of advantages over gasoline in terms of engine and vehicle efficiency. First, compression ratios as high as 12:1 can be used; second, the heat of alcohol vaporization per unit of fuel energy is six to eight times that of gasoline; third, it is possible to use leaner air-fuel mixtures with fuel alcohol (reducing NOx emissions, for instance).

[12] Subsidies for ethanol production and use were justified based on the positive economic, social, and environmental impacts of this program. Ethanol produced from sugarcane improves Brazil's balance of payments, eases unemployment and urbanization pressures, and provides both local and global environmental benefits. Ethanol production was stimulated through a combination of policies including: low-interest loans for the construction of ethanol distilleries, guaranteed ethanol purchases by the state-owned oil company at prices rated as adequate for guaranteeing ethanol producers reasonable profits; neat ethanol priced as competitive if not slightly favourable to the gasoline-ethanol blend; and sales tax incentives during the 1980s that encouraged purchases of neat ethanol vehicles.

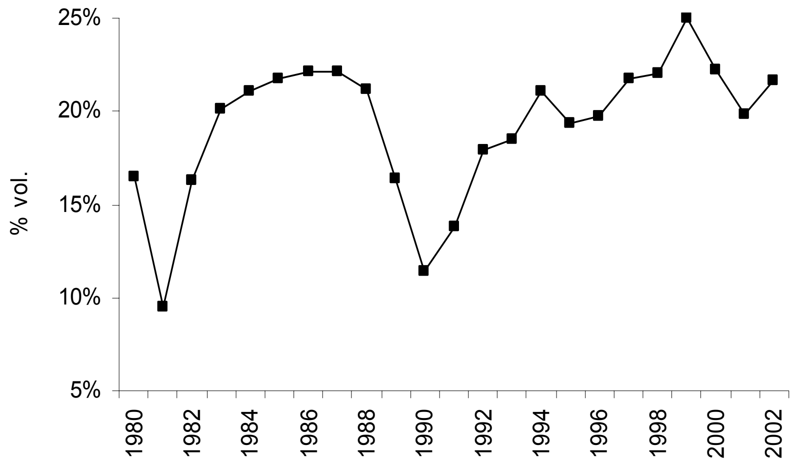

Figure 3.6. Anhydrous Ethanol Added to the Gasoline-Ethanol Blend (gasohol) – Additional ISED #11.4
Source: MME, 2001.

As mentioned earlier, the use of hydrated ethanol depends on the ethanol-fuelled fleet. Among other reasons, this explains why an indicator for the composition of the country's light vehicles fleet is so important. Figure 3.7 below displays the evolution of the light fleet by fuel (except for natural gas) in percentage.

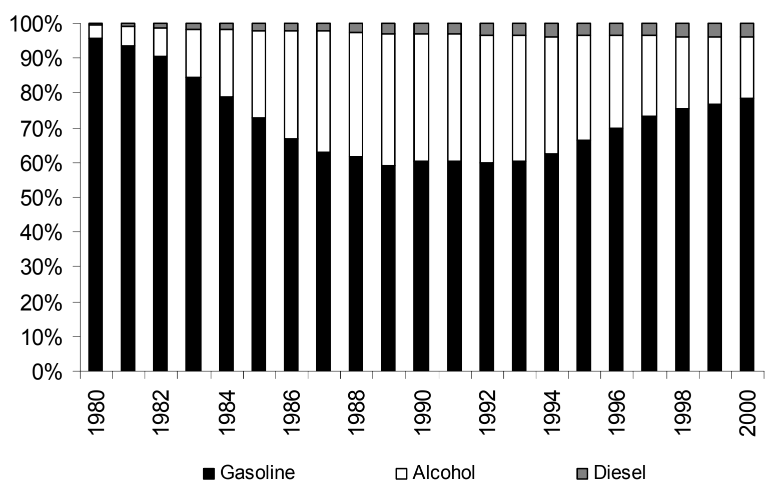

Figure 3.7. Shares of light fleet by fuel in Brazil – Additional ISED #11.5
Source: GEIPOT, 2000.
Note: Natural Gas (converted) vehicles are not reported separately from gasoline vehicles, but the natural gas fleet is not significant.

As noted, as of 2004, ethanol is used mainly as an additive for gasoline (24-26% in a volumetric proportion), i.e. anhydrous ethanol, mainly for local environmental reasons. The other alternative − the use of hydrated ethanol in engines solely fuelled by ethanol – lost ground through 2002. Actually, Brazil's ethanol incentive program for Otto Cycle engines automotive vehicles was extraordinarily successful until the 1990s, with new cars fuelled by ethanol accounting for more than 90% of light vehicles' sales in the 1985-90 period. However, a steep drop was noted in ethanol-fuelled automobiles over the following few years, owing mainly to three reasons: 1) a gradual increase in the price of ethanol, which is a trend that began to reverse after 2000; 2) incentives to produce 1-litre engine gasoline fuelled-automobiles at lower tax rates; and 3) unreliable ethanol supplies that culminated in the need to import ethanol/methanol to meet

demands.[13] As a result of the combination of these factors, the sales of cars fuelled by ethanol fell to almost zero, dropping to under 0.5% of new automobile sales by the late 1990s (Poole et al, 1998).[14] The fleet of automobiles in 2003 was fuelled almost solely by gasoline, with some 300,000 to 400,000 ethanol-fuelled cars scrapped each year.

Nevertheless, since 2003 flex-fuel vehicles began to be produced in the Brazilian market. These light-vehicles are capable of consuming a mixture of hydrated ethanol and gasoline at any proportion, basically because of its sophisticated electronic control of emissions, air-fuel composition and ignition delay time. In 2003, the flex fuel sales reached 48,178 units. By October of 2004, the annual sales of flex fuel vehicles reached 249,116 units, accounting for 24.1% of the national sales. Some studies forecast that the share of this alternative vehicle in the total light vehicle sale will reach 70% in ten years (Schaeffer et al., 2004).

In the last decades, electricity use increased tremendously, reaching 331 terawatt-hours in 2000 (Table 3.6). The key drivers of this growth were: the large ongoing share of electricity-intensive industries[15] in Brazil's industrial output since the 1980s; the country's urbanization allied with population growth, which changed household consumption patterns; modernization of the agricultural sector;[16] and low electricity prices, especially during the 1980s.[17]

Industrial sector power demand rose steeply during the 1970s, reaching 56% of total electricity use by 1980. During the 1980s, growth rates slowed, averaging only 5.11% p.a., compared to 14% experienced during the 1970s. The 1990's saw the restructuring of Brazil's industrial sector, with a slower expansion of electricity-intensive sectors resulting in an average annual growth of 2.64% in electricity use by this sector. Yet, as of 2001, the industrial sector still accounts for 44% of the country's electricity use, largely as a result of the use of electricity-intensive sectors.

TABLE 3.6. ELECTRICITY USE BY SECTOR, 1980- 2002, IN TERAWATT HOURS – ADDITIONAL INDICATOR

Sectors	1980	1985	1990	1995	2000	2001	2002	GR 1990-2000 (%)	GR 2000-01 (%)	GR 2001-02 (%)
Residential	23	33	49	64	84	74	73	6	-12	-1
Commercial	14	18	24	32	47	45	46	7	-6	2
Industrial	68	96	112	127	147	139	148	3	-5	7
Others	17	26	33	42	54	52	54	5	-4	5
Brazil	123	173	218	265	331	309	321	4	-7	4

Source: MME, 2003.
Note: GR means average annual growth rate.

Regarding the power generation mix (Table 3.7), as of today, three different electric systems supply the five macro political regions of the country (north, northeast, mid-west, southeast and south). The largest interconnected power transmission system, which includes the Southeast, South, and Mid-West regions, accounted for more than 70% of Brazilian total installed capacity in 2000. It includes the hydroelectric power plant of Itaipu, and the two nuclear power plants currently in operation in Brazil: Angra I, with 657 MW installed, and Angra II with 1,309 MW. The second grid system connects the north and northeast

[13] The Brazilian Government cut the price it paid to ethanol producers throughout the 1980s, particularly after the world oil price collapse in 1986. In addition, sugar prices spiked in the international market, where Brazil was the most important player. Consequently, fuel producers stopped increasing ethanol production by the late 1980s. This in turn resulted in ethanol shortages and the need to import ethanol and methanol for a short period of time in the 1989-1990 period.

[14] More recently, this trend seems to be shifting, with some 5% of the new cars sold in Brazil during the first half of 2002 consisting of vehicles fuelled by hydrated ethanol.

[15] Energy-intensive industrial sectors include: non-metallic minerals, iron and steel, non-ferrous metals, pulp and paper, and chemicals (although chemicals include non-energy intensive segments, such as fine chemicals, additives, advanced plastics, etc.).

[16] Since 1979, the Brazilian government has been promoting the modernization of the agricultural sector, focusing mainly on two different sets of goods: export oriented primary crops and fruits, and biomass for energy purposes. In addition, the Rural Electrification Program launched in 1999 also affected the use of electricity by medium and small Brazilian farms.

[17] Brazil's government took actions designed to curb inflation, imposing tight controls on tariff levels. This stimulated industrial and household electricity consumption.

regions, accounting for almost 25% of Brazilian total installed capacity. Finally, the country's electric power system includes small, independent grids that operate remotely, largely in the northern region. These isolated systems account for less than 5% of Brazil's electricity market and are based mainly on thermal power plants (SIESE, 2002). The interconnected hydropower systems have been complemented by thermal-power plants fired by coal, oil products and even biomass sources such as sugarcane bagasse and black liquor. An increase in the share held by thermal-power generation fuelled by natural gas is expected in Brazil. Designed to create a market for this energy source imported from Bolivia while simultaneously diversifying Brazil's energy mix, the use of natural gas to generate electricity began to gain force from 2002 onwards, with the start-up of operations of gas-fired thermal-power plants.

TABLE 3.7. ELECTRICITY GENERATION MIX (TWH) – ISED #11

	1980	1985	1990	1995	2000	2001	2002
PUBLIC SERVICE PLANTS							
Hydro	126.1	175.3	203.6	250.5	298.6	262.7	278.7
Fuel oil	1.6	1.2	0.9	1.3	6.2	6.1	3.7
Diesel oil	0.9	1.1	1.5	2.7	4.1	4.0	4.3
Natural gas	0.0	0.0	0.0	0.0	1.6	6.9	9.8
Nuclear	0.0	3.4	2.2	2.5	6.1	14.3	13.8
Coal	2.5	3.3	2.7	3.7	7.5	7.4	5.1
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL PUBLIC	131.0	184.4	210.9	260.7	323.9	301.3	315.3
SELF PRODUCERS							
Hydro	2.8	3.0	3.1	3.5	5.8	5.2	6.3
Fuel oil	2.5	1.3	2.0	2.1	1.8	2.0	1.7
Diesel oil	0.2	0.3	0.5	0.4	1.5	2.1	1.6
Natural gas	0.0	0.0	0.3	0.6	2.5	3.0	3.4
Coal	0.3	0.6	0.5	0.6	0.8	0.9	0.9
Biomass	1.8	3.0	3.6	5.4	7.4	8.4	9.6
Other primary	0.7	1.1	1.7	1.4	3.5	3.9	4.2
Other secondary	0.0	0.0	0.3	1.1	1.7	1.8	1.7
TOTAL SELF PR	8.4	9.3	11.9	14.9	25.0	27.2	29.3
PUBLIC SERVICE + SELF PRODUCERS							
Hydro	128.9	178.4	206.7	253.9	304.4	267.9	285.0
Fuel oil	4.1	2.5	2.9	3.4	8.0	8.0	5.4
Diesel oil	1.1	1.4	2.0	3.1	5.6	6.1	5.8
Natural gas	0.0	0.0	0.3	0.6	4.1	10.0	13.2
Nuclear	0.0	3.4	2.2	2.5	6.1	14.3	13.8
Coal	2.8	4.0	3.3	4.3	8.3	8.2	6.0
Biomass	1.8	3.0	3.6	5.4	7.4	8.4	9.6
Other primary	0.7	1.1	1.7	1.4	3.5	3.9	4.2
Other secondary	0.0	0.0	0.3	1.1	1.7	1.8	1.7
TOTAL GENERATION	139.4	193.7	222.8	275.6	348.9	328.5	344.7

Source: MME 2003.
Note: Non-combustible renewables are almost null in the period of analysis.

Although the power system is classified as “hydro-thermal”, there is a strong predominance of hydroelectric plants distributed in 12 different hydrographic basins located in different areas of the country. Moreover, there is still considerable hydropower potential unused in Brazil (almost 200 GW in 2000), so that hydropower is expected to keep its significant role in Brazil's power generation scene over the next few decades (Table 3.8). However, this potential is scattered unevenly throughout the country: only 11% lies in the Southeast, which is the region with the highest electricity consumption, while 54% is in the North, resulting in higher electricity transmission costs as well as environmental constraints on more effective use of Brazil's energy “stocks”. Besides, the potential for retrofitting the existing Brazilian hydro plants that are more than 20 years old (32 GW or 42% of the total power installed capacity in 2001) hovers between 1 and 8 GW, depending on how much is invested (Filho et al., 2003).

TABLE 3.8. POTENTIAL CAPACITY FOR HYDROPOWER GENERATION ISED #35

Region	TOTAL (MW)	Installed Capacity in 2000 (MW)	Installed Capacity / Total Potential
North	112,495	4,867	4.3%
Northeast	26,710	10,143	38.0%
Southeast	42,776	21,204	49.6%
Mid-West	36,255	8,337	23.0%
South	41,859	17,169	41.0%
Brazil	260,095	61,720	23.7%

Source: Eletrobrás (2002b)

In addition, wind-power can assume a complementary role in the next decades, if promoted by renewable energy policies. With regard to Brazil's wind-power generation potential, a detailed survey was carried out on Brazil's potential wind-power capacity and the findings were published in MME/ELETROBRÁS (2001). According to this survey, Brazil's wind-power could provide 143,470 MW (see Table 3.9). Of this total, 52% of the total potential is located in Northeast Brazil and 21% is located in the Southeast.

TABLE 3.9. ESTIMATED POTENTIAL WIND POWER. ADDITIONAL ISED #35.2

Region	Capacity (GW)	Power Generation (TWh/year)	Capacity Factor (%)
North	12.84	26.45	24
Northeast	75.05	144.29	22
Mid-West	3.08	5.42	20
Southeast	29.74	54.93	21
South	22.76	41.11	21
Brazil	143.47	272.2	22

Source: MME/ELETROBRÁS (2001)

In this case, it is assumed that the potential wind-power capacity covers only areas with average annual wind speeds of over 7.0 m/s, with turbines installed on pylons fifty meters high (state of the art for this technology) and a land occupancy rate of 2 MW/km^2 and an availability factor of 0.98, not including offshore potential (Schaeffer et al., 2002).

So far, only 20.3 MW wind power have been installed in Brazil, accounting for under 1% of the estimated technical potential, with the Prainha (10 MW) and Taíba (5 MW) wind farms in Ceará State being particularly noteworthy, as well as Palmas (2,5 MW) in Paraná State. Therefore, the remaining potential wind-power use in Brazil is almost 100%. Yet, more important than the remaining potential capacity in relative or percentage terms is the information on this potential in absolute terms. Given the low capacity factor of wind power generation, its uncompetitive costs compared with conventional generation and the stochastic nature of the wind, the wind energy technical potential will be feasible in the near future only if promoted by specific policies. However, in some specific locations wind is the less-costly energy option (in some isolated regions). In other specific locations it provides a complementary option to the hydropower generation (wind and hydro seasons are complementary).

Finally, additional indicators covering the Biomass Remaining Technical Potential, expressed by the area used by sugarcane production (see Figure 3.8), are particularly important for Brazil, owing to the significant use of renewable biomass as a substitute for oil products. The most outstanding example of this trend is automotive ethanol, with an entire agricultural and industrial chain established since the introduction of the PROALCOOL (Pro-Alcohol Fuel Program), which was set up to encourage the

production of this energy source[18]. For the entire historical series under consideration here, regardless of whether the sugarcane was grown to produce sugar or ethanol, it is quite clear that only a small fraction of Brazil's arable land is used for this crop[19].

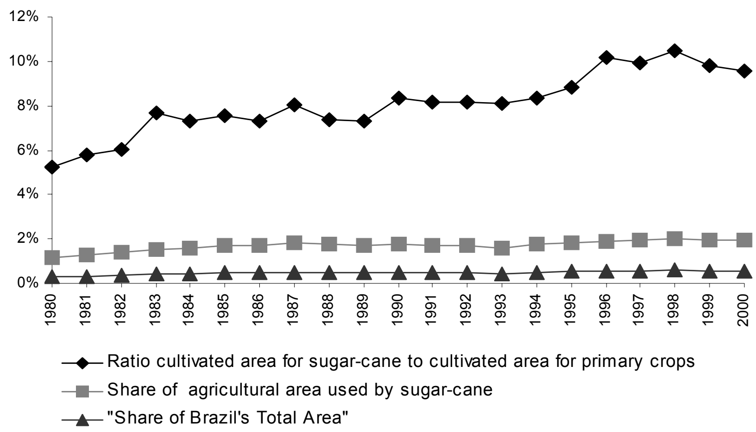

Figure 3.8. Land use for sugar cane in Brazil. Additional ISED #35.3
Source: FAO, 2002.

Brazil's oil reserves include crude and condensate reserves,[20] the latter being classified as liquid fractions of the natural gas obtained through separation processes and stored in the liquid phase under normal temperature and pressure conditions, according to the Brazilian Statistical Yearbook for Oil and Natural Gas ANP (2002b). However, the oil output consists of the production of crude, condensate and shale oil, which is obtained through processing bituminous shale[21] (Schaeffer et al., 2002). Around 65% of the proven oil reserves are located at Bacia de Campos, in Rio de Janeiro State, and almost 75% are located in deep and ultra-deep waters. Indeed, oil exploration and production in ultra-deep waters is a case of success for Brazilian oil engineering. Proven recoverable reserves of oil and gas are presented in Table 3.10 and Figure 3.9.

[18] Productivity gains along this entire chain have been considerable over the past few decades (Moreira et al., 1999). They reflect investments in technology and the absorption of expertise through learning by doing in the production chain, in addition to structured efforts fostering the production and consumption of renewable biomass on large scales.

[19] According to FAO (2002), Brazilian export crops such as soybeans and maize accounted for 21% and 24%, respectively, of the croplands producing primary foods in Brazil, from 1980 through to 2001. For soybeans, significant expansion was noted from 1980 to 2001, up from 17% to 27% of primary croplands.

[20] This indicator is related to the Indicator #37 of the ISED methodology. Data on Brazil's proven oil and natural gas reserves are based mainly on the Brazilian Statistical Yearbook on Oil and Natural Gas *(Anuário Estatístico Brasileiro do Petróleo e do Gás Natural)*, prepared by the National Petroleum Agency (ANP). The data on Brazil's proven coal reserves are taken from the National Energy Balance (BEN). In the case of oil, proven reserves in the Brazilian database are defined for a probability higher than 90% (or are P90 reserves).

[21] Bituminous shale: sedimentary rock, normally clayey, very rich in organic matter (cerogen). When subjected to high temperatures, bituminous shale releases oil, water and gas, leaving behind solid wastes that contain carbon ANP (2002a).

TABLE 3.10. PROVEN RECOVERABLE RESERVES OF OIL AND NATURAL GAS (1980 - 2002) – ISED #36

	1980	1985	1990	1995	2000	2002
				Oil		
Production (1,000 m^3/year)	10,562	31,710	36,590	40,216	71,844	84,434
Reserves (1,000 m^3)	209,540	344,694	715,516	989,385	1,345,746	1,560,158
Oil Res/Prod (years)	19.8	10.9	19.6	24.6	18.7	18.5
				Natural Gas		
Production (1,000 m^3/year)	2,205	5,467	6,279	7,955	13,283	15,568
Reserves (1,000 m^3)	52,544	92,734	172,018	207,964	220,999	236,592
Natural Gas Res/Prod (years)	23.8	17.0	27.4	26.1	16.6	15.2

Source: Based on MME (2001), ANP (2002a) and ANP (2002b).

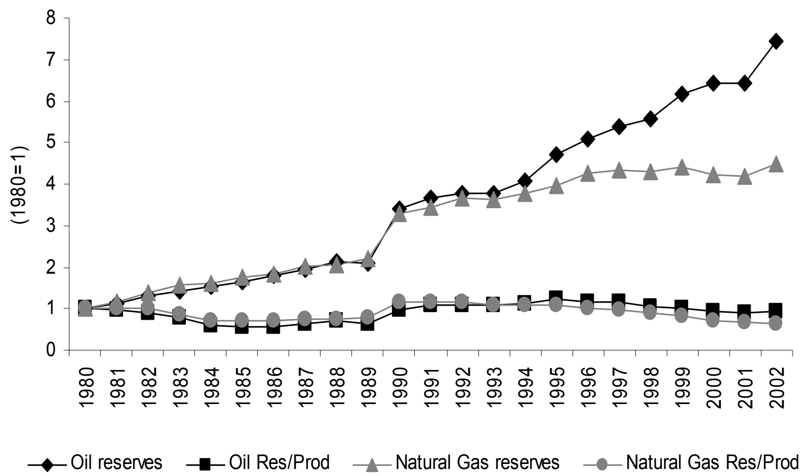

Figure 3.9. Proven recoverable reserves of oil and natural gas (1980 - 2002) – ISED #36
Source: Based on MME (2001), ANP (2002a) and ANP (2002b).

The Brazilian proven reserves of coal equal 32 billion tons and are located in the southern region of the country. Brazilian coal is characterized by its high ash content (average figure of 51%, and hovering between 48 and 54% ROM), low calorific value (hovering between 3,200 and 3,850 kcal/kg), and medium sulphur content (between 0.4 and 2.6%). It is predominantly sub-bituminous and is used mainly for heat generation in the industrial sector and power generation in the transformation sector.

3.2.2. Economic dimension

Economic development has different qualities (or different “development effectiveness”), which lead to different economic development paths. Some paths are more effective than others to create wealth and jobs, to promote well-being and social fairness, as well as to preserve natural resources and to protect the environment for future generations. Actually, quality does matter for economic development as much as for energy.

A common indicator to measure the relationship between energy use and economic development of a country through time is the country’s overall energy intensity. The overall energy intensity is the ratio between its total energy use and GDP.

This indicator will be discussed in Section 3.4, which presents the implementation of selected ISED indicators. Yet, it is worthwhile to discuss the evolution of GDP and sector shares in GDP, for manufacturing, agriculture, commercial & public services and transportation.

During the 1980s, the Brazilian economy grew at an average rate of only 1.6% per year and the income per capita growth was negative (-0.4% per year). After the second oil shock in 1979, followed by the financial indebtedness crisis after the 1982 Mexican Moratorium, Brazilian GDP decreased 2.9% in 1983 or 5.2% on a per capita basis. Moreover, after the oil price crises, Brazil had to reduce oil imports. On the demand side, the government introduced some incentives for consumers, mainly in the industrial and transportation sectors, aimed at replacing oil by other domestic sources, such as ethanol automotive fuel. It also reinforced the role of intermediate goods industries in the economy, by promoting electricity-intensive industrial sectors, which justified the undertaking of large-scale nuclear and hydropower projects.

In turn, during the 1990s GDP grew at an average rate of 2.7% per year, but this represented only 1.2% per year on a per capita basis. The most significant institutional reforms took place during this decade. After facing some political and economic instability, which provoked a severe contraction in 1990 (-4.4% growth rate) and stagnation in 1991 (1.0%) and 1992 (-0.5%), the economy bounced back during the 1993 to 1997 period, showing average growth rate of 4.0% p.a. Actually, the economy achieved unprecedented price stabilization after the introduction of an economic plan in 1994. Then, the Asian and Russian Crises, in 1997-98, adversely affected the Brazilian economy (GDP growth rates were 0.1% and 0.8%, in 1998 and 1999, respectively). After this turbulence, the GDP growth rate rose to 4.4% in 2000. Finally, in 2001 and 2002, the Brazilian economy was affected by an electricity supply crisis and growth slowed to 1.5% per year during this period.

Thus, Brazilian economic growth varied considerably during past decades. In general, the economic plans adopted during these decades largely focused on short-term policies, seeking to curb inflation and stabilize the economy.

Finally, it is important to note that the GDP reported is slightly underestimated owing to the share of underground activities in the Brazilian economy.[22] Available data do not allow the correction of this bias.

[22] At the end of the 1990s, this was equivalent to some 10% of Brazil's GDP (Szklo and Cunha, 2004).

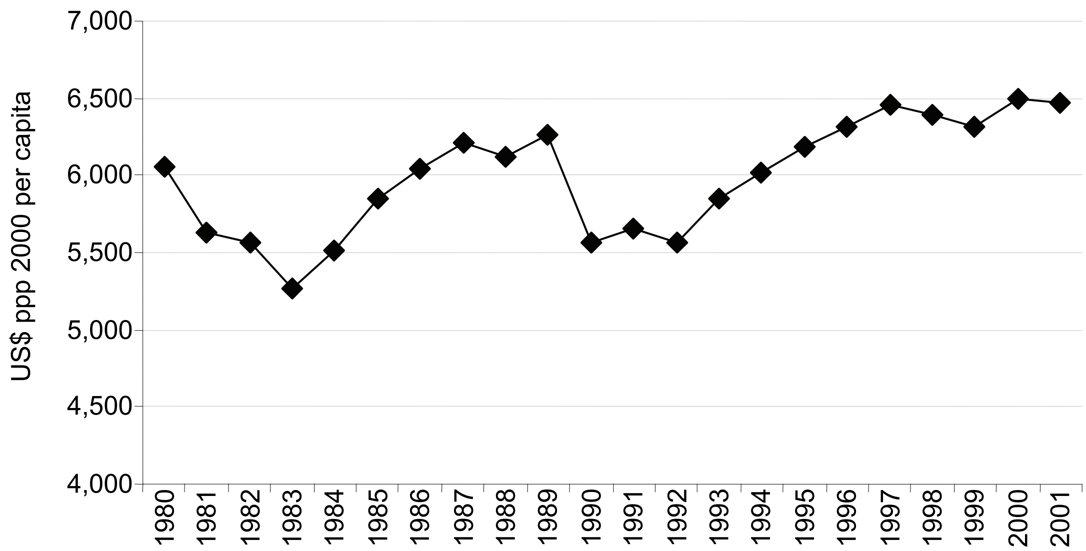

Figure 3.10. GDP per Capita - ISED #2
Source: Based on IBGE (2002), BCB (2002), IPEADATA(2002) and IEA (2000).

3.2.3. Social dimension

A major driving force affecting the country's energy system has been population growth and its concentration. Particularly significant was the growth in urban areas during the second half of the last century. Interestingly enough, eleven Brazilian states' capitals represented more than ¼ of the country's total population at the end of the 1990s (IBGE, 2003a), and in 2000 around 28% of the population was concentrated in cities with more than 500,000 inhabitants (ANEEL, 2002). Per capita GDP (ISED #2) is presented in Figure 3.10.

Given that the country has such marked and severe social disparities, estimates for the ratio between the poorest 20% and the richest 20% are also of interest.

Additionally, it should be stressed that the regional disparities in Brazil are not highlighted when using an average indicator such as those proposed here. For instance, in 1987, 1990, 1993 and 1996, the richest 20% absorbed 81% of the income of the economically active population of the Northeast, but this proportion dropped to 68% in Southeast Brazil over these same years. Consequently, a regional analysis of Brazil may well prove to have significantly different results and should be undertaken to complement this study.

Table 3.11 presents the findings for this indicator.

TABLE 3.11. RATIO OF AVERAGE INCOME PER CAPITA (20% POOREST TO 20% RICHEST) – ISED #19

Year	Ratio	Year	Ratio
1980	n.a.	1989	0.0290
1981	0.0412	1990	0.0319
1982	0.0385	1991	na
1983	0.0386	1992	0.0373
1984	0.0420	1993	0.0346
1985	0.0391	1994	n.a.
1986	0.0440	1995	0.0356
1987	0.0358	1996	0.0335
1988	0.0322	1997	0.0342

Source: Based on PNAD of IBGE (2002).
Notes: PNAD research was not conducted in 1980, 1991 and 1994. Does not include rural areas of the Northern Region. "n.a." means not available.

Therefore, given the income inequalities of the country, the social dimension of sustainable energy development is crucial for Brazil (see Table 3.12). This is even clearer, since regional disparities reinforce income inequalities. For instance, in 1999, although the Brazilian average Gini Index was 0.567, in Paraíba state the figure was 0.644, or around 30% higher than the figure of Santa Catarina State (IBGE, 2002).

TABLE 3.12. MAJOR SOCIAL INDICATORS[23]

Year	Line of Poverty (1)	Gini Index(2)	Income share of 10% richest (%)	Income share of 20% poorest (%)
1992	40.8	0.571	45.81	2.32
1993	41.7	0.600	48.58	2.24
1995	33.9	0.585	47.92	2.29
1996	33.5	0.580	47.59	2.15
1997	33.9	0.580	47.70	2.20
1998	32.8	0.575	47.92	2.25
1999	34.1	0.567	47.45	2.34

Source: IPEADATA 2003, IBGE, 2003a
Notes: (1) This level is defined as the percentage of people earning less than $2.0 per day, exchange rate values. There is no data for 2000. In 2001, the figure was 33.6%. (2) This is the degree of income concentration, considering the income distribution for all workers more than 10 years old; it varies between 0 (perfect equality) and 1 (maximum inequality).

3.2.4. Environmental Dimension

SO_2

Particularly for diesel oil, the Brazilian Government strove steadily to revive the quality specifications for this energy source. Particularly outstanding here is the Diesel Oil Upgrade Program. Table 3.13 shows specifications for sulphur content levels and and recent fuel quality.

For energy sources not based on oil and used in Brazil the following sulphur specifications are assumed (Shaeffer et al., 2001): (1) for Brazilian blended coal used at Candiota, Rio Grande do Sul State, sulfur content at 0.7% (High Heating Value (HHV) at 15 GJ/t) and for the Santa Catarina coal sulfur content at 2.0% (HHV at 19 GJ/t); (2) the most economic imported coal comes from Colombia at 6,000 kcal/kg, with a medium sulfur content level[24], (3) the average sulfur content level in the black-liquor consumed for thermal-power generation by the pulp and paper sector was obtained from Balestieri (1994), at 3.4 percent.

[23] Please note that the indicators presented in the table were not defined under the ISED Project but added by the Brazilian team to express social inequalities and complement the information presented in the ISED Indicator #19.

[24] A sulfur retention figure of 5% was assumed for the fly-ash, which varies from 5% (hard coal) to 30% (brown coal).

TABLE 3.13. SULPHUR CONTENT LEVELS SPECIFICATIONS – RECENT FUEL QUALITY SPECIFICATIONS

Fuel	Date	Sulphur level % w/w	Legislation Administrative Rule
Gasoline A	After 2001	0.12	ANP 309/2001
Gasoline C		0.10	
Gasoline Premium A		0.12	
Gasoline Premium C		0.10	
Regular Gasoline (added 24%±1%)	before de 2001	0.15	
Automotive Diesel A	before 1997	3.00	DNC 32/97
Automotive Diesel B		0.50	
Automotive Diesel C		0.30	
Automotive Diesel B	1998 to 2000	0.50	DNC 32/97
Automotive Diesel C		0.30	
Automotive Diesel D		0.20	
Automotive Diesel ("interior")	After 2001	0.35	ANP 310/2001
Automotive Diesel ("metropolitan")		0.20	
Jet-fuel	After 2000	0.30	ANP 137/2000
Fuel Oil B1	After 1999	1.00	ANP 80/1999
Fuel Oil A1		2.50	
Fuel Oil B2		1.00	
Fuel Oil A2		2.50	

Source: Schaeffer et al., 2002.
Note: The sulphur level standards presented here are based on more rigorous quality specifications for the fuels consumed in major cities.

Consequently, based on the information assumed and summarized here, it was possible to estimate the SO_2 emissions from Brazil's energy system. Table 3.14 and Figure 3.11 below summarize these findings.

TABLE 3.14. ANNUAL SO_2 EMISSIONS (KT) – ISED #23

Year	Total Energy Use	Electricity Generation	Transportation
1980	2,133	123	503
1985	2,125	151	530
1990	2,166	177	634
1995	2,824	288	763
2000	2,695	453	207

Sources: ANP Administrative Rules, and MME (2001), ABIQUIM (2002), ABIQUIM (2000), Schaeffer et al (2001) and Balestieri (1994).

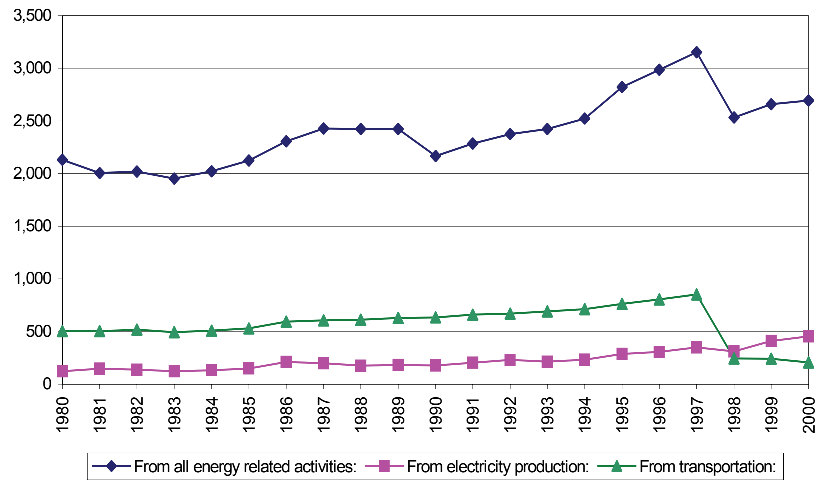

Figure 3.11. Annual SO_2 emissions (kt) – ISED #23
Sources: ANP Administrative Rules, and MME (2001), ABIQUIM (2002), ABIQUIM (2000), Schaeffer et al (2001) and Balestieri (1994).

NO_x

The estimated NO_x emissions are based almost completely on the methodology developed by Schechtman et al. (1998) for calculating the atmospheric emissions from Brazil's energy system. This methodology was applied to the Greenhouse Gases Emissions Inventory, using a bottom-up approach that is available through the website of the Ministry of Science and Technology (MCT, 2002). This also underpinned the development of an accounting model for estimating the emissions of atmospheric pollutants for 1990 through 1994, which is extended to cover an analysis period of 1980 through 2000 during the course of this project.

Nitrogen oxides – NO and NO_2 – are formed from both atmospheric nitrogen during the combustion process as well as the nitrogen found in the fuel. Consequently, the quantity issued depends mainly on the combustion temperature, the surplus air in the combustion chamber, the design of the burner in the furnace, and the fuel composition. These gases react to sunlight in the atmosphere, forming tropospheric ozone that is responsible for photochemical smog; however, it remains in the atmosphere for only a brief period. Using the Schechtman et al. (1998) methodology, almost all the NOx emission factors were obtained through the technology used by the energy-consumption sectors. Nevertheless, for the residential sector, although there was some consumption, there was no emission factor for the kerosene burned for lighting purposes. As fossil fuel use for lighting purposes is minimal and shrinking over time, the difference resulting from the exclusion of these emissions is also minor, and shrinking over time. Consequently, in principle it may be assumed that the total figures for the NO_x emissions by the sectors under analysis do not involve any significant errors owing to the non-inclusion of lighting kerosene. Another exception, for which no NO_x emission factor was found in Schechtman (1998), is the use of fuelwood by the transportation sector. However, once again this minimal use ended in 1991.

Table 3.15 and Figure 3.12 summarize the findings for the NO_x emissions by Brazil's energy system.

TABLE 3.15. ANNUAL NO_X EMISSIONS (KT) – ISED #23

Year	Total Energy Consumption	Electricity Generation	Transportation
1980	1,423	56	788
1985	1,489	67	840
1990	1,587	76	942
1995	1,895	112	1,168
2000	2,376	217	1,357

Source: Based on Schechtman (1998) and MME (2001)

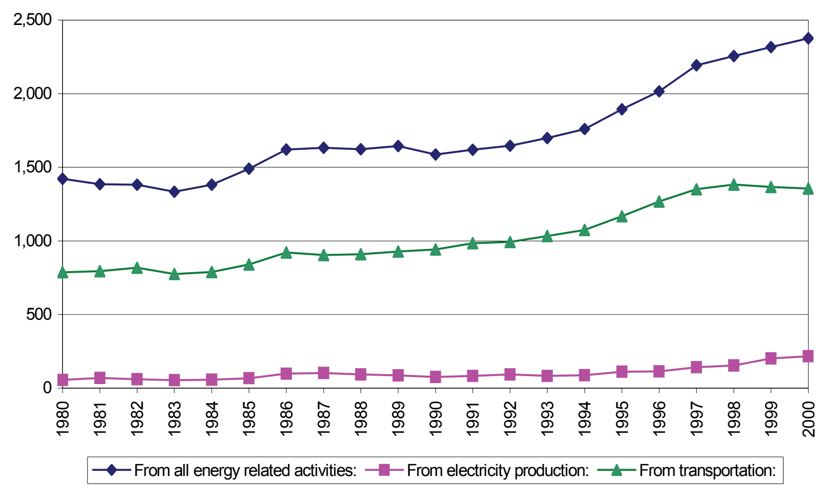

Figure 3.12. Annual NO_x emissions (kt) – ISED #23
Source: Based on Schechtman (1998) and MME (2001)

CO

The annual carbon monoxide emission estimates deriving from energy use in Brazil follow the same methodology used to estimate other atmospheric pollutants. Carbon monoxide results from incomplete combustion of the fuel and is a primary pollutant (formed at the source of the emission). The emission factors were established in Schechtman et al. (1998), according to the energy-consumption technologies in each sector under analysis. However, for the residential sector, although kerosene is consumed for the end-purpose of lighting, no CO emission factors were obtained for this end-use. This does not introduce any sizeable errors into the estimate, because this lighting kerosene use is minimal and shrinking. In fact, a similar line of thought may be followed for the use of fuelwood by the rail transportation sector, as no CO emission factors are available for this consumption, but it is quite low, and ended in 1990.

Table 3.16 and Figure 3.13 below summarize these findings for CO emissions by Brazil's energy system.

TABLE 3.16. ANNUAL CO EMISSIONS (KT) – ISED #23

Year	Total Energy Consumption	Electricity Generation	Transportation
1980	19,403	36	3,919
1985	17,138	59	3,735
1990	15,126	71	4,713
1995	15,181	101	6,323
2000	16,317	147	6,853

Source: Based on MME (2001) and Schechtman et al. (1998)

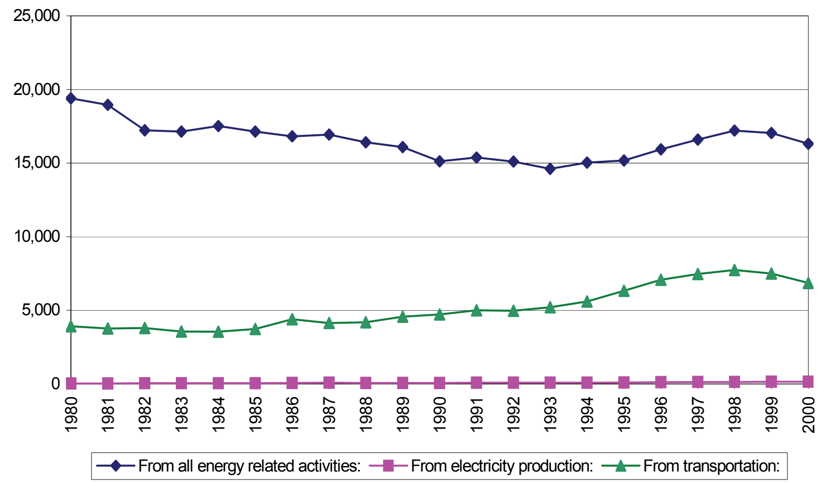

Figure 3.13. Annual CO emissions (kt) – ISED #23
Source: Based on MME (2001) and Schechtman et al. (1998)

GHG emissions

Similar to the previous calculations, estimates of greenhouse gases emissions are based on the methodology and accounting model developed by Schechtman et al. (1998) for the National Greenhouse Gases Emissions Inventory (1990-1994) (MCT, 2002), following a bottom-up approach[25]. However, in this study, it was decided to expand the calculation prepared by Schechtman et al. (1998) covering the Inventory period (1990-1994) to the period under analysis (1980-2000). Furthermore, even for the period covered by the previous inventory, the results of Schechtman et al. (1998) were reviewed, guided by more recent versions of the National Energy Balance (MME, 2001)[26]. This means that the findings obtained here do not necessarily correspond to the findings presented in MCT (2002), with slight deviations owing mainly to the review of the historical figures found in the last version of the National Energy Balance (MME, 2001).

The data provided by ABRACAVE (2002) were of the utmost importance here, covering the percentage of renewable fuelwood used to produce charcoal (see Table 3.17), and the analyses by Schechtman et al. (1996) and Aquino (1999) on fuelwood use in rural parts of Brazil. Consequently, based on these analyses, it was possible to estimate carbon emissions by non-renewable biomass consumed for energy purposes and consequently to total up CO_2 emissions by the Brazilian energy system (deriving from the use of fossil fuels and non-renewable biomass)[27].

[25] These are precisely the findings of this study, available in Brazil's National Greenhouse Gases Communiqué through the website of the Ministry of Science and Technology.

[26] Schechtman et al. (1998) used the National Energy Balance for the 1997 base year (MME, 1998).

[27] According to the analysis, the share held by renewable fuelwood in total fuelwood consumption in Brazil rose from 36% in 1980 to 58% in 2000.

TABLE 3.17. SHARE OF NON-RENEWABLE FIREWOOD CONSUMED FOR CHARCOAL PRODUCTION

Year	%	Year	%
1980	85.9	1990	66.0
1981	81.0	1991	57.7
1982	80.0	1992	61.1
1983	81.8	1993	56.5
1984	83.1	1994	46.0
1985	82.6	1995	48.0
1986	82.7	1996	30.0
1987	80.7	1997	24.6
1988	78.0	1998	32.6
1989	71.2	1999	30.0
		2000	28.4

Source: ABRACAVE(2002)

The emissions of CH_4 (methane) and N_2O (nitrous oxide) were based on conversions of CO_2 equivalent using the 100-year global warming potentials (GWPs) according to the methodology proposed in IPCC (2001), where the methane mass conversion to carbon dioxide equivalent is 23, while for nitrous oxide, this figure reaches 296. Moreover, for these two greenhouse gases, it should be borne in mind that methane emissions depend on both the consumption equipment as well as the fuel. For this hydrocarbon, Schechtman et al. (1998) obtained almost all the emission factors for the consumption technologies used in Brazil, other than (1) LPG emission factors for industrial boilers or boilers installed in tertiary sector enterprises; (2) emission factors for natural gas and city gas consumed in the household sector of Rio de Janeiro and São Paulo (cooking, for instance); (3) the emission factor for lighting kerosene in the household sector; and (4) the emission factors for sugarcane bagasse and other vegetable residues consumed by industrial boilers. Consequently, the findings of this study − based on Schechtman et al. (1998) − are approximate in terms of the average emission factors, and do not include some types of energy use owing to the lack of emission factors. In addition to bringing the total CH_4 emissions estimate down to the lower limit for the total emissions of this pollutant, this stresses the need for a fresh data survey of atmospheric emissions by energy use technologies in Brazil to obtain more complete estimates of the atmospheric pollutants directly related to use technologies, such as CH_4.

Nitrous oxide is one of the greenhouse gases that remain longest in the atmosphere. However, its main source of emission is not burning fuel but rather fugitive emissions from agricultural activities. Consequently, in contrast to what takes place with other atmospheric pollutants analysed here, with this pollutant Schechtman et al. (1998) did not obtain many emission factors for the technologies and equipment used by the energy consumption sectors, demonstrating the need to fine-tune this study through obtaining these emission factors. In objective terms, the N_2O emission factors were obtained in Schechtman et al. (1998) for the following sources: (1) in the industrial sector: fuel oil, diesel oil, kerosene, other secondary oil-based sources, coal, charcoal, petroleum coke and tar; (2) in the commercial and public sectors: fuel oil, diesel oil, natural gas, piped gas, other secondary petroleum and fuelwood sources; (3) in the residential sector: diesel oil, fuel oil, other secondary oil-based sources; (4) in the agricultural sector: fuel oil, diesel oil, fuelwood and charcoal; (5) in the transportation sector: natural gas, diesel oil, gasoline, steam coal, fuel oil, aviation gasoline and aviation kerosene; (6) and finally, for thermal-power generation: diesel oil, fuel oil, tar, petroleum coke and steam coal, consumed to generate high-pressure steam. Consequently, by excluding a considerable portion of the emissions deriving from fossil fuels in these calculations, the N_2O findings presented here are underestimated, calculated almost entirely for use of fossil fuels for Heat Processing purposes, and the transportation sector. In other words, the total findings should be interpreted as the lower limits for N_2O emissions deriving from energy use in Brazil.

Consequently, it is quite clear that there are some significant gaps in the database available for establishing the methane and nitrous oxide emission factors by the energy use technologies available in Brazil. This underscores the need to improve the only broad-ranging database currently available. Notwithstanding, and even though the findings for the emissions of greenhouse gases are underestimated here (which is not the case with the CO_2 emission estimates, for instance), it should be noted that nitrous oxide has a greenhouse effect that is of much significance for emissions deriving from agricultural activities, while only minor

quantities are emitted by the energy sector; and second, there are some (non-major) energy use categories for which no methane emission factors were obtained. Taking these comments into account, Table 3.18 summarizes the findings for the annual greenhouse gases emissions.

TABLE 3.18. ANNUAL GHG EMISSIONS RELATED TO BRAZIL'S ENERGY SYSTEM (MT CO_2 EQ) – ISED #26

Year	CO_2	CH_4 (1)	N_2O (2)	Total GHG
1980	263.6	2.0	0.4	266.0
1985	269.5	2.5	0.3	272.3
1990	273.9	2.6	0.3	276.9
1995	288.4	2.8	0.5	291.7
2000	334.5	2.5	0.6	337.6

Notes: (1) Methane emissions are slightly underestimated owing to the lack of emission factors for some non-major types of energy use. (2) The non-inclusion of a considerable portion of emissions deriving from fossil fuels means that the N_2O findings presented here are underestimated, calculated almost completely for fossil fuel use under the Process Heat heading and for the transportation sector.
Source: Based on MME (2001), Schechtman et al. (1998), ABRACAVE (2002), Aquino (1999), Schechtman et al. (1996), IPCC (2001).

3.3. Review of the Energy Statistical Data Capability

3.3.1. Brazil's Energy Database Review[28]

There are two key databases for the preparation of sustainable energy development indicators in Brazil:

One is run by the Brazilian Institute of Geography and Statistics (IBGE - Instituto Brasileiro de Geografia e Estatística) / www.ibge.gov.br, which is the main provider of data and information on Brazil, with the following functions:

- Collection and analysis of statistical information;
- Coordination and consolidation of statistical information;
- Production and analysis of geographical information;
- Structuring and implementing an environmental information system;
- Documentation and dissemination of information;
- Coordination of national statistical and geographical systems.

Based on these activities, the IBGE produces and makes available to the public:

- Social and Demographic Statistics: These are based largely on data collected from households. Outstanding among them are: the Demographic Census, which is undertaken every ten years and forms the core of Brazil's social and demographic statistics; the Headcount, which is carried out between demographic censuses to fine-tune the annual population estimates; the National Household Sampling Survey (PNAD - Pesquisa Nacional por Amostra de Domicílios) which is an annual survey of information on housing, income and the labor-force, as well as some demographic characteristics obtained through sampling Brazilian households; and the Family Budget Survey (POF - Pesquisa de Orçamentos Familiares) which is carried out every five years, offering more detailed information on the structure of family incomes and expenditures. Finally, surveys such as the Medical and Sanitary Assistance Survey (Pesquisa de Assistência Médico-Sanitária) and the National Basic Sanitation Survey (Pesquisa Nacional de Saneamento Básico) provide information on the basic infrastructure services rendered to the Brazilian residential sector.

[28] This section is based on the first-year progress report of the ISED project (Schaeffer et al., 2002).

- Agricultural Statistics: These are based on the agricultural census that surveys farming and ranching establishments, providing information on the land-owning arrangements (land ownership and use); the labour-force occupancy profile; and the technological levels absorbed by the production process. The latest version of this census covers 1995-1996. For annual information on this sector, the Municipal Agricultural Survey (Pesquisa Agrícola Municipal) is particularly helpful.
- Economic Statistics: Information on major economic sectors based on sampling surveys for establishments in each sector: Annual Trade Survey (Pesquisa Anual do Comércio); Annual Industrial Survey (Pesquisa Industrial Anual); Annual Construction Industry Survey (Pesquisa Anual da Indústria de Construção); and Annual Services Survey (Pesquisa Anual de Serviços).
- Price Indices: Produced systematically through an ongoing process, the Consumer Price Indices allow monthly monitoring of the prices of the main products and services consumed by the population.
- National Accounts System: This database offers an overview of the Brazilian economy as a whole, following the latest recommendations issued by the United Nations in its System of National Accounts (SNA) 1993, including the calculation of the Gross Domestic Product and the Input-Output Mix.
- Geographical Information, Geographical Mapping and Charting the Natural Resources in the Environment: This information is constantly updated, available through the IBGE website.

The second key database is the National Energy Balance. This is the only source of energy data in Brazil covering all energy supply, transformation and consumption sectors. In itself, this justifies the logic of assigning high importance to the National Energy Balance (BEN - Balanço Energético Nacional), turning to other specific sources of energy-based data only when this National Energy Balance does not provide reliable information. Elaborated annually by the Ministry of Mines and Energy (MME) since 1974, it has used the same methodology since 1981, presenting the energy flows for primary and secondary energy sources from production through to final consumption in the main economic sectors. Each year, the data for the previous year are included, with the data for the two years prior to the base year of the National Energy Balance being reviewed. In principle no alterations to the data for earlier years takes place. This Balance covers many different economic sectors, such as: the energy sector itself, residential, commercial, public, agricultural, transportation and industry. In turn, the transportation sector is broken down into: road, rail, air and water, while the industrial sector is broken down into: cement, pig-iron and steel, ferroalloys, mining and pelletizing, non-ferrous metals, chemicals, food and beverages, textiles, pulp and paper, ceramics and other industries. Finally, this publication is divided into nine chapters:

- Summary of fifteen-year historical series. This offers a synopsis of the energy data for the base year and the consolidated energy, production, consumption and foreign dependence figures. It also offers a breakdown of sectoral consumption by different groups of energy feedstock.
- Energy supply and demand by source for the fifteen-year series retrospective to the base year. For each primary and secondary energy source, it presents the production, import and export accounts, in addition to stock variations, losses, adjustments and total consumption, the latter broken down by economic sector.
- Energy use by sector for the fifteen-year series retrospective to the base year, presenting the final energy use for each economic sector, broken down by each primary and/or secondary source.
- Foreign trade in energy for the fifteen-year series retrospective to the base year, presenting the energy imports, exports and foreign dependency figures.
- Energy transformation units balance for the fifteen-year series retrospective to the base year, presenting the balances for the energy transformation units and showing their energy input and output with their respective processing losses.
- Energy resources and reserves since 1972. This presents the resources and reserves for the primary energy sources and their respective calculation methodologies.
- Energy and socio-economic factors. This presents the energy, economic and population indicators – specific consumption, energy/GDP ratios, outlays on foreign exchange earnings, energy source

prices, etc. In this case, some information made available through the Balance is similar to those provided by the IBGE. However, as the National Energy Balance does not always use the same methodology as IBGE for sectoral breakdowns, and as the constant currency data in the Balance does not indicate the deflation methodology used, it was considered that sources of information on monetary data other than the National Energy Balance would be more appropriate for this study.

- State energy information for the fifteen-year series retrospective to the base year, presenting partial information on State and regional energy balances and energy/population ratios.
- An appendix presenting the following information: Brazil's installed power generation and refining capacities; the concept behind the Balance methodology; the data source institutions for the Balance; and the Consolidated Energy Balances from 1974 onwards[29].

These two databases are used in this study on a preferential basis, as they are the broadest-ranging and consequently offer the largest amount of compatible data in terms of collection periods and activity classification. In other words, these two databases are used in this study unless other sources of information can bridge certain gaps, or if the information in either of these two databases seems less reliable than data from some other source for a specific reason [30]. It should also be recalled that both the National Energy Balance and the publications issued by the IBGE underpin much of the data collected from sectoral sources such as industrial producer associations, business associations for tertiary sector segments, town councils, energy enterprises, power regulators, etc. As these sectoral data sources frequently do not work with the same data classification as the two broader-ranging sources that are preferably used here, their selection for subsequent aggregation at the national scale should be handled with care[31].

Ancillary data sources for the type of study undertaken here are:

- IPEADATA: This is a database available over the Internet from www.ipeadata.gov.br, organized by the Institute for Applied Economic Research (IPEA – Instituto de Pesquisa Econômica Aplicada) that contains information on 1,900 annual series and 2,600 monthly series on the balance of payments, foreign trade, consumption and sales, national accounts, international economics, employment, public finance, social indicators, interest rates, currency and credit, population, prices, production, wages and income[32].
- Banco Central do Brasil (BCB): www.bacen.gov.br
- National Petroleum Agency (ANP): This Regulator provides information and documents for download, mainly through its website (www.anp.gov.br) in addition to its Statistical Yearbook.
- Petrobras: The Brazilian oil enterprise provides information, mainly through its website (www.petrobras.com.br).
- National Electricity Agency (ANEEL): This Regulator makes information available through its website (www.aneel.gov.br), with a database that is constantly updated for installed power generation capacity, electricity prices and power sector regulations. It also has historical series providing information on the power sector for periods after 1995.
- Eletrobrás: The website of the holding company of Brazil's power sector (www.eletrobras.gov.br) provides information on the power sector and also offers documents for download that range from technical analyses of market development and the power generation segment to information on rates and regulations (SIESE).

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[29] These are the annual matrices that consolidate all energy flows from the various primary and secondary sources.

[30] This is not the case with the IBGE (2002) data in general, although it does apply to some information in the National Energy Balance (MME, 2001).

[31] Although the National Energy Balance (MME, 2001) may be taken as summarizing Brazil's energy data, other sources of primary and secondary energy data are available, using different methodologies to obtain and process this information. For instance, industrial associations and power consumer groups produce these data, which are not always classified in the same way as in the National Energy Balance. Moreover, with the deregulation of Brazil's energy sector, more knowledge is needed about the databases set up by the private sector in terms of their regularity, availability and trustworthiness.

[32] Much of this information comes from primary sources, particularly the IBGE.

- Ministry of Science and Technology: This Ministry provides documents for download at its website (www.mct.gov.br) related specifically to the Brazilian National Inventory on Greenhouse Gas Emissions.
- Ministry of Mines and Energy: The website of this Ministry (www.mme.gov.br) offers the latest version of the National Energy Balance for download, in addition to documents linked to the websites of Government programs in Brazil's energy sector such as the Light in the Countryside Program (Programa Luz no Campo) and the State and Municipal Energy Development Program (Programa de Desenvolvimento Energético de Estados e Municípios).
- ANFAVEA (www.anfavea.com.br), ANTP (www.antp.org.br) and GEIPOT (www.geipot.gov.br): these three databases cover the transportation sector:
- The first is provided by the National Association of Automotive Vehicle Manufacturers (ANFAVEA – Associação Nacional dos Fabricantes de Veículos Automotores), which is an entity bringing together the manufacturers of automotive vehicles and agricultural machinery. Its website provides information on the automobile industry, the domestic market, and exports by Brazil.
- The second is the website of the National Public Transportation Association (ANTP – Associação Nacional de Transportes Públicos), whose website provides information drawn from statistical yearbooks dating back to the 1990s on passenger-kilometers, distances traveled, and urban bus fleets in major Brazilian cities.
- The third is the Brazilian Transportation Planning Enterprise (GEIPOT – Empresa Brasileira de Planejamento de Transportes) whose website provides information broken down by mode of transportation through the Transportation Statistical Yearbook.
- ABRACAVE (www.abracave.com.br): The website of the Brazilian Renewable Forests Association (Associação Brasileira de Florestas Renováveis) provides information on renewable biomass, particularly the production and consumption of charcoal made from renewable sources (planted forests).
- INPE (www.grid.inpe.br): The website of the National Space Research Institute (Instituto Nacional de Pesquisas Espaciais) provides information on deforestation, bio-diversity and satellite images of Brazil.
- EMBRAPA (www.embrapa.br): The Brazilian Agricultural Research Enterprise (Empresa Brasileira de Pesquisa Agropecuária) provides agricultural information through its website.
- The Brazilian Central Bank and Getúlio Vargas Foundation (FGV): these two databases provide financial and economic information through their websites (www.bcb.gov.br, and www.fgv.br).
- Energy Consumer Enterprise Association Yearbooks: Particularly ABIQUIM (Chemical Industry), ABAL (Aluminum), IBS (Steel), ABRASCE (Malls), ABRACE (Major Industrial Power Consumers).
- International Databases, particularly the United Nations Food and Agriculture Organization – FAO (apps.fao.org), the Energy Information Administration – EIA (www.eia.doe.gov), the International Energy Agency – IEA (www.iea.org) and the World Bank (www.worldbank.org).

Another important aspect concerning the database sources used in this study is related to the economic information found in the National Energy Balance, as well as the IBGE Statistical Yearbook, providing aggregate energy data. In this case, this study considered it more appropriate to tap the IBGE for economic information and the National Energy Balance for energy data, regardless of any possible intersections between these two main databases.

3.3.2. Building Database Capacity

As a summary, it is possible to say that Brazil's energy and economic data are reasonably adequate but should be improved. Firstly, as clearly identified in the first-year ISED report, it is particularly noteworthy that the Ministry of Mines and Energy − which is responsible for the National Energy Balance − implements a joint project with the IBGE aiming to harmonize this Balance with Brazil's National Accounts System. This also means that the IBGE should break down relevant energy products and services in the National Account System. For instance, in this database, Electricity, Water & Sewage, Gas Production & Distribution are grouped under Public Utilities Industrial Services (SIUP – Serviços Industriais de Utilidade Pública), while Fuelwood & Charcoal and Other Agricultural Products are grouped under Other Agricultural Products. At least, in the short-term, the IBGE should regularly disclose the weighting factors that allow these products and activities to be disaggregated.

Secondly, some coordination and better classification should be done to make different data sources compatible, especially the National Energy Balance and Yearbooks of Industrial Associations and Regulatory Agency. Particularly important is the fact that these data sources do not provide the methodology of their data compilation or acquisition, the validity of the database, and some important characteristics such as period of analysis and collection, and economic activity classification. Furthermore, the distinction of independent power producers and self-generators that eventually export surplus power, and the differences between self-consumption and energy transformation or commercialization are not clear in all sources, undermining the direct use of them.

Thirdly, some important information is missing in the Brazilian database. The information regarding power tariffs (with and without taxes) is not clear and lacks sufficient data. Information concerning investments is dispersed and not reliable. The transportation sector database lacks important information. Most of the official data on the transportation sector in Brazil is provided by the Brazilian Office for Transportation Planning – GEIPOT (a body of the Ministry of Transportation) in the Statistical Yearbook of Transportation [15][33]. These include data addressing the distance travelled by passengers, freight transport activity and fleets. Actually, like the Brazilian Ministry of Energy and Mines, GEIPOT itself does not perform primary data surveys to prepare its Statistical Yearbook. Instead, GEIPOT consolidates surveys performed by other institutions (both governmental and private). However, total passenger activity figures and, as a consequence, the indicators derived were underestimated in our study, since passenger activity by aquatic mode of transportation is not included in most of the years of GEIPOT statistics. Also, GEIPOT statistics do not included passenger activity by rail mode of transportation for the year 2000 either (not reported to GEIPOT yet). Additional efforts should be made in the future to correct those biases[34].

Furthermore, GEIPOT statistics for urban public transport contains only data on urban trains and trolleys, missing the lion's share of the urban public transport. To avoid misinterpretation, this indicator was not reported in this study. However, on behalf of sound transport planning and policies, it would be very important for Brazil to improve the basic information data on transportation, overcoming the weaknesses and limitations of the current approach (which is technically possible, but dependent on political and financial resource allocation priorities).

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[33] It is important to point out that, as part of the Brazilian State reform, GEIPOT will be eliminated (Decree # 4.135, Feb/20/2002) and its duties and responsibilities will be assumed by the new regulatory agencies for the transportation sector. However, it is not clear so far whether or not the Statistical Yearbook of Transportation will continue to be published (it could be published by the Ministry of Transportation; just as the Brazilian National Energy Balance which is published by the Ministry of Energy and Mines).

[34] Part of the problem seems to be related to the recent changes in the transport regulation in Brazil. On one hand, some state-owned transportation companies were privatized and stopped providing basic information on their activities (which might be temporary). On the other hand, changes associated with the state reform in Brazil (progressive replacement of GEIPOT by regulatory agencies) seemed to affect the ability of GEIPOT in requesting and organizing the primary data on transportation. It is expected that when this transitional period is over the relevant government bodies will recover their capacity for providing basic information on transportation.

In addition, the fleet database, which constitutes one of the major items of information for the Brazilian energy system, is not reliable since it can be based on different sources with very distinct information.[35] The use of hydrated ethanol depends on the ethanol-fuelled fleet. Among other reasons, this explains why the description of the country's light vehicles fleet is so important. The GEIPOT Statistical Yearbook of Transportation can be considered as the official source for fleet data.[36] However, according to the technical staff of Petrobras (the Brazilian National Oil Company), such a methodology overestimates the fleet by adopting a very conservative depreciation rate and by double-counting vehicles by waiting three years to deduct interstate transfers. After 1984, the latter problem seems to have been solved by checking double counting based on license plate and chassis numbers. Even so, according to Mattos et al (1996), GEIPOT fleet data are still overestimated. According to the alternative methodology to estimate the fleet proposed by Mattos et al (1996): first, the annual vehicles sales informed by ANFAVEA (time series: 1957-2001) are accumulated; then, based on probabilistic reliability theory, the vehicle depreciation curve of Brazil is derived; and, finally, the vehicles assumed to be depreciated out of total vehicle sales stock are deducted.

Fourthly, Brazil' s database lacks reliable information on renewable biomass. This study was based on academic works and the project team's experience regarding this issue, but reliable information on fuelwood gathering and planted forests is still a major issue. Moreover, the fuelwood use estimates in Brazil are also subject to several uncertainties.

Finally, the industrial energy use database is not as comprehensive as it should be. It has no reliable and recent energy data on equipment or useful energy levels that would help in specifying energy efficiency potentials and in assessing pollutant emissions. An equipment inventory would be very helpful in this sense. It does not provide the quality of energy used by the industry. Since this sector is responsible for the majority of the heat demand in Brazil, it will be very useful to have information concerning the quality of this heat. This kind of information is the basis for an integrated energy plan for the Brazilian industrial sector.

As a last comment, it should be stressed that the new context for Brazil's energy sector requires a study of the mechanisms for obtaining information from private companies. Actually, the transition from a model based on State-run enterprises to private utilities has endowed these data with strategic characteristics. Initially, the flawed definition of "strategic information" and the failure to establish protection mechanisms for this "strategic information" may well hobble its regulation and hamper the crucial task of planning for Brazil's energy sector.

Regarding the ISED database, the Brazilian team identified these major issues: (1) the ISED set does not consider the use of ethanol as an automotive fuel, besides its importance to Brazil's energy mix. An important indicator that could be considered is the ethanol final price, since this automotive fuel might compete with gasoline, provided that new cars fuelled by ethanol are produced in Brazil. In this sense, the fleet database could be used as a first proxy of the transportation sector when more detailed data are not available; (2) the ISED set does not include an indicator for the use of charcoal in the reduction process of Brazil's iron and steel industry; (3) the ISED set is not totally appropriate for determining the potential use of alternative sources in countries like Brazil, especially biomass-based power generation and wind power generation; and (4) the ISED set is not very useful for identifying regional and even social disparities. These are major issues for the Brazilian case.

Therefore, following the methodology developed under the ISED project, this study adopted a set of additional indicators to better reflect Brazil's energy sector specificities – for instance, the importance of hydroelectricity for power generation, the large use of ethanol as automotive fuel, the relevant remaining potential for using sugar-cane bagasse fired-cogeneration and wind-power, and the significant use of LPG in the household sector. These additional indicators were used for analysing the Brazilian energy system in Section 3.2, and for assessing energy policies according to the main priority areas defined in Section 3.4.

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[35] In the first-year report, we added the indicator "Fleet (light vehicles - road) (millions)" as an additional indicator to emphasize the importance of the Brazilian ethanol fuel program in the 1970-1980s.

[36] Such data are obtained by deducting vehicles assumed to be depreciated out of the total road motor vehicles registered in each State Transit Departments of Brazil (DETRANs), which are consolidated by a National Transit Department (DENATRAN). The criterion used to estimate the vehicle depreciation is the simultaneous occurrence of two events: no records of annual payment of the vehicle ownership tax (IPVA) and of fines for three subsequent years.

However, new indicators could be developed especially for assessing regional features of the Brazilian energy system.

3.4. Identification of Major Priority Areas

To fulfil the requirements of the ISED project, this report has identified two main priority areas of Sustainable Energy Development for Brazil, which are summarized below.

3.4.1. Diversifying the energy mix, while promoting sustainable development

Regarding the supply side, the identified priority area is to diversify the energy mix, while promoting sustainable development, mainly by increasing the use of renewable energy resources.

Diversifying energy supply would reduce the risk of power shortages or price shocks in the future. It also implies a more suitable utilization of Brazilian energy resources, to emphasise the expansion based on indigenous sources and domestically-developed technologies. Within this context, Brazil has plentiful renewable energy resources including hydro, wind, solar, and bioenergy resources. Expanding renewable energy utilization could help to diversify energy supplies, stimulate new industries, create jobs, and contribute to economic and social development of poorer rural regions of Brazil.

Another major consequence of such renewable-based energy supply expansion policy is the potential reduction of energy imports. Energy imports are mainly in the form of petroleum and petroleum by-products, but electricity and natural gas imports are up as well.

Finally, to some extent, these new energy supplies are also making feasible the reduction of some adverse environmental impacts, as is the case of existing ethanol production compared with high-impact oil drilling and refining. The same comparison can be done in the case of small-scale hydro power plants and bagasse cogeneration units, compared with high-environmental-impact large hydropower dams.

3.4.2. Promoting energy efficiency, whilst reducing regional energy use disparities and improving energy affordability

Regarding the demand side, the major priority area includes the promotion of energy efficiency, whilst reducing regional energy use disparities and improving energy affordability.

Within this context, it is of utmost importance to emphasize that enhancing the efficiency of energy use in Brazil is extremely cost-effective. For instance, a recent survey of electricity conservation measures implemented by distribution utilities shows an average of some US$ 20-30 per MWh saved by the project (Schaeffer et al., 2001). In contrast, during the first six months of 2002 the average residential tariff in Brazil was US$ 80/MWh and the average industrial tariff was US$ 36/MWh (ANEEL, 2002). Furthermore, the current marginal cost of supplying electricity from different power generation technologies varies from US$ 20/MWh for some hydroelectric power plants to US$ 40/MWh for natural gas-fired thermal power plants, which are the preferred choices for expanding the Brazilian power sector. This shows that saving electricity is cheaper than supplying it, with a wide range of benefits that include fewer possibilities of power shortages, a keener competitive edge for Brazilian industries and products on global markets, and the fact that conserving electricity has far more favourable environmental and social impacts than supplying it.

In addition, as pointed out by Szklo and Geller (2005), Brazil has had some success with increasing the efficiency of energy use. But many industries, businesses, and households still waste energy because of inefficient industrial processes, out-dated equipment, vehicles, and buildings. For example, motors used in Brazil are inefficient by international standards as well as oversized and poorly operated in many cases (Geller et al. 1998); in the residential sector, using more efficient appliances could cut electricity use by nearly 30 percent (Almeida et al., 2001); and heat integration in the chemical sector could achieve 5 to 15 % of fuel savings (Tolmasquim et al., 2003).

Increasing the efficiency of energy use would save consumers income, reduce the cost of the Brazilian enterprises and reduce the risk of new energy shortages. However, as important as these, a lower energy

intensive economy would release the pressure on the government's budget related to infrastructure. This particular feature is key to implementing large-scale effective social policies, which compete with other items of the Government's budget for limited funds.[37]

Finally, by promoting energy efficiency, Brazil should also be able to improve the standard of living of the poorest portion of the country's population, which has far from acceptable minimal energy use levels. Currently, about 5 percent of all households in Brazil do not have access to electricity service. Some low-income households earning less than $150 per month still rely on wood as a major energy source. Increasing access to and use of modern energy sources by all households would reduce social and regional inequality, and create jobs and job opportunities in underdeveloped rural areas.

3.5. Implementation of ISED Framework

3.5.1. Initial Comments

Following the methodology developed under the ISED Project, this study adopted a set of indicators that are related to its main concerns. In this set, a few additional indicators were developed to match more adequately Brazil's energy sector specificities – for instance, the importance of hydroelectricity for power generation, the large use of ethanol as an automotive fuel[38], the relevant remaining potential for using sugar-cane bagasse fired-cogeneration and wind-power, and the huge use of LPG in the household sector.

Table 3.19 and Figure 3.14 present the total set of indicators adopted. Given the purpose of this study, a number of additional comments regarding the importance of additional indicators are warranted, as follows:

The ISED set does not explicitly address the use of ethanol as an automotive fuel. One important indicator is ethanol's final price, since this automotive fuel might compete with gasoline. In this sense, the fleet database might be used as a first proxy of the transportation sector. The ISED set does not cover the specific use of charcoal in the reduction process of the iron and steel industry. The ISED is very conservative about the potential use of alternative sources in countries like Brazil, especially biomass-based power generation and wind power generation.

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[37] Investments in the energy sector averaged about 9 percent of total capital investments in Brazil during the 1990s. Much of the investment in energy supply is now provided by the private sector or by profitable state-owned (or partially state-owned) companies such as the national petroleum company, PETROBRAS. However, a significant portion of the investment comes from the public sector.

[38] Ethanol is used mainly as an additive for gasoline (26% in volume), i.e. anhydrous ethanol at 99.6 GL and 0.4% water, mainly for local environmental reasons. The other alternative is the use of hydrated ethanol (95.5 GL) in engines solely fuelled by ethanol or in flex-fuel cars.

TABLE 3.19. INDICATORS SET

Dimension	ISED set	Additional Indicators(3)
Economic		
Indirect Driving Force	1. Population (1.1, 1.2.)	3.1.4. End-use energy price for gasohol
	2. GDP per capita (2.1, 2.2)	3.1.5. End-use energy price for ethanol
	3. End-use energy prices (3.1 to 3.3)(1)	3.3.8. End-use energy price for city gas
	4. Shares of sectors in GDP value added (4.1 to 4.4)	11.1.8. Final Energy Mix. Combustible Non-renewable biomass (non-renewable firewood and charcoal)
	5. Distance travelled per capita by passengers (5.1 to 5.3)	11.3.9. TPES: Combustible Non-renewable biomass (non-renewable firewood and charcoal)
	6. Freight transport activity (6.1 to 6.5)	11.4. Anhydrous Ethanol Added to Gasoline.
	8. Manufacturing value added by selected energy intensive industries (8.1 to 8.6)	11.5. Fleet of cars (ethanol, gasoline, diesel)
	9. Energy intensities (9.1, 9.2.) (2)	
	10. Final energy intensity of production (10.1 to 10.7)	
	11. Energy mix (11.1 to 11.3)	
	12. Energy supply efficiency (12.1 to 12.6)	
Direct Driving Force	14. Energy per unit of GDP (14.1 to 14.3)	
	15. Expenditures on energy use (15.1, 15.3, 15.4)	
State	16. Energy consumption per capita (16.1 to 16.4)	
	17. Indigenous energy production (17.1 to 17. 2)	
	18. Energy net import dependency (18.1 18.6)	
Social		
Indirect Driving Force	19. Ratio of average disposable income/private consumption per capita to that of 20% poorest of population (19)	
	20. Ratio of daily disposable income of poorest 20% household to energy prices (20.1 to 20.3))	
Direct Driving Force	21. Fraction of disposable income/private consumption per capita spent on fuel and electricity (21.1 to 21.2)	
State	22. Fraction of households (22.1 to 22.2)	

Environmental		
Indirect Driving Force	--------------------------------------	
Direct Driving Force	23. Quantities of air pollution emissions (23. 1 to 23.3). 26. Quantities of GHG emission (26.1 to 26.5). 35. Fraction of technically exploitable capability of hydropower currently not in use (35) 36. Proven recoverable fossil fuel reserves (36.1 to 36.3)	35.2 Fraction of technically exploitable capability of windpower currently not in use 35.3. Share of agricultural area currently used by CRW 35.4 Share of potential agricultural area used by CRW 35.5 Technical Potential for Hydropower 35.6 Technical Potential for Windpower
State	37. Lifetime of proven recoverable fossil fuel reserves (37.1 to 37.3) 40. Intensity of use of forest resources as fuelwood. (40) 41. Rate of deforestation (41)	

Notes: (1) Indicators 3.1.1, 3.1.2, 3.2.2., 3.3.2, 3.3.4, and 3.3.5 for the end-use energy prices were not considered given Brazilian specificities – for instance, the irrelevant demand for space heating in the household sector. (2) The indicator 9.1.5 was not considered since Brazil's yearly demand for space heating is almost zero. (3) These additional indicators are related to Brazil's energy system specificities not comprised in the ISED set.

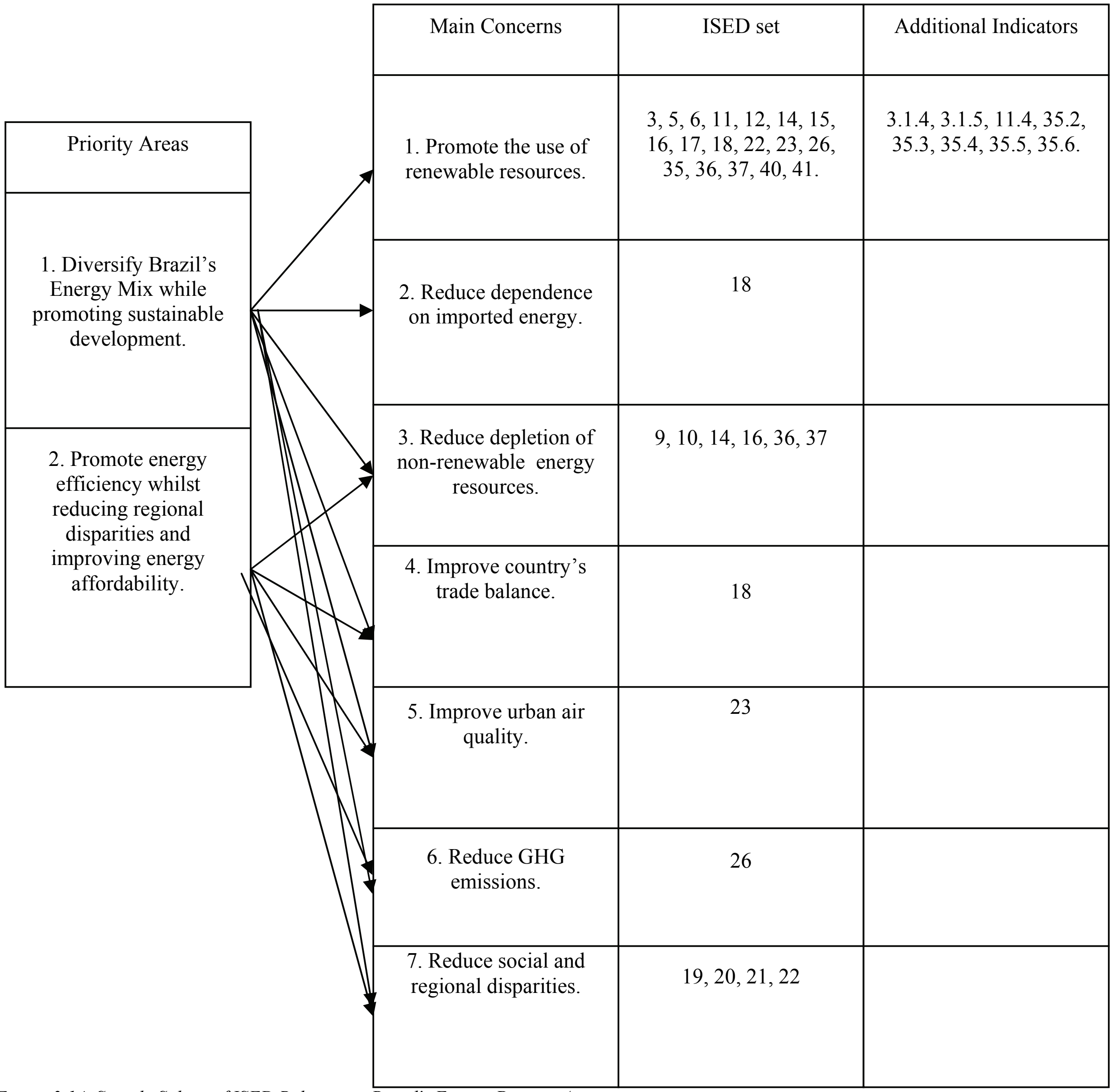

Figure 3.14. Sample Subset of ISED Relevant to Brazil's Energy Priority Areas

The data compilation related to the selected ISED indicators was presented by the first-year report of the ISED Project.

3.5.2. Implementation of the ISED Indicators[39]

The Section 3.4 identified two main priority areas: first, in Brazil's energy supply sector, to diversify the energy mix whilst promoting sustainable development, mainly by encouraging the use of renewable energy resources; second, in Brazil's energy demand sector, to promote energy efficiency while reducing regional disparities and improving energy affordability. These two main priority areas address the social dimension (energy disparities, accessibility and affordability), the economic dimension (energy pricing, end-use energy intensities, and external dependence), and the environmental dimension (air pollution and energy resources depletion) of Brazil's energy sector.

[39] This section is based on the 2004 draft chapter 2 of the study "Brazil: a country profile on sustainable energy development," written by Szklo and Cunha (2004).

This subsection conducts a preliminary review of the status of the priority areas defined above, following the ISED and the additional indicators proposed by the Brazilian team, whose data compilation was completed in the Section 3.3.

3.5.2.1. Economic and Social Dimensions

Urbanization and Energy Accessibility

The first ISED indicator refers to Population Data as an indirect driving force for the economic dimension of sustainable energy development. Indeed, although important in absolute terms, population growth is a driving force that is increasingly less significant for the expansion of energy use in Brazil, compared to other driving forces such as alterations in the consumption standards of the population, the income distribution and access to consumer goods. These other driving forces are more closely related to the rising concentration of the Brazilian population in urban areas, up from 67.6% in 1980 to 81.2% in 2000 (see Figure 3.4 in Section 3.1).

The urbanization process affected the number of households with access to infrastructure networks (electricity, water and sewage) in Brazil, the ownership of household appliances (even among the lower-income segments of the population), and above all the average behaviour standards for the Brazilian population, whose values shifted over the course of the past century from a predominantly agrarian field of influence to one that is almost completely urban. The use and even the perception of physical space, time and natural resources has thus changed dramatically.

Less than 5% of total households still lack electricity (see Figure 3.15), but some 25% of rural households in Brazil do not have access to electric lighting, and this proportion is even higher in the North and Northeast (Tolmasquim, 2003). Consequently, lack of access to the electric power grid (one indicator for sustainable energy development in Brazil) is primarily a regional problem. It is indirectly linked to the concentration of the population in rural areas and to income distribution patterns among the various regions of the country – around 90% of the households lacking electricity in Brazil have an annual income of less than 550 US$ ppp 2000 (Tolmasquim, 2003). Major cities tend to cluster investments in infrastructure, and larger scales offer network economies for public services.

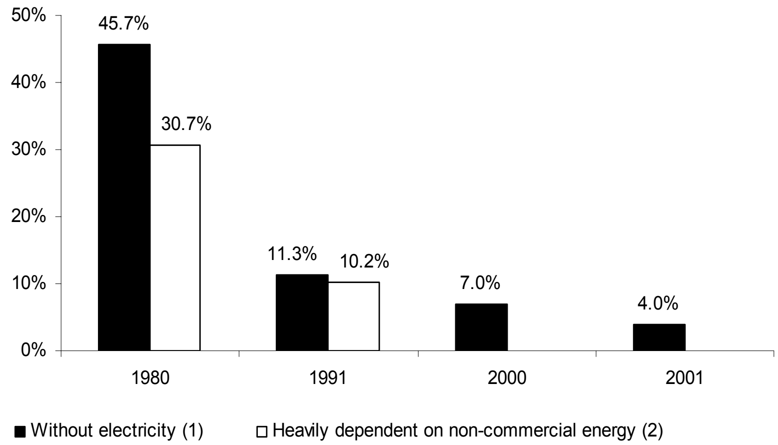

Figure 3.15. Energy Accessibility Indicators – ISED #22
Source: IPEADATA 2003.
Notes: (1) Families without electricity meter, (2) Families that own fuelwood oven. Data after 1991 are not available. However, recent estimates made by Szklo et al (2004) show that the share of households depending on fuelwood for dedicated or non-dedicated consumption (dual-fuel stoves for LPG and fuelwood) was still 10% in 2000. These lesser-income classes' households are mostly located in rural areas, and their fuelwood consumption is explained not only by lack of accessibility to modern fuels (e.g., LPG and natural gas), but also by affordability issues (which is the case of consumption in dual fuel stoves).[40]

Therefore, although per capita power consumption varies considerably by income level among the population, access to electricity among the lower-income layers is almost universal in urban areas in Brazil. Constraints on higher per capita power consumption are related to available income, not the lack of physical access to the power grid. In this case, access to the power grid is a problem more specific to rural areas, and direct driving forces that explain this problem more clearly, such as the extent of the geographical dispersal of potential consumers that currently lack access to electricity, might well be inferred from regional demographic density levels.

Power Rates

Regarding electricity use, there are various ISED Indicators that cover this energy source specifically. For instance, of particular importance for the high-priority areas listed in this study are the ISED Indicators # 3 (end-use energy prices). For this group of indicators, which constitute indirect driving forces in the economic dimension, electricity rates were surveyed and adjusted according to the study methodology, for end-consumers in the industrial and residential sectors. This survey showed that during the period under analysis, the rate for electricity acquired by Brazil's residential sector (not including taxes charged on the rate) was on average at least twice as high as the rate for the industrial sector (See Figure 3.16). As the tax is charged as a percentage of the electricity rate, this difference between the rate values becomes even greater in absolute terms.

[40] These estimates are in line with the results of the pilot study undertaken by Schechtman el al (1996).

Figure 3.16. Power Rates – ISED # 3
Source: Eletrobras, 2001

Among other reasons, this difference in values derives from the way in which electricity is contracted by the various consumption sectors, depending on the supply voltage and the contracted demand. For Brazil's residential sector, a "conventional" rate system is used, characterized by electricity use and/or capacity demand rates that are not scaled by times of use during the day and seasons of the year. In the case of the industrial sector, the "hourly/seasonal" rate is used, with consumption and demand rates scaled to times of use in the course of the day (peak and off-peak periods) and the months of the year (dry season: May – November: wet season: December – April).

More important still were the historical incentives benefiting electricity-intensive industrial sectors over the past two decades, such as primary aluminium production. Mainly commodity exporters, these sectors are affected to a considerable extent by lower electricity rates. Within this context, they were able to purchase electricity at prices slashed to 25% of the average electricity price acquired by other consumption sectors in Brazil.

Another important issue underlying the electricity rates charged to the residential sector is the link between the historical dynamics of this rate (which dropped considerably in the mid-1980s to almost 60% of the rate at the start of the decade), and the lack of electricity conservation incentives among consumption sectors. The drop in the rate levels implemented in Brazil reflected the anti-inflation policies introduced by the Brazilian Government. But there was a counter effect that weakened the self-financing capacity of the power sector, particularly the start-up of operations of large-scale hydropower plants whose operating costs were relatively low.

In turn, during the 1990s, two milestone events were noted for establishing the end-prices of electricity: the Disequalization Act (1993) which eliminated the regional homogenization of electricity rates, and the reform of Brazil's power sector, whose beginning can be related to the establishment of the National Electricity Regulatory Agency (ANEEL) in 1995. In general, contrasting with the 1980s, a steep increase in electricity rates was noted in the residential sector from 1995 onwards; the 2000 rate was 37% higher than the figure for 1995. It is interesting to note that this rate increase coincides with (and is partially explained by) the restructuring of the power sector, falling far more heavily on the residential sector than the industrial sector (from 1995 through 2000, the rate for the latter sector only rose 12%).

Moreover, the power supply rate in 1991 (including the electricity imported from the Itaipu Hydro-Power Complex) represented 67% of the average final rate for all energy consumption sectors in Brazil, but from 1995 onwards this proportion shrank considerably to around 40%. In brief, from 1995 onwards, the power supply rate began to remunerate the distribution utility more than the power generation one, with this

increase falling more heavily on the residential sector. Oddly enough, one of the benefits of the Real Economic Stabilization Plan launched in 1994 – which introduced Brazil's new currency – was expanding ownership of household appliances among the lower-income classes. However, the increase in rates offsets this benefit. Another interesting point in these data is their link to the privatization of Brazil's power utilities, focused mainly on the distribution side. To some extent, the recovery of rates during the 1990s affected the residential market more heavily, because it is more widely dispersed, benefiting the power distribution utilities instead of expanding Brazil's power generation segment.

Energy Intensity[41]

Figure 3.17 presents overall final energy use, GDP (producers' prices) and final energy intensity indicators for the Brazilian economy through the last three decades (ISED Indicator #9). It may be verified that both the final energy use and the GDP (producers' prices) of the Brazilian economy grew more than three and a half times during the 1970-2000 period. Furthermore, one might observe that both indicators, final energy use and the GDP (producers' prices), are highly correlated in the last 30 years[42]. As a consequence, the final energy intensity of the Brazilian economy coefficient was considerably stable through the whole period. However, starting in 1980 a net increasing trend is observed in the overall final energy intensity.

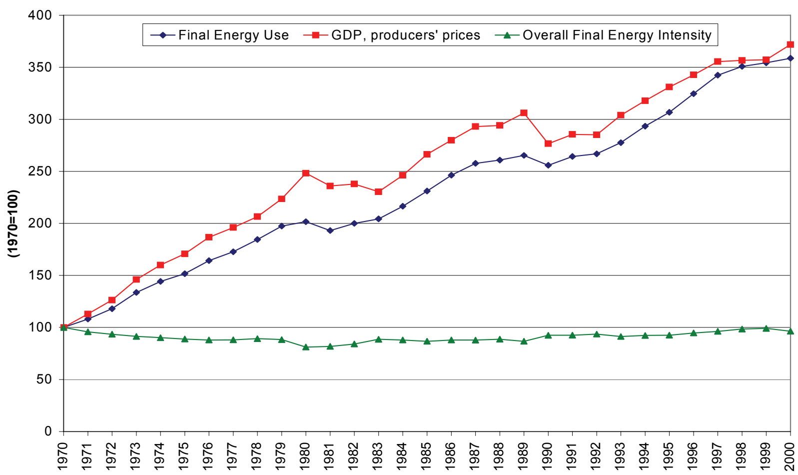

Figure 3.17. Final energy use, GDP at producers' prices and final energy intensity of the Brazilian economy – ISED # 9 Source: MME (2001), IBGE (2002), IPEADATA(2002, 1994) and World Bank (2003).

The results for the ISED Indicator #12 (Energy Supply Efficiency) show that the ratio of final energy to TPES for the Brazilian energy system is relatively high and remained steady throughout the past two decades under analysis (Table 3.20). The relatively high efficiency is the result, to a certain extent, of the predominance of hydro-based power generation in Brazil. This indicator shows a similar trend to that of the overall energy intensity of the economy shown in Figure 3.17. These aggregated data, however, do not provide sufficient insights about energy intensity changes at the sectoral level. Therefore a decomposition method (Park, 1992) was used to help identify the factors affecting final energy use in the Brazilian economy.

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[41] This section is based on chapters 2 and 5 of Brazil: *A country profile on sustainable energy development*, (IAEA et al., 2006).

[42] Statistical correlation does not necessarily imply any causal relationships, however.

TABLE 3.20. FINAL ENERGY TO TPES ISED # 12

Year	%
1980	83.8
1985	82.6
1990	83.3
1995	84.7
2000	83.8

Source: Based on MME (2001)

Figure 3.18 displays the results of the energy use decomposition analysis for the Brazilian economy from 1970 to 2000, divided into periods of five years. It shows the basic effects (activity, structural and intensity) and the term of interaction.

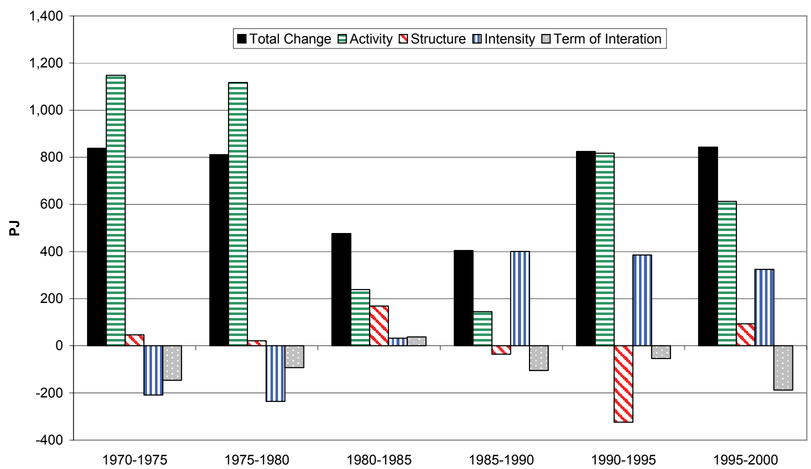

Figure 3.18. Decomposition of energy use changes in the Brazilian economy
Sources: MME (2001), IBGE (2002), IPEADATA(2002, 1994) and World Bank (2003).

Figure 3.18 shows that usually the activity effect (economic and demographic growth) was the major effect behind energy use changes in the Brazilian economy through the 1970-2000 period (except for the 1985-1990 sub-period). The analysis of the contribution of the activity effect to energy use changes in Brazil shows that, similarly to any other country, everything else remaining the same, higher economic growth leads to higher energy use. Nevertheless, "everything else" usually does not remain the same: changes in the structure of the economy and intensity effects might magnify or offset the activity effect. Thus, a fundamental task to help decipher the energy use of a country is to further analyse how "everything else" is evolving.

Looking at Figure 3.18 again, it is possible to observe that the structural effect was negligible during the sub-periods of 1970-1975 (46 PJ), 1975-1980 (21 PJ) and 1985-1990 (-36 PJ), modest during the 1995-2000 sub-period (94 PJ), but relevant during the sub-periods of 1980-1985 (168 PJ) and 1990-1995 (-324 PJ). In addition, it is possible to observe that the intensity effect was negative during the 1970s and positive through the 1980s and the 1990s.

To understand better the trends behind the intensity effect results, Figure 3.19 shows the evolution of final energy intensity by sector (Agriculture, Industry, Services) and the Economy as a whole. Differently from the overall final energy intensity indicator, it can be verified that in the long-term all the intensities show relative increasing trends. All sectoral final energy intensity trajectories presented in Figure 3.19 experienced fluctuations, resulting either from changing sectoral trends or from conflicting intra-sectoral trends.

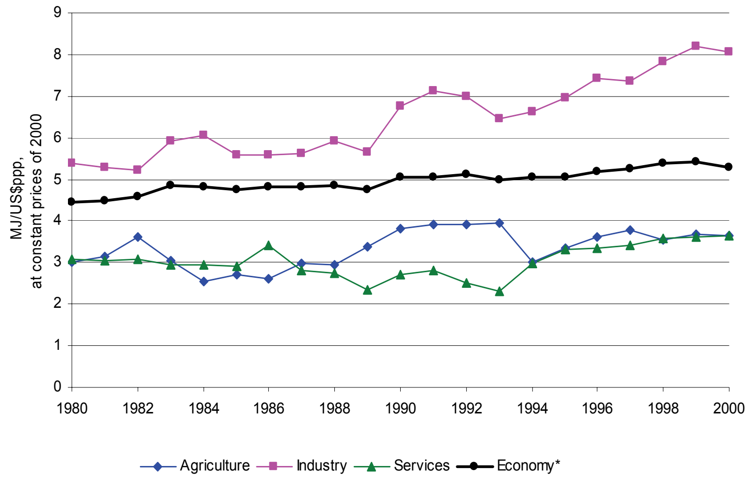

Figure 3.19. Evolution of overall and sectoral final energy intensity indicators – ISED #9
Sources: MME (2001), IBGE (2002), IPEADATA (2002, 1994) and World Bank (2003)
*Note: * Economy excludes household Sector. Non-energy use is not included.*

In sum, it is possible to say that the overall economic growth of Brazil was the most important effect influencing energy use changes in Brazil during the 1970-2000 period as a whole, either to push it up (1970-1975, 1975-1980, 1990-1995 and 1995-2000) or to push it down (1980-1985 and 1985-1990). Nonetheless, structural and intensity effects have also influenced the energy use change of the Brazilian economy significantly during the last three decades. In this sense, a strategy to enhance energy sustainable development in Brazil should consider not only the impact of economic growth on energy use, but also the influence that structural changes and sectoral final energy intensity might have on energy use.

To understand better the trends behind the intensity effect results, it is important to look at the evolution of final energy intensity by industrial branch. It can be verified that the Industry's final energy intensity registered an upward trend in the 1970-2000 period as whole (0.4% per year). As a matter of fact, if one breaks the 1970-2000 period down, different trends emerge. In the 1970-1975 period, the Industry's energy intensity actually decreased at 5.0% per year and 0.2% per year in 1975-80, while it increased at 0.7% per year in 1980-1985, 3.9% per year in 1985-1990, 0.5% per year in 1990-1995 and 3.0% per year in 1995-2000.

Finally, an important fact of the 1990s was related to incentive economic policies designed to guarantee the international competitiveness of semi-finished goods exports and to the lack of adequate institutional supports for promoting dynamic competitiveness. Owing to this fact, export-focused industrial sectors, such as Iron & Steel and Pulp and Paper, have shown a shift to less-value added goods in the mix of their industrial output. Interestingly enough, such an intrasectoral product mix change is usually mistaken as a technical effect by the country's statistics. In the case of pulp and paper, the trend was the reduction of paper's share in total output. For metallurgy, the trend was the increased production of pig iron, primary aluminium and semi-finished goods.

On the other hand, Transportation registered final energy intensities of 47.0 MJ/US$ppp, 2000 prices in 1970, 35.8 MJ/US$ppp, 2000 prices in 1980, 42.2 MJ/US$ppp, 2000 prices in 1990 and 73.3 MJ/US$ppp, 2000 prices in 2000. Such a trend seems to be related to an energy efficiency program in the 1980s (CONSERVE Program), inter-mode substitution towards freight road transportation and towards private transportation (away from passenger public transportation) and a fall in value added (tariff control and deterioration of public transportation system reinforcing preferences for private and alternative transportation).

Electricity Intensity

The electricity intensity evolution (see Figures 3.20 and 3.21) did not follow the per capita GDP contraction of the 1980s and the slight per capita GDP expansion of the 1990s, because:

- The expansion of electricity-intensive industries was strongly promoted by the Brazilian government during the 1980s. These industries account for a large share of the industrial electricity use but for a small share of its output. Aluminium, iron, cement, petrochemical, chlorine, and pulp and paper manufacturers represented 27% of Brazil's total electricity use as of 2000 (MME, 2002a), while their contribution to the GDP value added was less than 8%.[43]
- Since 1979, the Brazilian government has been promoting the modernization of the agricultural sector, focusing mainly on two different sets of goods: export-oriented primary crops and fruits, and biomass for energy purposes. In addition, the Rural Electrification Program launched in 1999 also affected the use of electricity by medium and small Brazilian farms.
- Electricity use grew considerably in the household sector, mainly owing to the urbanization process and the increasing access to the electricity grid.
- During the 1980s, Brazil's government took actions designed to curb inflation, imposing tight controls on tariff levels. This stimulated industrial and household electricity use.
- Finally, electricity commercial losses increased in Brazil (See Figure 3.22). These losses were driven by the increased number of clandestine hook-ups made by households in slums and by ventures of the informal economy.[44] Both ventures of the informal economy and households in slums increased during the 1980s. Interestingly enough, the informal economy increases electricity use but is not accounted for in the GDP, meaning that it increases the electricity use intensity by either the commercial losses or the underestimation of the GDP.

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[43] Since 1980, electricity-intensive industrial sectors have accounted for more than 45% of industrial electricity consumption. By 2001 these sectors accounted for 99.8% of the industrial electricity consumption in the Northern region, 39.9% in the Southeast, and 45.8% throughout the country (CCPE, 2003).

[44] Informal economy includes the underground activities that have legal ends but employ illicit means. These activities do not intrinsically have a criminal content, but must be carried out illicitly, even though they are licit and desirable activities for the country. In general, the informal economy includes street vendors, labours for less qualified services, and small-scale manufacturers. For instance, the street vendor is a merchant with licit goals, but illicit means, because of non-compliance with legal regulations and labour laws, and the non-payment of taxes.

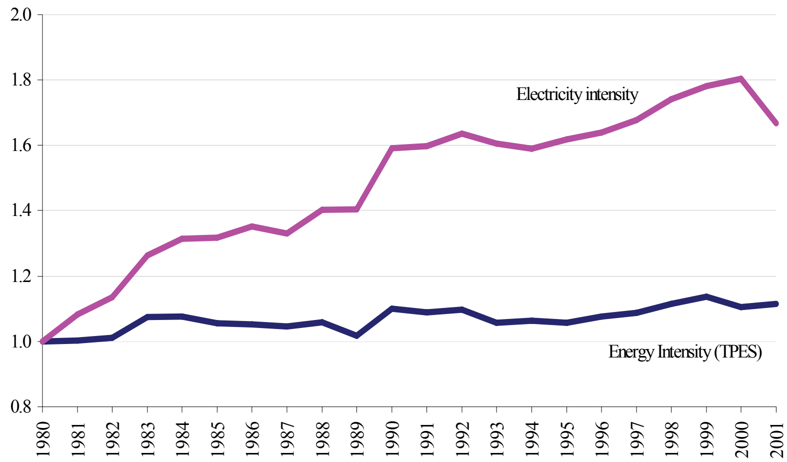

Figure 3.20. Energy and Electricity Intensity – ISED # 9 and # 10
Source: Based on Schaeffer et al., 2002 and on World Bank (2003) for the exchange rate used.
Note: In 1980, the TPES intensity was 0.187 toe/1,000US$-ppp2000, and the electricity intensity was 0.204 kWh/US$-ppp-2000.

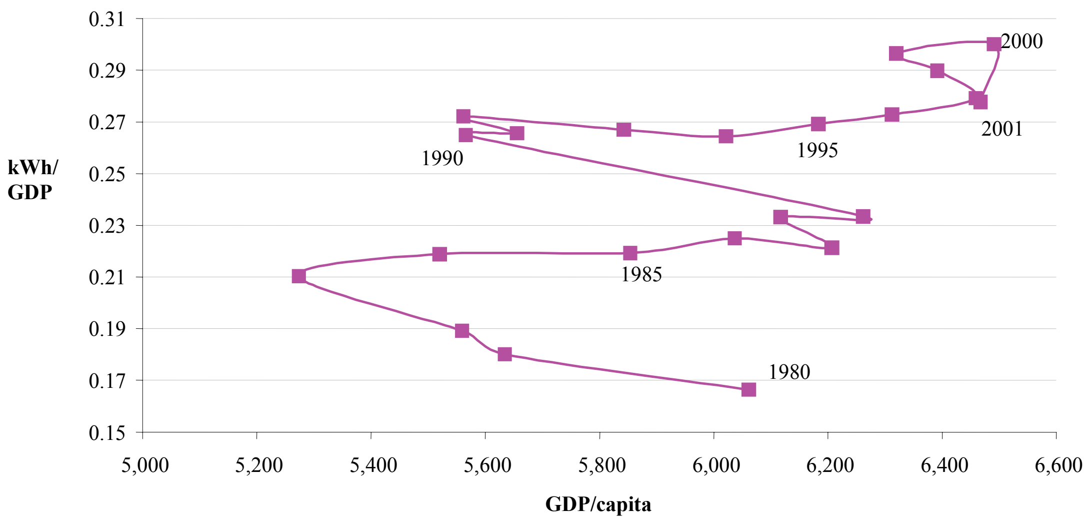

Figure 3.21. Electricity Intensity and GDP per capita
Source: Szklo and Cunha (2005)
Note: GDP in US$ ppp-2000.

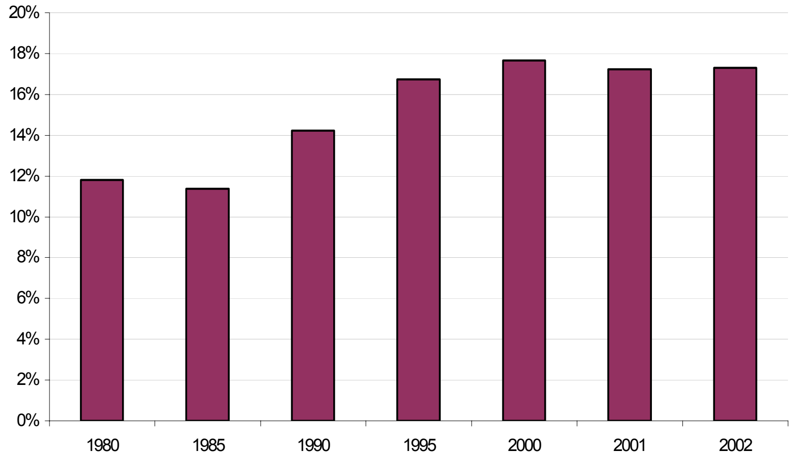

Figure 3.22. Electricity Losses – ISED #12
Source: MME, 2003.

Per capita energy consumption

On the other hand, the per capita energy intensity indicator initially leads to the conclusion that there has been some shrinkage in this indicator over the past two decades, owing to the increase for electricity and LPG, counterbalanced by a drop in fuelwood and lighting kerosene in the energy consumption mix for this sector (see Figure 3.23).

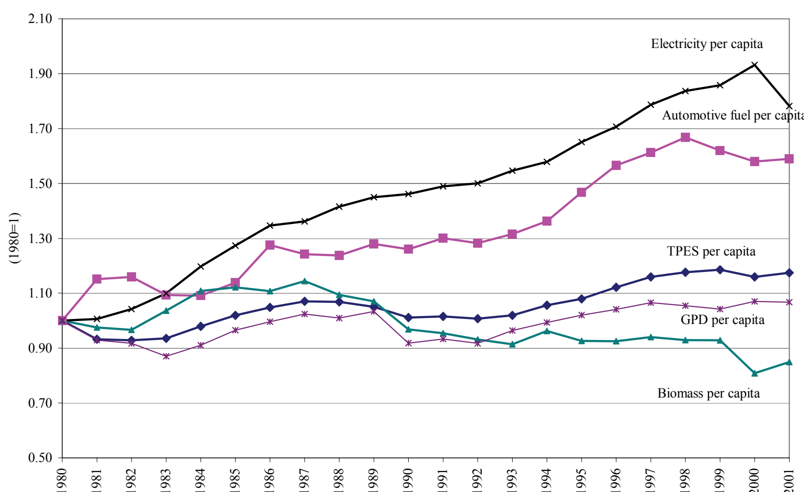

Figure 3.23. Energy per Capita – ISED #16
Sources: MME, 2002a; IBGE, 2003a, World Bank, 2003
Notes: In 1980, per capita total electricity consumption was 3,631 MJ; per capita total biomass consumption was 12,318 MJ; per capita automotive fuel consumption was 7,726 MJ, per capita TPES was 39,554 MJ, and per capita GDP was 6,062 US$-2000 ppp.

The findings also indicate a somewhat "repressed energy demand" in Brazil's residential sector, characterized by striking regional and social disparities. Although the total energy intensity of the residential sector dropped over the period under consideration, intensity based on "modern" energy sources such as electricity and oil products rose significantly over the period, reflected in the considerable shrinkage in the use of fuelwood, which to a certain extent is also related to the increase in the urban population of Brazil, as already discussed in this document.

However, per capita electricity consumption by Brazil's residential sector is still relatively low and very heterogeneous throughout the country. For instance, the per capita electricity consumption in the Southeast region is twice the level noted in the Northeast region. Once again, this fact underscores Brazil's regional

disparities and the potential increase in energy consumption by the residential sector as a whole. It also indicates that the more available income among the poorer sectors of the Brazilian population may well result in a propensity to consume electricity among a considerable portion of the Brazilian population, resulting in a substantial improvement in the quality of life.

This type of analysis also denotes a strong link between the two priority areas identified here for the sustainable development of the Brazilian energy system. On the one hand, "promoting energy efficiency whilst reducing regional disparities and improving energy affordability" means both a reduction and an increase in primary energy sources use[45]. On the other hand, on the energy supply side, an increase in energy use among the lower income classes – assuming that this increase would not reflect improper use of energy resources but rather better access to basic energy services – is a challenge for the strategy designed to "diversify the energy mix, mainly by promoting the use of renewable resources".

3.5.2.2. Environmental Dimension

Local Pollutants

The high-priority areas defined in this study failed to clearly explain the environmental impacts of atmospheric emissions produced by Brazil's energy system. The need to avoid or prevent these impacts was implicit in the objectives of diversifying Brazil's energy mix through renewable sources while enhancing energy efficiency. To characterize these impacts, this study obtained data for the ISED Indicators 23, 26, 40 and 41.

For ISED Indicator 23 (Quantities of Air Pollutant Emissions), an analysis of the SO_2 findings showed that most of the historical emissions deriving from fossil fuel use lie within the industrial sector (see Figure 3.11 in Section 3.1).

This is owing to three main factors:

- first, the energy use profile of this sector, with major segments consuming considerable amounts of waste oils with high sulfur content levels and segments with significant coal products use, such as steel-making;
- second, Brazil's power generation sector, where hydro-based generation predominates, supplemented to a minor extent by power generation fuelled by coal, diesel oil, biomass and waste oils;
- finally, looking at the emissions by the transportation sector, it is worthwhile noting a considerable drop in these emissions from 1997 onwards, owing to Brazil's diesel oil upgrade program. Moreover, sulfur emissions by automobiles running on pure ethanol in Brazil have been eliminated since the implementation of the National Fuel Alcohol Program, resulting in a double dividend. Consequently, the use of ethanol indirectly paved the way for the introduction of engines fitted with catalysts.

Similar to SO_2, a significant portion of the NO_x emissions produced by Brazil's energy system takes place in the industrial sector, owing mainly to the high temperatures of its boilers and furnaces (see Figure 3.12). In the power sector, NO_x emissions by diesel engines driving stand-alone systems are particularly noteworthy, while automotive diesel emissions are noticeable in the transportation sector, followed by gasoline and automotive ethanol emissions. Particularly important over the past two decades for NO_x emissions produced by energy biomass are charcoal and sugarcane bagasse consumed by the industrial sector, fuelwood burned by the residential sector and automotive ethanol. In terms of expectations, increased participation by the electricity sector in these emissions is expected, with the start-up of

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45 This is a crucial distinction for this study, because access to commercial energy sources does not necessarily ensure efficient supplies of the energy-base services required by the poorest segment of the population. An interesting example of this issue was identified by Schechtman et al. (1996) in a pilot survey on fuelwood and LPG consumption in rural areas in Rio de Janeiro State, which is Brazil's largest producer of oil and associated gas. This survey noted that there was a progressive shift from LPG consumption to gleaned fuelwood (i.e. non-commercial use) in the course of the month among lower income classes.

operations by the thermal-power plants and the cogeneration plants fuelled by natural gas, resulting in significant emissions of nitrogen oxides.

Global Pollutants

According to ISED Indicator 26 (Quantities of GHG Emissions from Energy-Related Activities), most greenhouse gas emissions deriving from energy consumption and production are related to CO_2. For the period under analysis, total GHG emissions rose by an average of 1.20% p.a. Compared to emissions in 1990, the 2000 emissions are 22% higher. These emissions will tend to increase even more, as renewable charcoal is replaced by metallurgical coking coal and to a greater extent by the expansion of Brazil's power generation industry, based on thermal-power plants fuelled by natural gas.

The results also showed that, although greenhouse gas emissions rose over the period under analysis in absolute terms, total per capita GHG emissions dropped slightly (see Table 3.21).

TABLE 3.21. ANNUAL CO_2 EMISSIONS PER CAPITA RELATED TO BRAZIL'S ENERGY SYSTEM ISED # 26

Year	t CO_2 eq/capita
1980	2.19
1985	2.02
1990	1.88
1995	1.83
2000	1.98

Source: Based on MME (2001), ANEEL (2002), Schechtman et al. (1998), ABRACAVE (2002), Aquino(1999), Schechtman et al. (1996), IPCC (2001).

This renewable mix places Brazil in a favourable position in terms of greenhouse gases emissions. For instance, in 1998, Brazil's energy use per capita CO_2 emissions reached 1.94 tCO_2 /inhabitant (carbon dioxide only), which is lower than the average global figure and the average figure of the OECD countries, at 3.89 and 10.93 tCO_2/inhabitant, respectively, this same year.

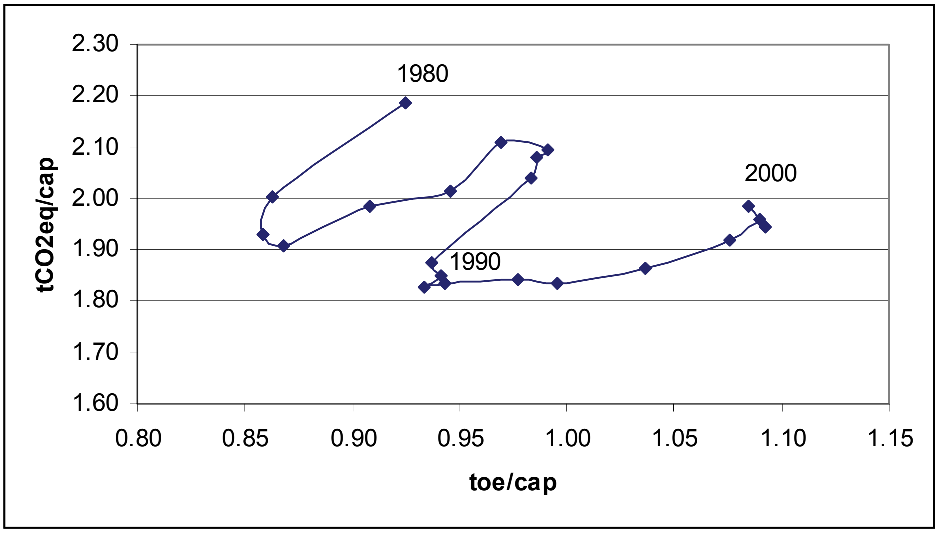

Figure 3.24. GHG emissions per capita versus TPES/capita
Source: Szklo and Cunha, 2005

Figure 3.24 indicates that total per capita GHG emissions were implicitly influenced by the country's economic development, and by specific driving factors related to the country's energy system.

The commissioning of large hydro-power plants[46] in the first half of the 1980s was followed by an economic crisis that created temporary imbalances between the electricity supply and demand, and by governmental policies promoting electricity-intensive industries and electric heat generation.

From 1982 to 1986, some specific industrial sectors, which concentrate fossil fuel industrial consumption in Brazil, recovered their economic activity. For example, the average growth rate of the iron and steel and the chemical sectors between 1982 and 1985 was 13% and 11% (value added), respectively. These sectors account for a significant share of the GHG emissions in Brazil.

Between 1986 and 1991, industrial activity reduced considerably, especially for those fossil-fuel intensive segments noted above: the iron and steel sector value added decreased 6% p.a., and chemical sector value added decreased 3% p.a. On the contrary, electricity use kept increasing at high rates and ethanol use in the transportation sector reached its apogee.

Finally, since the 1990s (and especially after 1995, the year after the price stabilization), economic activity rebounded. In addition, in the 1990s, specific policies increased fossil fuel use in Brazil. First, incentives given to the export of semi-finished industrial goods promoted export-oriented industrial segments, which also represent a major share of the fossil fuel industrial use; second, the ethanol supply crisis of 1989 and the discontinuation of the Ethanol Incentive Fuel Program during the 1990s promoted inter-fuel substitution in the transportation sector, increasing fossil fuel use.

The intensity of CO_2 emissions per GDP for the energy system, which is another finding drawn from ISED Indicator 26 (see Table 3.22), is also lower in Brazil than in the industrialized countries. While emissions deriving from energy transformation and use in Brazil brought this Indicator to 0.36 kg CO_2/US$90 (ppp) in 1998, worldwide and in the OECD countries, this Indicator reached 0.66 and 0.62 kg CO_2/US$90 (ppp), respectively (Oliveira, 2001).

[46] There is still much uncertainty over GHG emissions by hydropower plants. For this aspect, see Rosa et al. (1996) and Rudd et al. (1993). However, according to the preliminary estimates, except in a very few cases, GHG emissions from hydropower plants are far lower (in fact, almost negligible) than those produced by their thermo-power counterparts burning fossil fuels (Rosa et al., 1996).

TABLE 3.22: ANNUAL CO_2 EMISSIONS PER GDP RELATED THE ENERGY SYSTEM ISED # 26

Year	t CO_2 eq/1,000 US$-1990 ppp
1980	0.45
1985	0.40
1990	0.38
1995	0.34
2000	0.35

Source: Based on MME (2001), ANEEL (2002), Schechtman et al. (1998), ABRACAVE (2002), Aquino (1999), Schechtman et al. (1996), IPCC (2001).

Analysing Brazil's GHG emissions by energy use sectors, it is quite clear that the emissions by the power sector are minor in retrospect, owing only to thermal-power generation fuelled by coal, diesel oil and heavy oils. From 1980 through 2000, the electricity sector produced only 2.6% to 7.7% p.a. of the total GHG emissions resulting from energy use in Brazil, with the transportation and industrial sectors together accounting for almost all GHG emissions deriving from energy use in Brazil[47]. The rate of increase in the emissions by the transportation sector was far higher during the 1990s than during the previous decade, owing basically to the virtual elimination of new automobile sales fuelled solely by ethanol during the 1990s. While new models fuelled by alcohol accounted for 96% of automobile sales in 1985, they reached less than 0.5% by the end of the 1990s (Poole et al., 1998).

Finally, although the use of fuelwood as an energy source tends not to be the driving force behind deforestation in Brazil (as discussed in Section 3.1.1.1 of this chapter during the estimation of ISED Indicators 40 and 41), deforestation is still the main cause of Brazilian carbon dioxide emissions. A recent series of studies on greenhouse gas emissions in Brazil for the period of 1990-1994 rates land use changes and forestry, energy, and soils and liming, in this order, as the most important sources of carbon dioxide emissions in the country (MCT, 2002). New forest plantings, mainly eucalyptus and pine, constitute the most important carbon dioxide sinks in this sector (see Table 3.23).

TABLE 3.23. BRAZIL: CARBON DIOXIDE EMISSIONS AND UPTAKE - 1990-94

Source	Average per year (million tons of carbon)
Energy	75.8
Fugitive carbon dioxide emissions from coal mining and handling	0.4
Land use change (deforestation)	139.9
Soils and liming	22.2
Total carbon dioxide emissions	238.3
Removals from planted forests	11.0
Net carbon dioxide emissions (emissions minus uptake)	228.3

Source: MCT (2002).

3.5.2.3. Institutional Dimension

During the 1990s, major structural reforms were conducted in the Brazilian energy sector aiming at achieving, simultaneously, six major objectives: 1) to promote competitive pressures over segments inside industrial energy chains presenting low or even null scale and scope economies; 2) to attract private investors for expanding energy supply; 3) to diversify Brazil's energy system, mostly by increasing natural gas use; 4) to widen the access to modern energy services; 5) to guarantee minimum quality standards in energy services; and, 6) to foster the performance of energy companies. Within this context, Brazil's

[47] In terms of GHG emissions accumulated from 1980 through 2000, the Brazilian power sector accounted for 4.2%, while the transportation sector produced 30.4% of these emissions.

current institutional dimension is characterized by transition phases inside and crossing-over the main energy industrial chains. This poses uncertainties, opportunities and risks for the country's sustainable energy development.

3.6. Identification of Response Actions and Energy Policies[48]

A wide range of policy options and initiatives might pave the way for Brazil to soundly progress socially and economically, thus reaching higher standards in terms of sustainable energy development. Therefore, the fundamental division of response actions reported here focuses primarily on each priority area. Each response action unfolds into one or more energy policies that focus on specific aspects of the Brazilian energy sector. Figure 3.25 below depicts the two main priority areas identified and their related response actions. Nonetheless, there are still many other intersections amongst all strategies, and a policy strategy that addresses one priority area might well unfold indirectly into another priority.

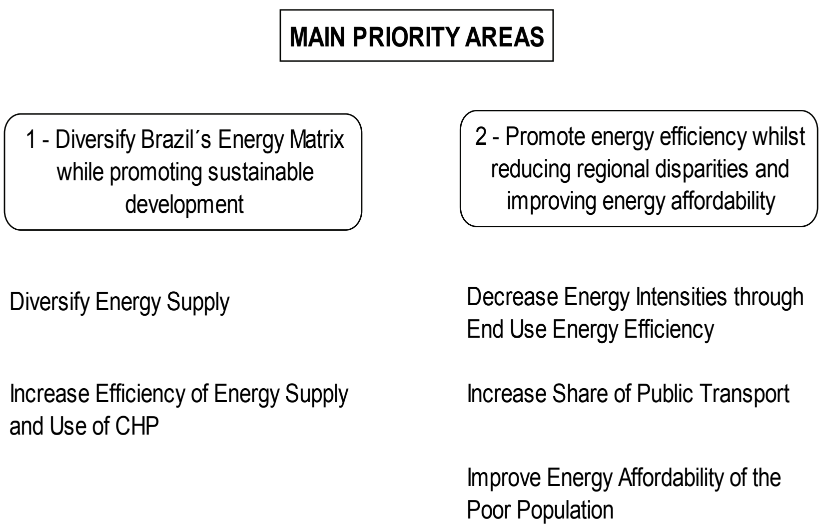

Figure 3.25. Main Priority Areas and Related Response Actions

3.6.1. Priority Area 1 and related Energy Policies

3.6.1.1. Ethanol Automotive Fuel and Sugarcane Bagasse Cogeneration

Sugar production in Brazil yields not only an important agricultural commodity - sugar - but also a renewable liquid fuel (ethanol) and a major source of biomass (bagasse) from which power can be generated.

In 1975, Brazil launched the National Alcohol Fuel Program, known as PROALCOOL, to increase the production of ethanol as a substitute for expensive and extremely scarce gasoline. Ethanol production was stimulated through a combination of policies, including: low-interest loans for the construction of ethanol distilleries, and guaranteed purchase of ethanol by the state-owned oil company at a price considered attractive for producers.

[48] This section was partially based on Geller et al (2004) and Szklo and Geller (2005).

In spite of its sound success, the PROALCOOL ethanol fuel program has had major setbacks (as discussed in Section 3.1). The most likely scenario that could revamp ethanol as a fuel is the so-called flex-fuel technology, i.e., the allowance of any possible blend of ethanol and gasoline, electronically detected and adjusted as a fuel.

To avoid some of the problems the country has faced in the past, the government could create a "strategic ethanol reserve" (Geller et al., 2004). The reserve would be tapped in case of significant shortfall between supply and demand.

Bagasse cogeneration is the other major source of wealth and well-being derived from sugar-cane. Combined heat and power generation (CHP) fuelled by sugar-cane bagasse is a particular case among Brazil's distributed generation alternatives, since sugarcane bagasse is a by-product.

To promote the efficient use of bagasse in Brazil, the government could:

- Continue to develop and demonstrate more efficient technologies such as bagasse gasification and combined cycle power generation in sugar mills; or
- Provide long-term loans at attractive interest rates to sugar mills that adopt more efficient CHP technologies.

3.6.1.2. Non-Combustible New Renewable Energy Sources for Power Generation

Other energy sources have been encouraged via Government programs or policies in Brazil: for instance, Small Scale Hydropower (SSHs),[49] wind power, and solar photovoltaic energy.

In 2002, a policy known as PROINFA was announced to increase electricity generation by wind, biomass, and small-scale hydropower. In its first phase, 1,100 MW of each type of renewable power technology will receive up to 80 percent of the average retail electricity price in Brazil over a 15-year period. Also, PROINFA includes a goal of having alternative renewable energy sources (i.e., sources other than large scale hydropower) provide 10 percent of total electricity supply in Brazil by 2022. As a consequence of this policy, many new wind farms were proposed or under development as of 2002 and early 2003. Wind power is on the cusp of becoming a significant electricity source in Brazil.

Regarding solar photovoltaic energy, small amounts of solar power generated by photovoltaic panels in remote communities have long been a natural application for Brazil, easily outweighing costly solutions such as extending the traditional power grid to service a few widely-scattered consumers, or shipping in generator fuel to these remote communities.

If the PROINFA policy fails to result in a significant and orderly expansion of new renewable electricity sources, an alternative approach known as a renewable portfolio standard (RPS) could be enacted. An RPS obligates utilities to supply or purchase a specified amount of electricity from renewable sources, expressed either as a percentage of capacity or electricity sales. An RPS provides certainty that renewable energy sources will be implemented, stimulates competition among renewable energy providers, and encourages cost reductions.

[49] The SSHs are hydropower plants with an installed capacity of 1 to 30 MW and a reservoir area no larger than three square kilometers.

3.6.1.3. Develop and stimulate the adoption of new biomass sources

The following policies could be adopted to promote both the production and use of vegetable oils and biodiesel fuel in Brazil:

- To continue developing the application of ethanol infrastructure for biodiesel. Such a move is of special interest given the strong existing infrastructure dedicated to ethanol.
- To continue investing in R&D on vegetable oil productivity and crop diversification, thus avoiding significant dependence on only a single biodiesel vegetable oil source (e.g., soy bean oil).
- To enhance the profitability and attractiveness of the whole biodiesel economic chain via the creation of markets for by-products of biodiesel.
- To implement either time- or quantity-bound fiscal incentives to spark the development of a sustainable biodiesel industry.

These renewable energy policy options could be grouped into one response action, related to the diversification of the energy mix. To illustrate the effects of such policies, Figure 3.26 shows their correlation with the key ISED indicators presented in the previous section.

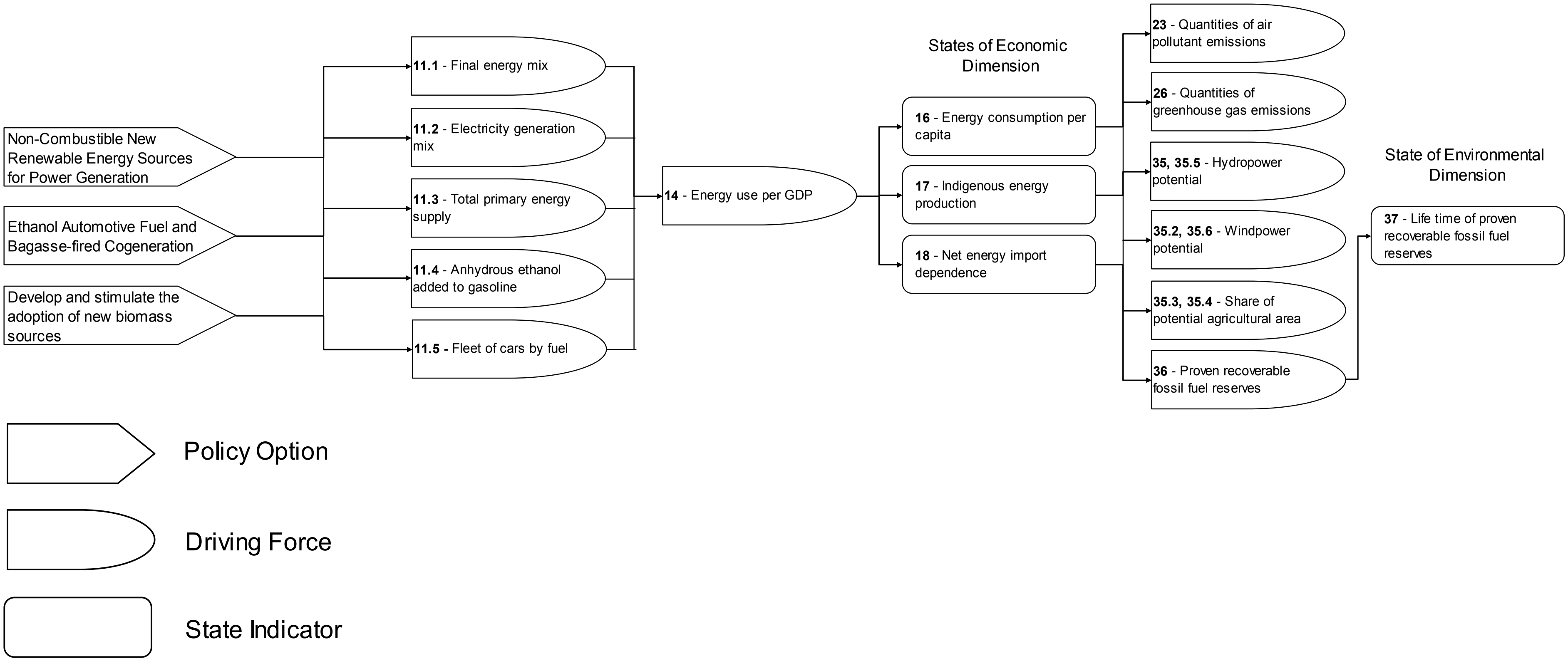

Figure 3.26. Priority Area #1 – Diversify Energy Mix – Policy Options

3.6.1.4. Lift Barriers to Natural gas CHP Implementation

Energy policy makers could implement such measures as:

- Requiring that distributors interconnect existing and future CHP enterprises to the power grid with minimum requirements, and without excessive delays.
- Encouraging energy generation efficiency, via performance-based contracting with energy service companies (ESCOs), working together with gas suppliers or electric utilities, or equipment suppliers.
- Reviewing the import taxes on CHP equipment (such as gas turbines) to accelerate the return on these investments.

This energy policy option relates to the second response action, which is devoted to the promotion of energy efficiency on the supply side through the use of CHP. Figure 3.27 below shows the links between this energy policy option and the affected ISED indicators.

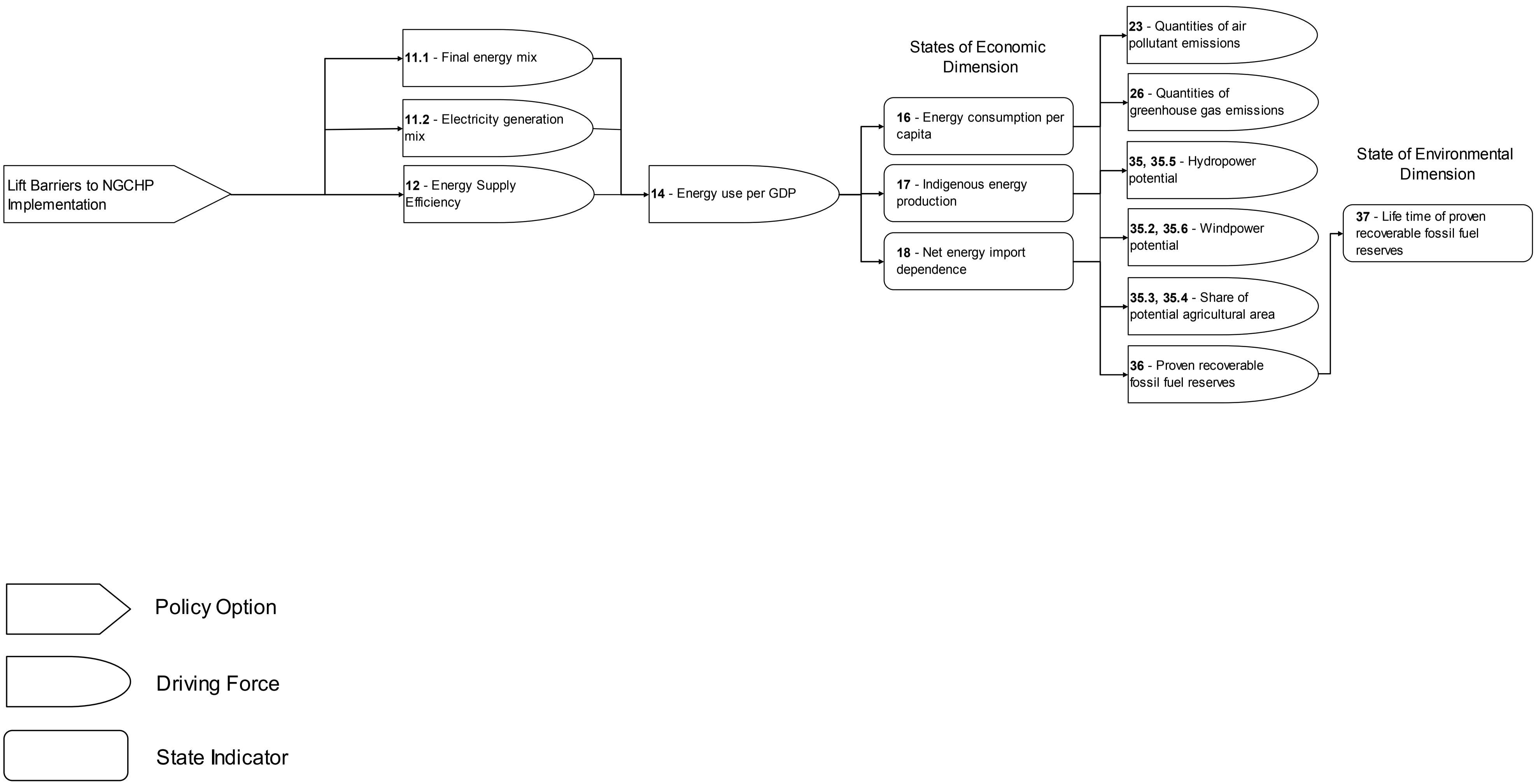

Figure 3.27. Priority Area #1 – Increase Efficiency of Energy Supply and Use of CHP – Policy Option

3.6.2. Priority Area #2 and its related energy policies

3.6.2.1. Fully Implement the Appliance Efficiency Standards Law

In 2001, a law was enacted requiring that manufacturers of certain electric-power consuming devices achieve a minimum efficiency standard. Such efficiency standards for motors were issued in 2002. Standards should also be adopted for other devices, including all new major household appliances (refrigerators, freezers, clothes washers, stoves, and air conditioners), lighting products (lamps and fluorescent lighting ballasts), and commercial sector air conditioning equipment sold in Brazil. Standards should also address the issue of standby power consumption of electronic devices such as TVs, VCRs, microwave ovens, personal computers, printers, and fax machines. The existing standards are set at the maximum efficiency levels that are technically and economically feasible.

3.6.2.2. Expand Utility Investments in End-Use Energy Efficiency

As a measure to boost end-use energy efficiency, the regulatory body ANEEL could increase the energy efficiency-spending requirement by distribution utilities to a higher level. Part of these funds could be spent directly by the utilities and part could be allocated to state and federal energy efficiency programs. Moreover, the funding could be used to support energy efficiency investments made by households, businesses, and industries; alternatively, these resources could finance energy services and help to establish the market for innovative energy efficiency measures, such as the dissemination of information, provisions for training, etc.

The regulations introduced in 1998 caused an increase in investment by utilities in energy efficiency programs. As the programs were selected, designed and implemented by the utilities themselves, much of the investment was used to reduce their energy losses, including commercial losses. Over the following years, the regulatory agency (ANEEL) gradually restricted the percentage allowed for supply side energy efficiency investments and created rules to limit the approval of loss reduction projects. As a result, since the year 2000, all regulated investments must be used for end-use efficiency programs (Jannuzzi, 2005).

The most cost effective end-use efficiency programs typically include improvements in public illumination systems (mostly changing incandescent lamps for mercury vapour and mercury for sodium high-pressure lamps), which accounted for half of the total investments. Marketing was also another area that attracted utilities’ investments. However, since the year 2000, this type of project has not been allowed by the regulatory agency. Despite the recent improvements that have been achieved, there are still a number of issues that must be addressed and improved over time, such as the high costs for conserved energy; the difficulty in verifying program performance on energy saved; the duplication of programs over the years; and expenditure patterns (i.e., the high proportion of expenditure on small, uncoordinated projects) (Jannuzzi, 2005).

3.6.2.3. Adopt Industrial Energy Intensity Reduction Targets and Protocols

Highly sensitive to regulatory impositions and economically-driven incentives, industry is a key element within the overall strategy of efficiency increases on the demand side. There is significant room for achieving higher efficiency levels for fuel and electricity use within the industrial sector in Brazil. Straightforward measures include improving operating and management practices, using better equipment (such as high efficiency motors and motor speed controls), and adopting innovative industrial process technologies.

3.6.2.4. Fossil Fuel Savings

Passenger vehicles sold in Brazil are relatively inefficient because of the outdated technology employed in one-litre Brazilian engines. Most of these engines are derived from 1.6 litre-engines used to equip older models. On the other hand, vehicle production by the multinational auto manufacturers is growing in Brazil. As production expands, it would be reasonable to insist that new vehicles include a variety of fuel-efficient technologies. These standards could be expressed in terms of either an increase in fuel economy (the approach followed in the United States) or a reduction in CO_2 emissions per kilometre travelled (the approach in Europe).

In sum, Figure 3.28 shows the indicators that can positively be affected by the adoption of these energy policies.

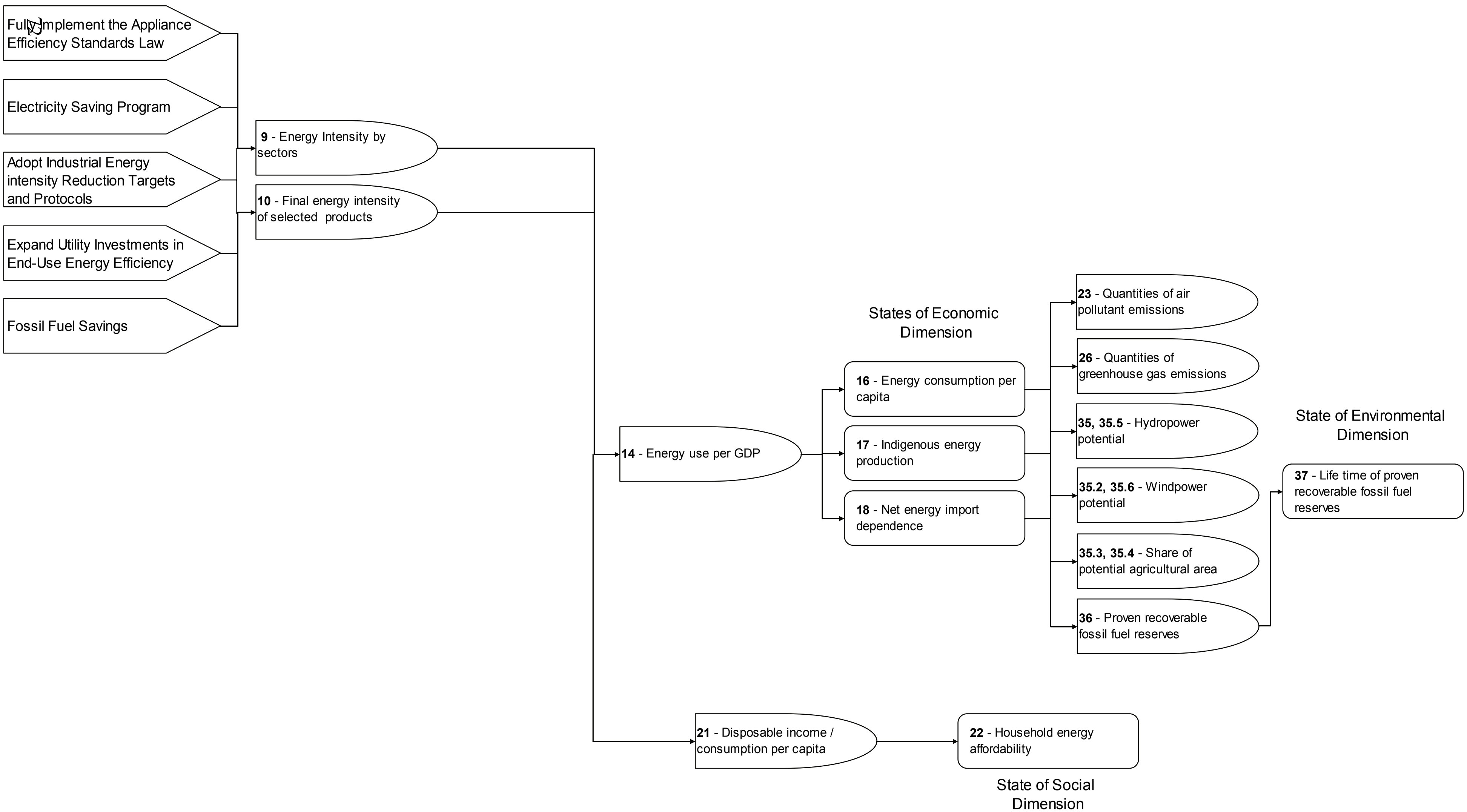

Figure 3.28. Priority Area #2 – Decrease Energy Intensity through End-Use Energy Efficiency – Policy Options

3.6.2.5. Improve the Efficiency of Passenger Transport, through Transport Planning and Shifts to Less Energy-Intensive Modes

A truly long-term sustainable and efficient transportation network can only be achieved with the foundation of coordinated urban and transportation planning policies to reduce less efficient light vehicles and fuel share in the overall transportation mix. Policy options for improving urban passenger transport systems would include the displacement of individual transportation by mass transportation through better inter-modal integrations and improved quality of service; improvement of infrastructure for buses; increases in the load factor of cars and light trucks through ride sharing and greater access of higher occupancy vehicles on major urban highways; and encouragement of pedestrian and bicycle trips through construction of dedicated pedestrian and bicycle lanes. Figure 3.29 depicts the positively affected indicators by the adoption of such policies.

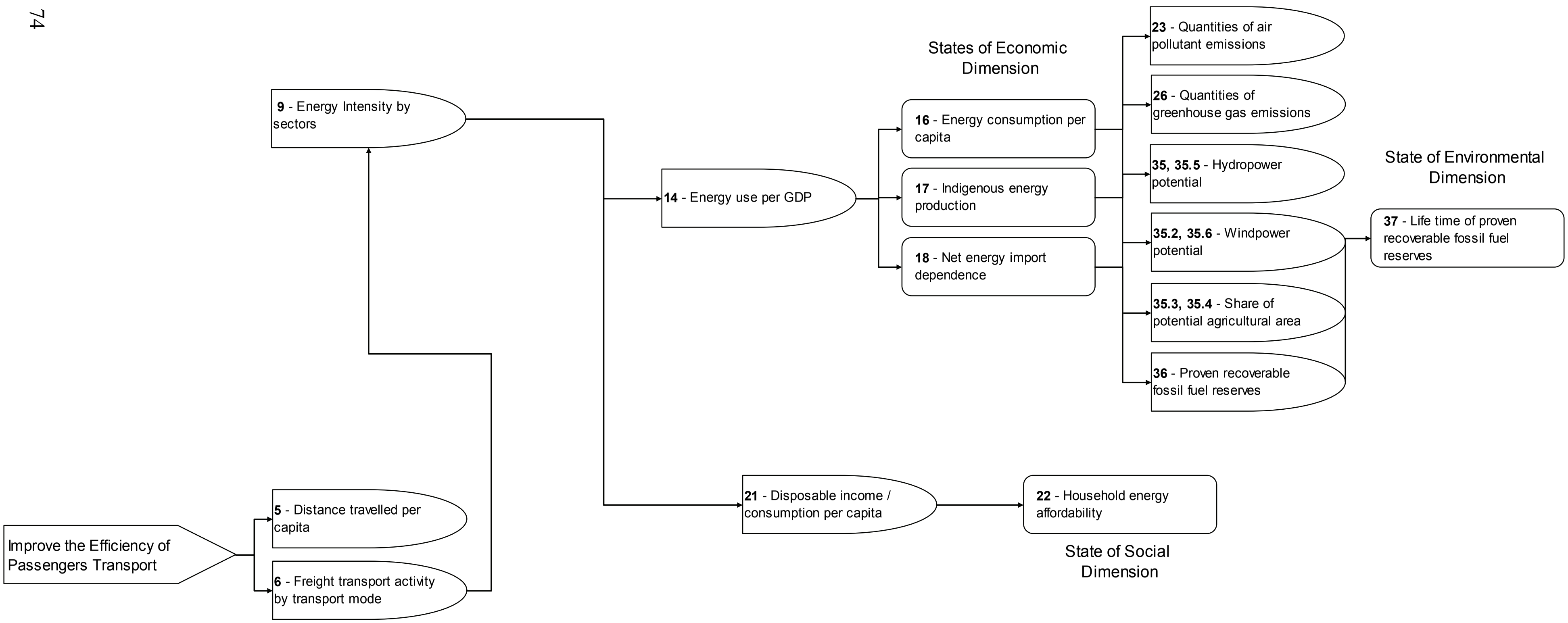

Figure 3.29. Priority Area #2 – Increase Share of Public Transport – Policy Option

3.6.2.6. Creation of a fund for helping poor people to buy energy services

To improve energy affordability for the poor, a policy would be developed to create a fund that would provide low-income segments of urban and rural areas of the country with a refund for part of their expenses on energy (e.g., gas and electricity). This fund's main financial resources would be derived from energy tariffs or from other social government funds. Different from other types of policies based on tariff differentiation among distinct energy consumption levels, this policy's primary advantage is the maintenance of a sufficiently high (real) energy price that would stimulate energy efficiency as well as improve energy affordability among low-income classes. This policy would be an extension of similar policies previously adopted in the country. However, these previous efforts proved to be isolated, and did not affect the target population owing to the lack of adequate information. Finally, Figure 3.30 shows the possible affected social indicators associated with the adoption of such an energy policy.

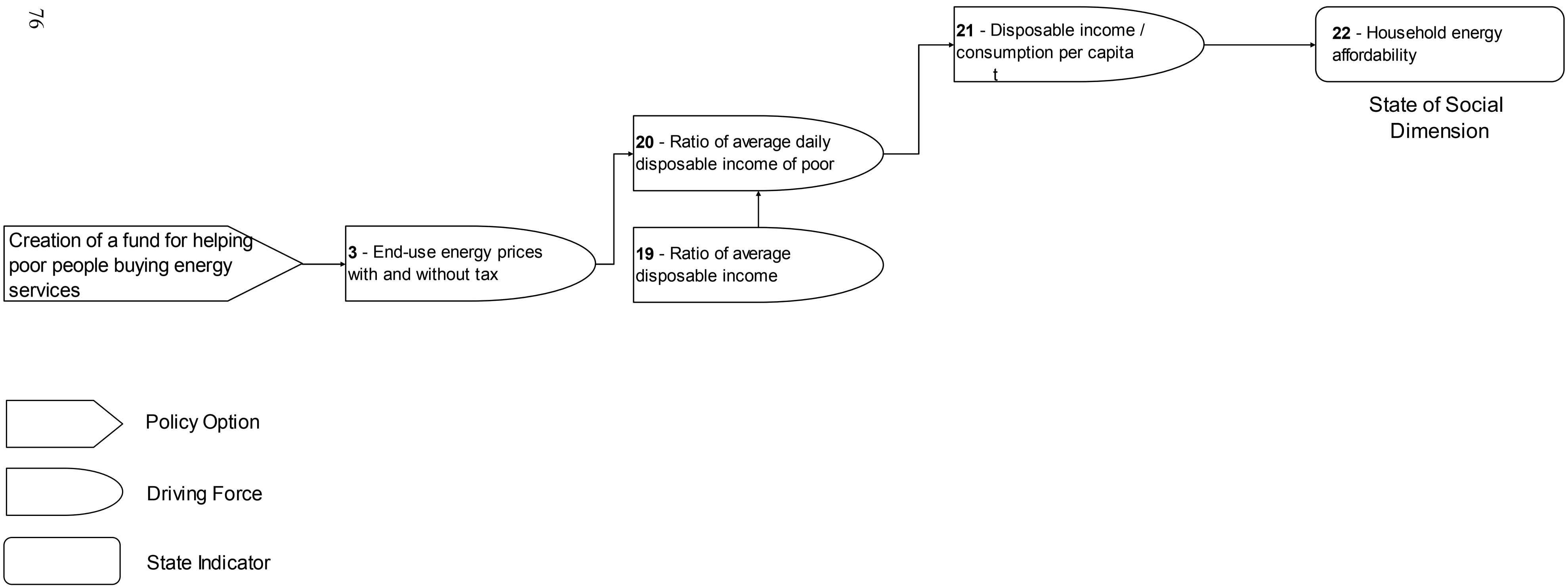

Figure 3.30. Priority Area #2 – Increase Energy Affordability of the Poor Population – Policy Option

3.7. Conclusions and recommendations

As this chapter has shown in previous sections, the ISED set of indicators is very useful for assessing Brazilian sustainable energy development. This assessment also allows the proposition of strategies for improving the use and production of energy in the country towards sustainable development, as shown in Figure 3.31.

Brazil is a country characterized by a historically high share of renewable energy in its total energy supply. Even though it is a Non-Annex I party to the Convention, and as such does not have binding commitments for GHG reductions, the country has nevertheless implemented a series of national measures over time which have resulted in even lower carbon emissions (especially for a country which already has extremely low carbon emissions by any standard). For instance, in the power generation sector, the country invested in hydropower plants; and in the fuel sector, it has implemented the largest program in the world for commercial biomass source, the Ethanol Fuel Program (see Section 3.1.1). Therefore, Brazil is an interesting case for sustainable energy development and a challenging example for the ISED set application.

However, the country's relatively favourable position regarding its GHG emissions indicators does not imply a similar situation for all dimensions of sustainable energy development. Indeed, while technical efficiency, measured by specific energy consumption, has been slightly decreasing over the past decades in almost all industrial segments, Brazil's total primary energy supply intensity has remained almost unchanged during the last two decades. This shows that inter-fuel substitution (mostly oil by hydro electricity, and fuelwood by oil products) and technical progress were compensated by the shifts to energy-intensive industries and the increased use (and ownership) of private cars during the period. Especially, the electricity intensity evolution did not follow the per capita GDP contraction of the 1980s and the per capita GDP slight expansion of the 1990s, because:

- The expansion of electricity-intensive industries was strongly promoted by the Brazilian government during the 1980s. These industries account for a large share of industrial electricity use, but for a small share of its output.
- Electricity use grew considerably in the household sector, primarily due to the urbanization process and increasing access to the electricity grid.
- During the 1980s, Brazil's government took actions designed to curb inflation, imposing tight controls on tariff levels. This stimulated industrial and household electricity use.
- Finally, electricity commercial losses increased in Brazil. These losses are driven by the increased clandestine hook-ups made by households in slums and by ventures of the informal economy. Both such user groups increased during the 1980s. Interestingly enough, the informal economy increases electricity use but is not accounted for in GDP, suggesting that it reduces the electricity use intensity by either the commercial losses or the underestimation of GDP.

In relation to the ISED, this set of indicators does not present a complete picture of the Brazilian energy system, given the income inequalities of the country and the regional disparities that reinforce these income inequalities. Within this context, the social dimension of the Brazilian sustainable energy development becomes crucial. For instance, in 1999, although the Brazilian average Gini Index was 0.567, the Paraíba state figure was 0.644, or around 30% higher than the figure of Santa Catarina State (IBGE, 2002). In addition, in 1987, 1990, 1993 and 1996, the richest 20% of the population absorbed 81% of the total income of the economically active population of the Northeast, with this proportion dropping to 68% in Southeast Brazil over these same years.

The poorest regions of the country have dwellings without access to the electricity grid. Therefore, an average figure for energy accessibility and affordability does not clearly express the heterogeneity of Brazil's various regions, and lack of access to the electric power grid is mainly a regional problem. It is indirectly linked to the concentration of the population in rural areas and to income distribution patterns among the various regions of the country – around 90% of the households lacking electricity in Brazil have an income of less than 550 U$ ppp 2000 (Tolmasquim, 2003). As major cities tend to cluster investments in infrastructure, larger scales offer network economies for public services.

Finally, aiming to assess social inequalities in Brazil's household energy use, some studies expressed how different income classes in Brazil perceive direct energy consumption (Schaeffer et al., 2003; Szklo and Cunha, 2005). In terms of expenditure, by 2000 the highest income class spent 4.3 times more for the final energy it consumed than the lowest income class. Nevertheless, that expenditure represented less than 4% of the average income of the richest income class, while it was 9% for the lowest income class (Szklo and Cunha, 2005).

Therefore, there is room for improvement in the ISED set of indicators that would be able to incorporate regional and income disparities. In fact, one of the main priority areas defined in this study concerns the reduction of regional disparities and the improvement of energy affordability. Yet, as of today, the average figures, especially when referring to the household sector, do not address these major issues of the Brazilian energy system.

Finally, Brazil's energy and economic data are only partially adequate and should be improved. The first-year progress report and Section 3.2 of this chapter identified this need, and an analysis of the suitability of data addressing sustainable development was one of the major goals of this study.

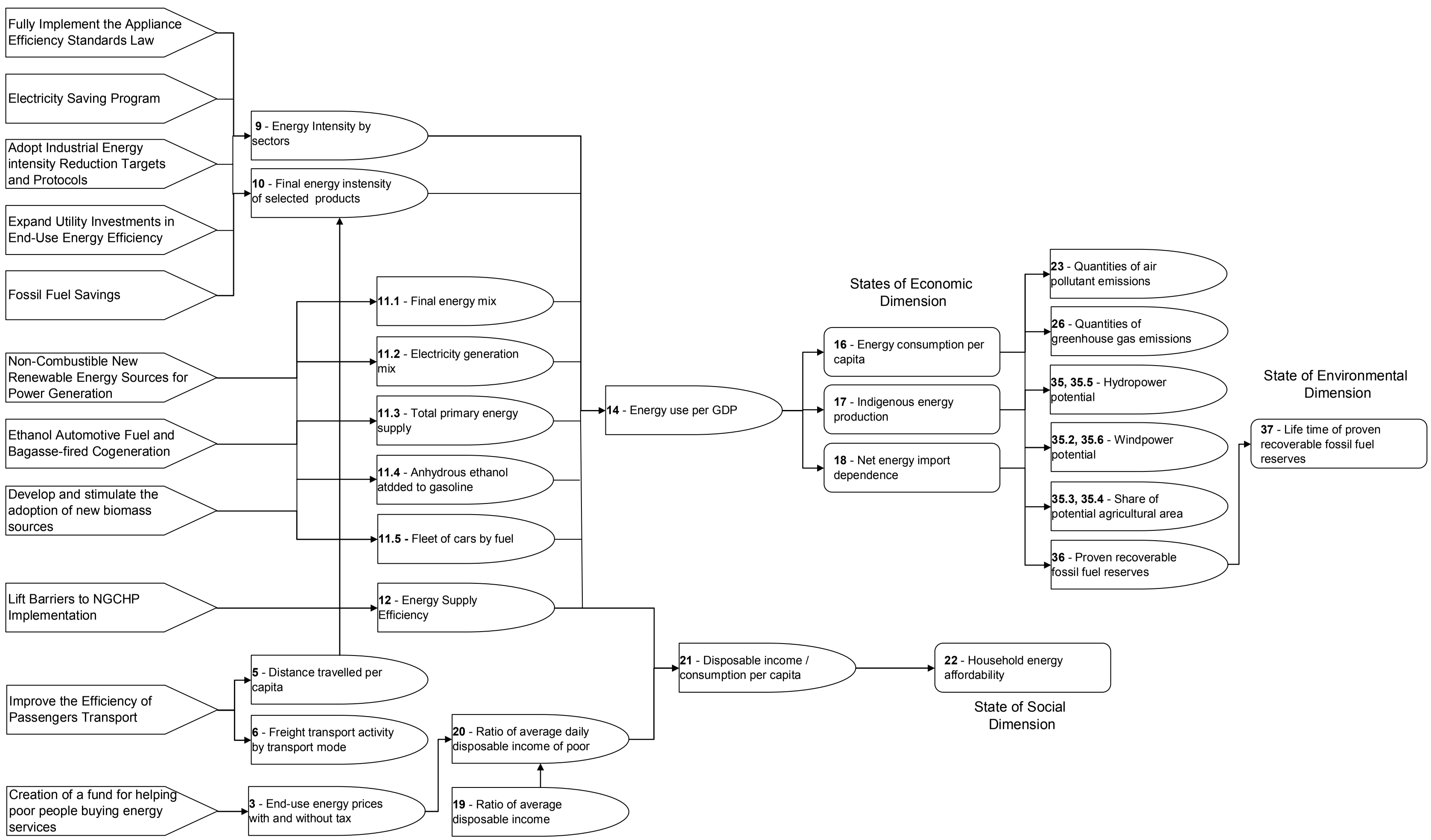

Figure 3.31. Brazil's ISED Set Map – Links between Priority Areas, Energy Policy Options and Indicators

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4. CUBA

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4.1. Introduction

Between 1959 and 1989, Cuba sustained economic development with social equity as a result of favourable relationships maintained with the now dissolved Council of Mutual Economic Assistance formed by the former European socialist countries. When these relations ended, a crisis occurred in the 1990s affecting the whole country. Reforms and economic changes were necessary, while maintaining essential services to the population (education, health, culture, sports, and social welfare).

To a greater or lesser extent, energy supply affected all sectors, but especially agricultural activity, construction and transport. This was because energy was prioritised to be used by companies generating exports and/or US dollars, and to guarantee basic services to the population as much as possible.

Energy imports fell from 11 million of ton oil equivalent (toe) in 1990 to 5.9 million toe in 1993. Energy use decreased from 13.9 million toe to 7.6 million toe, and electricity generation dropped 27% in the same period.

The Cuban Government devoted special attention to improving the energy supply. In 1993, a National Energy Sources Development Program was passed by the Cuban Parliament aimed at progressively reducing energy imports, obtaining maximum benefits from domestic energy sources, and improving energy efficiency (CNE, 1993). The implementation of the program would also have important socio-economic and political effects, primarily for its contribution to the stability and energy security of the country, reinvigoration of the economy on a more efficient base, and general environmental benefits.

In order to achieve such objectives, it was necessary:

- To increase the use of domestic crude oil and associated gas for electricity generation in substitution of imported fuel oil;
- To have more efficient use of bagasse and sugarcane agricultural wastes. By enlarging the efficiency of steam generation in this way, it will fulfil the energy requirements of the sugar industry and increase electricity delivery to the national electricity system; and
- To achieve increased utilization of hydropower, wastes energy sources (industrial, agricultural and urban), solar energy, wind energy and biogas.

This program was planned in two phases, with phases divided by results and not by time. The first phase considered primarily the increase in the production and use of domestic crude oil, energy efficiency and sugarcane's contribution. It has made an additional 700,000 toe available each year. The second phase was planned for a later period, when further financial resources could be committed for energy sector development. The total contribution of the different actions was designed to change the structure of energy production as follows: 45% from the sugar industry, 40% crude oil and 15% other sources. The structure in 1990 was: 32% sugar industry, 42% crude oil and 26% other sources.

From 1993 until the present, increases in the production of domestic crude oil and associated gas, results obtained from energy saving programs, the modernization of thermoelectric power plants, a decrease of total losses, the investments made in infrastructures for fuel transport, the substitution of fuels programs and the reduction of energy import dependence have all played an important role.

Cuba joined the international effort on Indicators for Sustainable Energy Development (ISED), which included testing on a voluntary basis the original set of 41 indicators (first phase of International Atomic Energy Agency programme on ISED 1999-2001). In 2002, Cuba began a three-year coordinated research project for implementation (i.e., the second phase of ISED) jointly with Brazil, Lithuania, Mexico, the Russian Federation, Slovakia and Thailand.

The main purpose of this research is to evaluate the country's statistical capabilities, to implement the ISED methodology in order to assess Cuban energy policies, to select priority areas and to evaluate the results of energy policies implemented during past decades in economic, environmental, social and institutional dimensions. The set of ISED and the data series compiled by the National Statistic Office were employed. From this evaluation, new strategies and policies to improve sustainable development are proposed.

4.2. Overview of Energy Sector

In 2002, 78.2% of Cuba's total energy supply was made up of fossil fuels (47.1% crude oil, 26.4% oil products, and 4.4% associated gas) and 21.7% was from renewable sources, predominantly sugarcane biomass (see Figure 4.1), (ONE, 2003).

Other resources, such as forest and coffee wastes, wood sawdust and rice shells, contributed 2,150 toe in 2002, which represented an additional 0.02% of the total energy supply. Windmills, biogas, hydraulic systems (rams, motor winches, tanks of water, etc.), photovoltaic and wind systems contributed 25,138 toe, representing an additional 0.22% of the total energy supply (ONE, 2003).

In electricity generation, fossil fuels were predominant (93.3%), while renewable resources were limited to 6.7% in 2002 (ONE, 2003).

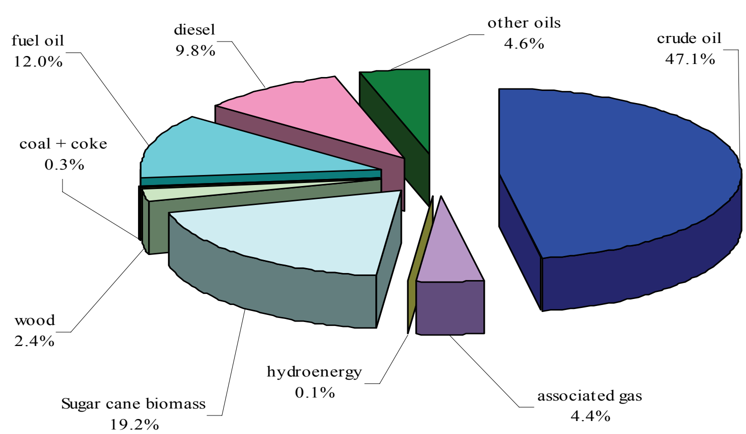

Figure 4.1. Total energy supply
Source: ONE, 2003

4.2.1. Cuban Energy Organizational Structure

The absence of a Ministry of Energy makes the organizational structure of energy in Cuba different from that in other countries, as described in detail below.

The Ministry of Economy and Planning (MEP) rules the energy and economic policy of the country. MEP presides over the Energy Council (CAAE), which is the body in charge of controlling the Programme for National Energy Sources and energy efficiency, fostering renewable energy sources and elaborating laws and legislation to improve energy efficiency in the national economy.

The Energy Council is made up of:

- The Ministry of Basic Industry (MINBAS), which in turn is formed by Electric Utility (UNE) and Union Cubapetroleo (Cupet). They are responsible for electricity and fossil fuels activities.
- The Sugar Ministry (MINAZ), constituted by sugar mills that co-generate electricity, and enterprises for energy services, sugar refineries, biogas production plants and energy research centres.
- National Institute of Hydraulic Resources (INRH) dealing with small, mini- and micro-hydroelectric power plants and hydraulic development.
- The Ministry of Information Sciences and Communications (MIC) embraces several electronic component facilities where solar photovoltaic panels are produced. MIC also includes several enterprises, which commercialise renewable energy and energy efficiency technology. The operation of the Turiguano wind farm is also a responsibility of this ministry.
- The Ministry of Steel and Machinery Industry (SIME) produces and commercialises hydraulic turbines and solar heaters.
- The Ministry of Agriculture (MINAG) manages forests and is in charge of operating wind mills for water pumping and biogas plants.
- The Ministry of Transport (MITRANS) is in charge of transport development policy, although each ministry has its own means of transportation.
- The Ministry of Science, Technology and the Environment (CITMA), through its Nuclear Energy Agency for Advanced Technologies (AEN-TA) and other institutions, especially CUBAENERGIA, constitute the scientific and technical support to the country's energy development. CITMA also coordinates the Renewable Energy Front, a specialized state instrument, which coordinates and elaborates proposals on renewable energy policies and its use to the government.
- Universities and Research Centres belonging to the Ministry of Higher Education (MES) support energy development in the country both with research and staff training.
- Ministry of Construction.
- Ministry of Internal Affairs.
- Ministry of Armed Forces.
- Ministry of Foreign Investment and Economic Cooperation.

MEP is also in charge of State Energy Inspection throughout the country.

In addition, the Energas Joint Venture and GENPOWER, another independent power producer in the Isle of Youth, contribute to electricity generation.

The Parliament or National Assembly of People's Power has an Industry and Energy Commission that represents the legislative power.

On the other hand, the Executive Power— the Council of State—is made up of Ministries within which the above-mentioned energy related structures are inserted.

Significant capacity in the country lies within its existing human capabilities, and capacity building includes staff preparation and training for the nuclear power program. The organization of research and development activities in national research programs such as "Sustainable Energy Development," as well as programs within the area and branches of industry, also contribute to the above-mentioned capacity building.

Since 2001, National Seminars on energy to support decision makers have been held every year, with the participation of numerous decision-makers and energy specialists. The wider debate about energy

at present and its future trends has resulted in the integration of institutions and specialists in energy activities.

4.2.2. Final Energy Use

The aggregated balance of final energy use in Cuba in 2002 is shown in Table 4.1. As it can be seen, 51.6% of the final energy use was in the manufacturing sector, while 20.2% was in the transport sector, 12% was in the household sector and 9.7% was in the commercial sector. Energy use by the remaining sectors was very small, accounting for 6.5% in total. Regarding fuel shares, 59.7% corresponded to fossil fuels, with motor fuel representing 39.5%. Electricity accounted for only 15.4%, while biomass played an important role at 24.9%.

TABLE 4.1. BALANCE OF FINAL ENERGY USE OF 2002, KTOE

Economic sector	Fossil fuel				Electricity	Total Commercial	Non Commercial	Total
	Fossil (substitutable)	Motor fuel	Coke	Total				
Manufacturing	1,590.2		12.3	1,602.5	329.0	1,931.5	1,418.9	3,350.4
Agriculture	95.0			95.0	5.5	100.5	39.5	140.0
Construction	47.7			47.7	16.9	64.6	0.7	65.3
Mining industry		220.6		220.6		220.6		220.6
Transport		1,315.5		1,315.5	0.2	1,315.6		1,315.6
Household	314.3			314.3	423.0	737.3	45.1	782.4
Services	288.6			288.6	224.2	512.8	118.5	631.4
Total	2,335.9	1,536.0	12.3	3,884.2	998.8	4,883.0	1,622.7	6,505.7

Source: Author's elaboration from ONE, 2003

Analysing the time series data, total final energy use increased by 34% from 1970 to 1990 in accordance with the energy-intensive economic and social development of the country during this period (Figure 4.2). The crisis of the 1990s forced a rapid decrease (35%) of final energy use in 1995, compared with the 1990 level. During the economic recovery observed since the mid 1990s, final energy use has not increased and has remained at 38% below the 1970 level. This has been due mainly to the success of energy conservation programmes launched by the Government, and efficiency improvements in the overall economy (ONE, 2003).

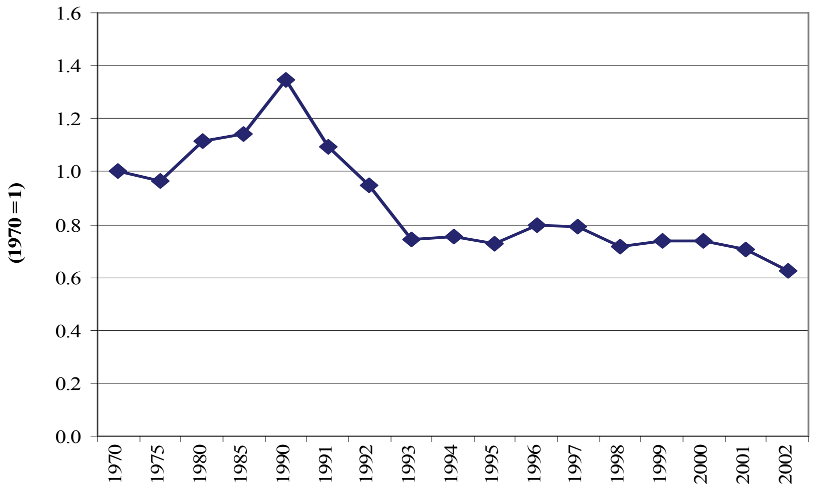

Figure 4.2. Index of total final energy use (1970=1)
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003
Note: The total final energy use in 1970 was 10.3 million toe

Figure 4.3 shows the final energy use by energy fuels and electricity. Electricity use increased by 300% in 1990 compared with 1970 (a period of energy-intensive economic and social growth). During the 1990s crisis, electricity use initially fell; however, from 1994 electricity use increased rapidly, so that by 2002 it was near the 1990 levels. In 2002, the use of all fuels was lower than in 1970, with the exception of associated gas and electricity.

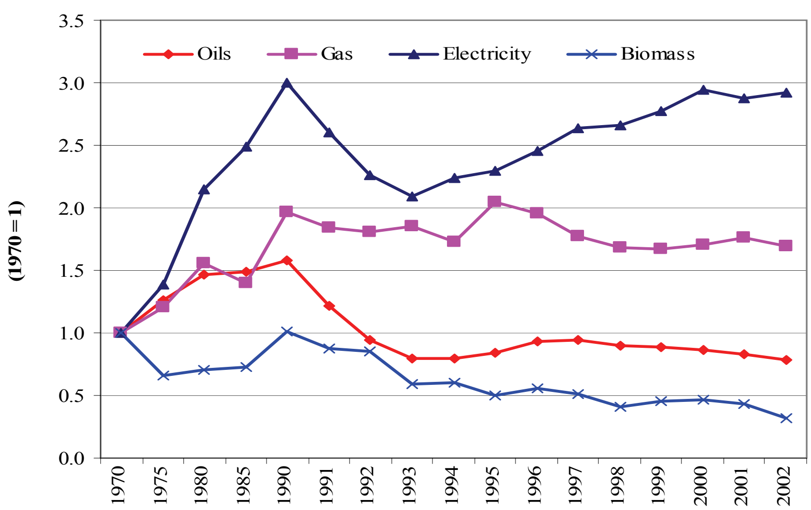

Figure 4.3. Index of final energy use by fuels and electricity (1970=1)
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003
Note: In 1970 the final use of oils (crude oil and oil products) was 4.8 million toe, gas 0.05 million toe, electricity 0.34 million toe and biomass 5.1 million toe.

The final energy use by sectors (Figure 4.4) has changed, according to structural changes occurring in the domestic economy, namely, lower use in the industry and agricultural sectors, but higher in transportation, households and mainly services; however, these sectors are low-energy users. The major energy use is found in the industrial sector (steel, nickel, sugar, cement, etc.).

The analysis of the final energy use dynamics (i.e., changes with respect to previous year) shows that it fell more than gross domestic product (GDP) using purchasing power parities (PPP 2000) (Figure 4.5). This implies a reduction in the energy intensity of the country, where the participation of the industrial sector (i.e., manufacturing, agricultural and construction sectors) is considerable. Less important was the participation of household and services sectors with respect to total energy use. These results in final energy use suggest a decrease in the well-being of society, despite the government's efforts to minimize the impact on social services.

To understand the behaviour of total final energy use dynamics, it is necessary to disaggregate it by sectors, as shown in Figure 4.6[1]. The peak of the energy use dynamics in 1996 is related to the services sector, and in particular to the increase of tourism in 1995. In the case of 1999, the peak corresponds to increases in tourism and household sectors.

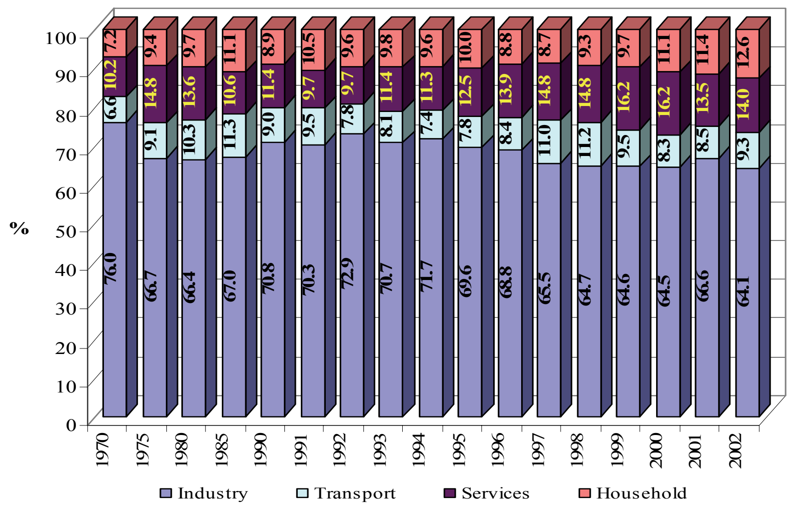

FIG 4.4. Share of final energy use by sectors, %
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003
Note: In 1970 the final energy use in Industry was 7.85 million toe, transport 0.68 million toe, services 1.06 million toe and household 0.74 million toe

[1] Data on final energy use desegregated by sectors before 1990 are not available.

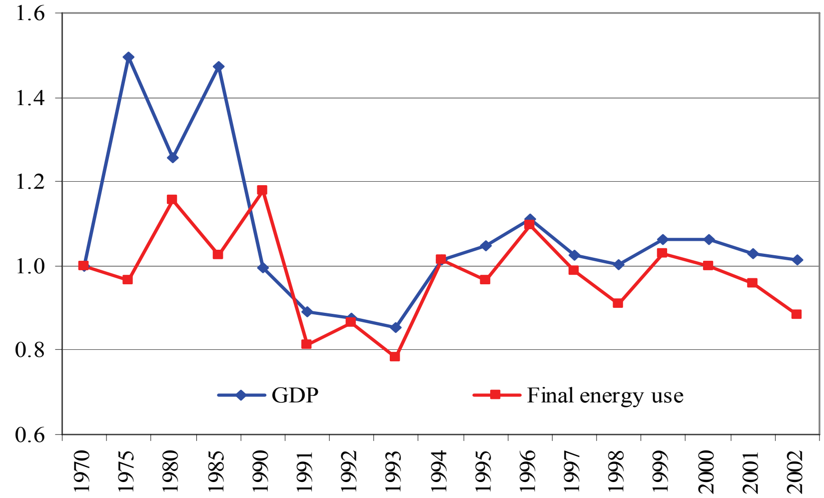

Figure 4.5. GDP₁₉₉₇ & total final energy use dynamics
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

4.2.3. Electricity Supply

Cuba's installed electricity capacity has increased rapidly to cover the electricity demand associated with economic and social development. Between 1970 and 1990, 160 megawatts (MW) were installed per year on average. Capacity has continued growing in the past few years, albeit at a low rate. The largest growth has been in thermal power plants and cogeneration in the sugar industry; however, since 1998, gas turbines and combined cycles using associated gas have become increasingly important (Figure 4.7). At the end of 2002, total installed capacity was 3,959.6 MW. More than 90% of this capacity is connected to the National Electric Grid (NEG). Isolated systems and cogeneration plants constitute the rest. The important reduction of the installed capacity in 2002 (with respect to 2001) occurred because of changes in the sugar sector (i.e., 300 MW were retired).

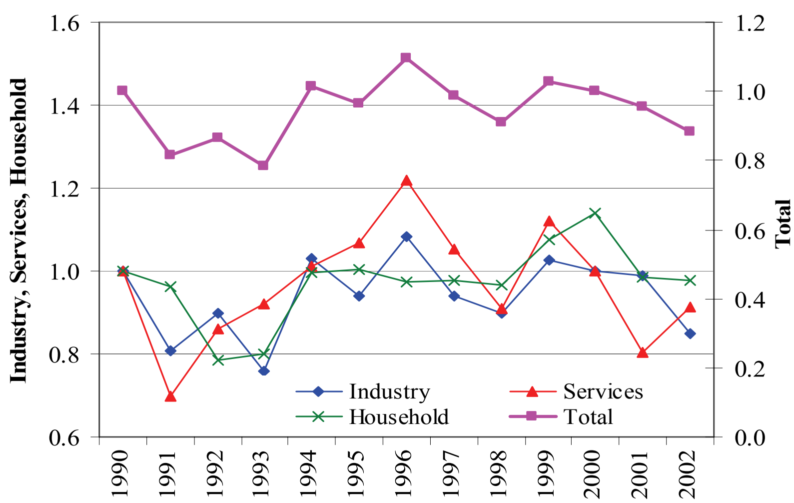

Figure 4.6. Final energy use dynamics by sectors
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

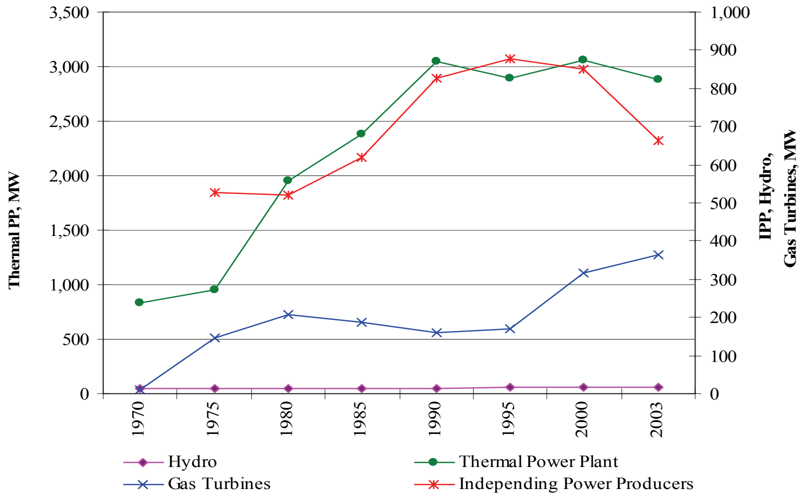

Figure 4.7. Installed capacity
Source: ONE, 2003

In the electricity generation mix, the role of fossil fuels increased from 80% in 1970 to 93% in 2002. In the same period, the share of biomass fell from 18% to 6.1% (CRW-combustion renewable and wastes), and the share of hydroelectric and wind power was below 1% (Figure 4.8).

There was rapid growth of electricity consumption (10.5% annually) in the 1970s, largely because of extensive industrial development during that period. In the 1980s, this use increased at a rate of 4% annually on average. However, in the 1990s, electricity use dropped in all sectors, though to a greater extent in the commercial/services, agricultural and industrial sectors. Activities were suspended and industries were closed mainly because of the lack of fuels and electricity, though in some cases, this was caused by lack of hard currency to purchase the necessary raw materials. Blackouts were a common practice and were planned daily. However, the household sector was affected only slightly, and by 1995 household electricity use was already at the 1990 level (Figure 4.9).

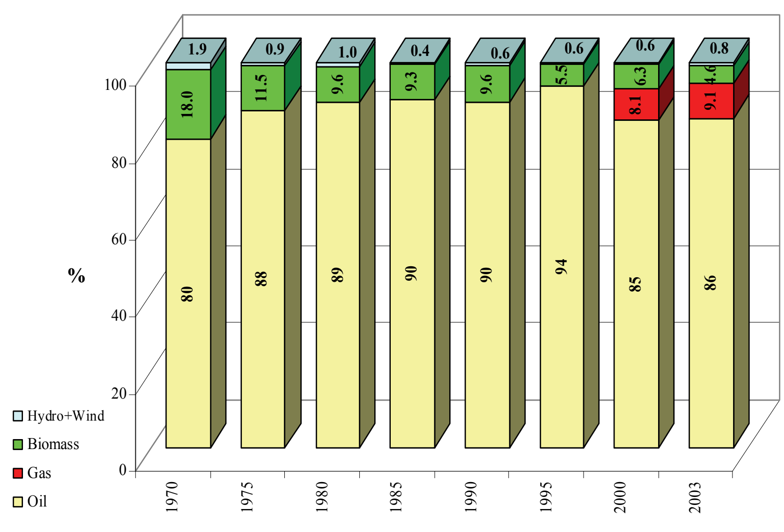

Figure 4.8. Electricity generation mix
Source: UNE, 2003

From 1994, with the beginning of economic recovery, electricity use in the services and household sectors grew at a greater speed than in the industrial sector. After 2000 the electricity use in industrial and services sectors did not increase, and household use was the determining factor for the overall

increases. On average, in the past five years the electricity use grew 4.2% yearly (Figure 4.9). However, with implementation of the Electricity Conservation Program, average maximum peak demand since 1997 has remained on approximately 2,150 MW, and growth rates have been smaller than 2% per year.

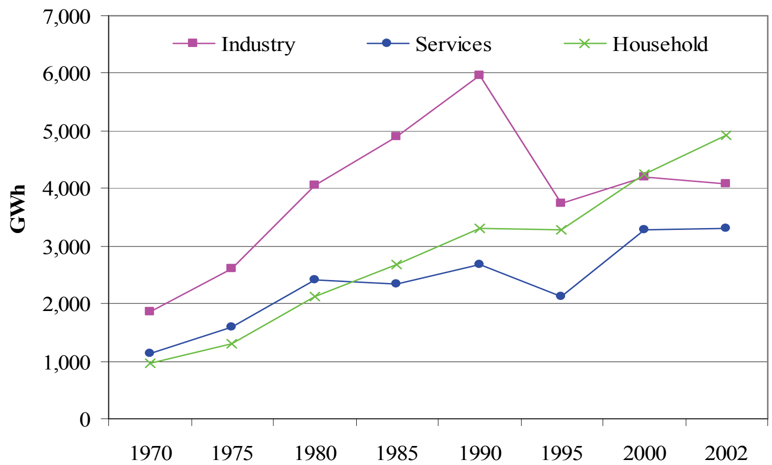

Figure 4.9. Electricity use by sectors
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

4.2.4. Energy Inequalities

In Cuba, energy inequalities are not only restricted in terms of energy access, but also in terms of energy prices, and the quality and time frame of energy services. Energy services in Cuba are rendered as a public service. All Cuban inhabitants are entitled to receive the services as customers with quality and safety standards. However, approximately 4.89% of the population in 2002, or about 550,000 persons did not have access to electricity. Fuel prices and electricity tariffs are structured in such a way that the population's access to this service is ensured, but domestic fuels distribution continues to be rationed to meet users' essential demands. A significant amount of electricity production costs are in hard currencies (i.e., fuel costs), but are paid for with Cuban pesos[2]. Thus, the household and government sectors are subsidized, leading to supply constraints as noted above.

4.2.5. Household Energy Use

Household energy use represented 12.6% of the county's energy use in 2002. Within this sector, electricity for lighting, air conditioning, and household appliances accounted for 52%; it is also used for cooking food to a lesser extent, but there are no reliable statistics. Kerosene and LPG (15.9% each one) are also used for cooking, as well as city or municipal gas (6.8%). The alcohol used for pre-heating/warming-up the kerosene stoves constitutes 3.8%, and the solid fuels charcoal and fuelwood accounted for 1.2% and 0.6%, respectively, (ONE, 2003).

Electricity use in the household sector has risen as an energy alternative because of the insufficient supply of other fuels, and because of population growth. This incremental growth was limited, because

[2] Currently there is a valid electricity tariff in hard currencies that embraces all final use sectors, excluding the household, based on the contracted power and the consumed energy, and that takes into account the different time schedules (dawn, morning and peak hours). Because of the price reform within the general policy of price increase in some considered "sumptuary" consumer goods and public services and the elimination of undue free-of-charges services, to reduce the tax deficit and the excess of circulating money, the household electricity tariff suffered the most significant change in the last 35 years (Somoza J. and Garcia A., 1998).

the acquisition of certain household appliances was restricted. Other causes that have hindered electricity use growth have been the conservation programs noted earlier, and the new tariff system for electricity.

The participation of LPG and the city gas has grown as a result of the fuel substitution programs, which have displaced some 30% of the kerosene, as well as alcohol and fuelwood. This program has benefited three million people in its first stage (Somoza J. and Garcia A., 2002) in which the delivery of gas stoves with two burners and the cylinder of LPG was subsidized by the government.

The country has created and modernized the production infrastructure and distribution of LPG. The bottling is carried out in 19 Kg gas cylinders (containing 10 Kg of gas), which are distributed to the points-of-sale in trucks. There, the cylinders are distributed to the population in established rationed amounts, depending on the number of people inhabiting a house. The price of the cylinder is 7 pesos and, for instance, for a 4-person family, the acquisition cycle is every 19 days. Gas demand could be increased if the rationed distribution were eliminated.

Kerosene and alcohol for preheating the kerosene stove constitute the main fuels employed in the household sector between 1970 and 1994, although already by 1985 their use began to diminish. It should be pointed out that the distribution of these fuels has always been rationed, and the 1990s crisis forced a reduction in distribution standards. Even then, in many (mainly rural) areas, distribution did not reach 50% of the established rationed amount. To cover the deficit of fuel supply during the crisis period, households made use of homemade electric stoves (which are very inefficient), illegally tapped into electric network connections, used diesel from transportation for cooking purposes, and indiscriminately cut down trees.

Fuelwood use grew abruptly in 1992, reaching its maximum levels in 1993. Later, a sustained decrease in fuelwood use took place, mainly in the industrial sector, as a result of the reduction in production and use of charcoal.

Methane has begun to be used in an experimental way for automotive transport. More than 100 cars, mainly taxis, have already been converted; and there could be a lot more if appropriate financing becomes available.

4.2.6. Rural Electrification

When the electric service passed to the hands of the State in 1960, electrification was used for eminently social and economic purposes. Rural electric grids were expanded, and the rural population's electrification grew from 46% in 1960 to 95.11% in 2002 (ONE, 2003).

Efforts have continued to solve the situation for the rest of the rural population, by means of installing micro-hydroelectric plants, solar photovoltaic panels (often as a solidarity contribution from people and non governmental organizations from Germany, Italy, Spain, Norway, etc.), and more recently wind or hybrid systems.

Taking into account that the majority of the rural population lives in isolated houses, extending electrification has become even more complicated from a practical and economic point of view. For this reason, since the 1980s, policy has focused on providing electricity only to population settlements with the aim of promoting a life in a community that facilitates access to social benefits, particularly education and free medical service.

The electrification of social goals has been prioritised, such as 350 family doctor’s offices, 5 hospitals, 2,364 primary schools, 1,864 TV rooms, 150 social clubs, dozens of houses, rural boarding schools, camping facilities, video equipment, telephone exchanges, fishing collection centres and cooperatives (PDFNER, 2003). Special efforts also utilize electrification to foster programs for the dissemination of culture, for audiovisual programs, etc.

Actions similar to those mentioned above have contributed significantly to improving the quality of life of large numbers of people. These actions also have contributed to the economic development of

the region, as well as to stem the flow of immigrants who come to the urban areas from the mountainous and rural areas.

4.2.7. Energy Prices

On energy prices (tariff) (see Table 4.2), different theories exist (i.e., consideration of marginal costs, favouring the poorest, etc.). In Cuba, differentiated electricity tariffs are applied in different sectors. They are designed:

- To guarantee the exploitation/operation and the development of the electric system with efficiency and quality;
- To transfer to the domestic economy the smallest prices necessary to increase the electric system's competitiveness;
- To get payment from each client according to the costs that he/she causes to the electric system;
- To provide a price structure that stimulates the rational use of energy.

As electricity is a natural public monopoly, the State must regulate the establishment of the electricity tariff. It is an international practice that the electricity tariff disaggregates costs according to levels of voltage to which clients are connected. This is the reason why there are fixed and variable factors such as fuel price, etc. The current rate eliminates subsidies and shows the real electricity cost, except in the household and government sectors[3].

In the household sector the tariff is 9 cents per kWh for the first 100 kWh of consumption, 20 cents per kWh for consumption between 100 kWh and 200 kWh, and 30 cents per kWh for consumption above 300 kWh (MFP, 2002).

Thus, the Cuban "population at risk"[4] that usually has smaller electricity use than a population with higher living standards also pays less for the electric service, since it does not reach 100 kWh per month because of the scarcity of electrical appliances and the fact that electricity is basically used for lighting. However, many families exceed the 300 kWh per month. The average electricity use in the country for a household consumer was 140.1 kWh/month in 2002 (ONE, 2002), which is equal to an average monthly price of 17.02 pesos/month per house (for an average 3.16 inhabitants). The above-mentioned average household client price represents 4.8% of the average wage per worker in 2004.

It is estimated that 72% of the electricity generation costs are in hard currency, which far exceeds the prices the population pays for this service.

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[3] Indeed, the variable component of the electricity tariff is based on a fuel price that is established yearly; this is the reason why any fuel price variation is transferred to the tariff by using an adjustment coefficient K that is the ratio of real fuel price/base price.

[4] The studies on poverty carried out in the country differentiate Cuban poverty from that observed in Latin America and the Caribbean, and suggest that the term "Population at Risk" be employed to denote the population with insufficient revenues to acquire basic food products and other goods, but at the same time having qualitatively higher social services than those typically received by Latin America's poor.

TABLE 4.2 ANNUAL AVERAGE PRICES OF DOMESTIC FUELS

Products	Unit	1995	2001	% increment
City gas	Pesos/103 m^3	155.8	180	15.5
Electricity	Cent/kWh	12.45	13.33	7.1
LPG	Pesos/bbl	20.98	20.98	0
Gasoline/Alcohol	Pesos/bbl	19.08	19.08	0
Kerosene	Pesos/bbl	13.43	13.43	0

Source: ONE, 2001 b/

4.2.8. Energy Demand Projections

Energy demand projections for the period 2001-2020 for the reference scenario developed using the IAEA's Model for Assessment of Energy Demand (MAED) are presented by energy fuels in Table 4.3 and by sectors in Table 4.4.

The main assumptions in this scenario are: a moderate economic and social development; 4.16% annual increases of GDP; favourable atmosphere for foreign investment in tourism and mining; moderate growth in oil extraction; energy intensity of industries decreasing annually by 1%; revenues per capita increasing until 5,000 pesos/capita in 2020; cars per capita increasing; inhabitants per house decreasing; urbanization level reaching 80%; limitations to acquire domestic appliances are eliminated and they become more efficient, etc.

TABLE 4.3. FINAL ENERGY DEMAND PROJECTIONS BY FUELS AND ELECTRICITY, KTOE

	2001	2005	2010	2015	2020
Non commercial	2,196.5	2,743.2	3,405.6	4,154.0	5,050.9
Electricity	1,032.5	1,276.7	1,583.2	1,945.3	2,378.7
Thermal use	0.0	3.0	4.5	7.4	14.5
Fossil fuel	2,438.4	3,119.4	3,800.2	4,605.8	5,620.2
Motor fuel	1,665.9	1,860.4	2,139.5	2,462.3	2,808.7
Feedstock	15.3	21.1	27.1	34.0	42.9
Total	7,348.6	9,023.7	10,960.1	13,208.9	15,915.9

Source: Authors' calculations

TABLE 4.4 FINAL ENERGY DEMAND PROJECTIONS BY SECTORS, KTOE

	2001	2005	2010	2015	2020
Industry	4,422.3	5,683.6	7,129.5	8,796.4	10,746.6
Freight transport	602.8	664.7	724.3	789.1	846.4
Passenger transport	804.0	910.0	1,062.8	1,238.5	1,438.8
Household	805.0	927.3	1,113.7	1,376.9	1,787.3
Services	714.5	838.0	929.8	1,007.9	1,096.8
Total	7,348.6	9,023.7	10,960.1	13,208.9	15,915.9

Source: Authors' calculations

4.3. Review of Energy Statistical Data Capability

The National Office of Statistics (ONE) is Cuba's agency in charge of collecting economic, demographic and social data. The collected information is used in planning, management, economic analysis, monitoring international commitments and public information. The National Office of Statistics has 14 provincial and 169 municipal delegations across the island. The ONE has central and territorial levels for administrative control. ONE uses different questionnaires to collect energy information on indicators of energy use, electricity generation balance, fuel use, electrification, use of renewable resources, supply and distribution of energy sources, territorial energy efficiency, etc.

The main limitations of the statistical data are: although exhaustive, they often are not very responsive; some data are of poor quality; complicated organizational flows; and difficulties in use. The major enhancements expected for the NSIS are: to reduce the volume of data collected; to enhance data validation and statistical verification; to integrate all of the information systems; and to use modern information support systems.

The main sources of data employed for the ISED data compilation included the Statistic Yearbook of Cuba, and Energy Statistics for different years. Other sources of data (which have the weakness that they contain non-official data) included: Electric Utility Memories; Electricity tariff data (Resolutions of the Ministry of Finance and Prices); Greenhouse Gas Inventories (Ministry of Sciences, Technology and Environment); Environment Panorama and situation reports (Information, Management and Environment Education Centre); and various papers and presentations of different authors and institutions in national and international meetings.

After a detailed analysis of complete ISED lists (disaggregated), Table 4.5 shows the ISED which are not applicable to Cuba at the present time. The country does not use space heating; coal or nuclear power in electricity generation; abatement technologies are not required; and Cuba does not import natural gas or electricity. Nevertheless, energy projections for the period through 2020-2025 include consideration of nuclear power plants, the introduction of abatement technologies in conventional power plants, the desulfurization of crude oil, and the introduction of other fuels and technologies.

Data for the following indicators were not available for this study:

- Energy mix (heat): In sugarcane production, process steam is utilized, but there are no special accounting procedures employed to track the total amount;
- (ISED #15, 15.2.3) Expenditures on energy sector and hydrocarbon exploration;
- (ISED #21.3) Fraction of disposable income/private use per capita spent on fuel and electricity by a group of 20% poorest population[5];
- (ISED #19) Income inequality;
- (ISED #20) Ratio of daily disposable income/private use per capita of 20% poorest population to the price of electricity and major household fuels;
- (ISED #23.1.3, 23.3.3) Quantities of particulate emissions from energy and transport activities;
- (ISED #24) Ambient concentration of pollutants in urban areas;
- (ISED #28.1) Storm water discharge;
- (ISED #28.3) Discharges of oil into coastal waters;
- (ISED #29.1) Generation of solid waste from energy activities;

[5] For Cuba, the denomination "population at risk" is employed to differentiate this situation with the poorest in Latin America and the Caribbean. Not enough statistics currently exist for this indicator.

- (ISED #29.2) Generation of solid waste from thermal power plants;
- (ISED #36) Proven recoverable fossil fuel reserves[6];
- (ISED #37) Life time of proven recoverable fossil fuel reserves;
- (ISED #40) Intensity of use of forest resources as fuelwood;
- (ISED #41) Rate of deforestation.[7]

TABLE 4.5. INDICATORS NOT APPLICABLE TO CUBA

Dimension	Indicator
Economic	(3) End-use energy prices with and without tax/subsidy:
	Industry: Heat and steam coal
	Household: Heat, steam coal and light fuel oil
	(9) Energy intensities:
	Household: Space heating
	(11) Energy mix:
	Electricity generation mix by fuel types: coal and nuclear power
	Total primary energy supply mix: nuclear power and electricity net import
	(13) Status of deployment of pollution abatement technologies
	(17) Indigenous energy production: coal and nuclear power
	(18) Energy net import dependency: gas and electricity
Environmental	(27) Radionuclides in atmospheric radioactive discharges
	(28) Discharges into water basin: Radionuclides in liquid radioactive discharges
	(31) Generation of radioactive waste from fuel cycle chains of nuclear power generation
	(32) Accumulated quantity of radioactive wastes awaiting disposal
	(34) Fatalities due to accidents: for coal and nuclear chain
	(36) Proven recoverable fossil fuel reserves: for coal
	(37) Life time of proven recoverable fossil fuel reserves: for coal
	(38) Proven uranium reserves
	(39) Life time of proven uranium reserves

Data for all other ISED indicators were available and used in this evaluation.

As a result of this research project, the lack of some statistics was identified as a concern, and work was carried out to enhance the national statistics system.

The principal modifications introduced in the national statistics system were:

- The elimination of information found to be not particularly useful for decision makers and planners;
- The collection and concentration of new needed information;
- The establishment of three new surveys (on environment management, water use and distribution, and wastes);

[6] Data are collected from authors' presentation. These are not official data.

[7] Time series for this indicator are not available. Starting from 2002, data are collected in aggregated manner (include all kinds of deforestation, by forest fire, hurricanes, etc.)

- An incorporation of the concept of hydro basins into the analysis of investments;
- A reduction of the level of disaggregating information on investment, but the compilation of additional information on hydro basins and the environment, and on energy development and research;
- The introduction of data verification for collected information.

This improved effort allowed the collection of data necessary to construct the majority of necessary ISED indicators.

The elaboration of the "Environment Compendium" was initiated by the National Office of Statistics, with the important collaboration of the research project team. It now includes a chapter on energy and the environmental impact of its use.

During the Workshop to define the Environment Indicators to be used in the country (organized by the Ministry of Sciences, Technology and Environment in May 2004), the research team proposed definitions and adjustments for the energy indicators related to the environment.

4.4. Major Energy Priority Areas

The major priority of the country, particularly during the economic crisis of the 1990s, was to improve the economic and energy situation.

Taking into consideration the objectives of the National Energy Sources Development Program passed by the Parliament in 1993 (to progressively reduce energy imports, obtain maximum benefits from domestic energy sources, and improve energy efficiency), and given the priorities of research and development for the next five years in the country (i.e., sustainable energy development is one of seven of these priorities), the selected major energy policies for evaluation are:

- Reducing energy dependence;
- Increasing the penetration of renewable energy; and
- Improving energy efficiency.

These energy policies are considered the most important because of their economic, environmental, social and institutional impacts. These policies also receive the most government support. Other implemented energy policies had lower relevance and scope in the evaluated period, and for these reasons, these specific energy policies were selected for evaluation using the ISED methodology.

Table 4.6 presents the indicators used to evaluate these polices.

4.5. Implementation of ISED Framework

The drastic changes that affected the Cuban energy system were caused by several factors, including the economic changes that took place during the crisis period, increased urbanization, the decrease of demographic growth rates, the educational and health system development, and the incremental improvement of life expectancy. Before 1990, information about GDP at constant prices disaggregated by sectors is not available. For this reason, the indicators related to GDP by sectors are from 1990 until the present. All GDP data are shown using 1997 constant prices.

TABLE 4.6. INDICATORS SET USED FOR ENERGY POLICIES EVALUATION

Dimension	Indicators
Economic	Indirect Driving Force
	1. Population
	2. GDP per capita
	3. End-use energy prices
	4. Shares of sectors in GDP value added
	5. Distance travelled per capita by passengers
	6. Freight transport activity
	9. Energy Intensities
	11. Energy Mix
	12. Energy Supply Efficiency
	Direct Driving Force
	14. Energy use per unit of GDP
	State
	16. Energy use per capita
	17. Indigenous energy production
	18. Energy net import dependency
Social	Direct Driving Force
	21. Fraction of disposable income/private use per capita spent on fuel and electricity
	State
	22. Fraction of households without electricity
Environmental	Direct Driving Force
	23. Quantities of air pollution emissions
	26. Quantities of GHG emissions
	35. Fraction of technically exploitable capability of hydropower currently not in use
	State
	24. Ambient concentration of pollutants in urban areas

4.5.1. Analysis of economic situation

4.5.1.1. Activity effects

The Cuban population has doubled in the past 50 years. Average annual growth rates were higher than 1% until 1990. During the past decade, however, the economic crisis, along with raised standards attained in education, culture, medical care, sexual education programs, migrations, etc., led to a steadily falling growth rate which reached 0.26% in 2003 (a very low rate) (see Figure 4.10 for population totals).

From 1970 until 1990, the GDP increased by a factor of 2.8, but during the economic crisis, all activity levels decreased. From 1990 to 1993, the GDP fell by 25%. The economic recovery began in 1994, and between 1995 and 2003 the average yearly growth in GDP was 0.41%. However, the levels of 1990 were still not reached, and the GDP remained 6% smaller (Figure 4.10).

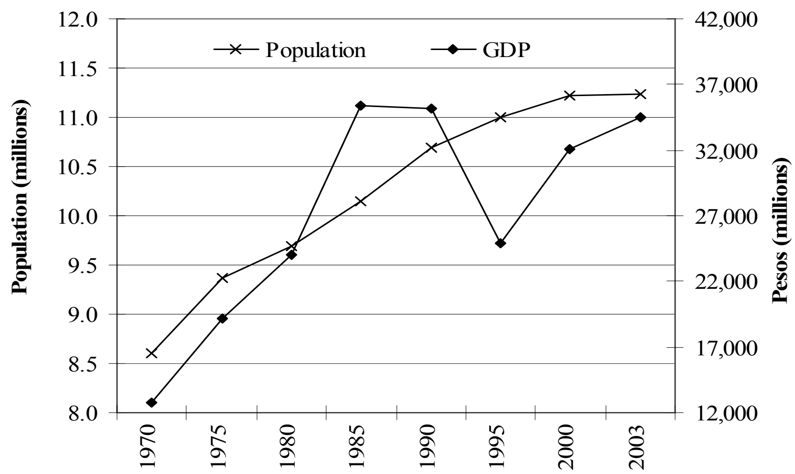

Figure 4.10. Population and GDP$_{1997}$
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

The effects of the economic activities are reflected in a different way in the main indices of energy use per capita (an index is the relation of the indicator with respect to a fixed year). Electricity use per capita rapidly increased until 1990 (1.8 times with respect to 1970), but the total primary energy use per capita decreased due to the more rapid increase in population than primary energy production. Between 1990 and 1993, primary energy and electricity use per capita fell by a factor of 1.7 and 1.5, respectively, (Figure 4.11) as a result of the crisis. After 1994, electricity use per capita increased and is slightly larger in 2002 than in 1990, but a decrease of primary energy use per capita in later years is observed. This is due to the fact that decreases in biomass use per capita are larger than increases in crude oil and gas use per capita.

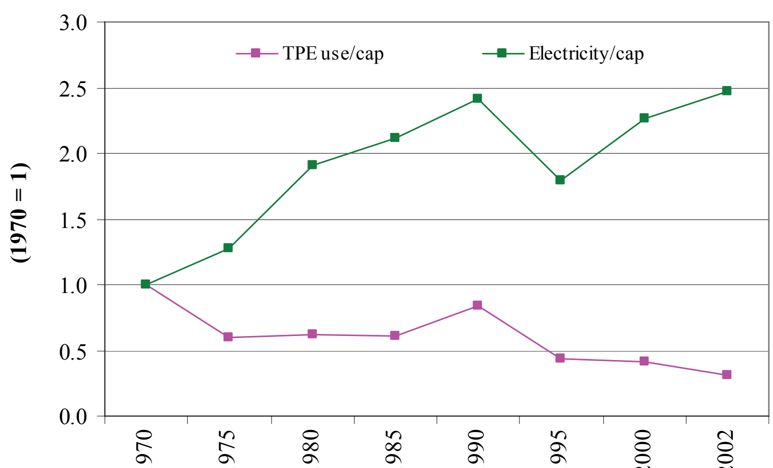

Figure 4.11. Index of Total Primary Energy and electricity use per capita
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003
Note: In 1970, the TPE/cap was 0.585 toe/cap and the Electricity/cap was 0.463 MWh/cap

Passenger activities (passenger-km) increased very rapidly during the 1970s and 1980s with economic development, but freight activities (ton-km) did not match such growth. The 1990s crisis seriously affected these activities, as can be observed in Figure 4.12. The passenger index fell 40% and freight index 86% with respect to 1970. Nevertheless, the passenger statistics do not reflect the real increases that occurred in the past year, mainly in tourism and the private sector, because it includes only data

from the Ministry of Transport. The analysis of fuel use in transportation is limited for the same reasons. Starting in 2003, the Statistics Year Book will include all of the fuel used for transportation, and all transport activities in the country, as a result of this project.

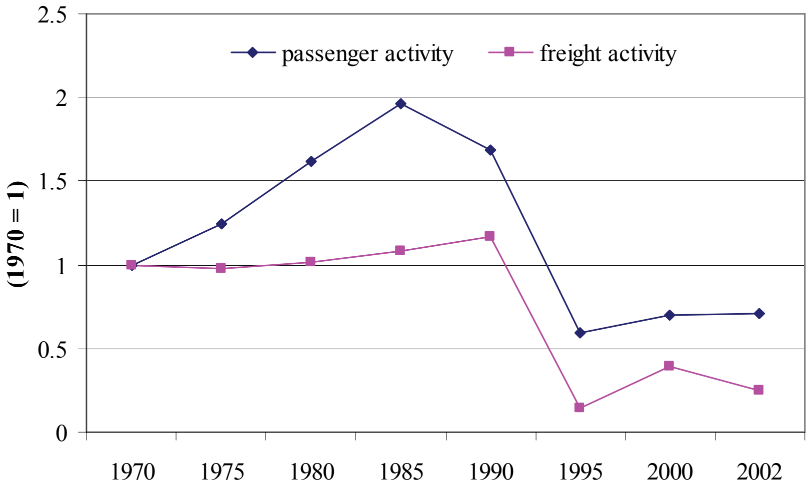

Figure 4.12. Index of Freight and Passenger transport activities
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

The energy intensity of the total primary energy supply (TPES) shows a decresing trend for almost all of the analyzed period (1970-2002), for different reasons (Figure 4.13). During the 1970s and 1980s, Cuba's economy depended on oil imports. Due to the similar increment in TPES and GDP during the 1975 to 1980 period, no change in the energy intensity in this period occurred. The 1990s economic crisis lowered the GDP; nevertheless the TPES had greater decrease, with a consequent reduction of the energy intensity. During the most critical year of the crisis (1993) and with the economic recovery starting in 1994, the energy intensity of the TPES continued decreasing even with higher levels of crude oil and associated gas production, because the GDP also grew in this period. Later, the structural changes made in the overall economy and the implementation of energy conservation and efficiency programs contributed to the drop in intensity. With the increases in the use of crude oil and associated gas after 1999, energy intensity of TPES in 2002 reached the values of 0.44 toe/1,000 pesos.

The electricity intensity (Figure 4.13) with small fluctuations (from 0.34 to 0.46 kWh/pesos) slightly increased along with the electricity sector recovery and with the increased electricity supply. The electricity conservation program, electricity loss reductions and efficiency increases contributed to maintain the electricity intensity at the same level during the last 10 years. In 2002 electricity use increased, but GDP growth was very low (i.e., 1.5%), and the electricity intensity indicator grew.

The relation between the electricity intensity and the GDP per capita presented in Figure 4.14 shows that with economic development from 1970 until 1990, the electricity intensity increased by 9%, but the GDP per capita increased by a factor of 2.2 (i.e., 220%). During the 1990s crisis, the GDP per capita decreased by a factor of 0.6, but the electricity intensity increased by 10% (from 1990-1994). The effect of different efficiency programs kept the electricity intensity at the same level, except for an incremental increase of 11% in the last year.

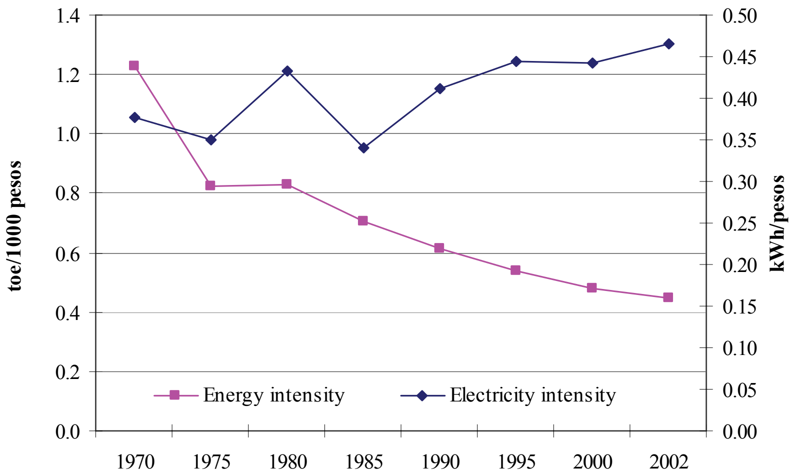

Figure 4.13. TPES and electricity intensities
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

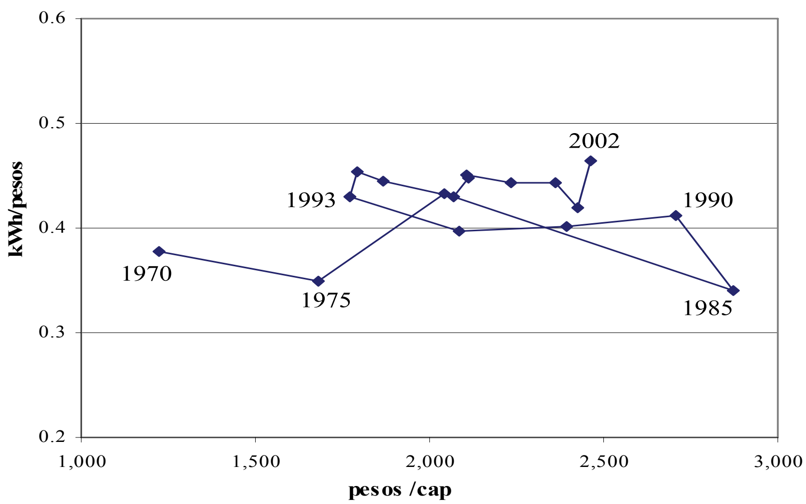

Figure 4.14. Electricity intensity and GDP per capita
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

4.5.1.2. Structural effects

The Cuban economy has undergone significant structural changes in the past. In the 1950s, Cuba was essentially an agrarian-based economy, with only moderate industrial development in the sugar industry. Industrialisation began in 1959, when energy-intensive industries began operating in the fields of nickel, steel, cement, machinery, etc. The role of the commercial and services sectors also grew significantly.

During the crisis of the 1990s, a contraction of the industrial sector took place (Figure 4.15), accompanied by a fall of the added value generated by this sector, the partial closing of industries, and a decrease in industrial production (Figure 4.16). The services sector occupied a more predominant role, and the transportation sector also played an increased role, while agriculture's role in the GDP diminished.

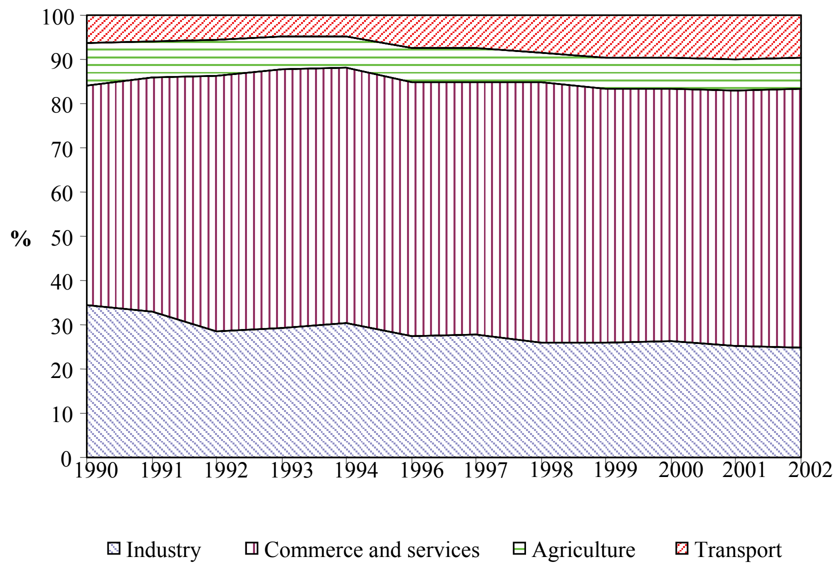

Figure 4.15. Share of added value by sectors
Source: ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

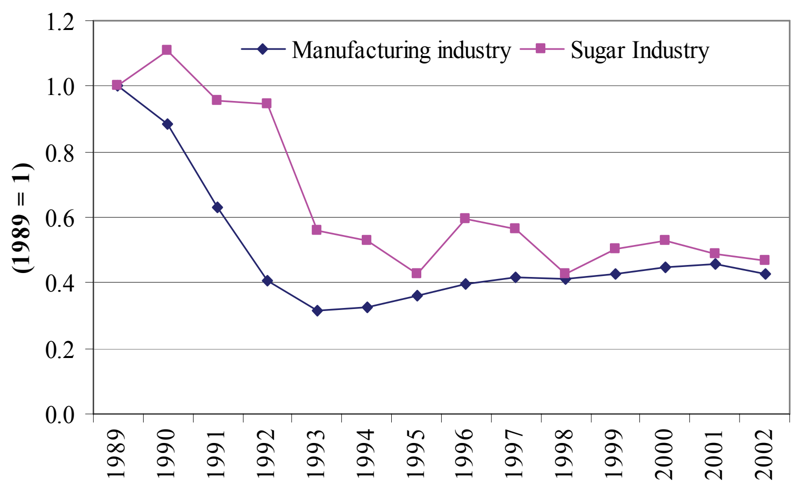

Figure 4.16. Indices of manufacturing and sugar industries production
Source: ONE, 1989, 1998, 1999, 2000, 2001 a/, 2002, 2003

The total energy use per unit of GDP (aggregated energy intensity) indicates the general relation of energy use to economic and social development. The analysis of the reduction of this aggregated indicator can provide an incorrect view of the economic and social development, and it is necessary to analyse the indicators at a more disaggregated level to see the real situation.

Industry is the most intensive energy and electricity sector (Figures 4.17 and 4.18), and used 58% of the total energy and 33% of Cuba's total electricity in 2002. The total energy intensity decreased over time. During 1991 until 1995, forced by the effect of the crisis, and then by the effect of energy conservation and efficiency programs, the total energy intensity decreased (Figure 4.17). The total energy intensity is less than that of industry because the total energy use considers the energy used in the household sector.

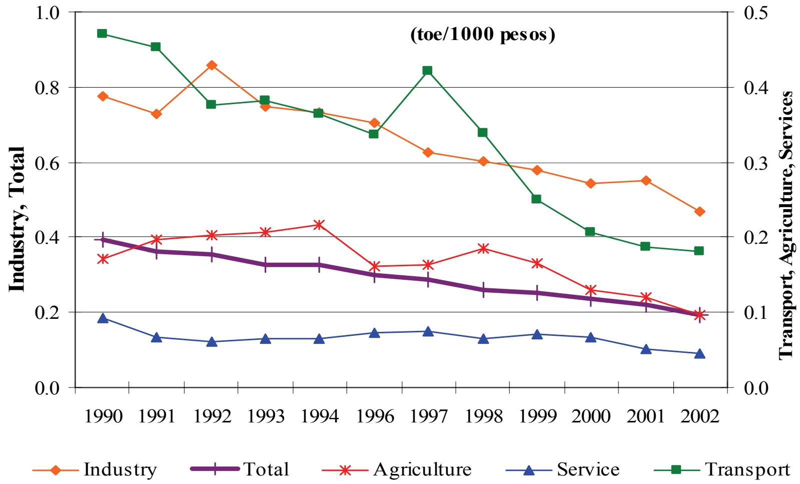

Figure 4.17. Final energy intensities by sectors
Source: ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003
Note: Data for 1995 are not available

The total electricity intensity, except with small fluctuations (from 0.34 to 0.46 kWh/pesos), slightly increased and was kept at practically the same level due to electricity conservation programs, fuel substitution for cooking, electricity loss reduction, increased efficiency in electricity generation (i.e., the modernization of power plants and the introduction of new ones), as well as structural changes in industry and services.

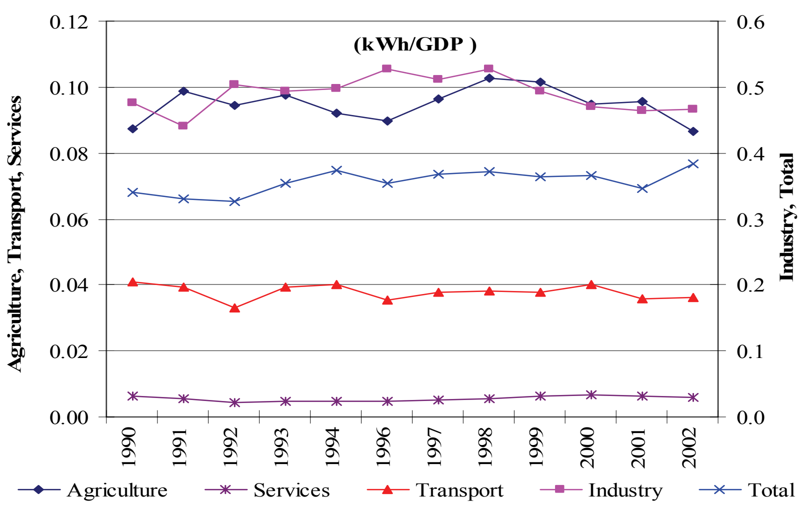

Figure 4.18. Electricity intensities by sectors
Source: ONE, 1998, 1999, 2000, 2001 a/, 2002
Note: Data for 1995 are not available

4.5.1.3. Technological effects

<u>Supply side</u>

The installation of new infrastructure and technologies for the extraction and transport of domestic crude oil and associated gas led to increased production. These fuels are used mainly for electricity generation, the manufacture of cement, and the production of liquefied petroleum gas (LPG). The increase in domestic production of fossil fuels and their use throughout the economy were important steps enabling Cuba to reduce its dependence on imports.

Total electricity losses increased slightly until the 1990s crisis. Then, illegal electricity connections, the use of inefficient electric domestic stoves, and inadequate maintenance and lack of investment in electric grids increased electricity losses to a level of 23% of generated electricity (Figure 4.19). Later, measures were undertaken to eliminate illegal electricity connections, and maintenance of transmission lines and stations brought electricity losses down to 17.5% in 2003 (UNE, 2003). Nevertheless, they were still higher than in 1985.

Refinery production increased until the crisis, reaching 8.8 million tonnes in 1989. There was then a five-fold drop by 1994, and production then continued near this level with some fluctuations. A slight recovery occurred during 2000-2003, although still at a level well below 1990 (Figure 4.20). Significant improvements took place in the fuel transportation infrastructure, however, with the construction of pipelines that link the supply with major consumption centres.

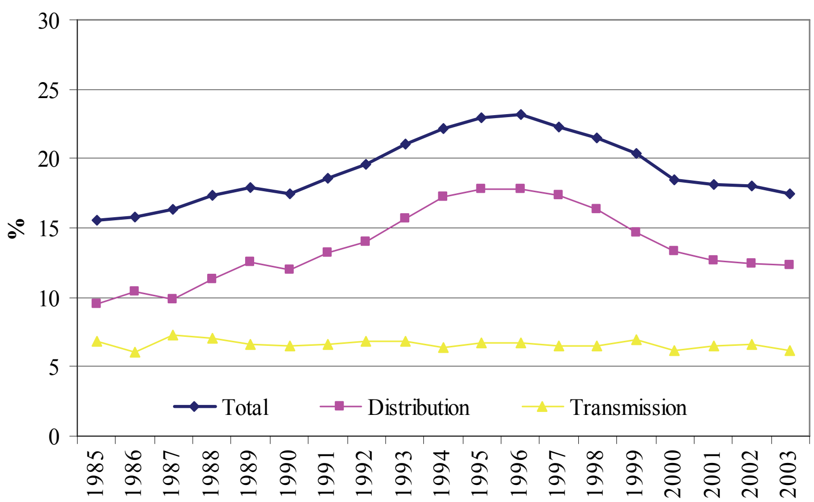

Figure 4.19. Electricity losses
Source: UNE, 1990-2003

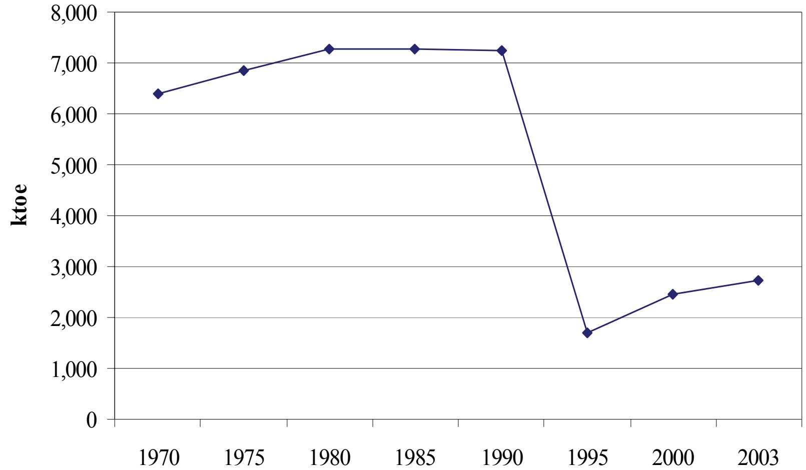

Figure 4.20. Refinery production
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

<u>Demand side</u>

Since 2002, a new electricity tariff system for sectors receiving US dollars was put into effect (MFP, 2002). It contributed to electricity conservation, except in households and in government institutions paying electricity in Cuban pesos.

The Cuban Electricity Conservation Program has played an important role in the reduction of demand for electricity use since 1997; it has enabled the deferral of the installation of more than 150 MW of capacity, and has contributed to the reduction in the maximum demand growth rate, etc. In this program, engineers working as load regulators were assigned to major consumers, and achieved both adjustments (i.e., outside peak hours) and reductions in their demand. With the savings that were accomplished, the sale of fluorescent tubes and energy-saving lamps and bulbs to the population were subsidized. A book for primary and secondary school students was also published, thereby contributing to the education of new generations in energy saving and environmental protection. Similar saving programs were started in 2001 for fuels and lubricants.

4.5.2. Reduction of Energy Import Dependence

As a result of implementation of the National Energy Sources Development Program, the country was able to increase the domestic production of crude oil by a factor of 5.4, and that of associated gas by a factor of 17.3, in 2002 from a 1990 base (Figure 4.21). Both fuels were used to cover 93% of Cuban power generation in 2003, lowering the use of naphtha in city gas production and the use of crude oil in cement production. These actions resulted in a reduction of import dependence. It could be lowered even further if the sugarcane agro-industry were to rebound, and be able to replace fossil-fuel generated electricity with biomass generation.

Electricity generation has increased, except for the big drop during the 1990s crisis (Figure 4.22). The availability of domestic crude oil has permitted electricity generation to increase again, beginning in 1994.

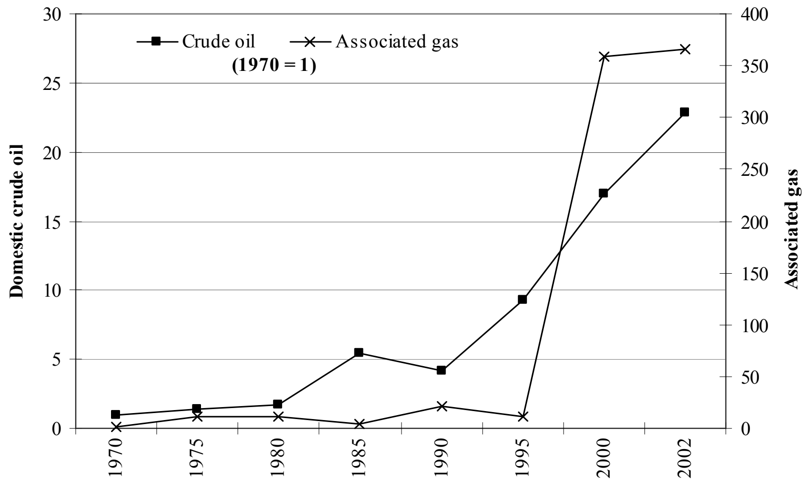

Figure 4.21. Crude oil and associated gas production
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

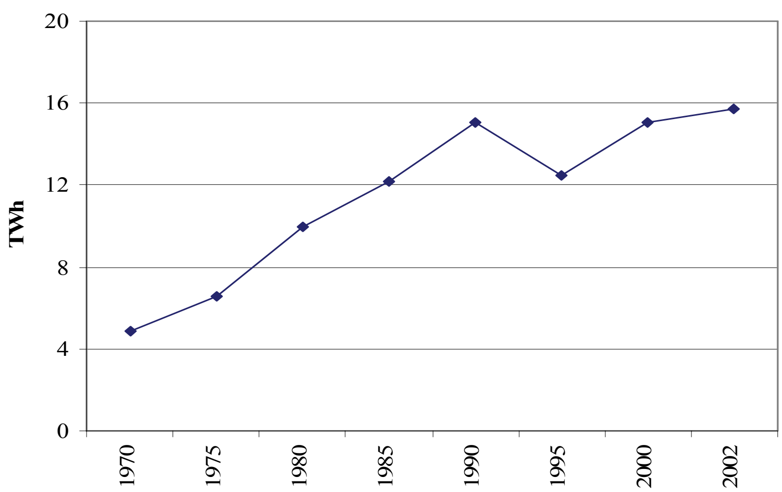

Figure 4.22. Electricity generation
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

Cuba's net energy import dependence (the ratio of total energy imports to TPES) rose from around 51% in 1970 to 71% in 1985, as the country was able to rely on a stable supply of crude oil and petroleum products from the former Soviet Union at preferential prices. After 1980, this dependence increased slightly until 1989. During the crisis in the 1990s, as these advantages ceased, Cuba was forced to reduce energy imports for lack of financial resources, especially foreign currency. While domestic production of crude oil and associated gas has increased, imports of oil products nevertheless have continued and as of 2002, the country's net import dependence was 40% (Figure 4.23).

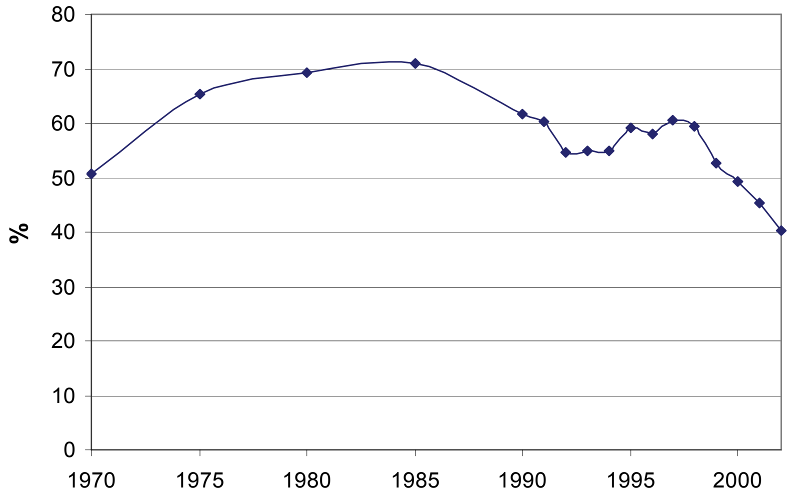

Figure 4.23. Net Energy Imports in TPES
Source: Authors' elaboration from CEE, 1986, 1990; ONE, 1998–2003a and 2004

There is no comprehensive information on estimated reserves and potentials of energy resources. Nevertheless, the authors have estimated them from the information available and they are shown in Table 4.7.

TABLE 4.7 RESERVES AND POTENTIALS OF ENERGY RESOURCES[8]

Resources	Units	Reserves or potentials	Oil Equivalent, Million toe
Crude oil and gas	PJ	4,095	97.8
Crude oil and natural gas (EEZ)	PJ	29,308	700
Bagasse and crop residues	Annual GWh	17,500	1,505
Peat	PJ	8,374	200
Hydropower	Annual GWh	1,300	0.1
Biogas	Annual PJ	7.5	0.18
Wind energy	Annual GWh	2,418	0.2
Firewood	Annual PJ	21	0.5

Source: CUPET, 2003; CNE, 1993; Curbelo A., 2000; PDFNER, 2003; author's estimates.

The reserves of associated gas and crude oil are those estimated for the on shore fields of 3,546 PJ (84.7 million toe) by CUPET in 2003. Such estimates foresee an increase in these reserves in 2005 up to 4,095 PJ (97.8 million toe). The most important part of crude oil reserves, in this case natural gas, corresponds to the EEZ (Economic Exclusion Zone) in the Gulf of Mexico.

The sugarcane biomass potential is estimated from bagasse and agricultural sugarcane residuesvolumes that are produced in a year. The potential of electricity cogeneration using sugarcane biomass is determined on the basis of the optimal use of installed capacities, increases in efficiency of the existing boilers, introduction of high-pressure boilers and introduction of gas turbines and biomass

[8] Reserves are the discovered fossil fuel deposits, and they can be used immediately. Resources are deposits not discovered yet. As renewable energy can be regenerated in adequate terms for human activities, it is necessary to look at potentials.

integrated gasification combined cycle schemes, a reason for which the maximum potential is obtained (500 kWh/ton of crushed sugarcane).

Regarding wind energy, the potential shown in the Table 4.7 corresponds to wind energy potential estimated to date, to generate electricity. This potential includes only a part of the national territory and is valued at 1,200 MW with utilization factor of 23%, although preliminary estimates of other projects show up to 2,555 MW.

4.5.3. Increasing the Participation of Renewable Energy Sources

The main renewable energy resource in Cuba is sugarcane biomass. It is used for generating necessary steam for the sugarcane production process and to co-generate electricity. Sugarcane production increased from 1970 to 1990, but the energy use of bagasse decreased and in the same 1970-1990 period had the lowest increase trend, due to its non-energy use (i.e., production of pulp, bagasse panels, etc.). After 1990, sugarcane biomass had a significant reduction, due to the low prices for sugar on the world market, and the lack of financial resources and fertilizers that produced an important reduction in productivity (Figure 4.24).

In 2002, a restructuring process of the sugar sector was implemented, which had been postponed because of its social implications. Nearly half (45.5%) of the 156 sugar mills operating on the island were closed, and half of the surface given over to sugar crop was used for food production and forestation.

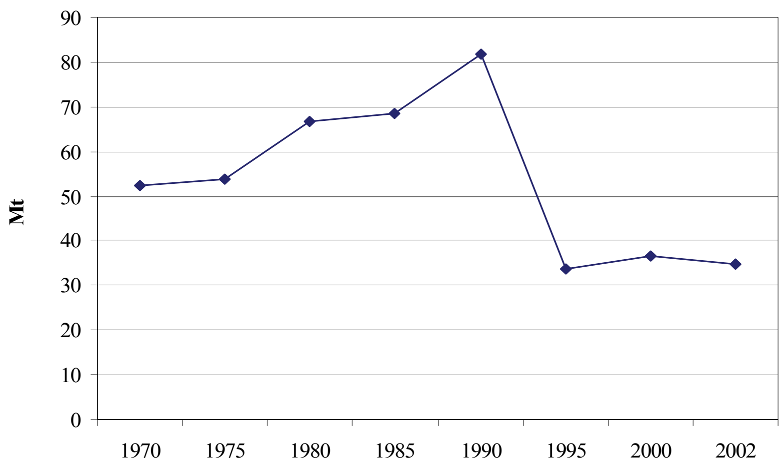

Figure 4.24. Sugarcane production
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

The biomass use per capita has not reached the levels that it had in 1990 due to this decrease in sugarcane biomass production, and because of the incremental change in the production of other fuels (LPG, city gas and electricity) for cooking, substituting for fuelwood and charcoal use. The use per capita of primary energy has increased since 1999, with important increases in the use of domestic crude oil and associated gas.

Before 1959, only 56% of the total population had access to electricity services, not because of physical access concerns, but because of a lack of money to pay electricity bills. The Cuban Government provided electricity to those locations that were economically viable, and 95.5% of the total population had access to it in 2003 (Figure 4.25). A program is being implemented to achieve 100% access to electricity, evaluating the feasibility of different supply sources to accomplish this,

including extension of the grid, photovoltaic panels, mini-hydroelectric, wind generators, hybrid systems and biomass.

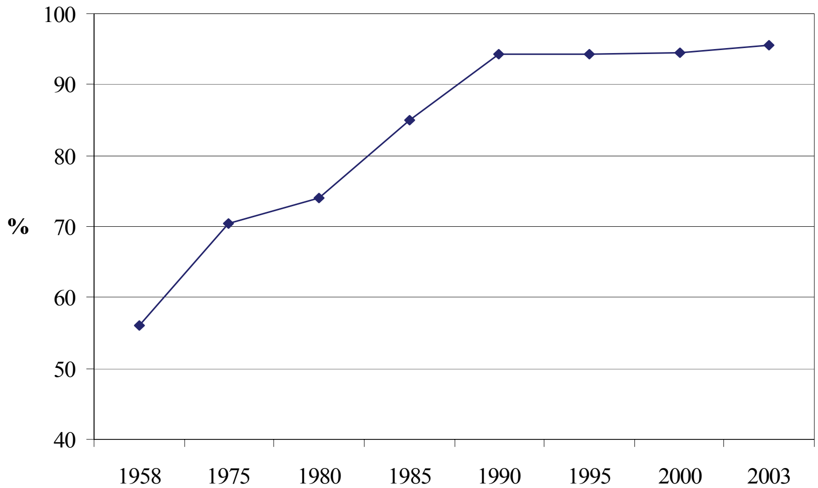

Figure 4.25. Electrification level
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003, 2004

The population of Cuba with no access to electricity typically depends on non-commercial energy. They tend to live in isolated rural areas, and primarily in the mountains. The eastern provinces are located in the most mountainous areas, and it is estimated that only 87% of their population have access to electricity in such far-away locations.

In the rural electrification process a capacity of 1.49 MWp (Wp-peak watt) was installed in 5,318 photovoltaic systems (350 medical clinics, 5 hospitals, 2,364 primary schools, 1,864 television rooms, 150 social centres, houses, rural boarding schools, camping centres, television broadcasting stations, phone rooms, fishing storing centres and cooperative communities) by the end of 2002, and this has had significant social impacts.

The average electricity use in the household sector grew from 82 kWh/month per consumer (i.e., household) in 1970 up to 140.1 kWh/month in 2002 (i.e., an increase of 1.7 times). The electricity use growth in households has been limited by restrictions imposed on purchasing new high-consumption electric appliances, though other factors have also contributed (e.g., the introduction of highly energy-conservation appliances, subsidized programs for changing refrigerator door gaskets, replacement of ordinary bulbs by energy-conservation bulbs, energy conservation campaigns broadcast by the media, etc.). In summary, electricity use in the household sector has increased from 1970 to 2002, except for a small reduction during the 1990s, which was followed by a very fast growth in recent years (Figure 4.26).

The main energy fuel used in the household sector was kerosene until 1993, but after that electricity has ranked first. Kerosene stoves using alcohol preheating were the most popular way of cooking, replacing wood and charcoal. It changed the standard of living of the population. The 1990s crisis drastically decreased all fuel supplies for the household sector, except wood, which rapidly increased in the absence of others fuels until the maximum level in 1993. Later the use of fuelwood was reduced to the level of 4.9 ktoe in 2002. Nowadays the use of fuelwood is considered sustainable since the population has other fuel supply options and the use of this fuel in industrial and service sectors is forbidden.

Since the 1990 crisis, LPG, city gas and electricity have undergone an important (increased) shift in household energy use (Figure 4.27), caused primarily by the reduced use of kerosene, alcohol, wood and charcoal.

Figure 4.28 shows the indices of the final energy use per capita in the household sector during the evaluated period.

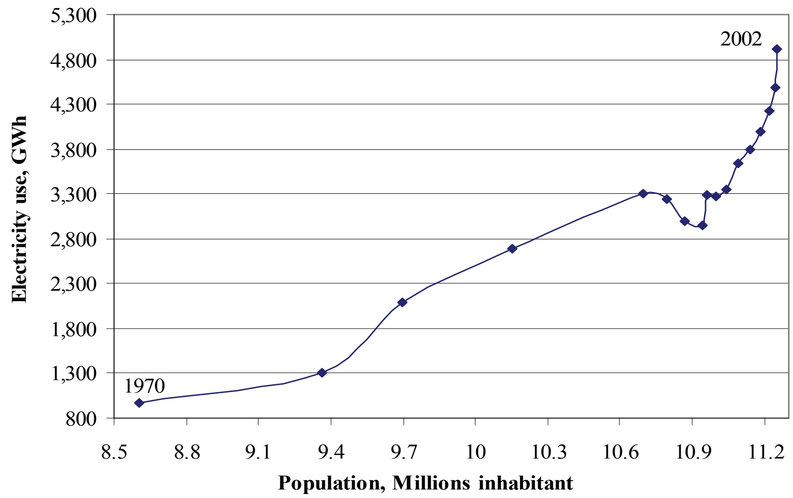

Figure 4.26. Electricity use in household sector versus population
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

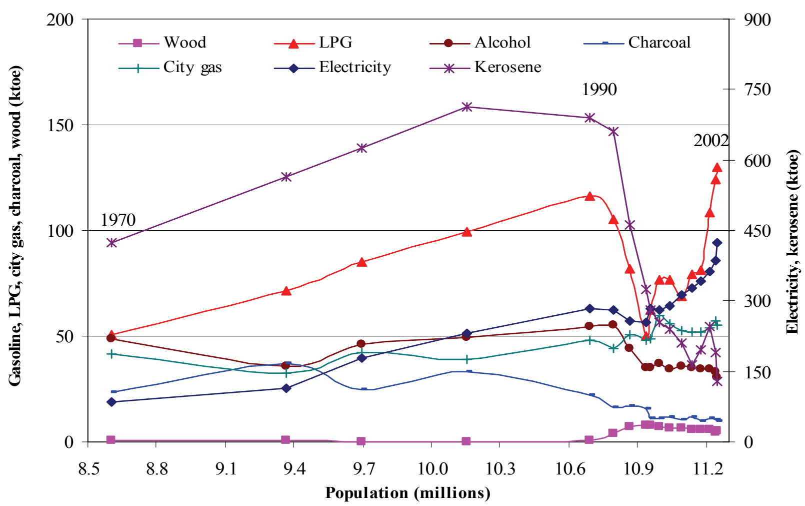

Figure 4.27. Energy use in household sector versus population
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

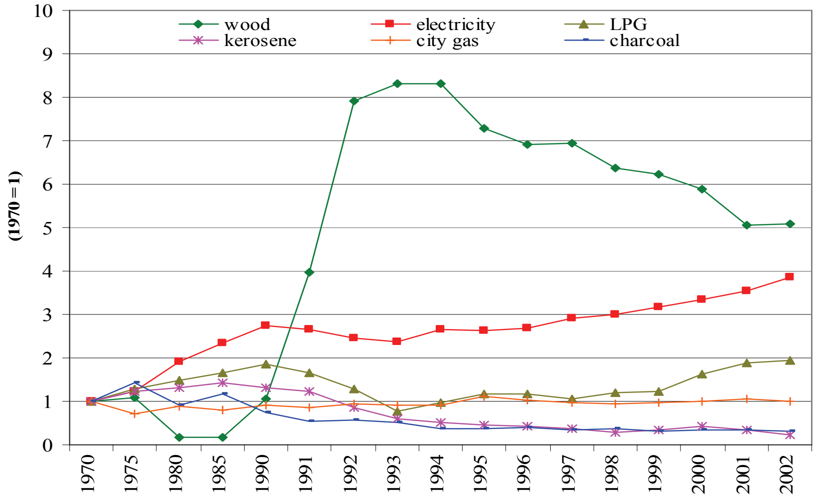

Figure 4.28. Indices of final energy use per capita in household sector
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

In 1995, a new program using the capacities of different reservoirs for electricity generation began. Also, very small hydroelectric power plants were built, primarily for the electrification of isolated regions. The estimated Cuban hydroelectric potential is roughly 650 MW, but only 57.4 MW of this potential is exploited at present. Nevertheless around 50% of this potential is found in the Toa-Duaba basin, a protected area with a large number of indigenous species that cannot be exploited.

Hydropower generation fluctuated during the period under evaluation, depending upon rain levels, but small hydroelectric plants increased their share (Figure 4.29). At the end of 2002, 169 hydroelectric power plants were in operation. A 71 MW installation program of new reservoirs and run-of-river hydro plants is being implemented.

At the end of 2002, 6767 windmills were used for water pumping, and 139 biogas digesters, 7 wind generators and 45 hydraulic ram pumps had been installed on the island (ONE, 2003).

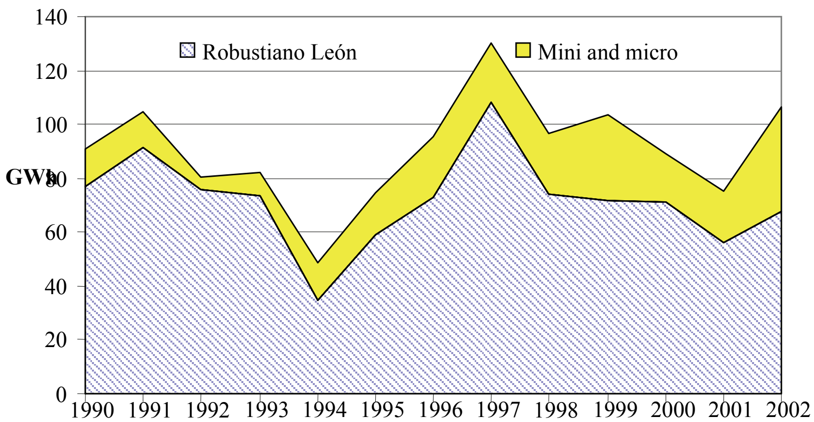

Figure 4.29. Hydropower Generation
Source: ONE, 2003

4.5.4. Energy efficiency improvement

An analysis of energy efficiency in Cuba is very difficult to do, because the influences of some factors are contradictory. In the 1970s and 1980s, the introduction of new thermal power plants reduced the fuel use per kWh, but the use of crude oil in thermal power plants in 1992-1993 (in plants designed to use fuel oil) lowered their efficiency of electricity generation and increased the fuel use (Figure 4.30). The implementation of new organizational measures in the operation of the electric system, and the connection of two new units (250 MW and 100 MW) to the grid, enabled the system to: a) reduce the operation of less efficient thermal power plants; b) increase the average efficiency of the system; and c) reduce the use of fuel per kWh in 1996-1997. During 1997-1998, the Electricity Conservation Program, the modernization process of 100 MW units, and the conversion program of thermal power plants to use domestic crude oil all contributed to increased efficiency.

Associated gas began to be used for electricity generation in 1998. This action also contributed to raising efficiency and lowered the fuel use in electricity generation. Nevertheless, the fuel use per kWh in 2002 remained higher than in 1990; similarly, the fossil fuel efficiency failed to attain the top level of 1985.

The fossil fuel efficiency increased because of installation of the new thermal power plants in the 1970s and 1980s, but was seriously reduced during the crisis, and fuel use associated with burning crude oil in the thermal power plants increased. During 1999-2002, this indicator recovered, because of the use of associated gas in an efficient manner (Figure 4.31).

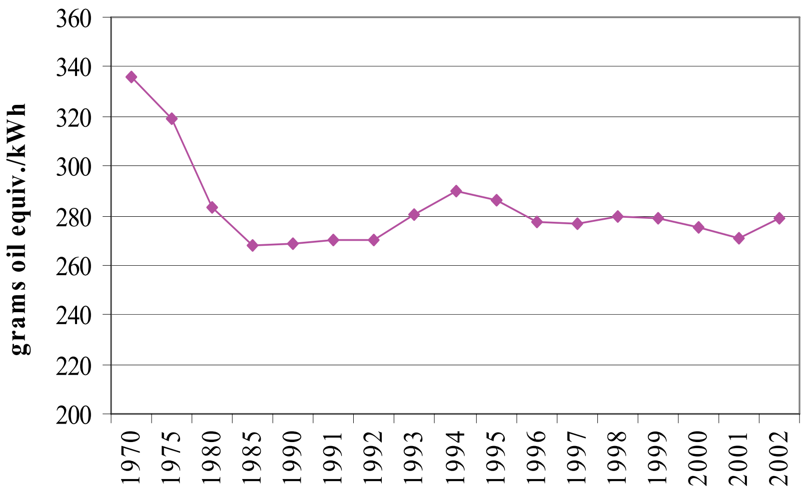

Figure 4.30. Fuel use in electricity generation
Source: ONE, 2003

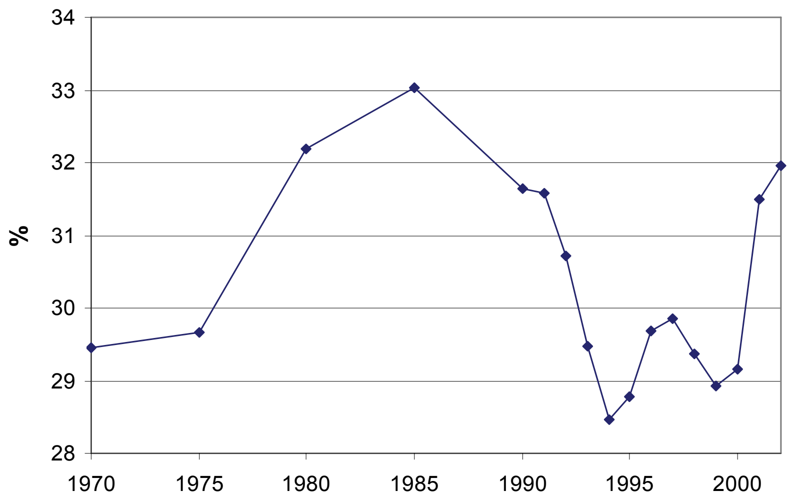

Figure 4.31. Fossil fuel efficiency in electricity generation
Source: Authors elaboration from ONE, 2003 and UNE, 2003

The fraction of electricity supply from co-generation heat and power plants (CHP), which are associated with sugarcane industries in the case of Cuba, decreased during the 1970-1990 period (i.e., from 18% to around 10%) due to a rapidly rising increase in thermal power plant production. Nevertheless, in terms of kWh, co-generation in the sugar sector increased in 1992 by a factor of 1.52 over 1970 levels. After the 1990s, the share of co-generation was substantially reduced because of sugarcane production changes. But in 2002, co-generation in sugar factories was still higher than in 1970, even though it accounted for only 6% of the electricity generation of the whole country (Figure 4.32).

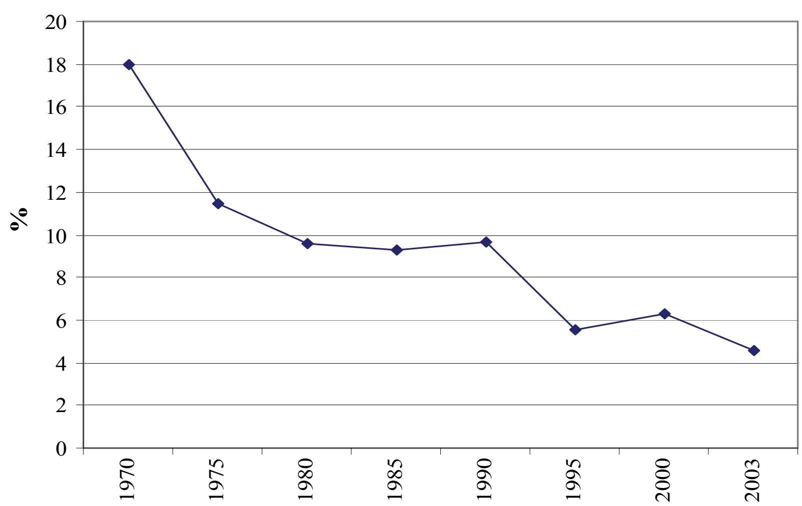

Figure 4.32. Electricity supplies from CHP
Source: ONE, 2003

Oil refining efficiency (Figure 4.33), calculated as the finished light product output per unit of crude oil fed into the refineries, had an overall tendency to increase after the changes suffered during the 1990s crisis, when the refinery production was reduced substantially.

Oil refining efficiency shifts were mainly due to changes in the share of output products. The gasoline and LPG production increased, but the share of heavy products production (fuel oil) decreased on

average (Figure 4.34). The main consumers of fuel oil (thermal power plants) were adapted to consume crude oil.

The economic crisis did not allow for proper maintenance of transmission and distribution (T&D) lines. Half of them have been operating for over 20 years. Inadequate placement of power plants (i.e., long distances from consumption centres) required long power transfers, with resultant losses. Illegal connections to the electricity grid increased during the economic crisis, generating additional electricity losses (i.e., distribution losses). After 1997, illegal electricity use was reduced, as thousands of electricity counters were installed and organizational arrangements were implemented. Also, the maintenance of transmission lines was re-established. These actions and changes in the tariff system contributed to a reduction of T&D losses, as previously shown in Figure 4.19.

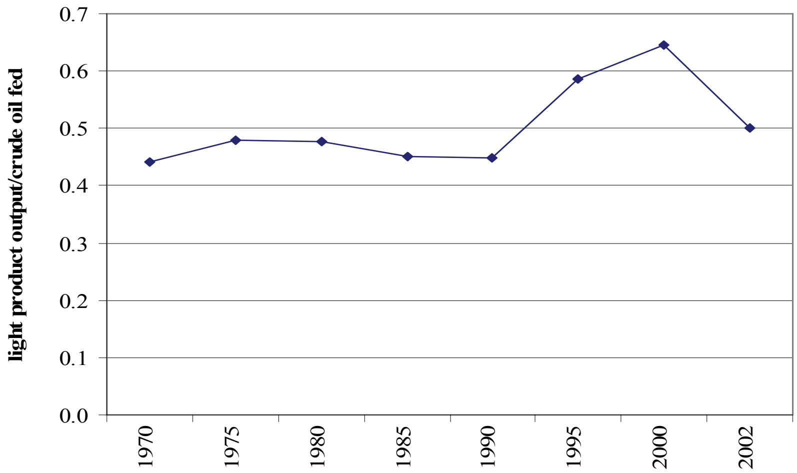

Figure 4.33. Oil refining efficiency
Source: Author's elaboration from ONE, 2003

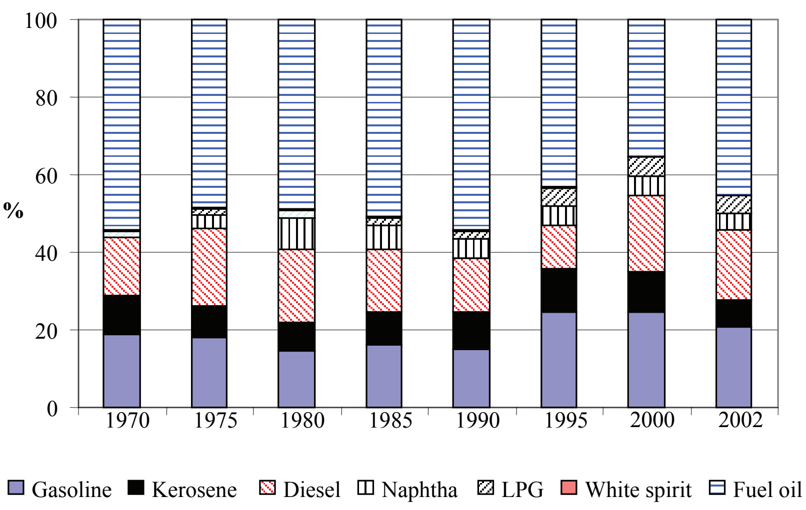

Figure 4.34. Share of refineries output products
Source: Authors' elaboration from ONE, 2003

Energy Not Served (ENS) is electricity not served to the consumers due to the loss of existing generation capacities (and the implied blackout) and/or shortages. Figure 4.35 presents the ENS due to the loss of generation capacities. It indicates the critical situation in electricity supply, especially during 1992-1995. The ENS in 1993 accounted for 12.4% of electricity served in that year.

Figures 4.36 and 4.37 show that the Electricity Conservation Program (started in 1997), the demand side management program, and the new tariff system shifted some electricity demand outside peak hours; the peak demand did not increase until 2000, while electricity use increased. After 2000, however, the peak demand increased because the effects of the above actions were not sufficient. A new peak during the middle of the day, at about the same level, complicates the operation of the electric system.

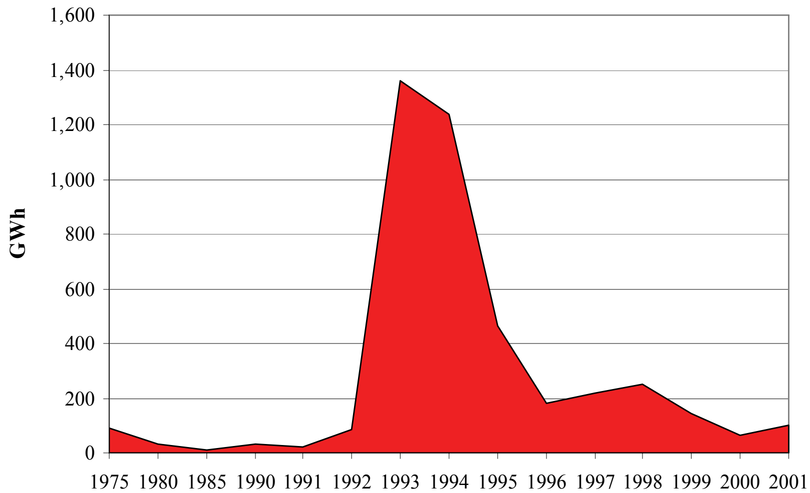

Figure 4.35. Energy Not Served due to loss of generation capacities
Source: DNC, 2000-2004

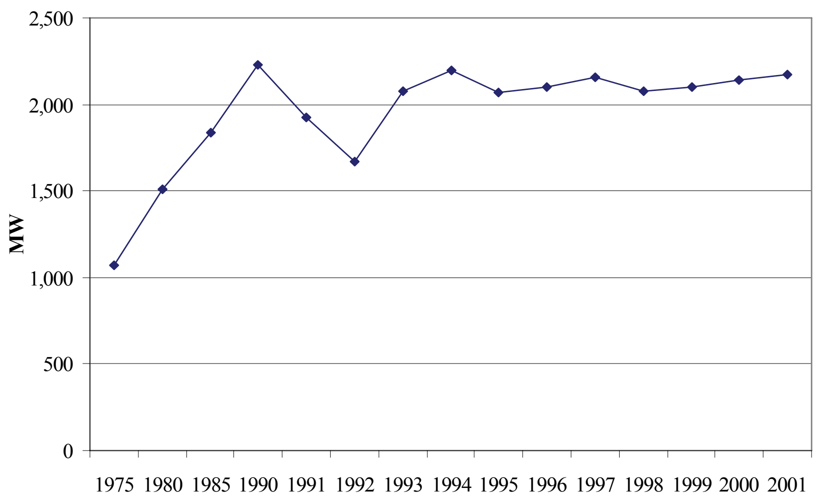

Figure 4.36. Electricity peak demand
Source: UNE, 2002

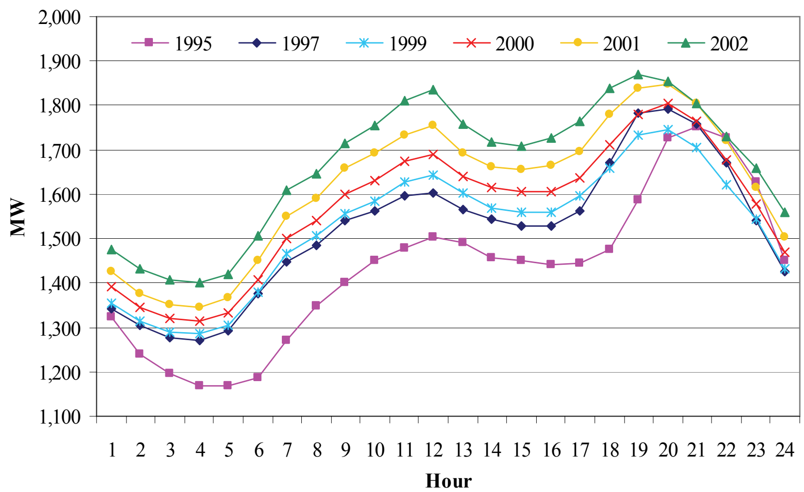

Figure 4.37. Average hourly demand
Source: DNC, 2000-2003
Note: Data before 1995 are not available

4.5.5. Influence of the Energy Policies on the Environment

The environmental implications of Cuban energy development are analysed by the local and global influence of the pollutant emissions, taking into account the prevalence of fossil fuels use within the energy system. The local effects of SO_2 emissions from national crude oil use are considerable.

The major data presented in this section are related to years 1990, 1994, 1996 and 1998, corresponding to Greenhouse Gases Inventories prepared in the country.

4.5.5.1. Greenhouse Gases (GHG)

Emissions of carbon dioxide (CO_2) from energy-related activities represent about 95% of the total emissions of CO_2 in the country (Figure 4.38)[9]. The principal sources of these emissions are the energy, manufacturing and construction industries.

[9] 1998 estimations are under review.

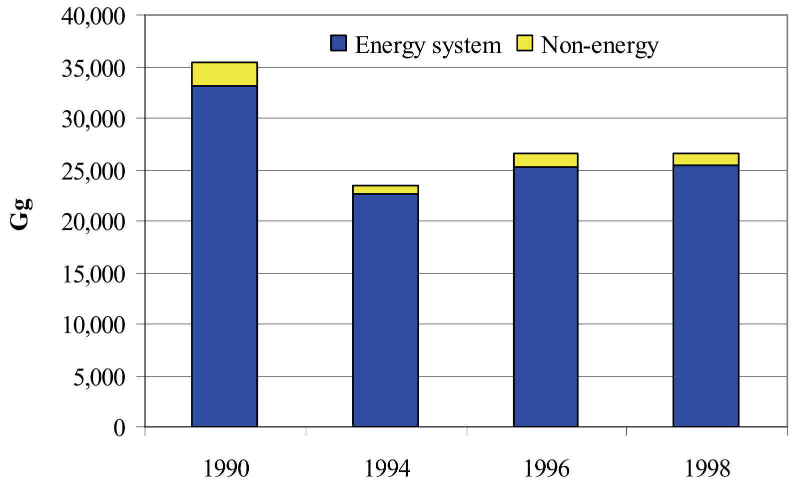

Figure 4.38. Contribution of energy sector to the total CO_2 emissions
Source: CITMA, 2002; CITMA 2003.

In 1990, the total CO_2 emissions from energy-related sources totalled 33,155 gigagrams (Gg) of CO_2. That year, 17,527.36 Gg of CO_2 were absorbed due to changes in land use[10] (Figure 4.39).

Fuel use was reduced by 43.8% in 1994, compared with 1990, because of the economic crisis. The CO_2 emissions from the energy sector decreased by 31.8%, but absorptions increased by 13.3%.

From 1994, with the economic recovery, emissions of greenhouse gases from the energy sector increased, and by 1998 reached 76% of the CO_2 emissions reported for 1990. Absorption has also increased; and by 1998 was 50% higher than in 1990.

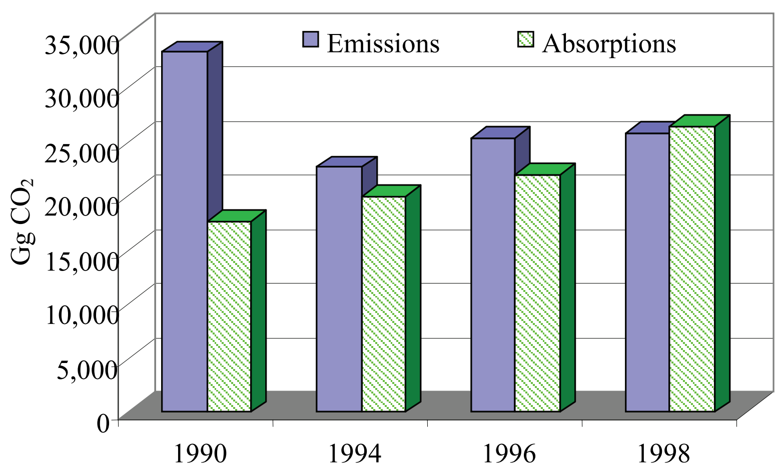

Figure 4.39. CO_2 Emissions from energy sector and absorptions of CO_2
Source: CITMA, 2002; CITMA 2003

The contribution of the energy sector to the emissions of methane (CH_4) is lower in comparison with CO_2. For the years 1990 and 1994, this contribution was 0.6%. However, from 1996 an increase took

10 Protected areas are not included.

place due to the increment of the petroleum and the associated gas activities, reaching 4.5% in 1998 (Figure 4.40).

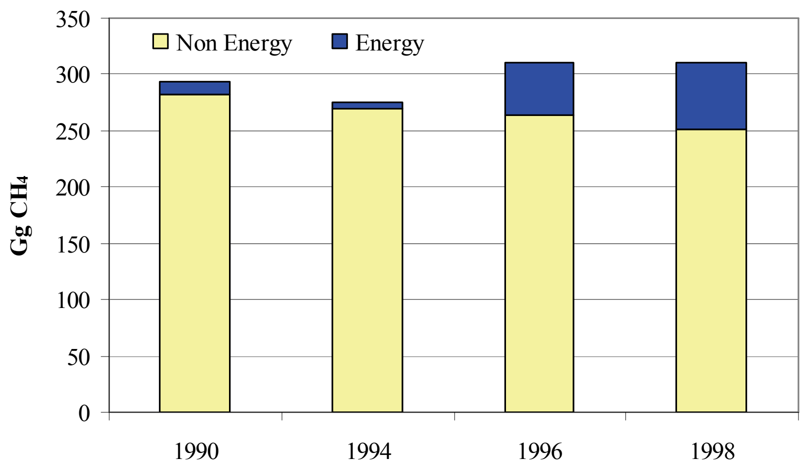

Figure 4.40. Contribution of energy sector to total methane emissions
Source: CITMA, 2002; CITMA 2003

Emissions of nitrogen dioxide (N_2O) from the energy sector are small, constituting on average 0.98% of the total emissions of the greenhouse gas in the sector (Figure 4.41).

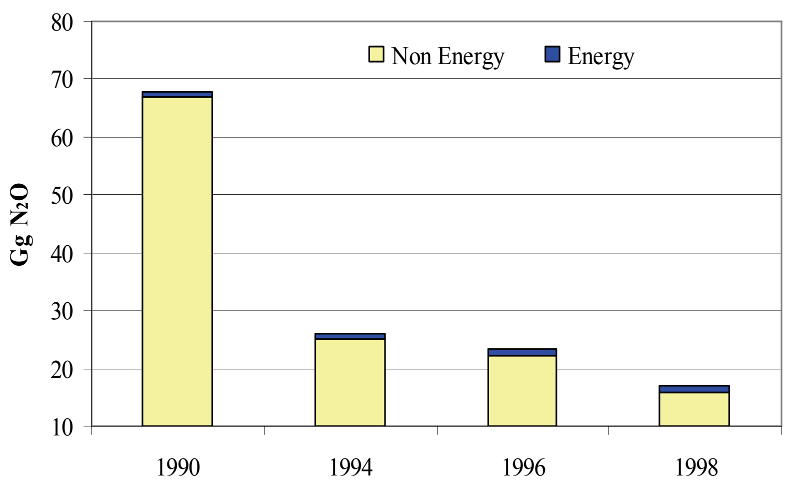

Figure 4.41. Contribution of energy sector to total N_2O emissions
Source: CITMA, 2002; CITMA 2003

4.5.5.2. Air pollutants

Emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO) and non-methane volatile organic compound (NMVOC) coming from the energy activities diminished in 1994 due to the decrease in fuel use (Figure 4.42). From 1996, these emissions began to grow, but only SO_2 reached the levels of 1990 due to the national crude oil use. The emissions of SO_2 in the energy sector represent 98% of the total emissions of SO_2 in the country.

More than 90% of the total emissions of NO_x in the country come from the energy sector. The main sources of these are the energy industries, the transport, and the manufacturing and construction industries.

The CO emissions in the energy system are fundamentally associated with transport and bagasse burning. In 1996, the emissions of CO reached 63.5% of their 1990 level.

The main sources of NMVOC emissions in the energy sector are transportation and the manufacturing industry. In 1996, emissions of this pollutant from energy activities constituted 37% of the total NMVOC emissions in the country.

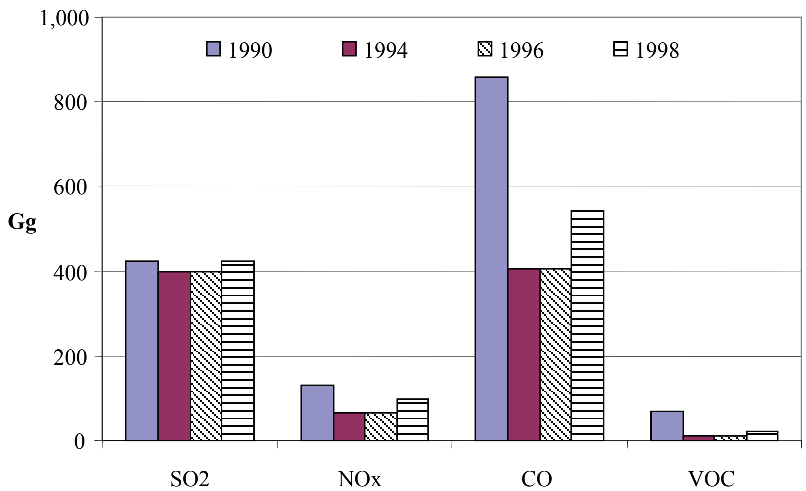

Figure 4.42. SO_2, NO_x, CO, NMVOC emissions from energy sector
Source: CITMA, 2002; CITMA 2003

4.5.5.3. *Effects on air quality*

In recent years, an increase of the mean concentrations of gaseous oxidized compounds has been observed (CIGEA, 2001; CIGEA, 2003). These compounds are the principal precursors of acid rain, and they can cause diverse harmful effects on the terrestrial and aquatic ecosystems. Emissions caused by industrial and agricultural sources bear primary responsibility for this incremental change.

The economic crisis caused monitoring systems in the country to deteriorate, which has influenced both the quantity and quality of studies carried out. Further, the results of such studies are not included in the national statistics, which hinders access to them.

In certain areas of the country, the quality of the air has been seriously affected. Among these areas are the mining-metallurgical area north of Holguín, the area near Mariel (with a thermal power plant, cement industry, etc.), and the City of Havana.

Cuesta O. et al. (2003), of the Atmospheric Environment Research Centre, Meteorological Institute, carried out a study during the year 1999 in the eastern area of Havana Bay. There, the urban area converges with a major industrial concentration (i.e., thermal power plant, refinery, food industry, port activities, ship construction and naval repair, etc.), and it was determined that the emissions associated with the refinery process and the remainder of the polluting sources significantly affected the quality of the air in the area. H_2S is the primary pollutant, reaching concentrations that surpass the acceptable maximum concentration established in the Cuban Standard of Air Quality by a factor of between three and twenty-seven times.

With regards to ground level ozone (O_3), typical mean concentrations of 30 $\mu g/m^3$ (from April to September) and 120 $\mu g/m^3$ (from October to March) have been observed. These periods coincide with the optimal development season of the principal cultivations of the country, which are affected by

concentrations of 70 µg/m^3. Accordingly, some provinces are applying an Early Alert System to warn producers about the dangers for crops in the presence of this pollutant (CIGEA, 2001).

4.5.5.4. Electricity generation

As 93.4% of the electricity generation in the year 2002 was carried out using fossil fuels, this sector has a decisive effect on pollutant emissions.

The principal pollutants from electricity generation in the country are CO_2, SO_2 and NO_x. The emissions of CO_2 represent 99.3% of the total GHG from electricity generation (Figure 4.43).

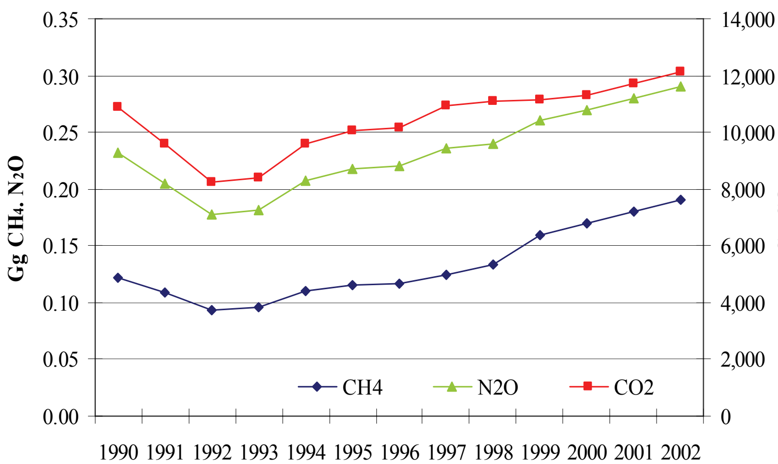

Figure 4.43. Greenhouse gas emissions from electricity generation
Source: Authors' estimations

During 1991 and 1992, the emissions of CO_2, and NO_x from the electric sector diminished due to the forced decrease of electricity generation owing to a lack of financial resources to buy fuels. The SO_2 emissions decreased in 1991, but started rapidly to increase after that year. The CO_2 and NO_x emissions began to grow again in 1993, even though generation continued to fall through 1994, due to the incremental use of domestic crude oil. This fuel has a high sulfur content (around 7%), and the power plants were designed to use fuel oil. Because of a lack of financial resources, the plants were not adapted to use crude oil, and maintenance was also inadequate, diminishing the efficiency (Figure 4.44).

In 1997, CO_2 emissions reached the levels of 1990. From 1998 the rate of growth of these emissions diminished due to the use of the associated gas in more efficient gas turbines, the modernization of 100 MW in the system, and the incorporation of 250 MW of new units with improved efficiency. Electricity generation once again reached the levels of 1990 in the year 2000.

Electricity generation is one of the main sources of SO_2 emissions in the energy sector (Figure 4.45). Because of the contribution of crude oil in electricity generation, the SO_2 emissions increased considerably during the entire period. The 1990 levels were exceeded in 1993 by 7.3%.

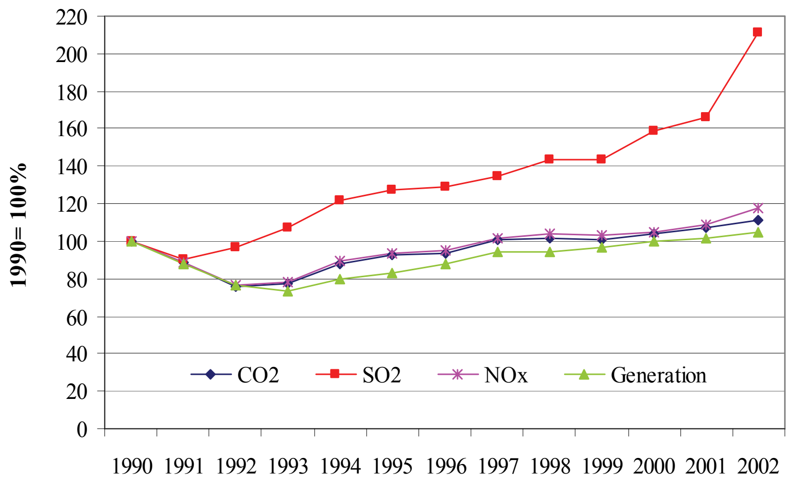

Figure 4.44. Indices of CO_2, SO_2, NO_x emissions, and electricity generation
Source: Authors' estimations

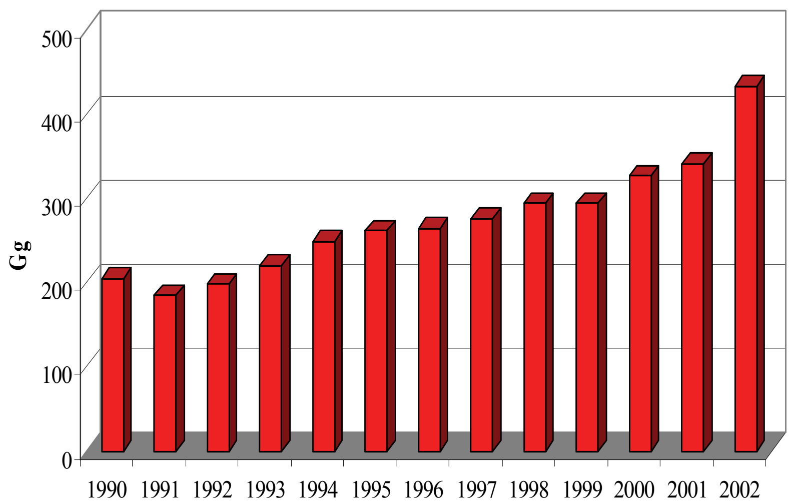

Figure 4.45. SO_2 emissions from electricity generation
Source: Author's estimations

At the end of 1998, associated gas was introduced for electricity generation. In 2002, the generated electricity using the associated gas represented 7% of the total electricity generated in the country (ONE, 2003), which is reflected in SO_2 emissions. However, in the year 2002 an increase of the emissions took place because of an incremental increase of 8.2% in crude oil usage in relation to the previous year.

The estimated values of CO and VOC emissions from electricity generation are shown in Figure 4.46. Since 1993, these emissions have increased proportionally to the use of domestic crude oil.

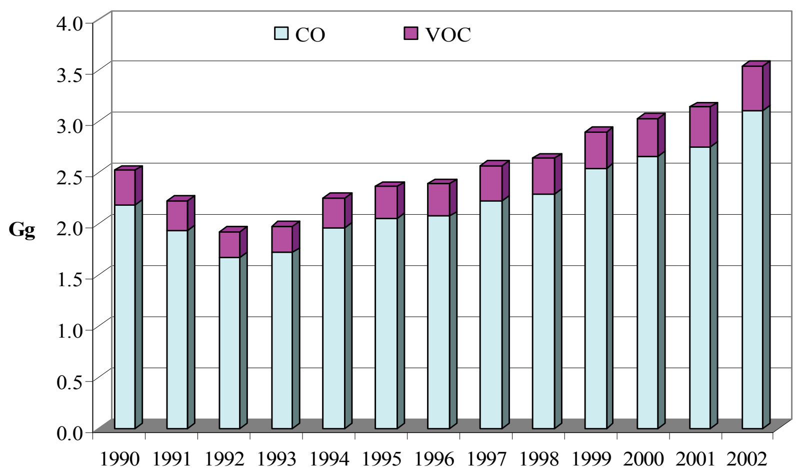

Figure 4.46. CO and VOC emissions from electricity generation
Source: Authors' estimations

4.6. Assessment of Current Energy Policies in Priority Areas

Oil activity in Cuba began in 1881, but a systematic and detailed exploration program only started in 1960. From 1991, explorations were carried out with foreign companies from Canada, France, Brazil, Sweden, Spain, etc., resulting in the discovery of new oil deposits.

After 1959, three well-defined stages were experienced in the development of the electric sector:

- **First stage:** From the beginning of the 1960s until 1989, this stage was marked by expansion based on technology transfer (although not very efficient technology), and a reliable supply of fuels at preferential prices; the installed electric generating capacity grew to around 2,600 MW (based on fuel oil), and the country's refining capacity was tripled.
- **Second stage:** Covering 1990-1995, this period was marked by strong restrictions in fuel supplies, and everything in the national economy was seriously affected.
- **Third stage:** Extending from 1996-2004, this period was marked by economic recovery.

With current energy policies and the positive effect of the Foreign Investments Act (which foresees private capital involvement in energy industries), oil and associated gas exploration and production were increased. These actions played an important role in reducing energy import dependence and increasing electricity generation, but at the same time they resulted in an increase in emissions.

On the other hand, the substitution of city gas and LPG for kerosene, charcoal and the non-sustainable use of fuelwood for cooking purposes, enhanced the quality of life of the population and contributed to reduce energy import dependence.

Several actions have increased energy efficiency and reduced the overall energy intensity of the country, including the modernization and adaptation of thermal power plants for burning domestic crude oil; the installation of new electrical generating capacity (mainly gas turbines and combined cycle units using associated gas); the reduction of electricity losses; the use of more efficient domestic appliances, cars, and machinery; and the implementation of various energy saving programs. These actions have positively affected the environment. In those local areas where associated gas for electricity generation is used, the ambient concentration of sulphur compounds was substantially reduced.

Low prices in the world market for sugar and a lack of financial support caused a decrease in sugarcane production and productivity, a decrease in co-generation in the sugar industry, and thus a

decrease in renewable energy in the energy matrix of the country. A program for the electrification of isolated areas by means of photovoltaic panels, small hydropower plants and wind generators was implemented by the government, with important social impacts. However, the overall policy of increasing participation of renewable energy was not successful.

The most important institutional reforms implemented during the recent period were:

- Establishment of the National Energy Commission, which coordinated the energy policies of different ministries. It allowed the elimination of fuel oil use in raw sugar production, and has improved the results of energy use indices in the sugar refinement process, in thermal power plants, in cement production, in textiles, etc.
- In 1994, the main central Government institutions were restructured. The functions of the National Energy Commission were passed to the Ministry of Economics and Planning. It created the Advisory Council of Energy Matters, but except for State Energy Inspections, the other activities related to energy decision integration were not treated in an appropriate manner by this body. In June 2004, the Government requested that the Ministry of Economics and Planning restart and fully comply with all the functions of this council, and check the execution of the National Energy Sources Development Program. The integrated energy development plan will be examined by this revitalized Council.
- Implementation of the National Energy Sources Development Program (CNE, 1993).
- Increase of the electricity tariff (staged tariff) for the household sector.
- Introduction of the obligatory payment in hard currency for oil products and electricity in self-financed companies.
- Controlled fuels distribution.
- Reorganization of the big electricity consumer industries (nickel, steel, cement, textile, construction materials and food industry); promoting the general and intensive use of bicycles; using trucks with trailers and railroad cars for the transportation of passengers.
- Implementation of the Cuban Electricity Conservation Program; distribution of lamps and subsidized energy-saving bulbs; replacement of households' refrigerator door gaskets and promotional videos and advertisement on energy conservation.
- Enforcement of Law No. 260 (issued in December 1998) penalizing the illicit use of power by means of using altered power meters or illegal connections made.
- New electric tariffs currently paid by non-household sectors, based on voltage levels, schedule of use and type of consumers (MFP, 2002).
- Implementation of sectoral programs of efficiency improvements, especially in nickel, cement, sugarcane, steel, and machinery industries, and in tourism and agriculture sectors.
- Implementation of the fuel and lubricants conservation program in 2001 similar to the electricity conservation program.
- The fuel changes program, which replaced kerosene and alcohol as household fuels, mainly in Havana City and in Santiago de Cuba. Financing from foreign companies enabled the Program to provide the service to a larger number of consumers. In Havana City, the household supply is expected to be 50% with city gas and the remaining 50% with LPG. The LPG stoves and gas bottle (10 Kg of gas capacity) are sold at subsidized prices.
- In 1998, re-motorization and a change of fuel from gasoline to diesel were encouraged to improve efficiency, fuel use and the environmental impacts of transportation. In addition, the renovation of existing vehicles in the country has been carried out, along with the implementation of import standards, to achieve more economic and less polluting transports. In 2002, the change from gasoline to diesel vehicles was stopped, and the import of diesel cars was reduced to the minimum necessary.

- Cuban banks financing energy efficiency projects in hard currencies.
- The Renewable Energy Front established (October 14, 2002) as a specialized State body to coordinate and integrate the different institutions involved in renewable energy issues; it was designed to integrate and raise the participation of renewable energy sources within the Cuban energy matrix.
- Law 81 on Environment (1997) establishes the corresponding responsibilities on technological processes and technology imports for gas and particle emissions.
- Enforcement of the National Program "The global changes and the evolution of the Cuban environment," which contains major research projects from the environmental and socio-economic point of view.
- The establishment of relative provisions for the conservation of the ozone layer and prevention of climate change.
- The elaboration of new ambient air quality standards.
- A tax system to be implemented on the sources of residuals and emissions was analyzed.
- The National Team on Climate Change drafting of the National Strategy for the Framework Convention on Climate Change Implementation, involving the main economic sectors, universities, research centers and NGOs.
- The requirement of an environmental license for any investment.
- Tax exemptions for renewable energy projects.
- The establishment of the National Fund of Environment for financing environment-preserving projects.
- The implementation of the National System of Environment Recognition.

4.7. Strategies for improvement in priority areas

The main proposed strategies for improving the results of energy policies are:

- Enhance offshore hydrocarbons exploration. In the event that offshore oil and natural gas were to be found, current energy policies would be changed. Power generation could be based on natural gas-fired combined cycle units; light crude oil could be refined to supply all of the oil products needed in Cuba, and the island could become an oil exporting country, instead of an oil importing one.
- Expand pilot projects for the use of LPG in buses and taxis. An assessment should be made of the possibilities of producing bio-methane from organic wastes, and bio-diesel from oleaginous plantations.
- Expand the use of LPG to all of the population.
- Use the developed capacities and experience in the production of solar heaters, photovoltaic systems and in solar cell production; turbines for mini-hydroelectric; windmills; hydraulic applications such as water pumps; solar dryers and distillers, and controlled-climate chambers; etc. Find appropriate financing mechanisms for their rapid introduction (on a large scale), and for implementing the government’s goal of electrification for 100% of the population in the coming future, using proper systems.
- Increase parameters (and efficiency) for sugarcane boilers, which could double or triple electricity co-generation. The introduction of new technologies (e.g., fluidized bed combustion boilers, biomass integrated gasification combined cycle, etc.) might tremendously raise electricity co-generation in this industry. Likewise, alcohol production for motor fuels, alone

or mixed with gasoline and diesel, is an important opportunity for this sector, and an evaluation is needed for such options.

- Evaluate nuclear power as an option in long-term energy expansion scenarios.
- Enhance energy efficiency.
- Finalize the exploration of wind resource potential and use it.
- Use the exploitable hydro potential.

Energy policies implemented in the country during recent years were successful, except in the case of sugarcane biomass. The policy measures adopted by the Government during the 1990 crisis in the National Energy Sources Development Program had an important contribution to the economic recovery after the crisis, and in the enhancement of different social programs implemented in recent years. Sugarcane faced different constraints, and has not fully recovered after the crisis.

Special efforts need to be made to increase the efficiency and support recovery in the sugarcane sector, in order to fulfill its energy potential.

The implementation of the above-mentioned policy measures can contribute substantially to sustainable energy development, and reduce the environmental impact of energy use in the country.

4.8. Conclusion and Recommendations

The ISED framework methodology is an appropriate tool for analysing different energy policies, with respect to their social, economic, environmental and institutional dimensions.

The lack of certain data prevented a complete analysis of all the implemented energy policies in Cuba at the necessary level of detail. Nevertheless, with collected data, analyses were performed with acceptable results.

The use of the ISED framework methodology contributed significantly to enhancing Cuba's statistical capabilities. It was possible to introduce appropriate changes into the national statistical system within a short period of time. Three new surveys were introduced into the system, and capabilities were enhanced to make the national statistics system compatible with international standards for the first time.

Fuel import dependence decreased by rising domestic crude oil and associated gas production, but this dependence could be further lowered if the sugarcane sector recovered from its depressing trend. Nevertheless, the use of associated gas for electricity generation eliminated contamination by sulphur emissions in a major tourism area, and contributed to the enhanced efficiency of electricity generation with the introduction of new technology (i.e., combined cycle units).

Increased domestic crude oil and associated gas production provided fuel for the generation of 93% of the electricity produced in the country in 2003.

The potential for renewable energy has not been fully realized, since the principal sources from which it is obtained (i.e., biomass, and especially sugarcane biomass) faced considerable constraints—low prices in the international market, lack of funds and fertilizers required for better performance in production, etc. Nevertheless, electrification with PV systems, hydro and wind power have had an important social impact for major social entities (e.g., schools, hospital, etc.). A new programme for the exploitation of reservoirs and "run of river" possibilities for hydroelectric generation is currently under way. The use of windmills for water pumping is also growing. The wind potential for electricity generation, which is estimated at about 400 MW, is being further evaluated.

Important efficiency steps have been taken (e.g., modernizing and adapting thermal power plants to burn domestic crude oil, using associated gas in combined-cycle power plants, etc.) to improve transformation processes and utilize co-generation (even though its share of electricity generation on the island has actually been reduced). Similarly, the country has invested in electricity transmission

lines to decrease electricity losses, and has sought to improve fuel transportation infrastructure (i.e., gas and oil pipelines, tanker stations for oil imports, etc.).

The Cuban Electricity Conservation Programme has had a significant impact by reducing electricity use in households during peak hours, and also by managing and shifting the electricity demand of main consumers to non-peak hours. A comparable fuels and lubricants conservation programme began in 2001.

The energy sector is the main contributor to adverse emissions to the environment, especially of SO_2 emissions from the use of domestic crude oil in electricity generation. This fuel contains very high levels of sulfur, affecting the environment by contributing to acid rain and harming human health.

Future options to achieve sustainable energy development include an increase in efficiency in the sugar sector, the exploitation of hydro and wind potential, an expansion in the use of solar applications, an evaluation of potential nuclear power penetration, and the development of biodiesel and alcohol programs.

The use of the ISED framework methodology is recommended for evaluating sustainable energy development scenarios that could be undertaken in Cuba, and for evaluating possible options to reduce the environmental impact of Cuba's energy development.

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5. LITHUANIA

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5.1. Introduction

Lithuania has had three National Energy Strategies, adopted in 1994, 1999 and 2002 (Lithuania Ministry of Economy, 2002). The third National Energy Strategy can be considered a sustainable energy development strategy. The next National Energy Strategy should be approved in 2007. Lithuania entered the European Union (EU) in 2004 and its energy policy should be consistent with EU energy policy. A main goal of international and EU energy policy is to secure a sustainable energy future. The application of ISED to Lithuanian energy policy should help to address sustainable energy development challenges and monitor progress achieved in approaching main energy indicators of EU-15 countries as a result of energy policy harmonization and law approximation.

The purpose of this case study is to apply ISED in order to assess energy sector developments and to monitor progress achieved towards established targets. Appropriate ISED address priority concerns or strategic priorities of the Lithuanian energy sector with respect to defined related targets. Analysis of trends of selected indicators and their interlinkages with other indicators (driving force indicators, etc.) allow definition of problematic issues, assessment of the effect of policy measures proposed in the strategy, and the definition of new policy measures and actions to be implemented in order to achieve progress on priority targets established by the third National Energy Strategy. The application of modern strategic planning methods such as the ISED tool in the preparation of national energy strategies will help to create a consistent and well-structured strategy framework addressing all three dimensions of sustainability and to enhance the quality of policy analysis.

The scope of the study is to define priorities of energy sector development based on the third National Energy Strategy and to conduct policy analysis using the ISED tool. The main priority areas of energy policy are addressed using targeted indicators, driving force indicators and response actions on selected targeted indicators.

5.2. Overview of the Lithuanian Energy Sector

The Republic of Lithuania, located on the south shore of the Baltic Sea, regained its independence in 1991 after the break-up of the former Soviet Union. The population in the country is about 3.69 million (2000), and its density is 56.6 inhabitants/km^2. Lithuanian territory is 65,300 km^2, and it is bordered by Latvia to the north; Belarus to the east; Belarus, Poland, and The Russian Federation to the south; and the Baltic Sea to the west. The Lithuanian currency, the litas, has an exchange rate of 2.97 litas to the U.S. dollar (as of October 2003). The GDP (based on purchasing power parity) was $27.6 billion in 2002, which ranks 84th out of 212 countries around the world. In 2004 Lithuania joined NATO and the European Union. Table 5.1 provides the total primary energy supply and final energy consumption structure dynamics in Lithuania 1990-2000. In the structure of primary energy supply in the year 2000, oil products amounted to 31%; natural gas 31%; solid fuel 10%; and nuclear 28%.

Lithuania's relatively small oil resources are not nearly enough to meet its needs, and so the country has become heavily dependent upon petroleum imports. Consumption of crude oil has been about one order of magnitude greater than domestic production. All of Lithuania's natural gas is imported from Russia by the gas pipeline company, Lietuvos Dujos, as there is no natural gas production within

Lithuania. The security of supply is a very important issue for the Lithuanian energy sector. The net energy import amounted to more than 50% in 2002.

The current structure of Lithuania's primary energy supply is very favorable with respect to greenhouse gas (GHG) emissions. Emissions of the main pollutants (SO_2, NOx, NMVOC, dust) from fuel combustion are quite low and Lithuania meets the requirements of all international conventions in the field of atmospheric pollution. Nevertheless, in the future when the Ignalina nuclear power plant (NPP) is closed, its share will be replaced by fossil fuels. This will have an impact on GHG emissions increases.

TABLE 5.1 ENERGY BALANCE STRUCTURE DYNAMICS IN LITHUANIA, KTOE

	1990	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Energy production	4,667	4,095	3,551	2,381	3,478	4,342	3,908	4,438	3,482	3,178	4,129	4,857
Crude oil	12	64	72	82	115	155	212	278	233	316	475	439
Peat	14	25	12	21	14	18	21	17	23	12	11	11
Nuclear	4,438	3,814	3,195	2,008	3,081	3,633	3,133	3,532	2,570	2,194	2,961	3,686
Hydro	36	27	34	39	32	28	25	36	36	29	28	30
Wood	167	165	239	231	237	508	516	576	621	627	654	690
Imports	11,891	7,054	5,849	5,654	5,313	4,945	4,904	4,811	4,407	4,298	3,933	3,751
Natural gas	4,678	2,768	1,496	1,731	2,028	2,168	2,002	1,754	1,826	2,323	2,145	2,169
Crude oil	7,282	4,277	4,113	3,483	3,245	3,007	3,037	3,442	2,694	1,999	2,050	2,013
Electricity	-1,033	-457	-236	99	-231	-444	-303	-523	-231	-115	-341	-558
Coal	963	466	475	342	270	213	169	138	118	91	79	127
Gross inland consumption	16,558	11,149	9,400	8,036	8,792	9,287	8,812	9,249	7,889	7,476	8,063	8,607
Oil products	7,294	4,341	4,185	3,565	3,360	3,163	3,249	3,720	2,926	2,315	2,525	2,453
Natural gas	4,678	2,768	1,496	1,731	2,028	2,168	2,002	1,754	1,826	2,323	2,145	2,169
Nuclear & hydro	3,442	3,384	2,993	2,146	2,882	3,217	2,855	3,045	2,375	2,108	2,648	3,158
Solid fuel	1,144	656	726	594	521	739	705	731	762	730	745	828
Final consumption by fuel	10,784	7,281	5,145	4,810	4,544	4,531	4,505	4,445	4,075	3,813	3,896	3,893
Natural gas	672	696	458	392	371	413	382	344	374	409	388	401
Oil products	4,538	2,747	1,769	1,643	1,650	1,535	1,624	1,645	1,502	1,357	1,420	1,411
Solid fuel	1,031	566	623	492	421	626	594	622	642	666	585	590
Heat	3,276	2,433	1,723	1,714	1,554	1,398	1,326	1,253	995	848	949	913
Electricity	1,267	840	571	570	548	560	579	581	563	533	554	578
Final consumption by sector												
Manufacturing	4,052	2,813	1,299	1,129	1,088	1,004	995	996	836	827	792	886
Transport	1,715	1,151	1,125	1,151	1,170	1,125	1,253	1,313	1,174	1,056	1,153	1,191
Agriculture	897	460	344	248	191	207	173	160	113	102	100	109
Households	1,946	1,764	1,603	1,522	1,409	1,553	1,498	1,450	1,419	1,354	1,372	1,385
Commercial sector	2,173	1,093	773	761	686	642	586	526	533	473	472	476

Final energy consumption in Lithuania amounted to 3.9 Mtoe in 2002. The structure of final energy consumption in Lithuania was the following in 2000: manufacturing 21.7%; transport 27.7%; agriculture 2.7%; household 35.5%; and the services sector 12.4%.

Almost three-quarters of Lithuania's total electricity production is presently generated by the Ignalina nuclear power plant. A historical summary of the structure of electricity generation and consumption in Lithuania is shown in Table 5.2.

Though there has been considerable attention devoted to improving the safety of Ignalina and analysts are looking at safety systems which could allow the plant to operate through 2025, instead of shutting it down in the 2005 to 2010 time frame, the European Union is concerned about the safety of Ignalina, and has pushed for its retirement. The Lithuanian parliament agreed to the closure of Unit 1 at Ignalina by 2005 as one of the conditions for Lithuania's admission to the EU. To help in planning the closure and in developing alternative power sources, the EU initially committed 10 million Euros to aid Lithuania in 2000, and announced an additional 20 million Euros per year from 2000 to 2006. The EU Phare program also pledged $195 million in June 2000 to help Lithuania shut down the facility.

The Lithuanian Economics Ministry estimates a much higher cost for closing both units: $2.4 billion by 2020, with the total cost eventually reaching more than $3 billion. In addition, Lithuanian energy officials have estimated that it would cost $910 million to modernize the non-nuclear plants to make up for lost capacity if Ignalina is retired. This will cause a significant burden on the Lithuanian economy. First, prices of electricity will increase significantly and will reach 10-14 EURct/kWh, according to some estimates (Lithuania Ministry of Economy, 2002). The closure of the Ignalina nuclear power plant will have a significant impact on unemployment as well: five thousand workers will be fired, and about four thousand people whose activities are related to the plant will also lose their jobs. The Ignalina region will thus be faced with these and other problems after the closure.

TABLE 5.2 ELECTRICITY PRODUCTION AND CONSUMPTION, GWH

	1990	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Gross electricity production	28,405	18,707	14,122	10,021	13,898	16,789	14,861	17,631	13,535	11,425	14,736	17,720
Ignalina NPP	17,033	14,638	12,260	7,706	11,822	13,942	12,024	13,554	9,862	8,419	11,362	14,142
Public CHP plants	10,809	3,527	1,244	1,563	1,275	1,917	2,001	3,108	2,734	2,254	2,589	2,638
Autoproducers (CHP)	149	72	38	34	50	56	68	74	79	109	85	160
Kruonis HPPS		159	187	266	378	548	474	478	447	304	375	427
Kaunas HPP	396	300	381	438	357	315	277	391	388	313	284	316
Small HPP	18	11	12	14	16	11	17	26	25	26	41	37
Net import	-11,975	-5,303	-2,732	1,099	-2,678	-5,159	-3,525	-6,082	-2,682	-1,336	-3,964	-64,87
Own use in power plants	2,109	1,760	1,574	1572	1,541	1,683	1,563	1,684	1,586	1,385	1,522	1,647
HPS water pumping	-	225	263	372	517	748	647	654	615	426	517	580
Losses in the network	1,552	1,686	2,204	1,981	2,008	1,779	1,585	1,519	1,330	1,281	1,416	1,426
Other Energy Sector	756	561	657	683	799	904	805	939	779	800	871	858
Final consumption	14,734	9,764	6,641	6,629	6,371	6,514	6,735	6,752	6,542	6,196	6,446	6,722
Manufacturing	8,274	4,537	2,771	2,802	2,813	2,519	2,776	2,620	2,407	2,294	2,346	2,546
Agriculture	2,942	1,513	705	576	523	501	426	413	226	188	197	188
Households	1,767	2,414	1,493	1,545	1,499	1,606	1,720	1,743	1,886	1,767	1,818	1,811
Commercial sector	1,504	1,159	1,579	1,604	1,441	1,803	1,724	1,895	1,949	1,871	1,995	2,095
Transportation	248	141	93	102	96	85	89	81	75	76	90	82

Disaggregated results of the final energy consumption dynamics and forecast in the case of the most probable base case scenario by economic sectors developed in the National Energy Strategy (Lithuania Ministry of Economy, 2002) are shown in Figure 5.1. Energy demand in the household sector will decrease during the planning period by 7.5%. As one can see from Figure 5.1, energy consumption in

the trade and service sector and agriculture will increase only by 20-30%. Energy consumed in the manufacturing and transport sectors will increase by 80%.

Development of final energy structure by fuel source, and demand forecasts until the year 2020 are presented in Figure 5.2.

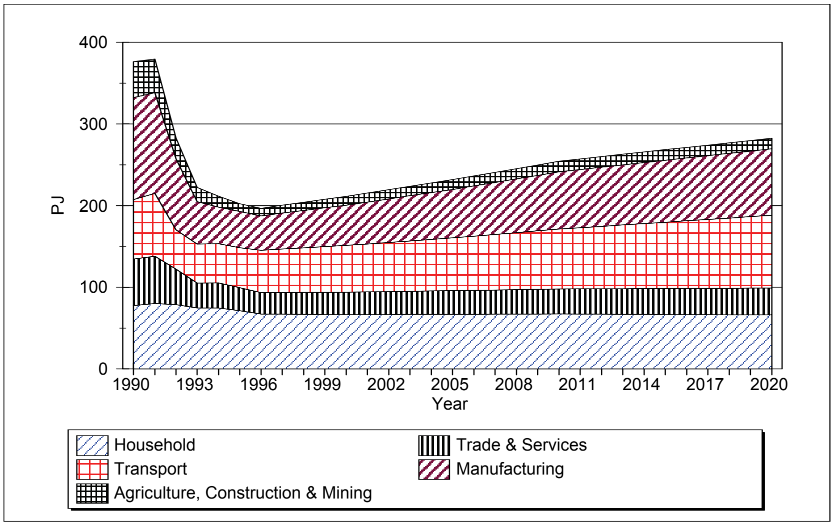

Figure 5.1 Final energy demand by sectors of economy (base scenario)

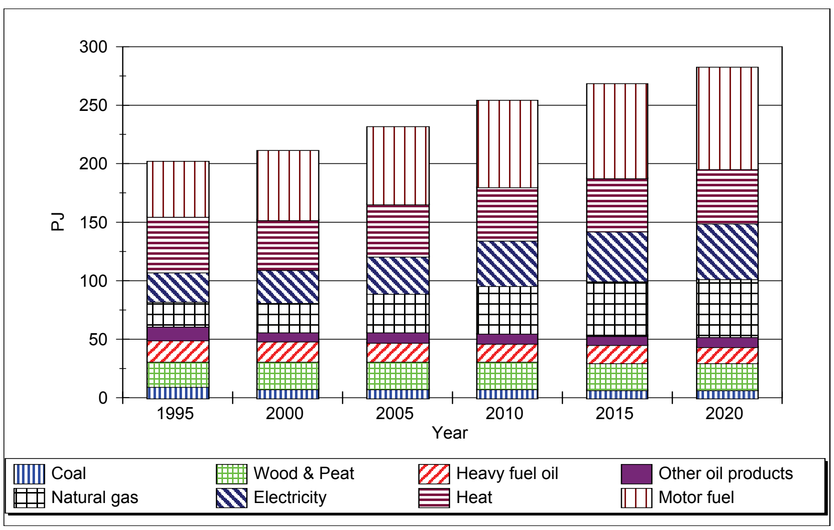

Figure 5.2 Final energy demand by fuel sources (base scenario)

Lithuania inherited from its Soviet past a strong energy sector, created with large-scale export possibilities (Table 5.3). Currently, the export and domestic consumption are almost half what they were in 1990. However, all of the generating plants and their operating staff have been fully retained. This represents a heavy burden on Lithuania's economy, as it increases energy production costs, reduces the competitiveness of goods, and hampers exports.

A considerable fraction of equipment and facilities within the country's power system (generation, transmission and distribution network), natural gas supply system, and refinery are obsolete and require modernization. Privatization programs have made considerable progress. Lithuania has privatized its oil industry and restructured the electricity and heat sectors. It has separated electrical generation, transmission, and distribution and has started privatization within this sector as well.

TABLE 5.3 CAPACITIES OF THE LITHUANIAN ENERGY SYSTEM

	Potential	Used in 1990		Used in 1993		Used in 1996	
		total	exported	total	exported	total	exported
Installed electricity generating capacity, GW	6.3	5.1	-	3.1	-	3.2	-
Electricity production, TWh	35[(1)]	28.1	11.7	14.1	2.7	16.8	5.2
Oil processing, Mt	12	9.6	3.2	5.2	1.2	4.3	0.9
Gas import by pipeline, 10^9, m^3	10	6.2	-	1.9	-	3.1	-

[(1)] Theoretical maximum output of power plants when load factor is assumed to be equal to 70%.

From the point of view of the three dimensions of sustainability, Lithuania's energy sector is characterized by low environmental pollution because of the current favorable primary energy supply structure; but this will change significantly after 2009. It also has low economic and energy efficiencies because of an obsolete energy infrastructure, and comparatively high energy prices given the low population incomes, which creates problems in energy affordability. Most of these problems are reflected in the energy policy priorities developed in the third National Energy Strategy.

5.3. Review of Lithuanian Energy Statistics Capability

Lithuania's energy statistics are comprehensive and publicly available, and there are sufficient energy statistics to construct all the relevant ISED for the country. The main institution responsible for energy statistics collection and maintenance is the Lithuanian Department of Statistics (LDS). Within this Department, the energy statistics group publishes comprehensive annual *Energy Balances* (LDS, 2001a). The Lithuanian Energy Institute (LEI) in co-operation with the Lithuanian Ministry of Economy publishes an annual energy statistics brochure entitled *Energy in Lithuania* (LEI, 2001a), providing readers with comprehensive information on primary and secondary energy development trends, energy balances (addressing oil refining, electricity and heat), and energy prices and tariffs.

Other stakeholders in the Lithuanian energy sector also publish annual statistics relevant to ISED. The energy company JSC "Lithuanian Energy" (JSC, 2001), the transmission system operator, publishes the annual activity report *Lithuanian Energy Annual Report*; JSC "Lithuanian Gas" (www.dujos.lt) publishes *Lithuanian Gas Annual Report*. The regulatory institution National Control Commission for Prices and Energy (www.regula.is.lt) publishes the annual *Activity Reports of the National Control Commission for Prices and Energy*.

Information about the transport sector is presented in the annual brochure *Transport and Communications* by the Lithuanian Department of Statistics (LDS).

All economic information is presented in the Statistical Yearbook of Lithuania (LDS, 2001b), also published by the LDS (www.std.lt), as well as the annual LDS National Accounts of Lithuania. (LDS, 2001c).

Information about atmospheric pollution from stationary and mobile pollution sources is provided in the LDS annual review *Natural Resources and Environmental Protection* (LDS, 2001d), and another LDS annual brochure, *Air Pollution in Cities*. The Ministry of Environment (www.gamta.lt) publishes an annual report on work done, entitled *State of the Environment*. This brochure also includes relevant information about the state of the environment, the level of pollution, and implemented measures.

Information relevant for the development of indicators in the social dimension may be found in the monthly brochure *Economic and Social Development in Lithuania* (LDS, 2001e) and the annual brochures *Social Protection in Lithuania* (LDS, 2001f) and *Household Income and Expenditure* (LDS, 2001g) also published by LDS.

Most indicators from ISED have been collected, although there are problems associated with some indicators. Consistent and comparable data are not available for prices, subsidies and taxes (#3). There

are no official statistical data for final energy intensity of selected energy intensive products (#10) and, for example, fossil fuel efficiency for electricity generation can be calculated only manually, subtracting fuel used for heat production at combined heat and power plants (CHP). There is no flue gas desulfurization installed in Lithuania. Some power plants have installed pollution abatement measures such as low NOx burners, electrostatic precipitators, but such information can be collected only personally because there are no official statistical data about status of deployment of pollution abatement technologies (#13). There are no official statistical data on (#15) expenditures in the energy sector for environmental control, hydrocarbon exploration, R&D, or net energy import expenses. National statistics provide data that may not be consistent for international comparisons addressing, for example, private consumption and prices of electricity, fuels, etc. (#20). Also, there are no consistent official statistical data on percentage of income spent for energy by average and poor populations (#21). There are no official statistical data about the fraction of the population heavily dependent on non-commercial energy or without electricity (#22).

Information on the following environmental dimension indicators is also lacking in official Lithuanian statistics:

24.4 Ambient concentration of CO pollutants in urban areas

24.5 Ambient concentration of ozone pollutants in urban areas

25 Land area where acidification exceeds critical load (CL)

27.2, 27.3 Radionuclides (tritium, carbon-14) in atmospheric radioactive discharges are presented in official data as total long-term radionuclides

28.1 Wastewater discharges

28.2 Radionuclides in liquid radioactive discharge

29 Generation of solid waste (only the micro level data)

30 Accumulated quantity of solid waste (only the micro level data)

31 Generation of radioactive waste from fuel cycle chains of nuclear power generation

33 Land area taken by energy facilities

34 Fatalities due to accidents with breakdown of fuel chain

37 Lifetime of proven recoverable oil reserves

40 Intensity of use of forest resources as fuelwood.

In general energy statistics capability is adequate enough to conduct energy policy analysis but some information on environmental issues related to the energy sector is lacking. This information should be included in energy statistics.

The Statistical Yearbook of Lithuania started to publish indicators of sustainable development in 2004. These indicators are to be used for the monitoring of implementation of the Lithuanian National Sustainable Development Strategy adopted in 2003. These indicators are directly linked to objectives and tasks outlined in the Strategy. The following indicators relevant to the energy sector are addressed in the Statistical Yearbook: GHG emissions, final energy consumption, final energy intensity of GDP and final energy intensities of economic sectors, share of renewables in TPES, in electricity generation and a balance of fuels consumed in the transport sector. The data for 1990, 1995, 2001, 2002 and 2003 are presented in the Yearbook.

5.4. Lithuanian Energy Priority Areas

At the beginning of 1994, the first National Energy Strategy, outlining the principal provisions of the Government on the renovation and development of the energy sector, was approved for a comparatively long period – until the year 2015. Clearly, great precision of predictions cannot be expected, because this forecast was made during a time of rapid change. The Energy Law adopted in 1995 includes an assumption that the energy strategy will be approved by the Parliament and will be

revised every five years. The second National Energy Strategy adopted by Parliament in 1999 amended and specified the energy development trends defined in 1994. During its preparation, obvious changes in the economy and energy sectors have been included, the experience and information needed for planning and forecasting the development of separate branches of the energy sector have been used, and changes in the neighboring countries and their plans for energy development have been assessed.

The third National Energy Strategy adopted in 2002 (Lithuania Ministry of Economy, 2002) deals with very important issues emerging within the Lithuanian energy sector, as well as related to the country's economy. Lithuania entered the EU in 2004, and the decision about closing the Ignalina NPP affected this strategy, requiring an evaluation of consequences and future energy sector development patterns. So the new energy strategy was adopted on the threshold of entering the EU. The main issue in preparation of the third National Energy Strategy was to establish priorities for energy sector development. For the third Strategy, the main priorities were reliable and safe energy supplies at least cost, seeking to prepare Lithuania's energy sector for the competitiveness in EU energy markets and pollution reductions required after the closure of the Ignalina NPP.

Preparing the Lithuanian energy sector for integration into EU energy markets while seeking to ensure its competitiveness is an important strategic objective for future energy sector development. All legal acts regulating the Lithuanian energy sector must be harmonized with EU directives and regulations including technical, environmental, and efficiency requirements, as well as economic, management and property components. The Association Agreement with the EU, the Energy Charter and other international treaties on basic requirements and provisions in the energy sector should also be taken into consideration during the formation of the aims of the National Energy Strategy. The principles and statements of the EU and its Member States in energy policy formation have to be assessed when preparing energy policy objectives.

The following priorities of energy policy were addressed in the third National Energy Strategy.

1. Decrease in energy intensity

Vast energy saving potential exists in the energy sector, including on the demand side which is inherited from the past when conditions of cheap energy existed. Rapid and comprehensive utilization of this potential should be the main aim of the Strategy. Lithuania has almost no indigenous cheap primary energy resources. Therefore rational, efficient and thrifty use of all energy forms in all stages of the energy system is a permanent objective and must have a high priority. Energy use per unit of GDP can be used to indicate the general relationship of energy consumption to economic development and provide a rough basis for projecting energy consumption and its environmental impacts with economic growth. Energy consumption per unit of commercial and service sector output can be used to monitor trends in energy consumption in this sector.

2. Promotion of renewable energy sources

Studies of the indigenous energy resources performed in Lithuania during recent years show that the European Union goal of satisfying approximately 12% of the energy demand of each country by renewable energy resources could be implemented in principle in Lithuania. Pilot projects implemented in recent years justify the possibility of accelerating the utilization of indigenous energy resources, particularly for heat supply. However, the current use of these resources is rather low. The increase of indigenous fuel utilization is restricted by regulated costs for domestic fuel (i.e., sod peat, wood chips) production, which has already reached or even exceeded the price of imported heavy fuel oil. The structure of energy supply in terms of shares of energy sources in primary energy supply and electricity generation could be used to monitor the trends in renewable energy source utilization.

3. Increase in security of supply

Increase in security of supply is one of the main principles of EU energy policy. Lithuania has few domestic energy resources and depends on imports from only one supplier – The Russian Federation. When making the energy sector development plans for Lithuania, security of supply must be

considered as a very important issue, and the possibility of increasing diversification of fuels and fuel supplies should be taken into account.

4. Improvement of quality of life

Energy is a key factor in development and in providing vital services that improve the quality of life. Limited access and limited affordability to energy are serious constraints of development in the developing world, where the per capita use of energy is less than one sixth of that of the industrialized world. Access to energy is one of the key issues of sustainable energy development. An indicator of energy access and affordability is energy consumption per capita.

5. Decrease in energy impact on the environment

A very important problem in the Lithuanian energy sector is related to the Ignalina nuclear power plant. This plant is the main source of electricity production in Lithuania. Over the period of the last five years it generated 80-85% of the total electricity production, so atmospheric emissions from the power and heat sector were very low. The future development of the whole energy sector is greatly influenced by the closure of this nuclear power plant. The first unit was closed in 2004 and the second will be closed in 2009. Limiting the increase in air emissions is a major environmental objective in Lithuania.

5.5. Implementation of the ISED Framework

For this case study, which aims to implement the ISED framework for future Lithuanian national energy strategies, the following priority areas were selected based upon the main energy policy directions developed by the third National Energy Strategy:

- Energy consumption;
- Energy intensities;
- Structure of the economy;
- Energy security;
- Energy prices;
- Environmental energy situation.

Seeking to review the state of energy priorities, it is possible to select relevant indicators from the ISED list and complete an analysis of trends and impacts of current energy policies. A very important step is to identify targeted indicators, as well as driving forces for selected targeted indicators (Table 5.4). As targeted indicators, the following indicators within the economic dimension were selected:

#3 Energy prices;

#4 Shares of sectors in GDP value added;

#9 Energy intensities of economic sectors;

#11 Energy mix;

#12 Energy supply efficiency;

#14 Energy use per unit GDP;

#16 Energy consumption per capita;

#17 Indigenous energy production;

#18 Net energy import dependency.

Social indirect and direct driving force indicators will be analyzed to address energy price and energy affordability issues, which are also within Lithuania's energy priority areas.

For the environmental energy situation, only two direct driving force indicators of the environmental dimension were selected: #23 Quantities of SO_2 and NO_X emissions and #26 Quantities of CO_2 emissions.

TABLE 5.4 INDICATORS ADDRESSING PRIORITY AREAS OF OUR STUDY

Number	Indicators	Dimension	Type
#2	GDP/capita adjusted at PPP in USD'95	Economic	Indirect driving force
#3	Current end-use energy prices	Economic	Indirect driving force
#4	Shares of sectors GDP adjusted at PPP in USD'95 value added	Economic	Indirect driving force
#9	Energy intensity of economic branches (GDP adjusted at PPP in USD'95)	Economic	Indirect within energy sector driving force
#11	Energy mix	Economic	Indirect within energy sector driving force
#12	Energy supply efficiency	Economic	Indirect within energy sector driving force
#14	Energy intensity of GDP (adjusted at PPP in USD'95)	Economic	Direct within energy sector driving force
#16	Energy consumption per capita	Economic	State
#18	Net energy import dependence	Economic	State
#19	Income inequality	Social	Indirect driving force
#20	Ratio of monthly disposable income per capita (in USD'95) of 20% poorest households to the prices of major energy sources	Social	Indirect within energy sector driving force
#21	Fraction of disposable income per capita (in USD'95) spent on fuel by average population and group of 20% poorest population	Social	Direct within energy sector driving force
#23	Quantities of SO_2 and NOx emissions from energy sector	Environmental	Direct within energy sector driving force
#26	Quantities of CO_2 emissions from energy sector	Environmental	Direct within energy sector driving force

Trends in economics and demographics are the main driving forces for energy consumption, energy intensities, environmental energy impacts, etc. So first it is necessary to assess the trends in economics and demographics. Then, trends in energy consumption and energy intensities, structural changes in the economy and other trends can be assessed. This analysis allows the evaluation of implemented energy policies, and the formulation of new policies.

A main objective of Lithuania's energy strategy is to ensure preparation of the Lithuanian energy sector for successful competition in EU energy markets. In order to evaluate the gap in convergence[1] between primary energy indicators in Lithuania and the EU-15, a comparison between selected targeted and affected state indicators of Lithuania and EU-15 averages were conducted. In addition, a comparison of Lithuanian indicators with some EU member states having some similar population and climate characteristics (Denmark, Ireland, and Finland) but different industrial structure was performed. Some general data for these countries are presented in Table 5.5.

[1] Convergence means the approaching of the main Lithuanian indicators to EU-15 levels.

TABLE 5.5 THE MAIN GEOGRAPHICAL, DEMOGRAPHICAL AND CLIMATE CONDITIONS OF LITHUANIA AND EU MEMBER STATES SELECTED FOR COMPARISON

Country	Territory, thousand km^2	Population, millions	Density of population, inhab/km^2	The mean annual temperature, ^oC	The share of final energy consumption in manufacturing, % (2000)	Value added of manufacturing in GDP, % (2000)
Denmark	43	5	116.2	8	25	28
Finland	338	5.2	15.3	3	50	34
Ireland	70	3.9	55.7	9	30	42
Lithuania	65.3	3.69	56.6	6	22	31

5.5.1. Trends in economics and demographics

Figure 5.3 presents the dynamics of Lithuanian population growth from 1990 to 2002. This is the first indirect driving force indicator of the economic dimension from the ISED list (#1) and has an impact on all other indicators. As one can see from Table 5.6 and Figure 5.3, population decreased in Lithuania, especially in 2001 and 2002. From 1990 to 2002, the population in Lithuania decreased by 5.9%.

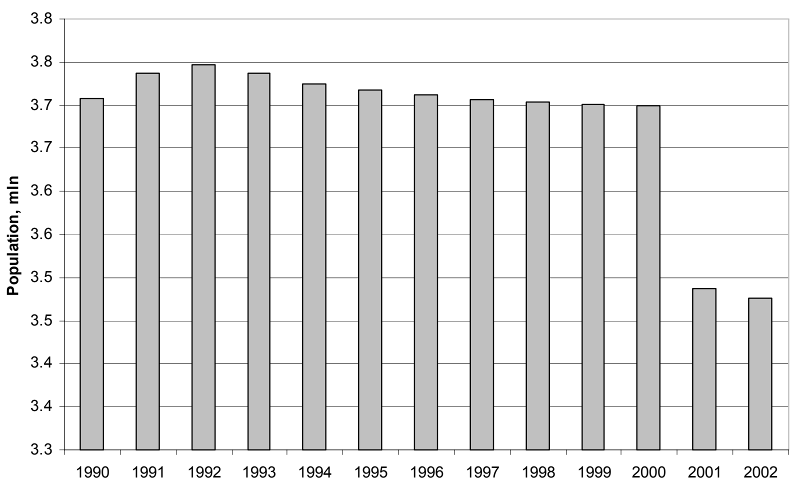

Figure 5.3 Population

TABLE 5.6 LITHUANIAN POPULATION, MILLIONS

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Population, millions	3.694	3.702	3.706	3.694	3.671	3.643	3.615	3.588	3.562	3.536	3.512	3.487	3.476

Figure 5.4 and Table 5.7 show the GDP trend in Lithuania. The restoration of independence in Lithuania provided a significant change in the economic system. The transition period and the re-organization of the economy brought about a temporary decline in GDP. The 1994 GDP was only 56% of the 1990 figure but since 1994 there has been economic growth every year with the exception of 1999 due to the impact of the economic crisis in Russia. The GDP grew in 2001 by 6.5% and in 2002 by 6.7%.

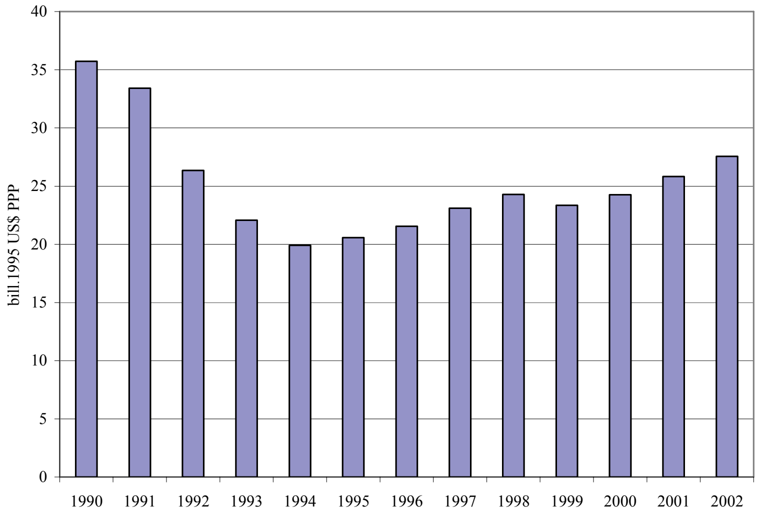

Figure 5.4 GDP

TABLE 5.7 LITHUANIAN GDP, BILLION 1995 US$ PPP

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
35.73	33.41	26.35	22.07	19.91	20.57	21.54	23.11	24.29	23.34	24.25	25.83	27.56

Figure 5.5 shows GDP per capita. This is the second (#2) indirect driving force indicator of the economic dimension from the ISED list, and it also has a significant impact on all other indicators. Levels of GDP per capita are obtained by dividing the annual GDP (at prices based on purchasing power parity, or PPP) by the population. This indicator is a basic economic growth indicator, and measures the level and extent of economic output. Since the population decreased while GDP increased during the 1994-2002 period a decoupling trend between economic growth and population growth is observed for this period.

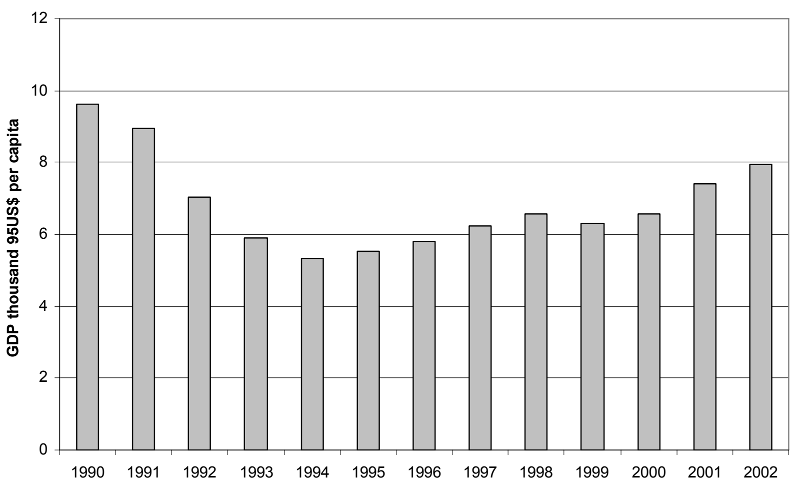

Figure 5.5 Lithuania: GDP per capita PPP 95 US$

The Lithuanian GDP per capita (expressed in PPP) can be compared with the same indicator for other EU countries (Finland, Ireland, Denmark) and with the EU-15 average (see Figure 5.6).

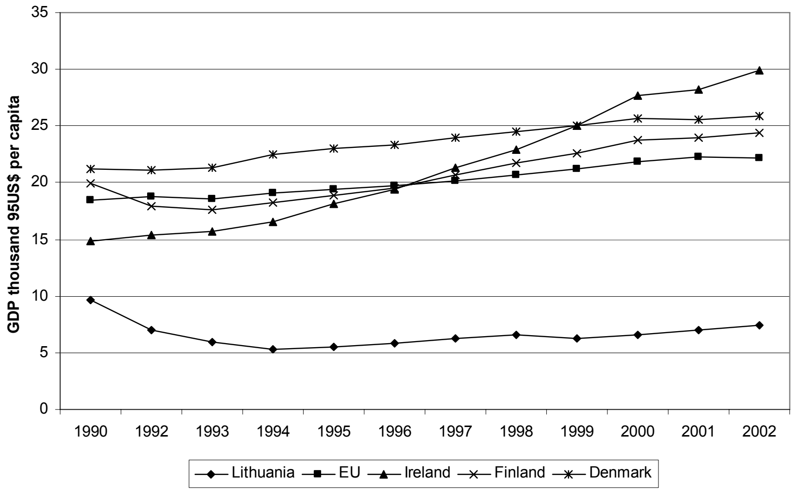

Figure 5.6 GDP per capita in Lithuania and some EU countries

From 1990 to 1994 GDP/capita was decreasing in Lithuania. Since 1995, it began to grow but in 1999 it slightly declined because of the economic recession. Since 2000, the positive trend in GDP/capita can be observed. As of 2002 this indicator was still only 70% of its 1990-year level. For the EU-15, this indicator is almost three times higher. Ireland has experienced a particularly high GDP per capita, during the 1990s, and in 2002 was fully twice as high as in 1990.

5.5.2. Energy consumption

Energy consumption per capita is the main state indicator (#16) from the ISED list. In addition to TPES per capita and electricity per capita, the analysis of final energy consumption per capita is included in this study.

This indicator was selected as a primary indicator for Lithuania though there are still a lot of debates about the desirable level of energy consumption per capita to be achieved by transition countries. From the sustainable development point of view, an increase in energy consumption per capita may not be desirable for some countries but for countries with transitional or developing economies, a sufficient level of well-being and other basic social needs may not be achieved without a considerable increase in per capita energy consumption.

An analysis is necessary to determine the trends on per capita energy consumption and the main driving forces for this state indicator including: energy intensities of economic branches, structure of economy, energy intensity of GDP, and end-use energy prices. This analysis allows the evaluation of current policies in these areas and the selection of policy actions on targeted indicators, which will positively affect energy consumption patterns in Lithuania.

The transition period from a centrally planned economy to a free market economy was accompanied by economic decline (Figure 5.4). The trend in total primary energy supply followed this economic development trend (Figure 5.7 and Table 5.8). The decline of GDP in all economic sectors (without exception) was followed by a similar decrease of total primary energy supply and final consumption in Lithuania. In 2000 TPES amounted to only 45% of the 1990 level. During the period 1996 to 2000 TPES has varied from 9.3 Mtoe in 1996 to 7.5 Mtoe in 2000, the variation depending upon electricity export. The electricity export to Belarus and other neighbouring countries was very unstable during this period because of problems related to non-payment for electricity provided.

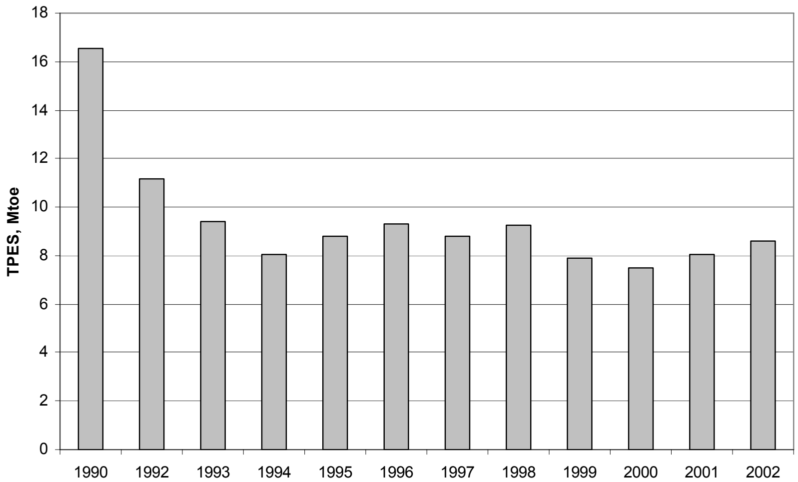

Figure 5.7 Lithuania: TPES, Mtoe

TABLE 5.8 TOTAL PRIMARY ENERGY SUPPLY (TPES), FINAL ENERGY CONSUMPTION (FEC) AND FINAL ELECTRICITY CONSUMPTION (FELC) IN LITHUANIA

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
TPESMtoe	16.56	17.20	11.15	9.40	8.04	8.78	9.29	8.81	9.24	7.86	7.47	8.04	8.59
FEC, Mtoe	10.78	8.78	7.28	5.14	4.81	4.54	4.53	4.51	4.44	4.08	3.81	4.01	4.14
FELC, TWh	14.73	11.90	9.76	6.64	6.63	6.37	6.51	6.73	6.75	6.54	6.20	6.43	6.78

Final energy consumption is presented in Figure 5.8.

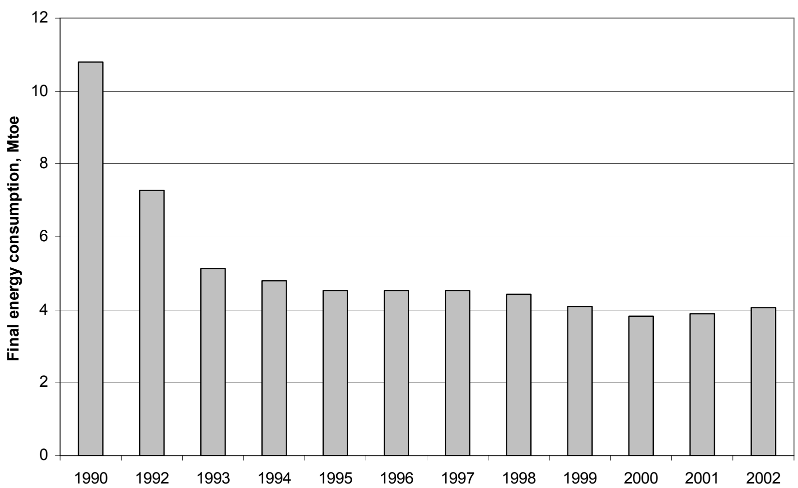

Figure 5.8 Final energy consumption

As one can see from Figure 5.8 and Table 5.8, final energy consumption was continuously decreasing from 1990 until 2000, when it stabilized. In 1995 final energy consumption amounted to 54% of the 1990 level and final electricity consumption decreased in 2000 to 61% of the same level.

Figure 5.9 shows final electricity consumption figures for the considered period.

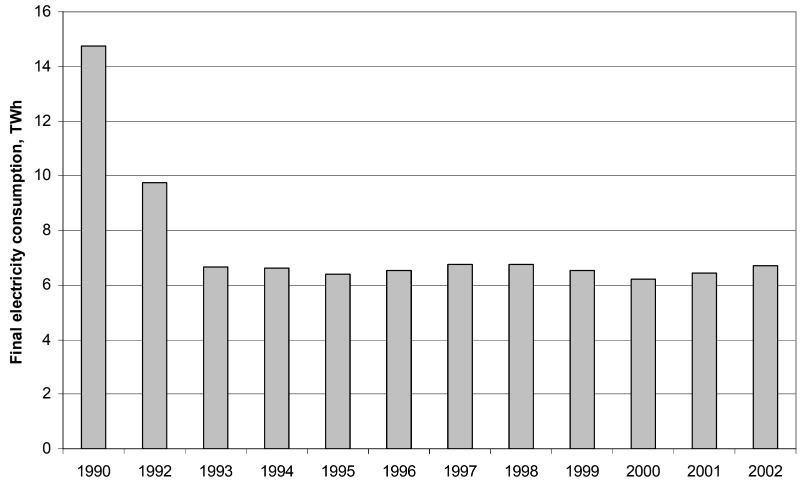

Figure 5.9 Final electricity consumption

Final electricity consumption has decreased in 2000 to less than 50% of the consumption of the 1990-year level. Since 1996, some increases in electricity consumption can be noticed, but from 1998 to 2000 electricity consumption again decreased. Since 2001 final electricity consumption has started to increase slowly.

In Figure 5.10 and Table 5.9 GDP, TPES and electricity growth indices are presented.

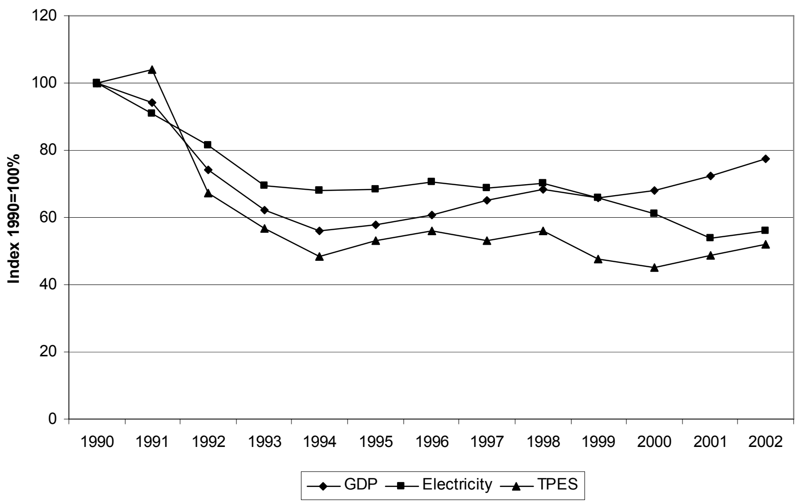

Figure 5.10 GDP, electricity, TPES growth index in Lithuania

TABLE 5.9 GDP, TOTAL PRIMARY ENERGY SUPPLY (TPES) AND ELECTRICITY CONSUMPTION GROWTH INDEX IN LITHUANIA

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
GDP	100	94.32	74.27	62.22	56.14	57.99	60.72	65.14	68.47	65.80	67.97	72.49	77.44
Electricity	100	90.79	81.59	69.33	67.95	68.29	70.54	68.76	70.05	65.82	61.19	53.7	55.9
TPES	100	103.87	67.33	56.75	48.54	53.05	56.08	53.23	55.83	47.47	45.11	48.69	51.98

As one can see from Figure 5.10, from 1999 to 2002 favorable trends decoupling economic growth from energy and electricity consumption can be observed.

In Figure 5.11 data on final energy consumption per capita for Lithuania, EU-15 and a few EU member states (Finland, Denmark, Ireland) are presented. As one can see from Figure 5.11 in 1990 the

final energy consumption per capita in Lithuania exceeded the EU-15 average in the past but starting in 1991 it became lower and by 2000 it was 2.5 times lower than that of the EU-15 average. Final energy consumption per capita in Denmark and Ireland is almost equal to the EU-15 average. In Finland, the final energy consumption per capita is very high. This is related to the high final energy intensity of the economy (especially industry), and the comparatively low energy prices combined with high population income and low population density.

Though Denmark has a similar industrial structure as Lithuania, similar climate, size of territory and population, final energy consumption per capita is significantly lower in Lithuania. This can be related mainly to the high-energy prices and low GDP per capita characteristics of Lithuania. The GDP per capita in Denmark is almost four times higher than in Lithuania.

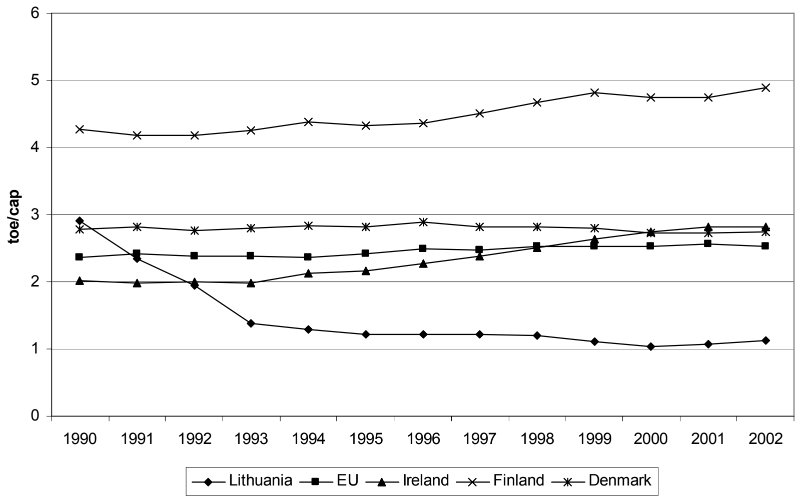

Figure 5.11 Final energy consumption per capita in Lithuania and some EU member states

In Figure 5.12 data on primary energy supply per capita in Lithuania, Ireland, Denmark, Finland and EU-15 are presented. The situation for TPES per capita in these countries is very similar to final energy per capita. This indicator for Ireland and Denmark is the same as the EU-15 average. In Finland, TPES per capita is more than 1.5 times higher than in EU-15. TPES/capita in Lithuania in 1990 was higher than the EU-15 average, but over ten years it has decreased significantly, and in 2000 it was almost half of the EU-15 average level.

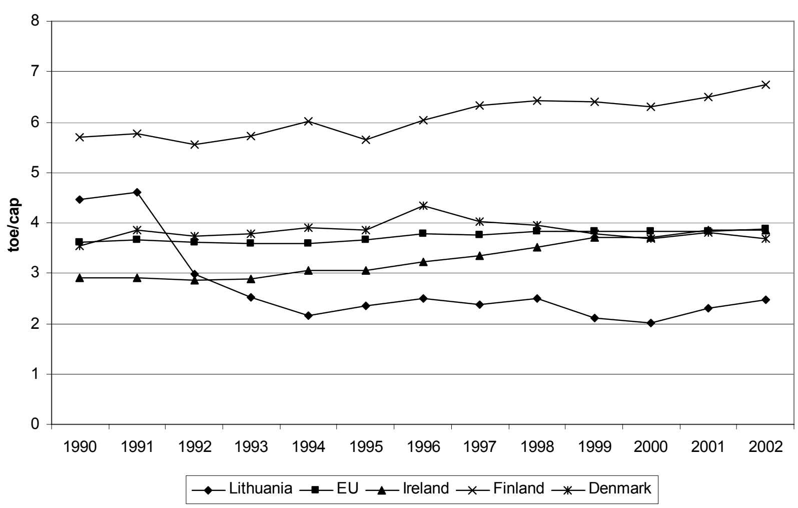

Figure 5.12 Primary energy supply per capita in Lithuania and some EU member states

For comparison, TPES per capita in eight EU accession countries are presented in Figure 5.13. As shown in this figure TPES per capita in 2000 was the lowest in Latvia. In Lithuania, this indicator was at the same level as in Poland and Hungary and slightly higher than in Latvia. Slovakia, Estonia and Slovenia constitute a second group of accession countries, for which the TPES/capita is about 1.5 times higher than in the previous group. Only in the Czech Republic the per capita TPES for 1999 and later years was at the same level as the one corresponding to the EU-15 average.

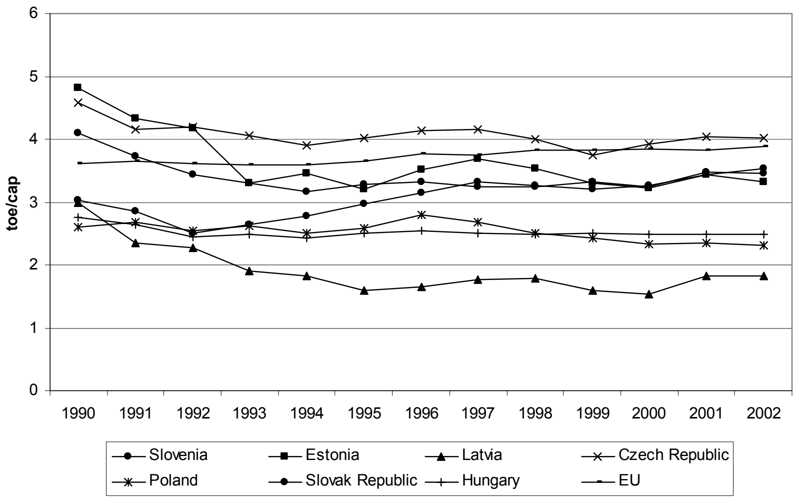

Figure 5.13 TPES per capita in accession countries and EU-15 average

Final energy consumption per capita in Lithuania is thus about 2.5 times lower than the EU-15 average, but TPES per capita is about 1.6 lower than the EU-15 average. Energy efficiency is therefore rather low in Lithuania. Losses during the transformation process in the Lithuanian energy sector are almost 1.5 times higher than the EU-15 average.

Electricity generation and use is one of the main criteria for assessing progress. The world average electricity consumption per capita in industrial countries was about 9,000 kWh/year/capita in 2000. There are, however, wide differences among industrial countries in terms of average rates of electricity utilization. In countries in transition, this indicator was 4,250 kWh/year/capita (UNDP et al., 2000). In Figure 5.14 electricity consumption per capita in Lithuania, Finland, Ireland and EU-15 are presented. The electricity consumption in Lithuania in 2000 was less than one-third of the EU-15 average, and only half of the average level of transition economies. Even in 1990, electricity consumption per capita in EU-15 was about 20% higher than in Lithuania (Table 5.10). During 1990–1994, the difference between Lithuania and EU-15 increased sharply. A stabilization of electricity consumption per capita since 1994 can be observed in Lithuania. Nevertheless, in the EU-15, electricity per capita is still increasing while at the same time final energy and TPES per capita in EU-15 are stabilizing. One can conclude then that final energy and electricity consumption per capita in Lithuania are very low compared to the EU-15 levels, and the convergence of these indicators will require some time.

TABLE 5.10 ELECTRICITY CONSUMPTION PER CAPITA IN LITHUANIA AND SOME EU MEMBER STATES, KWH/CAP

	1990	1994	1995	1996	1997	1998	1999	2000	2001	2002
Lithuania	3,973.5	1,780.2	1,713.8	1,755.0	1,816.7	1,822.8	1,767.7	1,675.2	2,893	3,013
EU-15	4,959.0	5,112.8	5,276.5	5,401.5	5,486.3	5,609.5	5,719.3	5,888.7	6,038	6,270
Ireland	3,379.7	3,942.5	4,122.5	4,365.6	4,560.1	4,762.3	5,013.9	5,330.1	5,470	6,115
Finland	11,811.8	12,779.3	12,779.6	12,965.9	13,688.9	14,137.1	14,352.0	14,564.9	14,919	14,609
Denmark	5,695.1	5,960.4	5,984.3	6,117.3	6,037.9	6,056.8	6,058.1	60,79.0	6,172	6,002

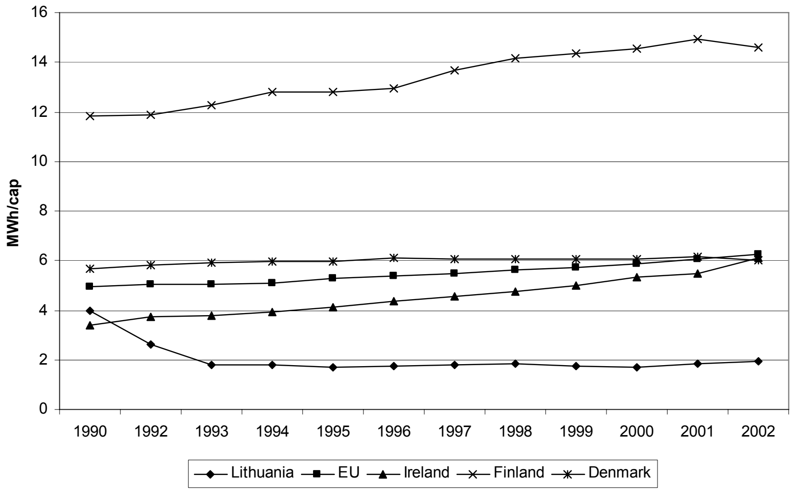

Figure 5.14 Electricity consumption per capita in Lithuania, EU-15, Denmark, Finland and Ireland

Growth indices of TPES, final energy and electricity consumption per capita in Lithuania, Denmark, Finland, Ireland and EU-15 are presented in Figure 5.15 through Figure 5.17.

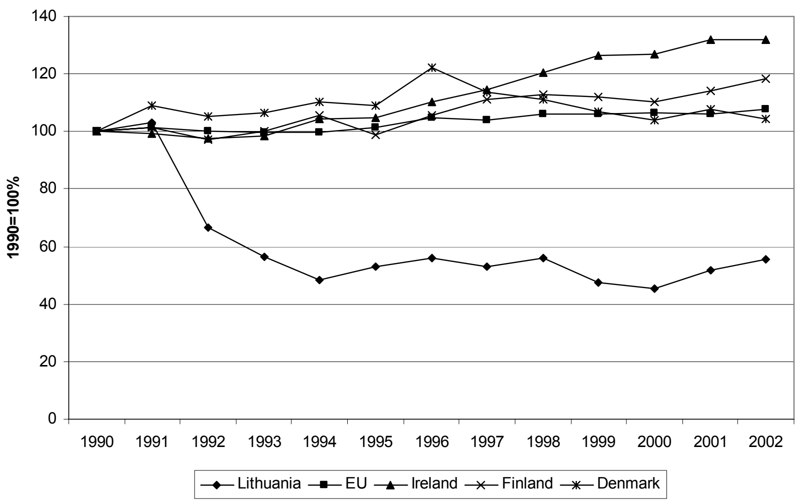

Figure 5.15 TPES per capita growth indices in Lithuania, Finland, Ireland and EU-15

As shown in Figure 5.15, the TPES growth index is the highest in Ireland. In Finland and Denmark, growth rates are similar to EU-15 average growth rates. Lithuanian TPES per capita growth rates tended to be negative until 2000, but from 2000 to 2003 some increase of TPES per capita can be observed in the country. As shown in Figure 5.16 and Figure 5.17, final energy and electricity consumption per capita growth rates are quite similar to the TPES per capita growth rates.

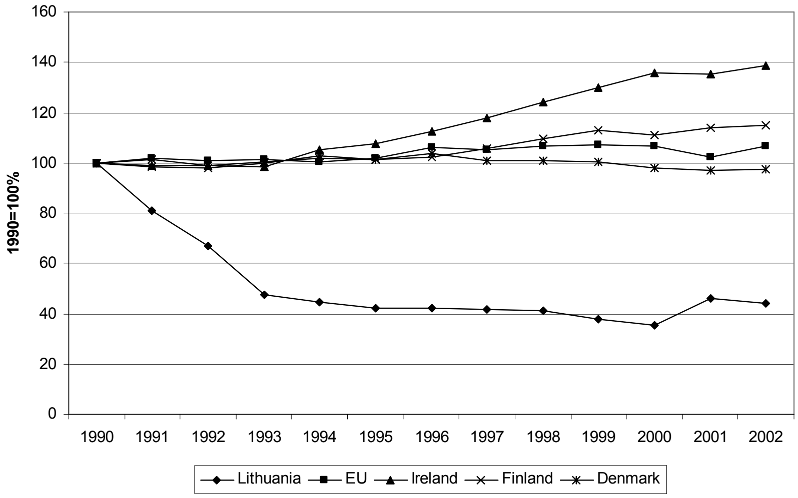

Figure 5.16 Final energy consumption per capita growth indices in Lithuania, Denmark, Finland, Ireland and EU-15

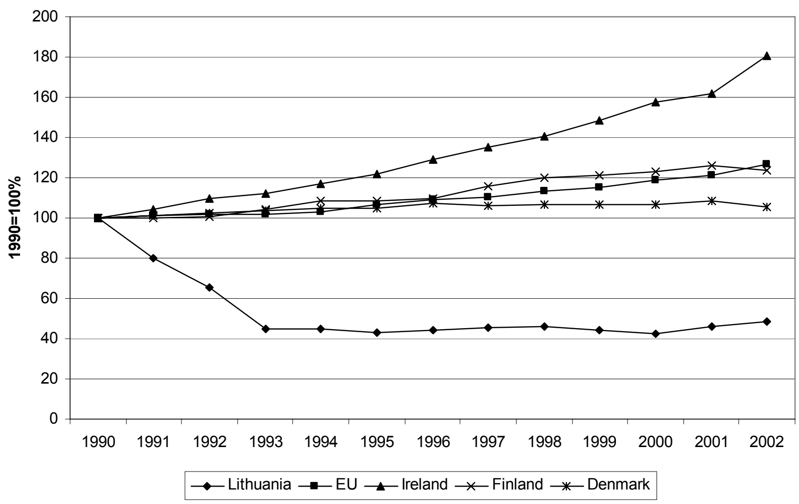

Figure 5.17 Electricity consumption per capita indices in Lithuania, Denmark, Finland, Ireland and EU-15

Electricity consumption per capita growth trends were negative in Lithuania until 1993 and stable until 2000. The very low final energy and electricity consumption per capita may imply low living standards in Lithuania. Therefore an analysis of energy affordability is necessary, in order to define reasons for such low final energy and electricity consumption levels, and to define measures which could improve the situation.

The big difference between TPES and final energy consumption per capita shows the low energy conversion efficiency in the Lithuanian energy system compared with the EU-15. Further analyses of energy use efficiency and energy intensities are necessary in order to define measures capable of improving the situation.

5.5.3. Energy intensities

TPES/GDP indicator (#14) from the ISED list was selected as a targeted indicator for the decrease in energy intensity of the Lithuanian economy. There is no doubt about desirable future trends for this indicator. Primary energy intensity of GDP is a direct driving force indicator of the economic dimension and has a significant impact on the energy consumption per capita levels analyzed in Section 5.2**.** In the ISED list it is being considered as a direct driving force indicator. It can be measured in toe per thousand US$ and kWh per US$ for electricity. This indicator shows the trends in overall energy use relative to GDP and indicates the general relationship of energy consumption to economic development.

Table 5.11 and Figure 5.18 show primary energy supply per unit of GDP for Lithuania, EU-15, and some EU member states.

TABLE 5.11 TOTAL PRIMARY ENERGY SUPPLY PER UNIT OF GDP IN LITHUANIA AND SOME EU MEMBER STATES, TOE/1,000 95US$ PPP

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Lithuania	0.46	0.51	0.42	0.43	0.40	0.43	0.43	0.38	0.38	0.34	0.31	0.27	0.27
EU-15	0.20	0.20	0.19	0.19	0.19	0.19	0.19	0.19	0.18	0.18	0.18	0.18	0.18
Ireland	0.20	0.19	0.19	0.18	0.18	0.17	0.17	0.16	0.15	0.15	0.13	0.14	0.13
Finland	0.29	0.31	0.31	0.32	0.33	0.30	0.31	0.31	0.30	0.28	0.26	0.27	0.28
Denmark	0.17	0.18	0.17	0.18	0.17	0.17	0.18	0.17	0.16	0.15	0.14	0.14	0.14

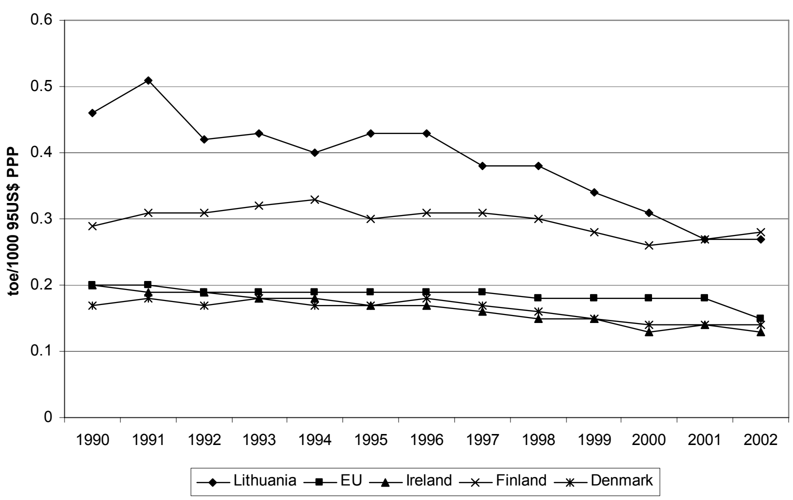

Figure 5.18 Total primary energy supply per unit of GDP in Lithuania and some EU member states

Table 5.11 shows the positive trends for primary energy intensity: that is, each unit of GDP requires less primary energy resources. In 1999 TPES/GDP in Lithuania amounted to 0.34 toe/thousand 95US$ PPP, a figure almost twice as high as the same indicator for 15 EU countries (IEA, 2001a). Figure 5.18 shows, however, a decreasing trend in this intensity indicating steady improvements in this indicator.

Primary energy intensity in Lithuania is higher than in Finland, even though this country is characterized by having both high-energy intensity and high energy consumption levels when compared with other EU-15 member states. Primary energy intensity in Denmark and Ireland (which have comparable national characteristics to Lithuania) is similar to the EU-15 average.

Final energy intensities in Lithuania, Denmark, Finland, Ireland and the average of EU-15 countries are presented in Figure 5.19. As one can see from Figure 5.19, final energy intensity in Lithuania was 1.3 times higher than in the EU-15 in 2000. But in 1990 it was even more than twice as high as in the EU-15. The positive trend in decreasing final energy intensity shows improvements in final energy use efficiency in Lithuania. Overall, final energy intensity is still quite high in Lithuania and significantly exceeds the EU-15 average level.

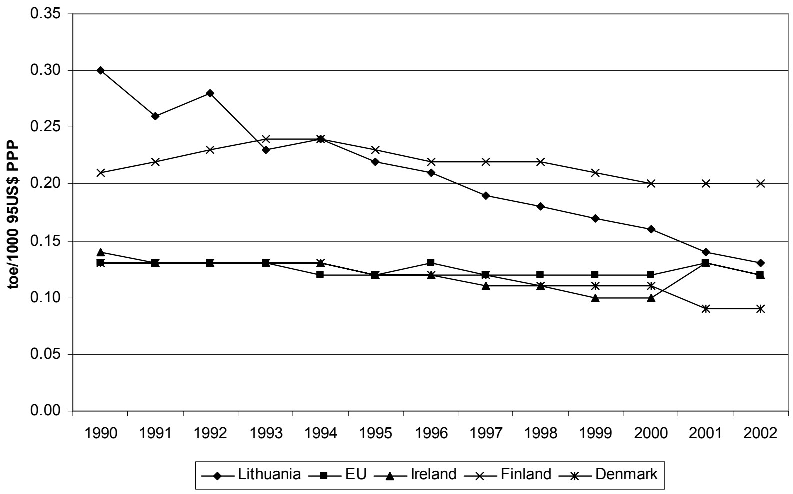

Figure 5.19 Final energy intensity in Lithuania, Denmark, Finland, Ireland and EU-15

Changes in final energy intensity and consumption were also analyzed. Growth indices of final energy intensity and final energy consumption per capita growth are presented in Figure 5.20. As can be seen, the rates of both indicators are decreasing, with energy consumption per capita decreasing more sharply within the country. For comparison purposes, trends of the same indicators for EU-15 countries (average) and Lithuania are presented in Figure 5.21.

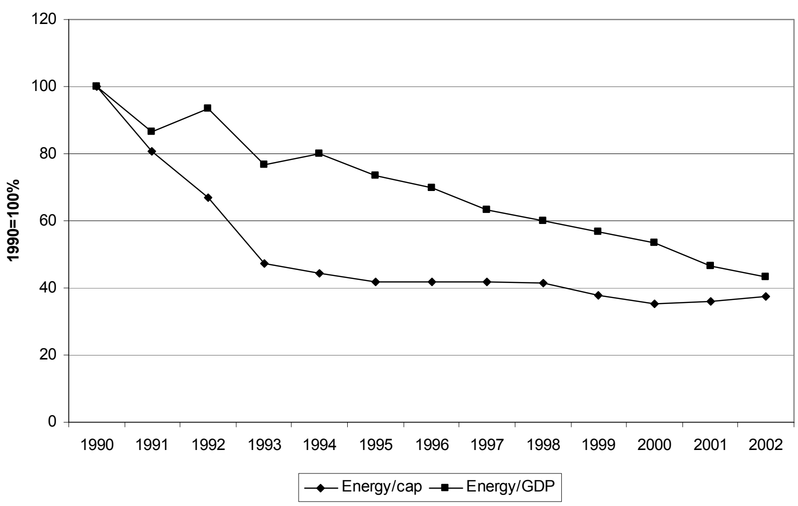

Figure 5.20 Lithuania: Final energy intensity and final energy consumption per capita

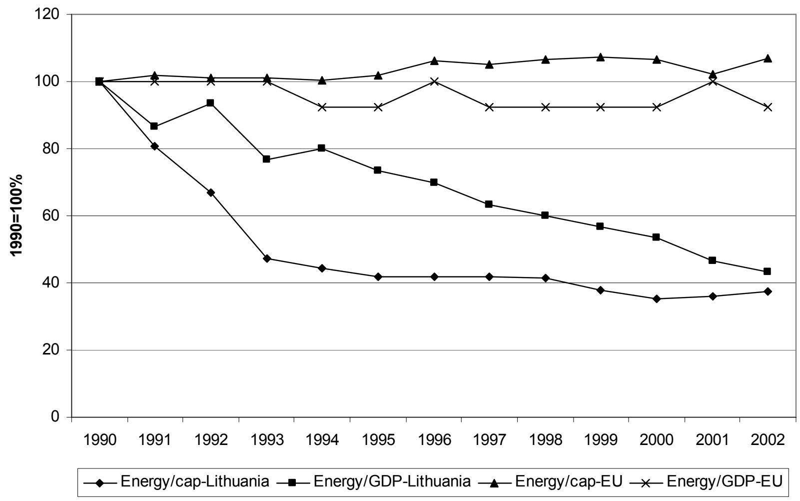

Figure 5.21 Final energy intensity growth index in Lithuania compared with EU-15 – Final energy/GDP and Final energy/capita

In EU-15 countries final energy intensity is also decreasing, but at slower rates than in Lithuania because the level of final energy intensity is significantly lower in the EU-15 than in Lithuania. Final energy consumption per capita is increasing in EU-15 countries, but in Lithuania it decreased through 2000.

In Figure 5.22 and Figure 5.23 TPES/GDP and final energy/GDP growth indices, respectively, are presented for Lithuania and selected EU member states.

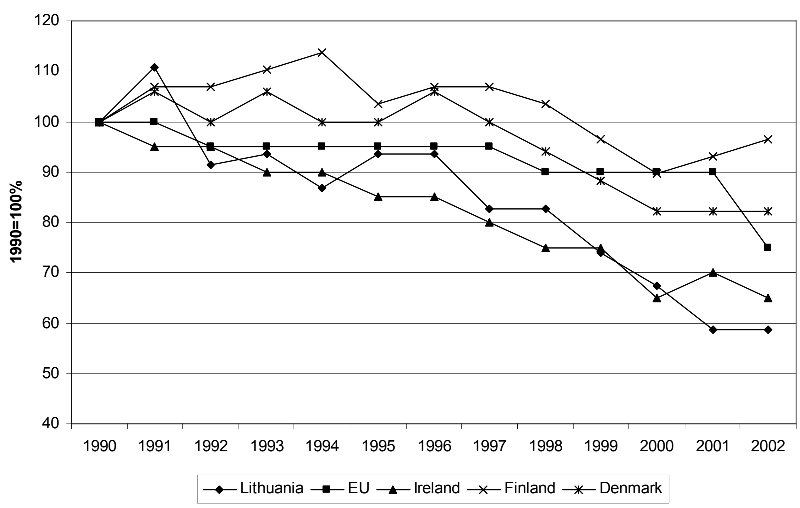

Figure 5.22 TPES/GDP growth indices in Lithuania, Denmark, Ireland, Finland and EU-15 average

As shown in Figure 5.22 primary energy intensity is decreasing at the highest rates in Lithuania and Ireland. In Denmark and Finland the rates of decrease are slower, and similar to the EU-15 average.

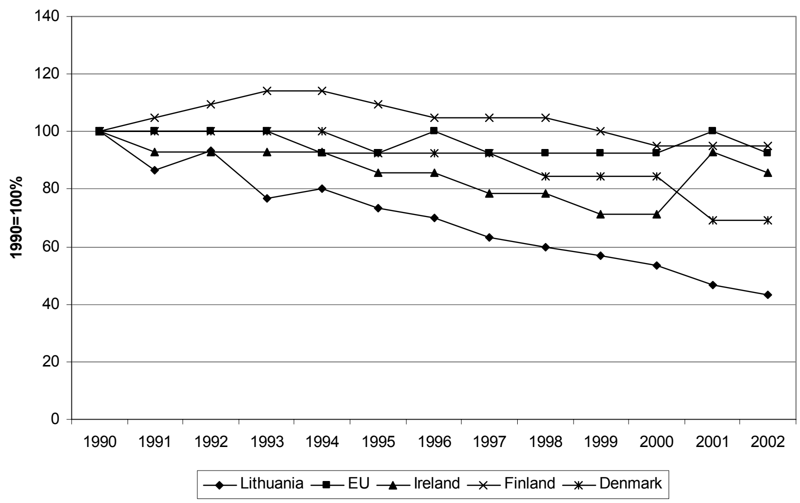

Figure 5.23 Final energy intensity growth indices in Lithuania, Denmark, Ireland, Finland and EU-15

Figure 5.23 shows that decreasing final energy intensity rates are quite different among the countries presented. The highest decreasing final energy intensity rates are in Lithuania followed by Ireland, Denmark and Finland.

Analyzing the same indicator (#14) for electricity, as shown in Figure 5.24 and Figure 5.25, the same trends as with final energy intensity and final energy consumption per capita can be observed. Electricity intensity per GDP is almost stable in EU-15 countries since 1990, but electricity consumption per capita is increasing, and at even higher rates than final energy consumption per capita.

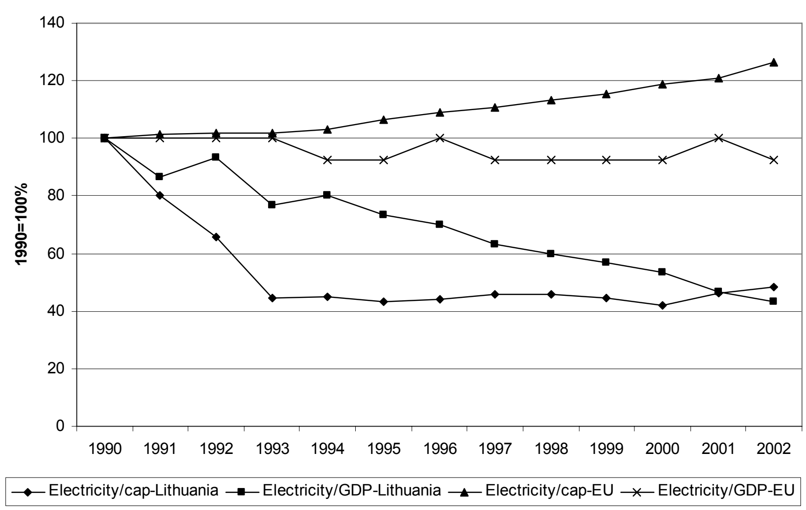

Figure 5.24 Growth indices in Lithuania comparing with EU-15 – Electricity/GDP and Electricity/capita

In Figure 5.25 final electricity intensity growth indices for Lithuania and select EU member states are presented.

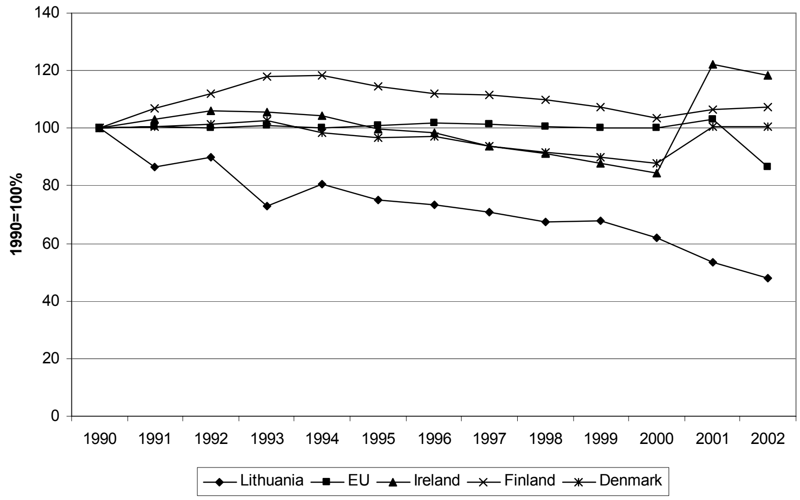

Figure 5.25 Final electricity intensity growth indices in Lithuania, Denmark, Ireland, Finland and EU-15 average

As shown in Figure 5.25 the situation with final electricity intensity growth indices is similar to the situation of final energy intensity presented in Figure 5.23. Final electricity intensity was decreasing in Lithuania at relatively higher rates.

Figure 5.26 shows the relationship between final energy intensity and GDP per capita for Lithuania and the EU-15. A decreasing trend is observed for final energy intensity in Lithuania during both the decreasing per capita GDP period (1990-1994) and the increasing per capita GDP period that followed. In EU-15, in general while the per capita GDP follows an increasing trend the intensity has remained fairly stable during the considered period. This Figure illustrates that Lithuania's per capita income is still far behind that of the EU-15 countries and that final energy intensity has decreased dramatically and was close to that of the EU-15 in 2002.

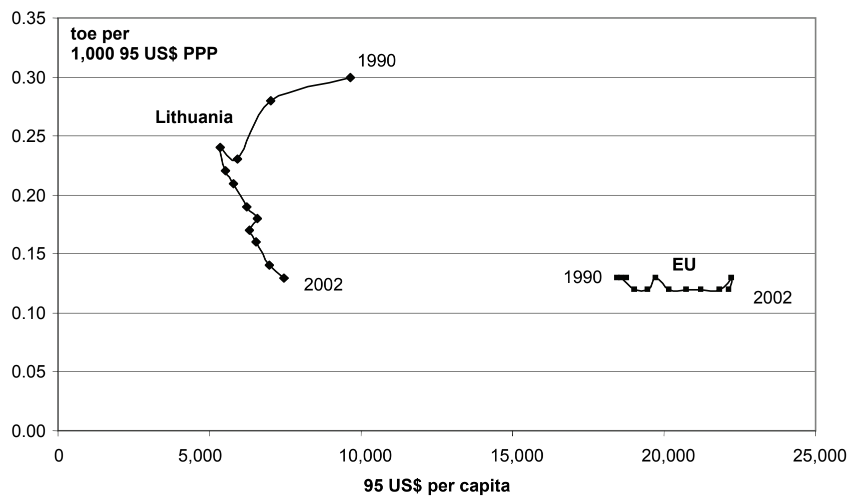

Figure 5.26 Final energy intensity and GDP per capita in Lithuania compared to EU-15

Figure 5.27 shows the relationship between final energy consumption per capita and final energy intensity for Lithuania and EU-15. As one can see, there are some differences in the trends between Lithuania and the EU-15. In Lithuania, final energy intensity decreases along with a decrease of final energy consumption per capita even after 2001 when some increase of final energy consumption per capita is observed. In the EU-15, final energy intensity is slowly decreasing along with a slow increase of final energy consumption per capita.

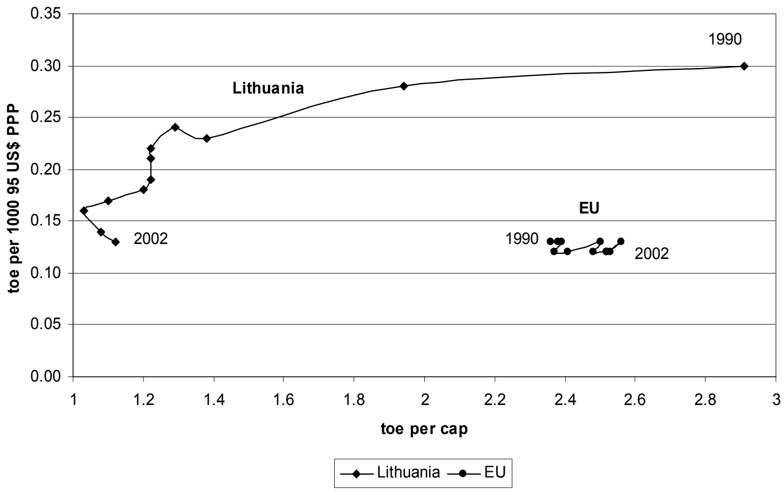

Figure 5.27 Final energy intensity and final energy consumption per capita in Lithuania compared to EU-15

Market economies had nearly linear relationships between GDP and TPES since 1982 (UNDP et al., 2000). This trend was associated with an elasticity of energy demand to GDP of about 0.85; each additional percentage of GDP growth resulted in 0.85% growth in primary energy demand. It averaged about 0.75 in developed market economies and a one-to-one relationship in developing market economies. The significant differences between developing and developed market economies had two origins: the transformation of some unaccounted non-commercial energy into commercial energy when the economy grows, and the relocation of some industries because the economic inputs, mostly labors and energy, are cheaper in the developing countries than in the developed countries. In general for market economies since 1997, GDP growth rates were faster than TPES growth rates.

Another situation is characteristic of transition economies. Since 1989 elasticity of energy demand to GDP has been negative. One might expect in the future, as restructuring comes to an end, that the elasticity of energy demand to GDP in transition economies will probably approach the level of market economies. Therefore the convergence of energy intensity and energy consumption per capita between accession countries and EU-15 member states is inevitable. The only question is when this will happen and what the future energy consumption per capita is likely to be in EU member states including the current accession countries.

The main conclusion from this section is that in EU-15, the positive trends of decoupling final energy and electricity intensity from final energy and electricity consumption per capita can be noticed. In Lithuania final energy and electricity intensity of GDP was much higher than the ones for EU-15 but have been decreasing and by 2002 have reached similar levels.

Lithuania primary energy intensity is still about twice higher than the EU-15 average. In order to define the impact of the structural changes in the economy on energy intensity, a less aggregated analysis of energy intensity is necessary.

5.5.4. Structure of economy

By analyzing energy intensity in less aggregated levels, the trends in energy intensity of different branches of the economy can be investigated using indicator #9 (energy intensities in economic sectors) as the targeted indicator. The increase of shares in GDP value added of economic branches consuming less energy is the favorable trend to reduce energy intensity of GDP. The share of sectors in GDP value added is an indirect driving force indicator of the economic dimension. This indicator also has a significant impact on energy consumption per capita (state indicator) and, of course, on energy intensity of GDP (direct driving force indicator).

In Figure 5.28 and Table 5.12, Lithuanian GDP structure is presented.

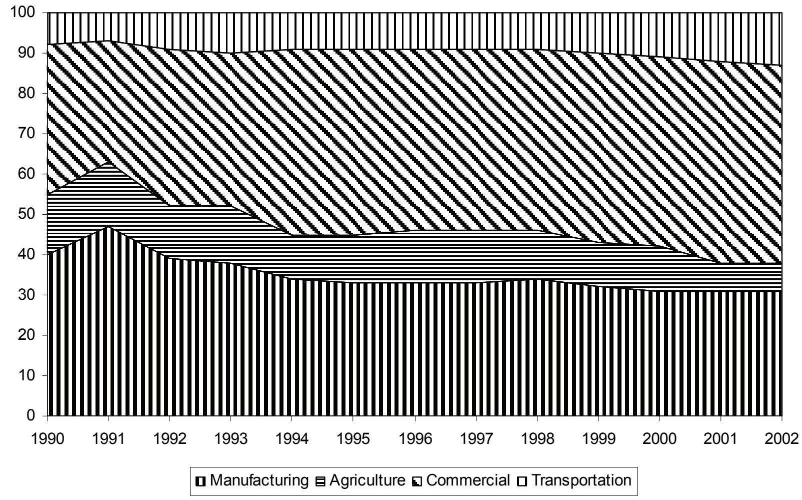

Figure 5.28 Lithuania: GDP structure

TABLE 5.12 GDP STRUCTURE, %

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Manufacturing	40	47	39	38	34	33	33	33	34	32	31	31	31
Agriculture	15	16	13	14	11	12	13	13	12	11	11	7	7
Commercial	37	30	39	38	46	46	45	45	45	47	47	50	49
Transportation	8	8	9	10	10	9	10	10	9	10	11	12	13

The largest share of GDP in 2002 was for the commercial sector at 49% followed by manufacturing at 31% and transportation at 13%. Since 1990 the structure of GDP has changed dramatically in Lithuania with the share of manufacturing decreasing from 40% to 31% in 2000 while the commercial sector share increased from 37% to 49%. The share of the transportation sector also increased from 8% to 13% in 2002.

The final energy consumption structure in Lithuania according to branches of the economy is presented in Figure 5.29. The structure of energy consumption in economic branches has changed dramatically in Lithuania since 1990. The largest share of final energy consumption in 2002 was in the household sector at 34% followed by transportation at 29%, and manufacturing at 22%. In 1990 the largest energy consumer in Lithuania was the manufacturing sector which had a 40% share.

As shown in Figure 5.29 and Table 5.13, the final energy consumption has significantly decreased since 1990 (more than two times). The decrease is observed in all sectors. For example, the final energy demand in manufacturing in 2002 amounted to only 22% of the 1990 level.

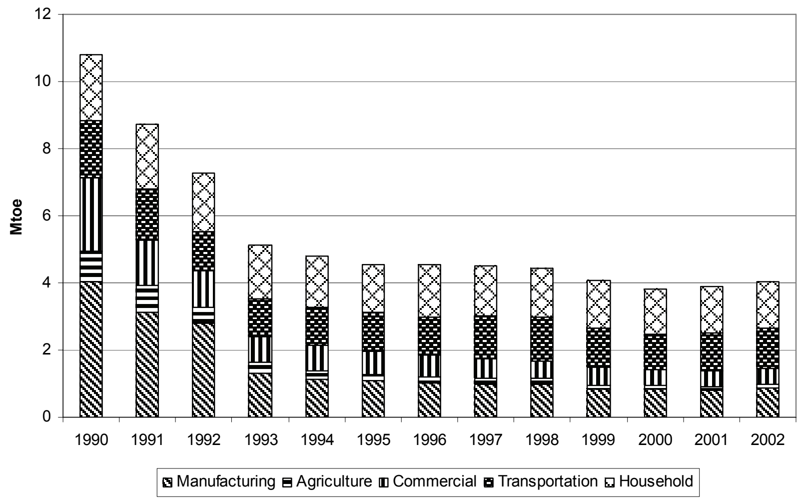

Figure 5.29 Lithuania: final energy consumption by economic sectors

TABLE 5.13 FINAL ENERGY CONSUMPTION BY ECONOMIC SECTORS, MTOE

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Manufacturing	4.052	3.119	2.813	1.299	1.129	1.088	1.004	0.995	0.996	0.836	0.827	0.792	0.886
Agriculture	0.897	0.814	0.460	0.344	0.248	0.191	0.207	0.173	0.160	0.113	0.102	0.100	0.109
Commercial	2.173	1.382	1.093	0.773	0.761	0.686	0.642	0.586	0.526	0.533	0.473	0.472	0.476
Transportation	1.715	1.549	1.151	1.125	1.151	1.170	1.125	1.253	1.313	1.174	1.056	1.152	1.191
Household	1.946	1.919	1.764	1.603	1.522	1.409	1.553	1.498	1.450	1.419	1.354	1.372	1.385

Energy intensity of branches of the economy (#9) is an indirect driving force indicator having an impact on the energy intensity of GDP analyzed in Section 5.2. Final energy intensity in economic sectors is presented in Figure 5.30. As one can see from Figure 5.30, and Table 5.14, final energy intensity has decreased in all sectors of the economy. In the manufacturing sector, final energy intensity decreased more than twice. In the agriculture sector, energy intensity decreased by four times.

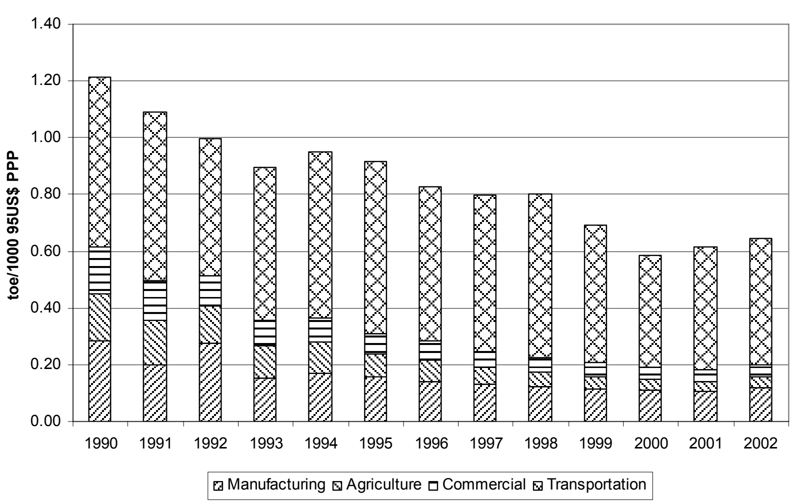

Figure 5.30 Lithuania: final energy intensity by economic sectors

TABLE 5.14 FINAL ENERGY INTENSITY BY ECONOMIC SECTORS, TOE/1,000 95US$ PPP

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Manufacturing	0.284	0.198	0.274	0.153	0.169	0.159	0.142	0.132	0.121	0.113	0.109	0.104	0.117
Agriculture	0.167	0.157	0.134	0.113	0.113	0.079	0.075	0.058	0.054	0.044	0.039	0.038	0.042
Commercial	0.164	0.140	0.106	0.091	0.084	0.073	0.067	0.057	0.049	0.049	0.042	0.042	0.042
Transportation	0.600	0.594	0.485	0.537	0.584	0.606	0.544	0.552	0.579	0.487	0.394	0.430	0.444

In Figure 5.31 the final energy intensities and shares of value added by economic sectors are presented.

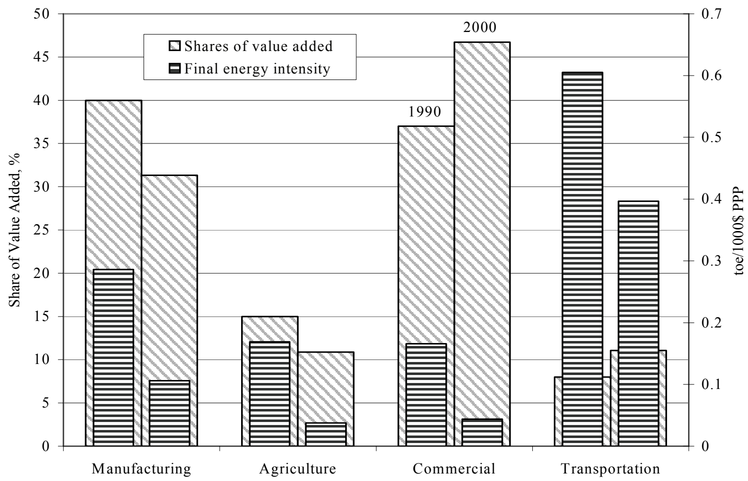

Figure 5.31 Lithuania: final energy intensities and shares of value added by sectors

As one can see from Figure 5.31, the highest shares of value added are in the commercial sector which has the lowest final energy intensity among all sectors. On the contrary, the share of value added of the transportation sector is the lowest while having the highest energy intensity. Since 1990 the share of value added from the commercial sector increased while the final energy intensity of GDP decreased. The share of value added from manufacturing decreased and the final energy intensity decreased as well. In general energy intensity decreased in all branches of the economy since 1990. The share of value added decreased in manufacturing and agriculture. All these trends have an impact on the decrease of final energy intensity of GDP in Lithuania.

Figure 5.32 and Table 5.15 show final electricity consumption by sectors of the economy. Final electricity consumption has decreased in all sectors except in the commercial and household sectors. The biggest decrease was in agriculture and manufacturing sectors. Final electricity demand in agriculture in 2002 was only 6% of the 1990 level and in the manufacturing sector about 31% of the 1990 level.

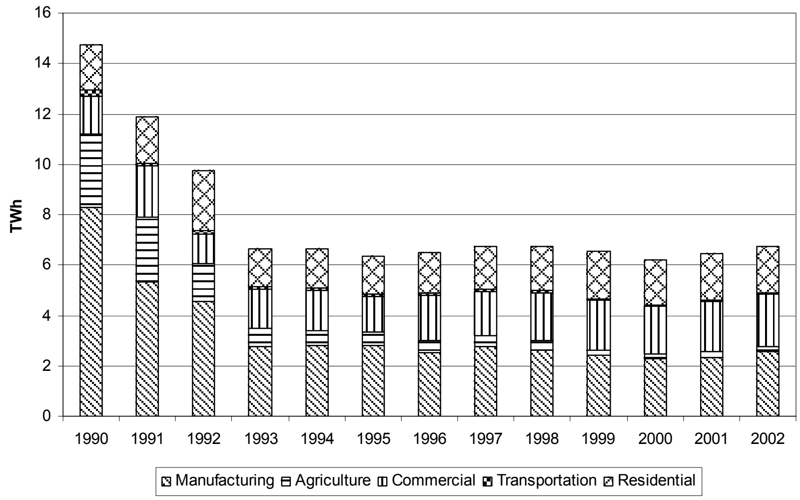

Figure 5.32 Lithuania: final electricity consumption by economic sectors

TABLE 5.15 FINAL ELECTRICITY CONSUMPTION BY ECONOMIC SECTORS, TWH

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Manufacturing	8.27	5.33	4.54	2.77	2.80	2.81	2.52	2.78	2.62	2.41	2.29	2.35	2.55
Agriculture	2.94	2.59	1.51	0.70	0.58	0.52	0.50	0.43	0.41	0.23	0.19	0.20	0.19
Commercial	1.50	2.01	1.16	1.58	1.60	1.44	1.80	1.72	1.89	1.95	1.87	1.99	2.10
Transportation	0.25	0.13	0.14	0.09	0.10	0.10	0.09	0.09	0.08	0.07	0.08	0.09	0.08
Household	1.77	1.84	2.41	1.49	1.55	1.50	1.61	1.72	1.74	1.89	1.77	1.82	1.81

Figure 5.33 and Table 5.16 show final electricity intensity by sectors. The average electricity intensity in 1990 amounted to 0.42 kWh/95US$. In 2002 it decreased by almost 1.6 times. In the manufacturing sector, electricity intensity decreased about two times and in agriculture about seven times.

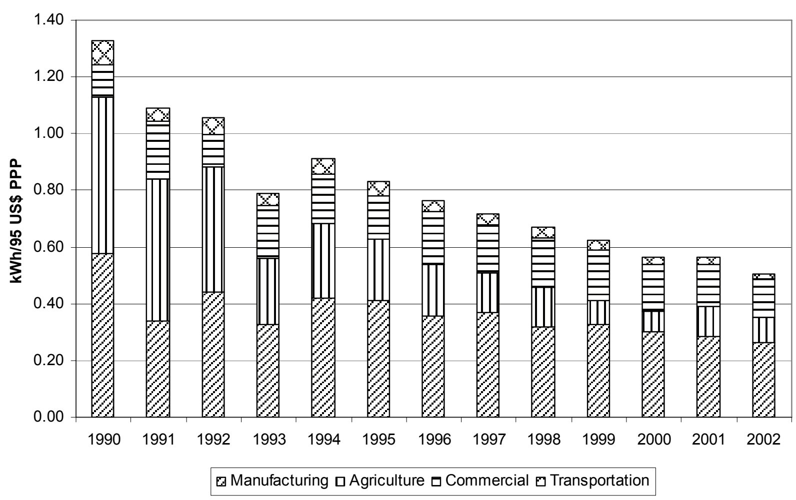

Figure 5.33 Lithuania: final electricity intensity by economic sectors

TABLE 5.16 FINAL ELECTRICITY INTENSITY BY ECONOMIC SECTORS, KWH/95 US$ PPP

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Manufacturing	0.579	0.339	0.441	0.327	0.420	0.411	0.356	0.368	0.318	0.325	0.302	0.299	0.263
Agriculture	0.549	0.500	0.442	0.231	0.262	0.217	0.181	0.141	0.141	0.088	0.071	0.107	0.089
Commercial	0.114	0.203	0.113	0.187	0.177	0.153	0.187	0.168	0.175	0.178	0.165	0.148	0.134
Transportation	0.087	0.050	0.060	0.045	0.052	0.050	0.041	0.039	0.036	0.031	0.028	0.028	0.020

The main conclusions from this section:

- The structure of the economy has dramatically changed in Lithuania since 1990. The share of value added of manufacturing has decreased and that of the commercial sector, which is the least energy intensive sector, has increased. In general energy intensity has decreased in all branches of the economy since 1990. All these trends have had a positive impact on the decrease of final energy intensity of GDP in Lithuania.
- The positive trends of final energy intensity decrease and structural changes in favor of less energy consuming sectors needs to be maintained and enhanced in the future in order to speed a convergence of Lithuanian energy intensities with EU-15 member states.
- The efficient use of energy resources and energy conservation is the priority of energy policy in Lithuania and is being fostered by constantly updating the National Energy Efficiency Programme (Lithuanian Ministry of Economy, 2001). The same polices should be followed in the future.

5.5.5. Energy prices

The next important issues related to energy consumption trends in Lithuania are energy prices and energy affordability. The analysis of energy prices for households can help identify reasons for low final energy and electricity consumption per capita in Lithuania. All monetary values applied in this section are based on current US dollars.

Though social targets of sustainable energy development were not addressed in the national energy strategy, the analysis performed in the sections above indicate that GDP per capita and final energy consumption per capita are very low and indicate the low living standards in Lithuania. Final energy consumption per capita in Lithuania is only half that of the EU-15, and electricity and GDP per capita less than a third. While GDP per capita is slowly increasing in Lithuania, electricity and final energy per capita are still decreasing, based on high household energy prices (especially for district heating) combined with low incomes.

Energy prices for households (indicators #3 from ISED list) are very important determinants of energy affordability. This indicator is the direct driving force indicator affecting the energy priority areas, energy intensity and energy consumption per capita levels. The changes of electricity, heat and natural gas prices for households (without taxes) are presented in Table 5.17.

TABLE 5.17 ELECTRICITY, HEAT AND NATURAL GAS PRICES FOR HOUSEHOLDS

Energy sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
# 3.3.1.2 Electricity without tax, USD/kWh											
Lithuania	0.0001	0.0002	0.001	0.014	0.02	0.04	0.05	0.05	0.047	0.047	0.058
EU-15	0.1087	0.115	0.1221	0.1232	0.127	0.1311	0.1305	0.128	0.1289	0.1284	0.1303
# 3.3.2.2. Heat without tax, USD/GJ											
Lithuania	0.018	0.09	0.36	2.7	14.4	33.3	64.8	80.1	94.5	97.2	103.5
EU-15	92.16	99.4	99.7	102.2	104.4	110.2	110.9	115.2	117.7	118.8	121
# 3.3.3.2 Natural gas without tax, USD/GJ											
Lithuania	0.003	0.007	0.099	2.2	3.6	4.8	5.7	5.8	5.6	5.6	8.8
EU-15	13.4	15.2	15.8	15.2	15.7	16.1	15.9	16.6	17.4	17.2	17.4

Energy prices were very low and stable for long periods of time, and uniform over large regions of the former Soviet Union. In the middle of 1992, when prices for Russian crude oil and natural gas sharply increased and started to converge with international prices, a price shock to final consumers in Lithuania became unavoidable. The Government quickly liberalized oil product prices, but they did not increase significantly as businessmen were actively buying them (very cheaply) in Russian markets and importing them into the country. Natural gas prices increased steeply, however, and caused increases in district heating prices as well. The Government put all of the burden of price increases on the still-strong manufacturing industry (i.e., prices and tariffs for gas and district heating were increased sharply for industry, but remained at low levels for households). Thus, industry was subsidizing households. Due to this experiment, industry suffered -- many industries reduced their activities, reduced heating, or switched it off entirely, and some even went bankrupt. It indirectly affected the residential sector as well, since prices for manufacturing goods went up and unemployment increased. Cross subsidies were gradually abolished in 1995, though district heating prices were subsidized until mid 1997.

From 1993 to 1997, electricity, gas and district heating tariffs rose drastically in line with overall Government policies in order to, at a minimum, recover production costs. Higher prices have an impact on energy demand but also on the ability of consumers to pay the increased rate. While the prices of crude oil, heavy fuel oil, petrol, diesel, industrial and residential electricity all increased substantially, they did so in equal terms—but the price of residential heat increased by a factor of ten. Finally, in 1997 the Government made two decisive steps: 1) it separated the district heating activities from the vertically integrated monopoly “Lithuanian energy” company; and 2) it stopped regulating energy prices. An independent Control Commission for Energy Prices and Energy Activities was established, and it was empowered to fix energy prices using technical and economic principles. The energy sector prices and tariffs are still regulated, except for prices of petroleum products and solid fuels. Price regulation and control is strong in the electricity, heat and gas sectors. This is understandable, since there is no competition in these sectors. The main objectives of the Commission are to set energy pricing principles and to implement energy policy goals for the control of energy activities. The Commission supervises the application of fixed prices for electricity, district heat, hot and cold water, and natural gas, as well as the implementation of the energy saving program.

The change in electricity prices for households in Lithuania and the EU-15 are presented in Figure 5.34. It can be seen that electricity prices in Lithuania are still only half the EU-15 average. In the EU-15, electricity prices for households were relatively stable for several years. In Lithuania electricity prices for households are increasing slightly. The closure of the Ignalina NPP in 2009 will cause significant electricity price increases, and some analyses suggest that they will reach current EU-15 average levels (Lithuania Ministry of Economy, 2002). This could cause significant social problems because, as noted earlier, GDP per capita in the country is only one-third of the EU-15 average.

GDP per capita expressed in PPP is the principal indicator of social welfare, and in 2000, this indicator was only 70% of its 1990 value in Lithuania. Though current GDP growth rates in Lithuania are quite high (6.7% in 2002 and 6.8% in 2003), the country will still not be able to reach the EU-15 average level in 2010 because GDP is also continuously increasing in the EU-15 (though at quite moderate rates).

The increase in electricity prices after the closure of the Ignalina NPP will cause considerable social problems because the support system for low-income population in Lithuania does not cover expenditures for electricity—only expenditures for heating, and hot water. The introduction of a new support scheme should therefore be considered.

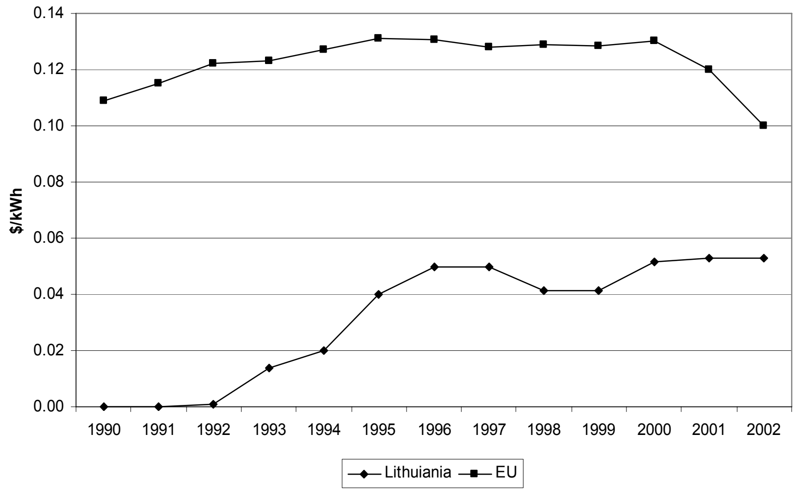

Figure 5.34 Dynamics of electricity prices for households in Lithuania and EU-15

The changes in natural gas prices for households in Lithuania and the EU-15 are presented in Figure 5.35. One can see from this figure that natural gas prices in Lithuania are roughly half of those in EU-15 countries.

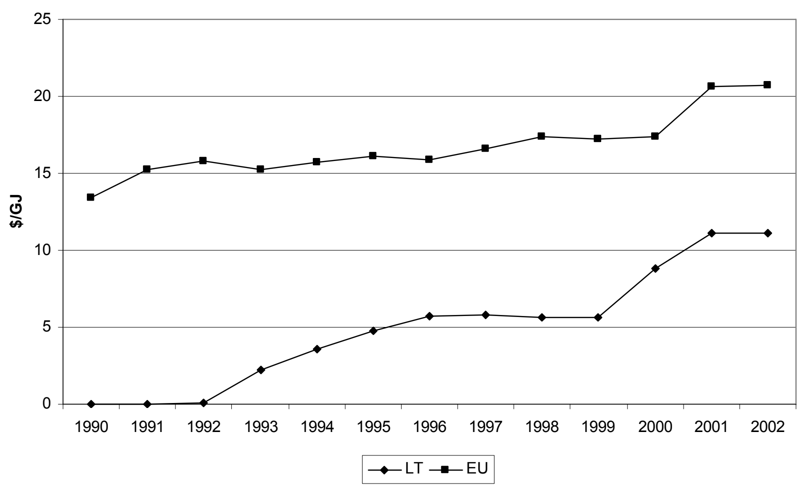

Figure 5.35 Dynamics of natural gas prices for households in Lithuania and EU-15

Changes of district heating prices for households in Lithuania and EU are given in Figure 5.36.

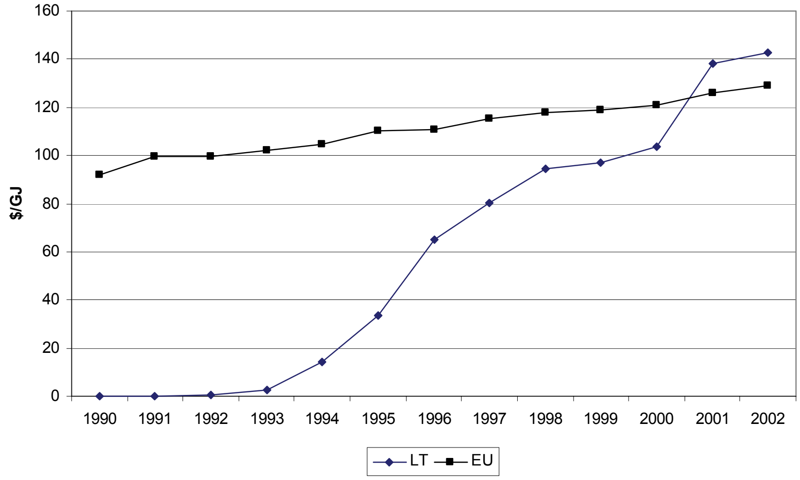

Figure 5.36 Changes in district heat prices for households in Lithuania and EU

District heat prices by 2001 were almost equal in Lithuania and in the EU-15, even though GDP per capita (adjusted at PPP) were considerably different. So one can conclude that energy prices are very high compared with the country's GDP per capita, and represent a burden for the Lithuanian population. This is evident especially in district heat prices.

The poverty level can be expressed as the percentage of population living below the national poverty line, or the population that is living below the region's extreme poverty level of 2.15 USD in PPP per day. The poverty gap is an indicator that shows the average gap between the poverty line and the mean expenditure of the poor. In Lithuania this indicator was 23% in 2000, a figure similar to other accession countries, but of course considerably higher than levels reported in the EU-15. In Ireland, for example, it was 10% in that same year and in Denmark and Finland was reported as 0%. In Moldova, the same indicator was reported to be 80% in 2001.

The national or relative poverty level is the proportion of the population in the country that has expenditures below the poverty line. The poverty line equals 50% of the mean consumption expenditures per month (260 Litas or 65 USD in 2000). Average consumption expenditures per month are calculated using an equivalence scale of the OECD: the first adult household member is equated to 1, each next adult to 0.7 and each child under 14 to 0.5.

The poverty level in Lithuania has been recorded and reported since 1996. Figure 5.37 and Table 5.18 show that the poverty level was decreasing up to 1999 and then started to increase because of the crisis. Since 2001 a positive trend of poverty level decrease can be noticed in Lithuania. The current poverty level in Lithuania is about 16%, which is still quite high compared with Western European countries.

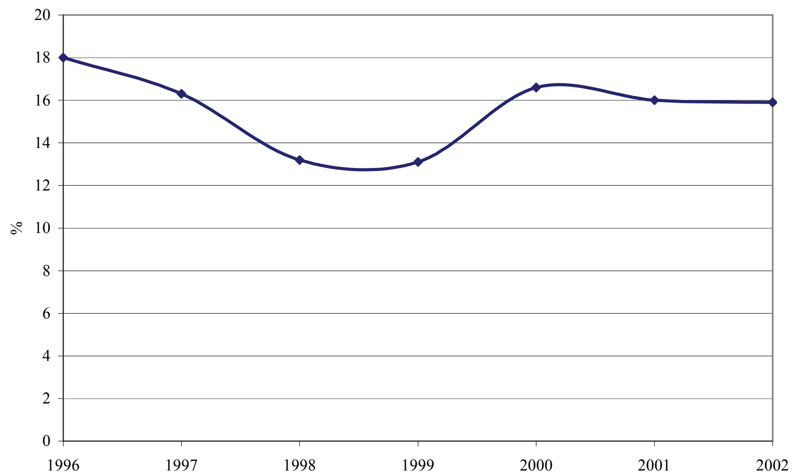

Figure 5.37 National or relative poverty level

TABLE 5.18 NATIONAL POVERTY LEVEL, %

	1996	1997	1998	1999	2000	2001	2002
Lithuania	18.0	16.3	13.2	13.1	16.6	16.0	15.9

According to World Bank data, the poverty level in Lithuania was 3.1% in 1999 when applying the international poverty indicator (2.15 USD/day). However it is doubtful that these data are correct, because the national poverty line reported in that same year amounted to 274.6 Lt/day or 2.4 USD/day, and the poverty level reported was 13.1%. It thus appears that the poverty level in Lithuania should have been significantly higher.

So it can be concluded that poverty, income inequality and low living standards are serious problems in Lithuania. Further analysis of the trends of social dimension indicators from the ISED list is outlined below.

The social dimension indicators from the ISED list (#19, #21 and #20) can be used to address the targeted goal of increasing the quality of life.

The main indirect social driving force indicator (#19) is the ratio of disposable income to private consumption in terms of individual income available to groups of the poorest 20% and richest 20% of the population. The monthly disposable income was used in our case study instead of daily disposable income because all statistical data on disposable income, poverty line, expenditures for fuels and energy is provided on a monthly basis. Therefore all social indicators were calculated on a monthly basis in order to be consistent. Indicator (#19), like the Gini index, is relevant to the equity component of sustainable development. Income distribution has a direct impact on the poverty level of the country. Changes in income inequality in Lithuania are presented in Figure 5.38 and Table 5.19. This shows that the poorest 20% had an average income that is less than 20% of the income of the richest 20%. This indicator is similar in Latvia and Estonia.

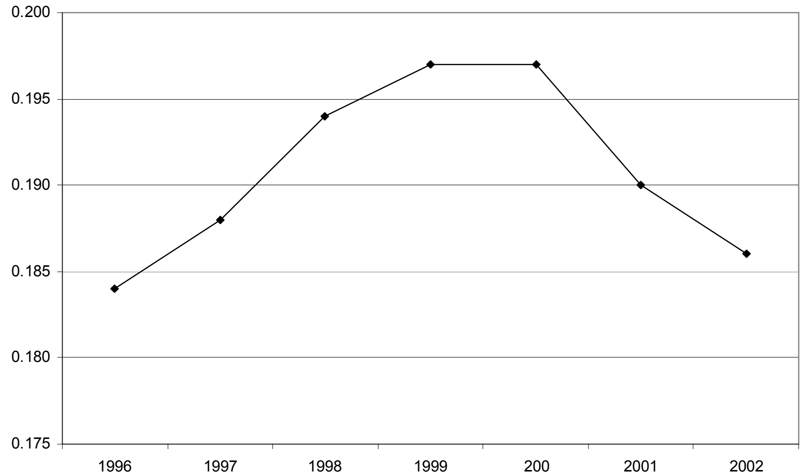

Figure 5.38 Income inequality

TABLE 5.19 INCOME INEQUALITY

	1996	1997	1998	1999	2000	2001	2002
Lithuania	0.184	0.188	0.194	0.197	0.197	0.190	0.186

The direct driving force social indicator (#21), namely the fraction of monthly disposable income/private consumption spent on fuel and electricity, shows the expenditures spent for household fuel and electricity as a percentage of total private consumption per capita per month by the average population, and by a group of the 20% poorest population. This indicator provides a measure of energy affordability for the average population and for the poorest households, indicating income inequality as well. This indicator is supplementary to such a general indicator of welfare as GDP/capita, because income distribution in the country can vary very widely. The low-income population have no possibility of meeting their full needs with commercial energy at current price and income levels.

In Lithuania, official statistics provide this information since 1996, but data sources report the share of average household consumption expenditures on electricity, fuel, water and housing. Data are given for deciles. Deciles are calculated by dividing the population surveyed arranged in an increasing order according to consumption expenditure levels into ten equal parts. The first decile covers households with the smallest expenditure; the tenth decile covers the richest population group. Average data from the two first deciles was employed to define expenditures of the 20% poorest population. Seeking to calculate the share of expenditures spent on electricity, heating and fuels, data on the average consumption structure in the expenditure groups for all deciles was applied.

As shown in Figure 5.39 and Table 5.20, the share of expenditures for electricity and household fuel by the average population is higher than for the group of the 20% poorest population. There is not a big difference between the share of expenditures for electricity and household fuels of the poorest and richest deciles. The biggest share of expenditures for electricity and household fuels correspond to the middle decile. This indicator was decreasing until 1999 but because of the economic recession it has increased since 2000.

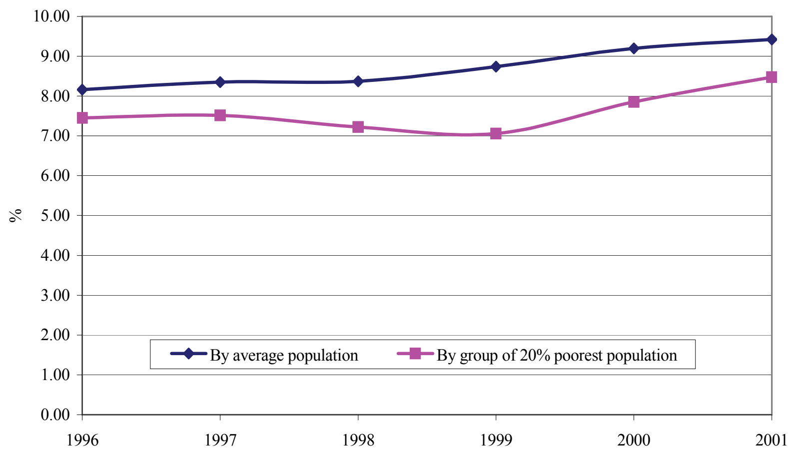

Figure 5.39 The fraction of disposable expenditures spent for household fuel and electricity as a percentage of total private consumption per capita by average population and by group of 20% poorest population

TABLE 5.20 THE FRACTION OF DISPOSABLE EXPENDITURES SPENT FOR HOUSEHOLD FUEL AND ELECTRICITY AS A PERCENTAGE OF TOTAL PRIVATE CONSUMPTION PER CAPITA BY AVERAGE POPULATION AND BY GROUP OF 20% POOREST POPULATION

	1996	1997	1998	1999	2000	2001
By average population	8.16	8.35	8.37	8.74	9.19	9.42
By group of 20% poorest population	7.45	7.51	7.22	7.06	7.85	8.47

The direct driving force social dimension indicator (# 20) is the ratio of monthly disposable income per capita of the 20% poorest population to the prices of electricity and major household fuels. Comparing this indicator with the one for the average population, one can observe that energy affordability for the low-income population is very low (Figure 5.40, 5.41 and 5.42 and Table 5.21). Figure 5.40 provides data based on a ratio of income to price, so it has an axis labeled “kwh/month”; if income is expressed in USD/month and prices of electricity in USD/kWh, the ratio of income to prices is kWh/month, and shows how many kWh of electricity per month is affordable for the average population and the poor. For example, electricity consumption of the low-income population is almost three times below the average. This shows that a socially desirable level of electricity consumption cannot be guaranteed for the low-income population without state aid. The situation is the same with natural gas and heat consumption. One can conclude that high-energy prices compared with low income of population in Lithuania are a serious problem.

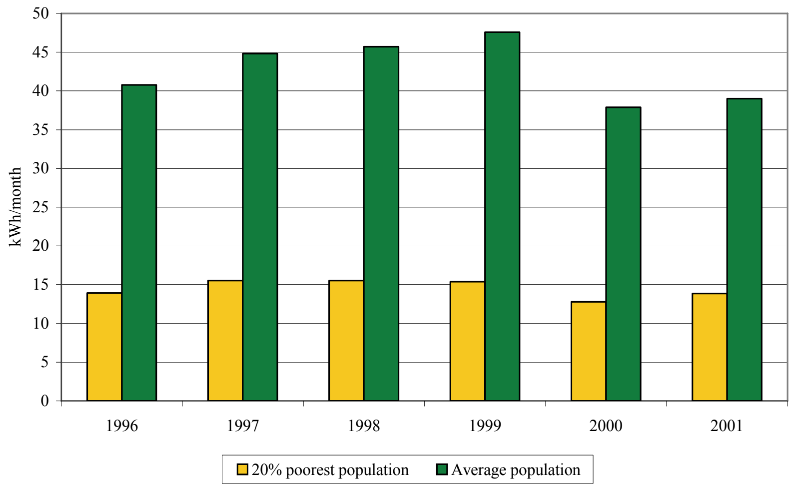

Figure 5.40 The ratio of monthly disposable income per capita of 20% poorest and average population to the prices of electricity

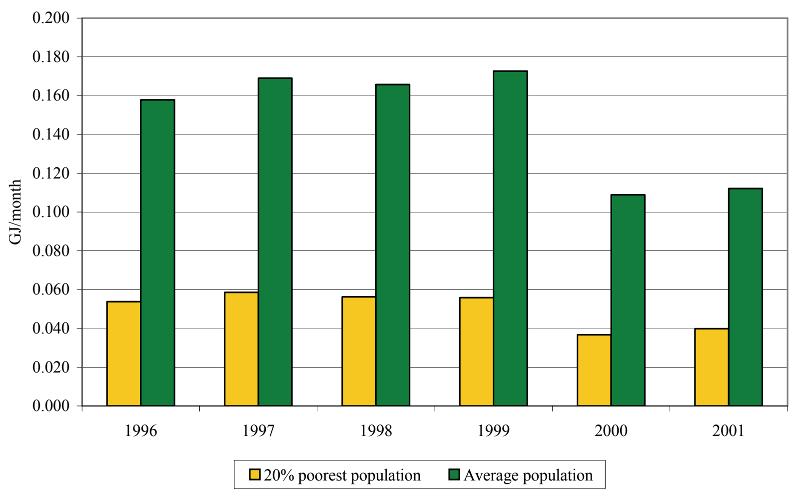

Figure 5.41 The ratio of monthly disposable income per capita of 20% poorest and average population to the prices of natural gas

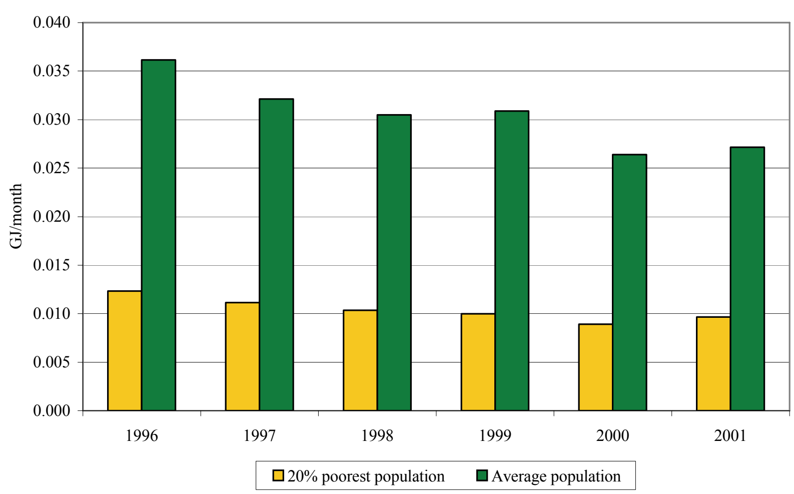

Figure 5.42 The ratio of monthly disposable income per capita of 20% poorest and average population to the prices of district heating

TABLE 5.21 THE RATIO OF MONTHLY DISPOSABLE INCOME PER CAPITA OF 20% POOREST AND AVERAGE POPULATION TO THE PRICES OF ELECTRICITY, NATURAL GAS AND DISTRICT HEATING

Year	Electricity, kWh/month/capita		Natural gas, GJ/month/capita		District heating, GJ/month/capita	
	20% poorest population	Average population	20% poorest population	Average population	20% poorest population	Average population
1996	13.91	40.78	0.054	0.158	0.012	0.036
1997	15.53	44.83	0.059	0.169	0.011	0.032
1998	15.54	45.70	0.056	0.166	0.010	0.030
1999	15.41	47.60	0.056	0.173	0.010	0.031
2000	12.78	37.89	0.037	0.109	0.009	0.026
2001	13.86	38.99	0.040	0.112	0.010	0.027

In order to compare Indicator #20 with the EU-15 average, data for 1996 was used, and a comparison of the ratio of monthly disposable income per capita of average population to the prices of district heating in Lithuania and the EU-15 average was made with the data available for 1995-1996 (EC, 1999).

Total expenditures of households in the EU-15 in 1996 amounted to 1963 USD/capita per month. Total expenditures on household energy consumption in the same year amounted to 74.6 USD/capita and represented 3.8% of total household expenditures in this year. Lithuanian total household expenditures in 1996 amounted to 68.7 USD/capita. Total expenditures on household energy consumption in Lithuania amounted to 7.3 USD/capita and represented 10.8% of total household expenditures. So EU-15 average household energy expenditures were more than 10 times higher than in Lithuania. At the same time total household expenditures in EU-15 countries were about 30 times higher compared with Lithuania. However, in Lithuania 10.8% of the total expenditures are for electricity and fuels versus only 3.8% in the EU-15.

Energy use expenditures in EU-15 on space heating amounted to 36.52 USD/capita per month (50% of total energy expenditures). In Lithuania it was 2.32 USD/capita or 31% of total energy expenditures. Natural gas for cooking represented 5.5 USD/capita, or 7.4 % of energy expenditures, in EU-15; and 0.89 USD/capita, or 12% of energy expenditures, in Lithuania. Electricity represented 15.7 USD/capita or 21% of household energy expenditures in EU-15 and 2.04 USD/capita or 27% in Lithuania.

Energy prices in EU-15 for electricity in 1996 amounted to 0.13 USD/kWh, so the ratio of monthly disposable income/private consumption to electricity prices in the same year amounted to 120.8 kWh/capita per month. In Lithuania the ratio of monthly disposable income/private consumption to electricity prices in the same year amounted to 39 kWh or about one-third as much.

Natural gas prices in EU-15 in 1996 were 15.93 USD/GJ, so the ratio of monthly disposable income/private consumption to natural gas prices in the same year amounted to 0.50 GJ/capita per month and in Lithuania the ratio of monthly disposable income/private consumption to natural gas prices in the same year amounted to 0.15 GJ/capita per month and was less than one-third that in the EU-15.

One can conclude that the worst situation with energy affordability in Lithuania is in the heating sector because district heat prices in Lithuania are very high (only about 14% lower than in EU-15 countries) compared to the low disposable income of the population. The amount of heat that could be consumed monthly, or monthly at current consumer prices and available disposal income, indicates that in Lithuania the heat which can be consumed by the average population is about nine times lower than in EU-15. The amount of electricity and natural gas consumed monthly at current electricity and natural gas prices in Lithuania was three times lower compared with the EU-15 average, and electricity prices was 2.3 times and natural gas prices three times higher in EU-15.

In order to ensure energy affordability, social support schemes to low-income population are necessary. The currently applied support system in Lithuania is based on burden limits for a notional amount that the household is "entitled" to spend for heating and hot and cold water is not efficient. First, because according to coverage criteria, it covers only 8% of the population in Lithuania. At the same time the poverty level in the country is about 16%. Second, according to targeting criteria, the scheme also is not good because expenditures of the richest decile for housing, water, electricity, gas etc. are about 13.6 % in all household consumption expenditures and for the poorest decile it is 15.2 % of their total expenditures. Moreover other important expenditures such as payments for house rent, electricity, gas, etc. are not included in the support scheme. The negative social effect of electricity price increases after the closure of Ignalina NPP can be mitigated by integrating expenditures on electricity into the support scheme. Therefore the new support schemes for low-income population should be developed in order to ensure energy affordability.

5.5.6. Security of supply

According to the EC COM (2000) 769 (Green paper *Towards a European Strategy for Security of Energy Supply*), the EU-15 long-term strategy for energy supply security must be geared to ensuring the well-being of its citizens and the proper functioning of the economy, the uninterrupted physical availability of energy products on the market, at a price which is affordable for all consumers while respecting environmental concerns. Security of supply does not seek to maximize energy self-sufficiency or to minimize dependence but aims to reduce risks related to such dependence. Among the objectives to be pursued are those balancing and diversifying the various sources of supply (by product and by geographical region). When preparing an energy sector development strategy for Lithuania, security of supply should be considered as a very important issue and possibilities to increase diversification of fuels should be taken into account.

For the increase of security of supply indicator #18 (net import dependency) and indicator #17 (indigenous energy production) were selected from the ISED list. Both these targeted indicators are state indicators and are affected by the following indirect driving force indicators: energy mix in primary energy supply and electricity generation (indicator #11), and energy supply efficiency (#12).

The net energy import dependency is presented in Figure 5.43 and Table 5.22 for the 1990-2002 period. A net decreasing trend is observed from 72% in 1990 to around 44% in 2002. This trend is the result of a dramatic decrease in total primary energy requirements (about 48%) which allowed a major reduction in imports throughout this time period. Imports of natural gas, crude oil and coal dropped from 12,923 ktoe in 1990 to 4,309 ktoe in 2002. At the same time, there was a considerable increase in domestic oil production and wood waste utilization, although these two sources could cover only about 12% of the TPES in 2002 (see Table 5.1). It is expected that this positive trend in net energy imports will reverse after the total shut down of the Ignalina nuclear power plant by 2009. At that time, an increase in imports may be necessary to cover about 90% of the future primary energy requirements; therefore, additional measures to increase security of energy supply are necessary.

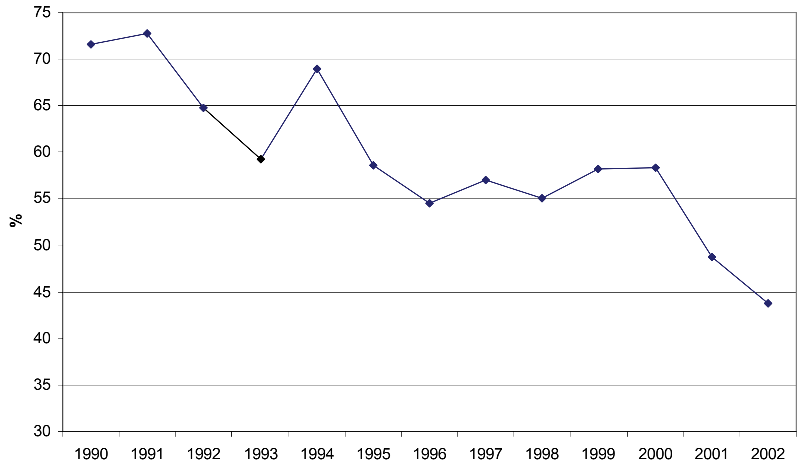

Figure 5.43 Lithuania: energy net import dependency

TABLE 5.22 ENERGY NET IMPORT DEPENDENCY, %

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Lithuania	71.65	72.74	64.71	59.31	68.91	58.60	54.52	56.99	55.01	58.15	58.33	52.0	43.8

Indigenous energy production is presented in Figure 5.44 and Table 5.23. The largest contributor, by far, is nuclear with a share of about 76% in 2002. The domestic production of crude oil and wood have increased dramatically while hydro and peat production have remained relatively stable.

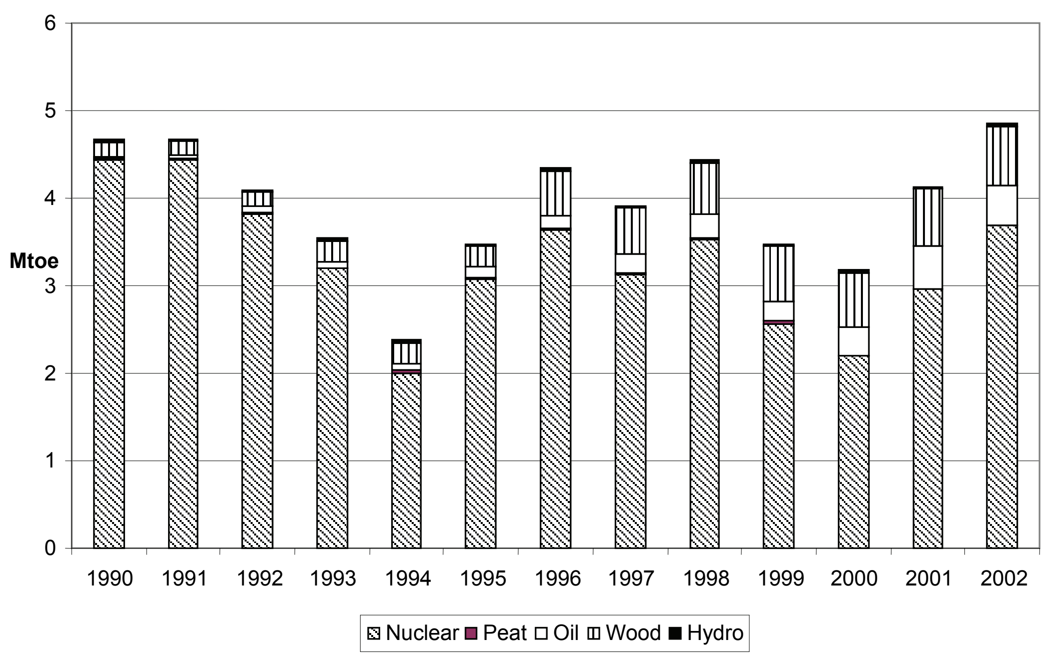

Figure 5.44 The structure of indigenous energy production

TABLE 5.23 THE INDIGENOUS ENERGY PRODUCTION, KTOE

	1990	1994	1995	1996	1997	1998	1999	2000	2001	2002
Nuclear	4,438.5	2,008.1	3,080.5	3,633.0	3,133.2	3,531.9	2,569.8	2,193.8	2,961	3,686
Peat	13.9	21.0	14.2	17.7	20.5	17.2	23.3	11.8	11.2	11.2
Oil	12.0	82.0	115.0	155.4	212.3	277.5	232.5	316.4	475	439.4
Wood	166.6	231.5	236.7	508.2	516.2	575.7	620.6	626.7	654.4	690.2
Hydro	35.7	38.8	31.9	28.0	25.3	35.9	35.5	29.2	28.0	30.4

Table 5.24 presents total primary energy supply mix by fuel types. Nuclear and CRW have gained considerable shares in the TPES against the oil and gas shares. In 2002, nuclear had the largest share at 36%, followed by oil at 28.5% and gas at 25%. .

TABLE 5.24 TOTAL PRIMARY ENERGY SUPPLY MIX BY FUEL TYPES, %

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Coal	5.9	4.9	4.4	5.2	4.5	3.2	2.5	2.1	1.7	1.8	1.4	1.1	1.5
Oil	44.1	43.0	38.9	44.5	44.4	38.3	34.1	36.9	40.2	37.2	31.2	31.3	28.5
Gas	28.3	29.3	24.8	15.9	21.5	23.1	23.3	22.7	19.0	23.2	29.0	26.6	25.2
Nuclear	20.5	21.6	30.2	32.5	26.2	32.4	34.3	32.1	32.5	29.8	29.2	32.6	36.3
Hydro	0.2	0.2	0.2	0.4	0.5	0.4	0.3	0.3	0.4	0.5	0.5	0.3	0.4
CRW	1.0	1.0	1.5	2.5	2.9	2.6	5.5	5.9	6.2	7.5	8.7	8.1	8.1

In Figure 5.45 the electricity generation mix by fuel types is presented. The share of fossil fuel in total electricity production in 2002 was 15.%; the share of nuclear was 79.8%. As one can see from Table 5.25, in 2002 electricity from renewable energy sources amounted to 4.4% and this was mainly the share of hydro. The EU-15 target for 2010 is 22.1%. Lithuania agreed with the EU-15 to implement 7% as the target for renewables in electricity generation. Electricity generation in Lithuania is dominated by nuclear fuel. After the closure of the Ignalina NPP in 2010, the structure of fuel consumption will change significantly. Therefore the increased utilization of renewable energy sources in electricity generation is a crucial task for Lithuania.

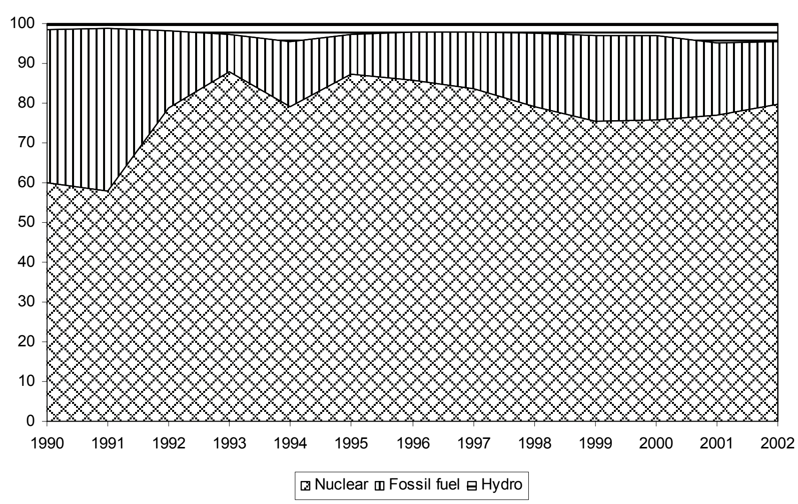

Figure 5.45 Electricity generation mix by fuel types

TABLE 5.25 ELECTRICITY GENERATION MIX BY FUEL TYPES, %

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Nuclear	60.0	57.9	78.9	88.0	79.0	87.4	85.8	83.6	79.0	75.4	75.7	77.1	79.8
Fossil fuel	38.6	41.0	19.4	9.2	16.4	9.8	12.1	14.4	18.6	21.5	21.2	18.2	15.8
Hydro	1.5	1.2	1.7	2.8	4.6	2.8	2.0	2.0	2.4	3.2	3.0	4.7	4.4

In Figure 5.46 and Table 5.26 the share of renewables in electricity generation in Lithuania and EU-15 is presented. As one can see from Figure 5.46, the share of electricity from renewables to total indigenous electricity production is very small in Lithuania, about 3%. In EU-15 this indicator is high, more than 14%.

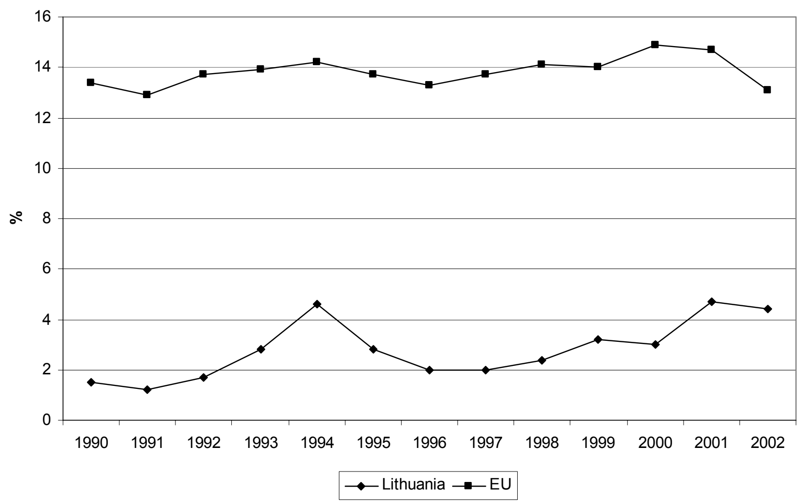

Figure 5.46 Renewable contribution to total electricity generation

TABLE 5.26 RENEWABLE ENERGY CONTRIBUTION TO TOTAL ELECTRICITY GENERATION, %

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Lithuania	1.5	1.2	1.7	2.8	4.6	2.8	2.0	2.0	2.4	3.2	3.0	4.7	4.4
EU-15	13.4	12.9	13.7	13.9	14.2	13.7	13.3	13.7	14.1	14.0	14.9	14.7	13.1

Energy supply efficiency (#12) (i.e., the ratio of final to primary energy consumption) has a significant impact on net energy import dependency because an increase of energy supply efficiency helps to reduce energy import dependency. Energy supply efficiency in Lithuania was 65% in 1990 and 47.6 % in 2002**.** A comparison of Lithuanian and EU-15 energy supply efficiency is presented in Figure 5.47 and Table 5.27. From 1990 to 2000, the energy supply efficiency has decreased. Energy supply efficiency is very low and indicates that twice as much primary energy resources are needed to cover domestic final demand. Policy measures aiming to increase energy supply efficiency (i.e., reducing losses in gas and oil transportation, electricity transmission and distribution, increasing efficiency of electricity generation, etc.) are necessary.

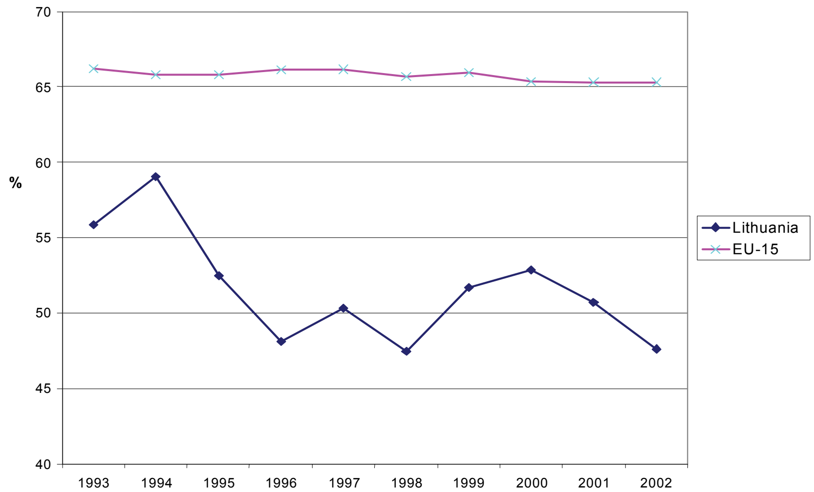

Figure 5.47 Energy supply efficiency in Lithuania and EU-15

TABLE 5.27 ENERGY SUPPLY EFFICIENCY IN LITHUANIA AND EU-15, %

	1990	1994	1995	1996	1997	1998	1999	2000	2001	2002
Lithuania	56	59.0	52.4	48.1	50.3	47.4	51.7	52.9	50.8	47.6
EU-15	65	65.8	65.8	66.1	66.2	65.7	65.9	65.4	65.3	65.3

The European Commission has developed programmes to encourage use of renewable energy in European countries. Lithuania has very limited domestic energy resources, and only biofuels, hydro and wind power can be considered as potential renewable energy sources for reaching the EU-15 target (Lithuanian Ministry of economy, 2001). An efficient policy to promote renewable energy sources, especially within the power sector, is therefore necessary in order to reach EU-15 targets (Baltic Environmental Forum, 2000).

5.5.7. Environmental energy situation

To express pollution reduction targets in relation to the final closure of the Ignalina NPP, two targeted environmental dimension indicators were selected:

- Quantities of CO_2 emissions from the power sector (Indicator #26);
- Quantities of air pollutant (SO_2 and NOx) emissions from the power sector (Indicator #23).

5.5.7.1. Reduction of CO_2 emissions

Most countries that signed the UN Framework Convention on Climate Change agreed upon the Kyoto Protocol in 1997. Lithuania signed the Protocol in 1998 and has thereby committed itself to reducing the emission of GHG in 2008-2012 by 8% compared to the 1990 level of emissions.

The designation GHG comprises CO_2, CH_4, N_2O, HFC's, PFC's and SF_6. They are measured as CO_2 equivalents according to their global warming potentials as defined by IPCC. A survey of the current emission of GHG in Lithuania compared with the Kyoto commitment is presented in Table 5.28. These data were derived from official GHG inventories presented to the UNFCCC secretariat. Official inventories of GHG in Lithuania are available only for the years 1990 and 1998. Inventory data for the year 2002 are preliminary in nature.

TABLE 5.28 COMMITMENTS AND EMISSIONS ACCORDING TO 1ST NATIONAL COMMUNICATION AND INVENTORY 2000 (BALTIC ENVIRONMENTAL FORUM, 2000).

	Aggregate (CO_2 equivalent) emissions excl. LUCF*		Aggregate (CO_2 equivalent) emissions incl. LUCF*	
	Mton	% Of base-year	Mton	% Of base-year
Base year, 1990	54.6	100	42.700	100
Kyoto commitment, 2008-12	50	92	39.284	92
Emissions, 2002	20.2	37	13.74	32

*- LUCF is an abbreviation of Land Use Change and Forestry.

According to the Kyoto Protocol, emissions and removals of CO_2 by sinks from Land Use Change and Forestry (e.g. through forestation and reforestation) are to be included in the national inventories of GHG emissions. However, agreement on guidelines and rules for how to include - and to which extent - removal of CO_2 by sinks has not yet been reached among the parties.

The EU-15 member states have made a burden sharing agreement, which “overrules” the 15 countries' individual Kyoto commitments. Instead of individual commitments, the EU-15 member states have as a whole accepted a reduction of 8%. Thus, some member states have accepted to undertake a larger reduction than 8%, while others will be allowed to reduce emissions by less than 8%.

It is not considered likely that the burden sharing agreement will be adjusted in connection with negotiations with accession countries. Therefore, it is expected that Lithuania will have to comply with its Kyoto commitment of reducing greenhouse gases by 8%.

The Framework Convention on Climate Change was ratified by the Parliament of Lithuania in 1995. Countries signing the Convention should prepare national or regional strategies for the reduction of greenhouse gas emissions. Lithuania prepared the National Strategy in 1996, as well as the First National Communication on Climate Change in 1998. In the National Climate Change Strategy (Lithuanian Ministry of Environment, 1996a) some steps were foreseen for improving the integration of Lithuania into the climate change regulation process. The steps are to improve data collection, to continue inventory of greenhouse gas emissions, to compare data received during the emission inventory with data from other studies, etc. Further, the strategy describes how the economy of the country would be affected by the climate change and greenhouse gas emissions and what measures could be implemented for the climate change mitigation.

To express the GHG pollution reduction target, indicator #26 (quantities of CO_2 emissions from power sector) was selected from the ISED list. Emissions of CO_2 accounted for about 97% of total GHG emissions in the power sector in 2002. In Figure 5.48 and Table 5.29 CO_2 emissions from the power sector are presented. This is the targeted indicator. The equivalent Kyoto target for CO_2 emissions from the power sector is about 16 Mt. The Kyoto target is being applied here in proportion to the power sector’s share in the base year’s emissions. As one can see from Figure 5.48, currently emissions from the power sector are significantly below the Kyoto target but this is related to the operation of the Ignalina NPP. As both units of Ignalina NPP will be closed by 2010 and CO_2 emissions from the power sector will increase significantly, additional policy measures to combat GHG emissions will be necessary.

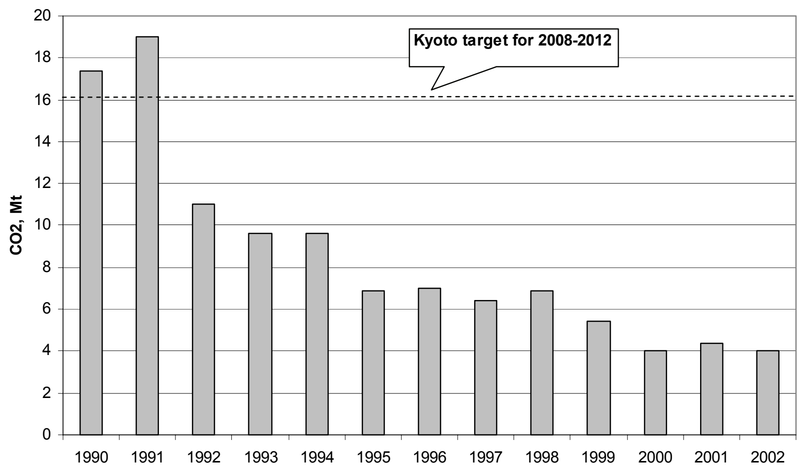

Figure 5.48 Lithuania: CO_2 emissions from power sector

TABLE 5.29 CO_2 EMISSIONS FROM POWER SECTOR, MT

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Lithuania	17.4	19.0	11.0	9.6	9.6	6.9	7.0	6.4	6.9	5.4	4.0	4.4	4.0

In Figure 5.49 and Table 5.30, CO_2 emissions per kWh from the power sectors in Lithuania and EU-15 are presented for further analysis in order to relate trends in CO_2 emissions to implemented energy policies (IEA, 2001b). As one can see from Figure 5.49, CO_2 per kWh in Lithuania is significantly lower than in EU-15 countries. This is related to the electricity production structure by fuel. In Lithuania about 80% of electricity is being produced at its nuclear power plant. This causes very low CO_2 emissions from the power sector. In 1994, CO_2 emissions per kWh amounted to 280 g/kWh and since 1995 it significantly decreased, down to 155 g/kWh. This is related to the changes of electricity generation structure by type of fuel in 1994. In 1994, fossil fuel provided 17% and nuclear 75%. Since 1995 the share of nuclear in total electricity production has increased, and therefore GHG emissions have decreased.

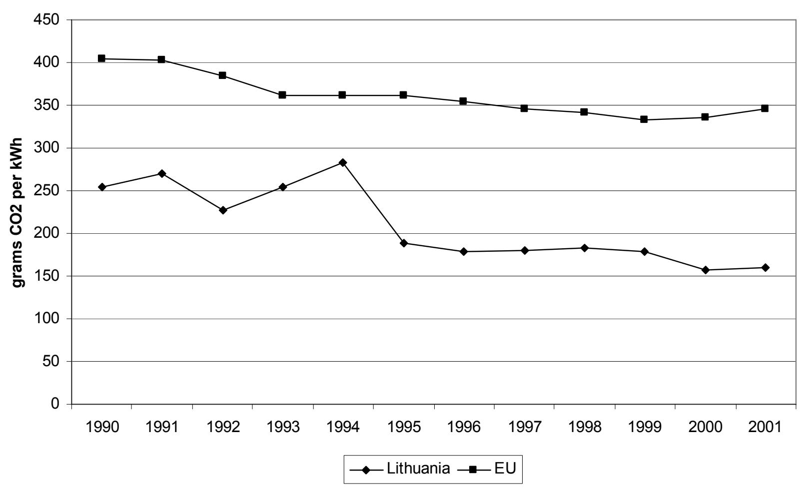

Figure 5.49 CO_2 emissions per kWh from power sector in Lithuania and EU-15

TABLE 5.30 CO_2 EMISSIONS PER KWH FROM POWER SECTOR, GRAMS CO_2 PER KWH

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Lithuania	254.8	269.6	227.4	254.3	283.1	188.7	177.9	179.5	183.5	178.3	154.8	160.5
EU-15	405	403	385	361	362	361	355	346	342	333	336	346

In Figure 5.50 and Table 5.31, growth indices for electricity consumption and CO_2 emissions from the power sector are presented.

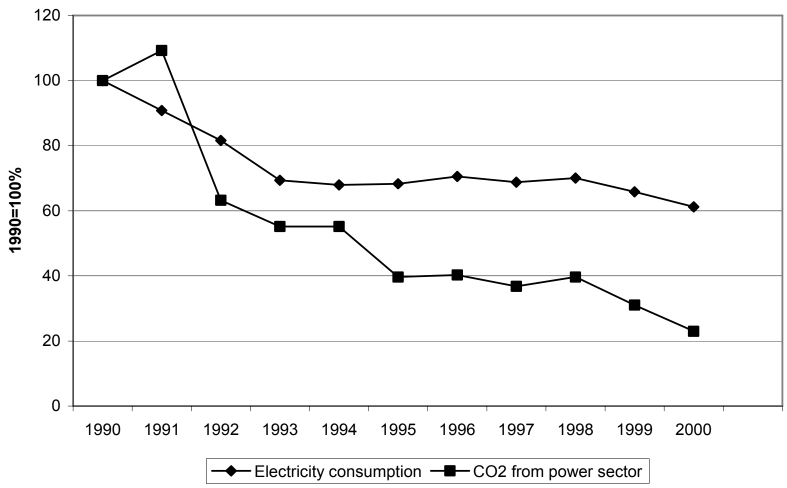

Figure 5.50 Decoupling – electricity consumption and CO_2 emissions from power sector growth index

TABLE 5.31 ELECTRICITY CONSUMPTION AND CO_2 EMISSIONS FROM POWER SECTOR GROWTH INDEX

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electricity consumption	100	90.79	81.59	69.33	67.95	68.29	70.54	68.76	70.05	65.82	61.19
CO_2 from power sector	100	109.20	63.22	55.17	55.17	39.66	40.23	36.78	39.66	31.03	22.99

A significant decrease in CO_2 emissions was stipulated by the steady decrease of electricity demand when the economic recession began in 1990. The structure of the economy has also changed significantly since 1990, influencing electricity consumption patterns as well as CO_2 emissions from the electricity sector. Some decoupling of electricity consumption growth and CO_2 emissions growth can be noticed because CO_2 emissions have fallen more sharply than electricity consumption has fallen.

In Figure 5.51 the relationship between emissions per kWh and electricity consumption per capita are presented for Lithuania and the EU-15 for comparison. As one can see CO_2 emissions per kWh are significantly higher in EU-15 than in Lithuania and electricity consumption per capita is higher. The declining trend of CO_2 emissions with an increase in electricity consumption per capita or a decoupling of electricity consumption per capita from CO_2 emissions per kWh can be observed. In Lithuania there is a decline in electricity consumption per capita and at the same time a net decline in CO_2 emissions per kWh for the same period. If applied to the electricity sector, the Kyoto Protocol target would imply CO_2 emissions for the period 2008-2012 of 230 g/kWh (reduced by 8% CO_2 emissions from power sector divided by forecasted electricity production levels in 2008-2012). Projections of per capita electricity consumption for Lithuania for that period indicate future electricity consumption of about 5,500 kWh per capita. It is not clear whether Lithuania will be able to maintain CO_2 emissions per kWh below the Kyoto target for 2010, given the expected increase in per capita electricity consumption and the expected retirement of the country's only nuclear power plant. Policy

measures are needed to maintain the low CO_2 emissions/kWh in the future as kWh per capita is expected to increase to levels closer to the EU-15 levels.

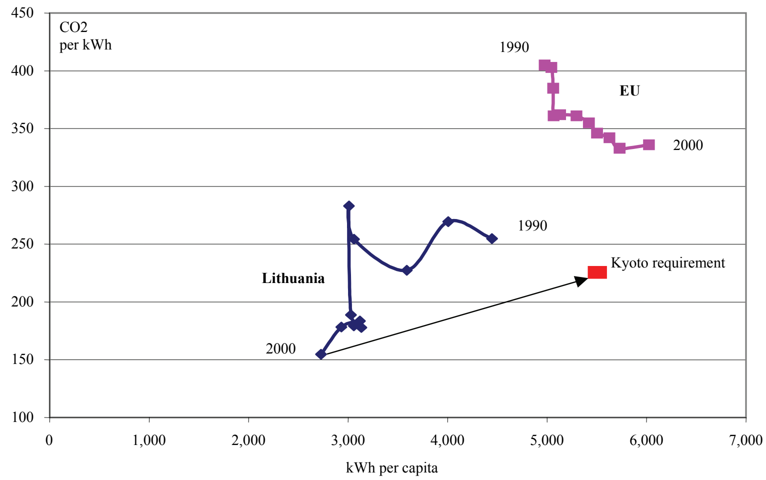

Figure 5.51 CO_2 emissions per kWh and electricity consumption per capita in Lithuania compared with EU-15

Since the Ignalina NPP is currently operating, GHG emissions are not a serious problem for Lithuania. After the closure of the nuclear power plant these emissions will increase significantly, however, and GHG mitigation policies should be implemented in Lithuania.

5.5.7.2. Reduction of SO_2 and NO_x emissions

The Long Range Transboundary Air Pollution Convention (LRTAPC) was signed by Lithuania in 1994 and its extension, the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (known as the Gothenburg Protocol), was expected to be signed in 2004. The Protocol sets emission ceilings for 2010 for four pollutants: sulfur, NO_x, VOCs and ammonia. These ceilings were negotiated on the basis of scientific assessments of pollution effects and abatement options. Parties whose emissions have a more severe environmental or health impact and whose emissions are relatively cheap to reduce will have to make the biggest cuts. In Table 5.32 national emission ceilings for 2010 for Lithuania, as established by the Gothenburg Protocol, are presented. These ceilings are the same as established by European Commission directive 2001/81/EC on national emission ceilings for certain atmospheric pollutants.

TABLE 5.32 NATIONAL EMISSION CEILING IN 2010 FOR LITHUANIA ESTABLISHED BY GOTHENBURG PROTOCOL

Pollutant	Actual total emissions		National emission ceiling for 2010 according to Gothenburg Protocol
	1990	1999	2010
SO_2 (tonnes per year)	222,000	70,000	145,000
NOx (tonnes per year)	158,000	54,000	110,000

To address the targets for the reduction of atmospheric emissions, Indicator #23, quantities of air pollutant (SO_2 and NO_x) emissions from power sector, was selected. Table 5.33 shows SO_2 and NOxcemissions from the power sector from 1990 to 2002.

For the power sector, the Gothenburg Protocol requirement is not to exceed 70 kt of SO_2 emissions. As shown in Figure 5.52, in 2000 SO_2 emissions were significantly lower than the Gothenburg Protocol requirement and amounted to 19.4 kt. This is related to the electricity production structure by fuel. After the closure of both units at the Ignalina NPP, sulfur dioxide emissions would increase but implementation of the EU directive requirements targeting large combustion power plants will prevent significant increases of pollution.

TABLE 5.33 DYNAMICS OF SO_2 AND NO_X EMISSIONS FROM POWER SECTOR, KT

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
SO_2	105	112	65	60	55	58	58	51	69	45	19.4	26.5	26.2
NO_x	47	46	28	25	24	19	19	17	20	15	11.2	8.0	9.6

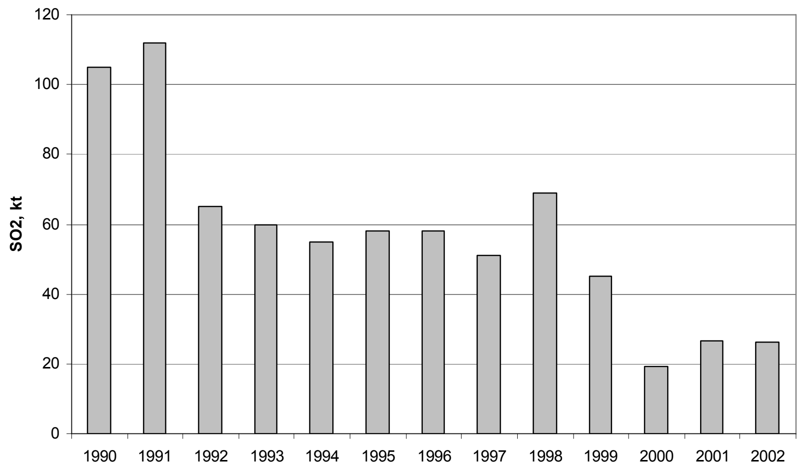

Figure 5.52 Changes of SO_2 emissions from power sector

In Figure 5.53 changes of NO_x emissions from the power sector are presented. The Gothenburg Protocol target as applied here is in proportion to the power sector's share in the base year's emissions.

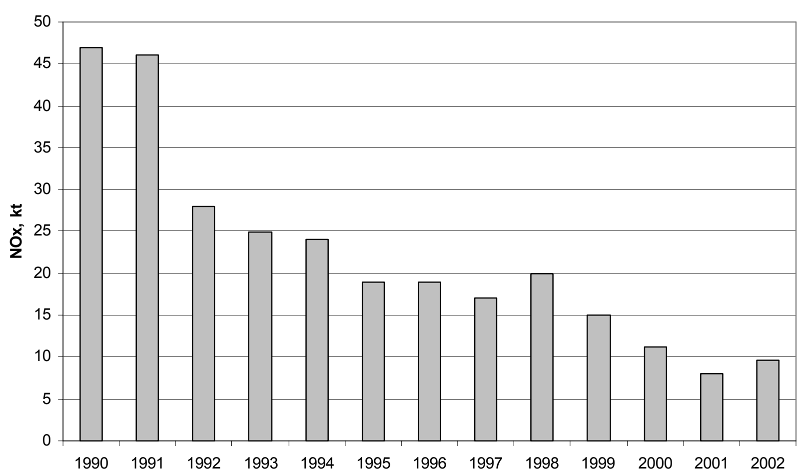

Figure 5.53 Dynamics of NO_x emissions from power sector

Since 1992 emissions of NO_x from the power sector are significantly lower than the Gothenburg protocol targets. Of course after the closure of the Ignalina NPP, NO_x emissions will tend to increase

but implementation of more stringent NO_x emission standards for Large Combustion Plants (LCP) since 2008, imposed by the LCP directive mentioned above, will force large power plants to implement low NO_x burners. The smaller power plants will switch to less polluting fuels.

5.6. Assessment of Current Energy Policies in Priority Areas

The main policies currently being implemented in the selected priority areas (energy intensity, security of supply, energy prices and affordability, and emissions into the atmosphere) are addressed below.

5.6.1. Energy intensity

The efficient use of energy resources and energy conservation is being guaranteed in Lithuania by constantly updating the National Energy Efficiency Programme (Lithuanian Ministry of Economy, 2001). The main directions of the energy saving policy are:

- Improvement of legal and normative basis;
- Introduction of modern technologies and energy conservation measures;
- Introduction of a pricing system stimulating energy conservation;
- Creation of favorable conditions for investments in the energy conservation field;
- Introduction of economic measures promoting the domestic production of energy saving devices;
- Energy auditing of manufacturing and buildings;
- Preparation of specific programmes of actions for each branch of the economy with concrete financing schemes.

The programme is the main tool for the integration of environmental policies. Most important are pricing issues for stimulating efficient energy use. The effect of this policy is positive and resulted in a decrease of energy intensities in all branches of the economy over the last decade.

5.6.2. Energy prices

Since 1997 energy prices were increased in Lithuania to cover all necessary production and supply costs. The currently valid electricity, gas and district heating tariff calculation methodologies are based on cost-of-service principles. All the fixed and variable costs incurred from the production (or for gas, from the state border) to the final consumer are calculated. By adding some rate of return (the Government Decree requires that the state capital should earn at least a 7% rate of return) and dividing the total sum by the planned useful output (electricity, gas or heat), an average tariff is ahieved. This tariff is differentiated among different consumer categories, consumption volumes and time, etc.

Since 2000, 27,000 household consumers living in the area around the Ignalina NPP received a preferential electricity tariff (reduced by 50%) and all households received lower VAT rates (reduced by 50%) for district heating. However, there are still some support measures to producers and consumers of fossil fuel, nuclear energy and electricity. All of these support measures can be treated as environmentally harmful energy subsidies.

From a purely economic point of view, the best way of protecting social welfare in the face of energy price increases is to support consumers' incomes through social welfare payments (i.e., the social safety net) rather than through the prices they pay. Income support is preferred for two reasons: a subsidized price will encourage unnecessarily high consumption, and subsidizing energy prices benefits all consumers rather than just those who find it difficult to afford the service.

The only economically worthwhile reason for preferring price support to income support is when the costs of administering income support greatly exceed those of price support. In Lithuania the main support of incomes for the low-income population is income support to cover heating costs. The first

system was introduced in Lithuania in 1993. This system limited payments for heat to 20% of a family's monthly income. The system was modified in 1999 with a similar system described below.

The Law on Compensation of Flat (Individual House) Heating, Cold and Hot Water Costs for Households Having Low Incomes was adopted in May 1999. According to the Law, if consumption of heat, and hot and cold water corresponds to the norm, compensation is foreseen for the low-income population:

- For the share of expenses related to flat heating exceeding 25% of their income;
- For the share of expenses related to cold water consumption exceeding 2% of their income;
- For the share of expenses related to hot water consumption exceeding 5% of their income.

These compensations are paid from the municipality budget. According to official statistics, in 2000 these support schemes were applied to 6 − 7% of the population in Lithuania. Since the financial situation is difficult in Lithuania, the state budget is not able to ensure sufficient compensation measures for the low-income population.

The effect of energy price increase and removal of subsidies has a positive impact on efficient use of energy and conservation, but on the other hand it has caused an energy affordability problem because support for low-income population has not been effective.

5.6.3. Security of supply

There are only a few direct support measures or tax incentives to encourage use of renewable energy sources available in Lithuania. These measures apply to biofuels. The reduced VAT of 9% is applied to denaturised dehydrated ethyl alcohol and methyl and ethyl ester produced from rapeseeds up to 31 December 2002. Since 1 January 2003 on, denaturised dehydrated ethyl alcohol and methyl and ethyl ester have been exempted from VAT. People using biofuels who can present the documents proving the use of biofuels are exempted from the tax for pollution from mobile pollution, which is based on the fuel consumption and is levied per tonne of fuel consumed.

The provisions on green electricity from the decision of the National Control Commission for Prices and Energy Concerning Prices for Public Service Obligations in the Electricity Sector (11 February, 2002) sets the average purchase prices for electricity produced from renewable and waste energy sources:

- 5.8 EURct/kWh for hydropower
- 6.4 EURct/kWh for wind power
- 5.8 EURct/kWh for power plants using biomass

The Lithuanian Electricity Act and a couple of Lithuanian regulations establish some prioritisation rights for electricity generated from local, renewable and waste energy resources in a manner that appears to be roughly consistent with the option listed in the existing EC Electricity Directive. At present, national rules imposing purchase obligations favouring electricity producers using renewable energy sources are within an area of Community law where wide discretion is available to the Member States.

There are several types of capital support for renewable energy source utilization available in Lithuania: investment subsidies, soft loans, interest subsidies, loan guarantees. The intermediate financing type between support and credits is risk capital. Available direct support for renewable energy source utilization is state aid investment support for any undertaking authorized to pursue the economic activity and National Energy Efficiency program financing provision for demonstration projects. Soft loans, interest subsidies, loan guarantees and risk capital are available for any RES-related small- and medium-sized business from the special closed stock company based on state capital and Small- and Medium-Sized Business Support Programs governed by Municipalities or County Chief Administrations.

The dominating form of support in Lithuania is indirect support. The reason is that once the renewable energy sources are used for energy production, they cannot be directly supported by the state because it distorts the markets and impinges on free competition. Lithuania is obligated to obey the respective provisions of the EU Treaty and bilateral or international agreements on free trade. Without limitations, direct support may be provided to demonstration and pilot projects in the RES field.

5.6.4. Reduction of atmospheric emissions

Reduction of energy consumption was followed by a reduction of emissions into the atmosphere. This process was accompanied by the introduction of new stricter standards for emissions into the atmosphere caused by fuel combustion.

In 1996 the Government of Lithuania approved new normative values for emissions from steam and water heating boilers, which were reduced on an average by 1.5 times compared with 1993 norms. The pollution norms of the EU-15 were taken as a basis. The new stricter standards were introduced in January 1996 and amended in 1998. The new standards for large combustion power plants are seven times more stringent than the current ones and will be implemented in 2008.

The main environmental regulation tool in the energy sector is pollution charges. The pollution charges should carry out their main functions: incentive, compensation and accumulation. The pollution charge system implemented by the Law on Pollution Charges in 1991 was not able to carry out the main functions it was designed to accomplish.

The new improved system of pollution charges was elaborated from 1993 to 1996, and the new Law on Environmental Pollution was adopted on 13 April 1999. The new system is considerably simplified, and pollution taxes are applied for the significantly reduced number of pollutants (from 151 to 18). The individual tariffs have been established only for principal pollutants (in the case of air pollutants for SO_2, NOx, V_2O_5 and dust), which are easier to control. The tariffs were established in order to achieve determined pollution reduction aims. The remaining pollutants were grouped according to the level of toxicity into classes (in the case of air pollutants, into IV classes) and the same tariff for each class was defined. Another important feature of the tax system reform is that the tariffs are not a linear function of emissions and norms. Only two tariffs apply for each pollutant and pollution source: a basic tariff (for emissions lower than established norms) and a penalty tariff (for emissions exceeding norms). The size of the fine is defined using a constant multiplier for the basic tariff, but these coefficients depend on the toxicity of the pollutant. New pollution tax rates were increased by a factor of four on average.

Excise taxes for fuels also have been increased continuously in Lithuania in order to achieve EU-15 levels. The excise tax for gasoline was increased from 300 EUR/t up to 400 EUR/t in January 2004. The excise taxes for gasoils and lubricants were increased at similar rates.

This environmental policy has a positive impact on the reduction of atmospheric pollutants from the energy sector. Atmospheric pollution from stationary pollution sources in Lithuania has declined more than four-fold compared with 1990 levels even though energy consumption has decreased by only a factor of two.

5.7. Strategies for Improvements in Priority Areas

5.7.1. Impacts and linkages among indicators in the implemented ISED framework

The implemented ISED framework, focused on Lithuanian energy sector development priorities, consists of economic, social and environmental indicators which are linked to each other. Figure 5.54 provides a graphic illustration of the impacts and linkages among indicators selected in this case study. The scheme is based on the general scheme of interlinkages among key indicators from the ISED list.

Relevant policy actions based on the analysis conducted in previous sections were selected for the targeted indicators.

The main policies were developed for the following energy priority areas:

- Structure of economy;
- Energy intensity;
- Security of energy supply;
- Energy prices and hence energy affordability; and
- Environmental situation improvements.

The structure of the economy is tightly related to energy intensity of GDP. Further optimization of economic activity levels in Lithuania through reducing share of energy intensive sectors and industries in GDP value added should be implemented. For a country which does not have plenty of natural resources, the structure of the economy should be as low energy intensive as possible. The commercial sector and low energy intensive industries (food and light industry, electronics, IT) should be developed in the future.

5.7.2. Policies to reduce energy intensity

The main policy measure or response action to reduce energy intensity is to increase end-use energy efficiency. An energy efficiency improvement programme is a good tool for achieving this. This programme has been continuously revised since 1996. Integration of energy efficiency in all sectoral policies is a very important tool. Implementation of legal and regulatory frameworks enabling environment-friendly energy conservation and efficiency is crucial in this sense. First of all, energy efficiency should be increased in the household sector in Lithuania. There are still many areas for improvement, in particular household consumption, which reflects patterns (and wastefulness) induced by a long period of very cheap energy. Heating is a key problem. As household consumption is a large share of total final energy consumption in Lithuania, overall energy efficiency is still quite low and far behind levels in the European Union. The transport sector is also an area for concern; old and inefficient motor vehicles result in an increase in energy consumption and pollution. In addition, despite the positive energy efficiency trends, delayed reforms in the energy sector, which can be noted in Lithuania, may cause higher-than-necessary energy use and related pollution, a slower-than-possible turnover of the energy-relevant capital stock, and higher energy supply costs. Therefore it is necessary to strengthen the legal and regulatory environment, favoring market formation activities and investments. In general in Lithuania the transport sector contributes less and household and industry contribute more to energy consumption compared to EU-15 Member Countries. This will change in relation to the increasing number of private cars and growing freight transport activity between Eastern and Western Europe.

Some energy support measures still exist in Lithuania (e.g. reduced VAT for district heat, exemptions from environmental standards etc.). Removal of these subsidies would provide further incentives to increase energy efficiency and reduce energy consumption. The introduction of a CO_2 tax or an increase in excise taxation (Council directive 2003/96/EC on restructuring the Community framework for the taxation of energy products and electricity) are very important as economic incentives to reduce energy intensity. Therefore to reduce energy intensity, the main policy actions are related to end-use energy efficiency improvements (affected by energy pricing policy as well) and to implement measures foreseen in the National Energy Efficiency Improvement Programme.

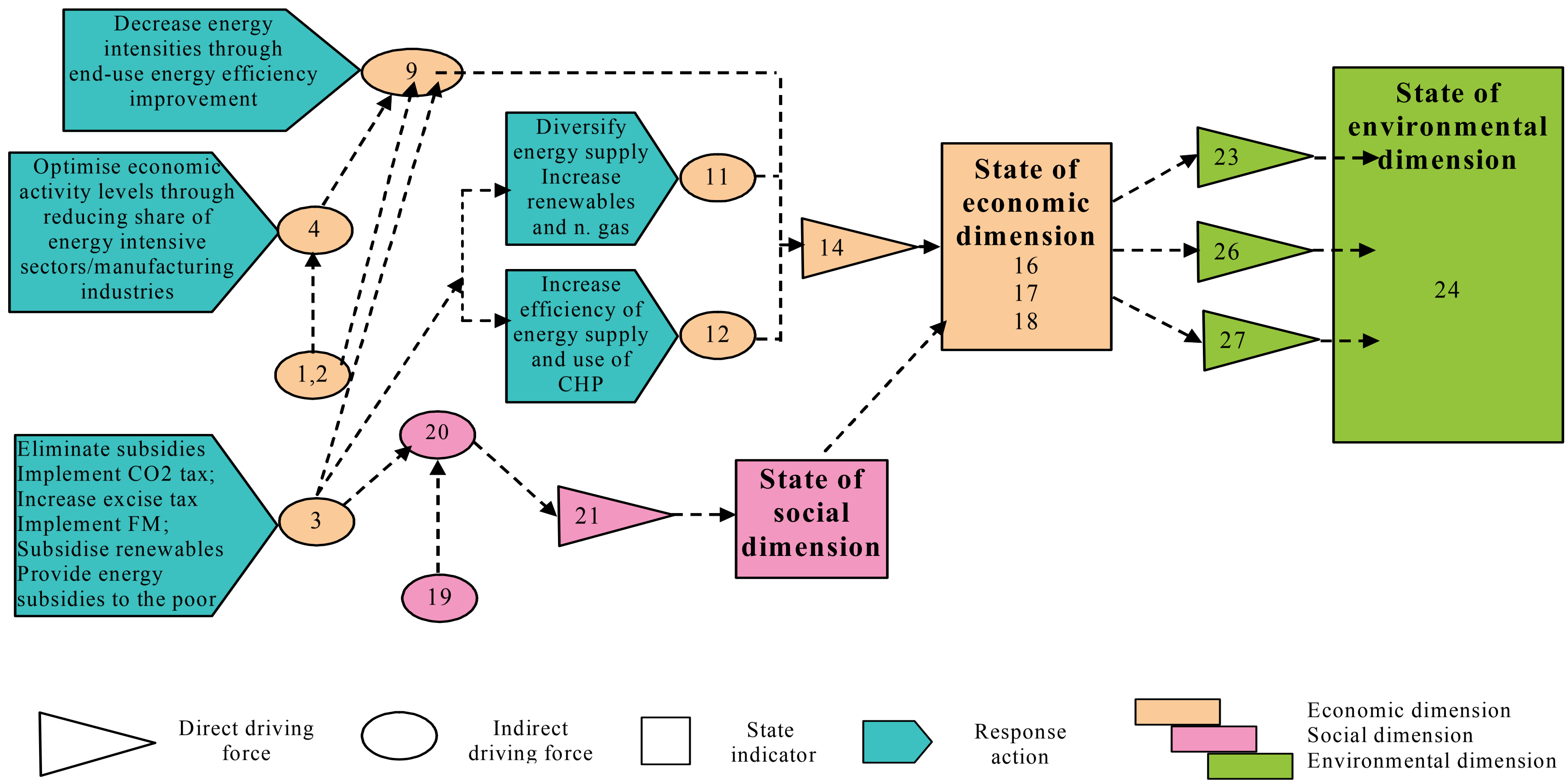

Figure 5.54 Linkages between indicators and relevant policy actions on targeted indicators

5.7.3. Policies to increase security of supply

In the field of security of supply, the main policy actions selected for targeted indicators for Lithuania are:

- Enhance the diversity of fuels in the energy mix;
- Improve maintenance and upkeep of existing energy infrastructure;
- Eliminate constraints hampering modernization and investment in new facilities;
- Increase efficiency of energy supply in electricity generation;
- Increase fraction of electricity produced by CHP;
- Increase share of renewable and energy sources in energy mix.

A very important issue is to ensure that, after the closure of the Ignalina NPP, all of the biggest power producers in Lithuania use the three major types of fuel available - natural gas, heavy fuel oil and Orimulsion – and that flue gas desulphurization equipment is installed in Lithuanian thermal power plants, Vilnius CHP, Kaunas CHP and Mazeikiai CHP. The funding for this equipment should be from the Ignalina NPP decommissioning fund established by the EU and other country donors.

Though net energy import dependency has decreased considerably in Lithuania, after the closure of both units at Ignalina NPP, it is expected to increase to almost 90%. The closure of the Ignalina NPP by 2009 even poses the threat of power shortages in the country as well. For security of supply and integration in the EU electricity market, it is necessary to build a power bridge between Lithuania and Western Europe. The EU Commission has already promised to support a power bridge of 1,000 MW between Lithuania and Poland, which might at least partially guarantee energy independence in the Baltic region. For energy infrastructure upgrading in Lithuania, foreign and local investments are needed. Restructuring and privatization of the energy sector will create a favorable environment for investments in the energy sector. The State policy aiming to eliminate constraints hampering modernization and flow of investments into the energy sector is crucial in this sense.

Efficiency of energy supply needs to be increased in Lithuania. High losses and low efficiency levels are characteristic of the power sector, which result from obsolete electricity grids and other infrastructures. The current privatization of electricity transmission networks will enable the upgrading of grids and equipment. Privatization of electricity and heat generating plants will also serve to increase electricity generation efficiencies. Though reforms in the energy sector were quite slow during the last decade, some positive results were achieved —but further measurements are necessary in order to ensure that the Lithuanian energy sector is modern and competitive in the EU energy market.

Policies to support the use of renewable energy sources should be continued in order to maintain positive trends in the use of renewable energy sources in Lithuania. The most important task is to promote renewable energy sources in the power sector (LEI, 2003). Lithuania has implemented a direct price support scheme for electricity generated from renewable energy sources. The average purchase prices for electricity produced from renewable and waste energy sources are set by the National Control Commission for Prices and Energy. New support schemes can be introduced in Lithuania based on provisions of Council directive 2001/77/EC for the promotion of electricity produced from renewables in the internal electricity market and on the experience of other countries. Flexible market-based support measures are green certificates. Currently Sweden is among the very few countries having already adopted the electricity certificates system. It is hoped that, in a few years, a large market for trade in green certificates will have developed and converged into a well-functioning tool. Lithuania can also adopt a system with the features that have proven to be most efficient. This system will ensure that electricity production from renewable energy sources will not be dependent on financial support from the state, but will be responsive to the deregulated market. The use of renewable energy sources can be supported in Lithuania also by implementing new environmental taxes (for example CO_2 or product taxes on fuels based on the carbon content in the

fuel). The green budget reform analysis is necessary to evaluate the impact of a pollution tax increase in Lithuania.

CHPs are the most efficient energy generation sources. Lithuania's energy and sustainable development strategy set as an objective to ensure that the share of CHP will be 35% of total electricity production by 2020. Implementation of this goal would significantly increase the electricity supply efficiency of the Lithuanian power system. Implementation of requirements and measures foreseen in the forthcoming EU directive on CHP support should help to achieve this quite ambitious target because, currently, electricity produced by CHP is only about 18% of total electricity generation in Lithuania.

5.7.4. Policies to get prices right

A number of international initiatives were taken recently to support national efforts for improving the environment by reforming energy pricing. It is widely recognized that prevailing pricing, fiscal and financing mechanisms in Central European countries do not support energy conservation or the wider use of new and renewable energy sources. Promotion of energy efficiency and conservation, increased production and use of cleaner energy sources and internalization of environmental externalities in energy prices are major approaches to breaking this trend. The increase in energy prices, however, should be followed by improving support schemes for low-income populations to ensure energy affordability.

In the field of energy prices and energy affordability, the following policy measures were selected:

- Eliminate energy subsidies which still exist;
- Introduce CO_2 tax and green budget reform;
- Increase excise taxes based on rates established by EU directive 2003/96/EC;
- Implement green certificates to promote use of renewable energy sources;
- Implement flexible mechanisms under the Kyoto Protocol;
- Improve system of energy price support for low-income population.

There are only a few direct energy price subsidies in Lithuania. Since 1997 energy prices have been increased to cover all the necessary production and supply costs. Only 27,000 household consumers living in the area around the Ignalina NPP received the alleviated electricity tariff (reduced by 50%) on the basis of the Law on Nuclear Energy (1996). The reduced VAT of 9% was applied for heating since January 1, 2000. There are some indirect support measures (such as temporary exemptions from environmental standards, custom duties for imported fuels, etc.) which act as subsidies, and these should be removed in the future in order to increase energy efficiency and reduce environmental pollution.

Some analysis of green budget reform costs/benefits was conducted in Lithuania. The Lithuanian Energy Institute applied the International Atomic Energy Agency (IAEA) analytical tool MESSAGE for the energy sector, in order to analyze the effects of the implementation of a CO_2 tax, an increase of excise tax on fuels and an increase of other pollution taxes (LEI, 2003). Results of the study indicated that, when emission taxes for SO_2 and NOx were increased, besides the expected increase in price of electricity and heat, as well as a clear shift to natural gas in the primary energy balance, there was also a major impact on refinery operations that significantly reduced oil refining and the export of oil products. A tax on CO_2 would cause smaller changes in the Lithuanian energy sector in comparison with increased taxation of SO_2 and NOx. However, it would lead to the highest electricity and heat price increases. The introduction of a CO_2 tax (at 13.3 Euro/t) would reduce CO_2 by about 6% compared with the status quo scenario. It has no significant impact on the utilization of renewable energy resources because of their low availability, but it would lead to a further shift from oil to natural gas and the import of electricity, and consequently to a more negative trade balance. From the point of view of security of energy supply in Lithuania, this measure would be considered negative because it favors the dominant position of imported natural gas in the primary energy balance.

Nevertheless, this measure reduces CO_2 and allows a significant supplementary income to the state budget.

The introduction of higher excise taxes reduces CO_2 by about 6% and SO_2 by about 4% and leads to significant additional income to the state budget—but at the same time, it causes some of the highest levels of electricity and heat prices. The results of the analysis indicated that emission taxation schemes, especially increased SO_2 and NOx taxes, seem to be the least economically attractive (or even negative) options of all the promotion schemes analyzed (lei, 2003).

Lithuania has no provision for a system of certificates of origin, as required by Article 5 of the Renewables Directive on Electricity (2001/77/EC). It needs to develop a mechanism based on the experiences of other EU-15 and candidate countries and to tailor it to the Lithuanian situation. Under a green certificates system, RES-E is sold at market prices. In order to finance the additional costs of producing RES electricity, and to ensure that the desired RES electricity be generated, an obligation should be placed on all consumers to purchase a certain amount of Green Certificates from RES-E production according to a fixed percentage, a quota, of their total electricity production. Since consumers wish to buy these certificates as cheaply as possible, a secondary market of certificates develops where RES producers compete with one another for the sale of the Green Certificate.

The Kyoto Protocol allows the use of three Flexible Mechanisms (FM): International emissions trading, Joint Implementation (JI) and Clean Development Mechanisms (CDM). International emissions trading allows Parties to the Protocol who reduce emissions below their assigned amount to sell part of their emissions allowance. Those who cannot meet the targets can buy the extra allowances from the Parties who have spare capacity and are willing to sell. Joint implementation is a specific form of emissions trading at the project level. Annex I Parties to the Convention can undertake projects (e.g. fuel switching for a power station) with other Annex I Parties, which result in additional emissions reductions in the country where the project is located. Those reductions can be used to increase their emissions allowance of the Party financing the project, while the emissions allowance of the Party where the project is carried out would be correspondingly reduced. Lithuania, as a country in transition, lacks financial resources and is able to benefit from International Emissions trading (IET) and Joint Implementation (JI), having lower emission abatement costs and attracting capital and technology transfer sponsored by developed countries in exchange for GHG emission credits. FM will permit more ways to get new, cleaner technologies adopted sooner in Lithuania because encouraging investments in cleaner technologies will enhance the rate of technology development and these developments also permit economies of scale, which will enhance the speed of commercialization.

JI frequently has been regarded as a first step towards IET. JI is based on a baseline and credits system. For IET another type of GHG trading (cap-and-trade system) is characteristic. In both schemes the generic term for the unit of trade is an emissions permit.

A “cap and trade” system starts by defining an aggregate, legally binding emissions limit for a group of polluters, i.e. countries or companies for a given period. This limit is a cap. The emissions authorized by this cap should be allocated to eligible participants in the trading system. The emissions permits should be allocated by the regulatory authority and are termed emissions allowances. In principle all allowances can be traded. The main feature of cap-and-trade schemes which are comprehensive by their nature is that they require an extensive regulatory involvement and efforts at the beginning to set them up. It is often considered that IET is more efficient in the context of CO_2 emissions from the power sector.

Preparation for the implementation of flexible mechanisms under the Kyoto Protocol is necessary for Lithuania. For the application of FM in Lithuania it is necessary to implement careful energy planning, GHG emissions monitoring, inventory, reporting and verification procedures assuring that claimed reductions have indeed been achieved.

In order to ensure energy affordability, social support schemes for the low-income population are necessary. A number of alternative mechanisms to support the low-income population and to ensure the socially desirable level of energy consumption can be evaluated (World Bank, 2000). Based on the analysis of different support schemes using appropriate criteria (coverage, targeting, predictability, welfare costs, and administrative costs), the conclusion can be drawn that the support system currently being applied in Lithuania should be replaced by “earmarked cash transfers”. The introduction of this

support scheme will allow increased targeting and coverage of the support scheme. Moreover, other important expenditures such as payments for house rent, electricity, gas etc., are not included in the support scheme. This scheme is popular in transition countries (Poland, Latvia, and Estonia).

The major difference between "earmarked cash transfers" and the burden limit scheme is the focus on residual income instead of on the share of expenditure on the utility. In terms of coverage, the scheme should do better than the burden limits because it should pick up all households falling in the poor category as far as income is concerned, whereas the burden limits scheme will exclude households that spend too low a share of income on the utility. In practice, however, unreliable income data means that coverage is not complete. Furthermore, not all households will apply. Likewise, the scheme is better at targeting the poor. It is not possible to apply unless you are demonstrably in the poor income group. This scheme merits a similar score for predictability as the burden limits schemes. The key issues are uncertainty regarding qualification and how low-income reports will be treated by the assessors. The welfare costs of this scheme are substantial because of the burden it places on the public budget. The scheme also suffers from the same problem as the actual payment version of the burden limits scheme – i.e. there is an open-ended subsidy to the utility. Such a subsidy can, however, be capped, by declaring a utility expenditure norm as in the burden limits case. In this analysis we assumed that this is the case, and thus compared the other earmarked transfer scheme with the burden limits scheme with expenditure norms. However, because coverage is expected to be better with the earmarked transfers, the revenue needs and, therefore, the welfare costs are expected to be higher. The scheme has similar administrative costs as the burden limits scheme.

5.7.5. Environmental policies

Though currently, with the Ignalina NPP operating, GHG and other emissions do not seem a serious problem for Lithuania, after the closure of the nuclear power plant these emissions will increase significantly. New policy options to deal with increased atmospheric pollution will be necessary.

5.7.5.1. GHG mitigation policies

In general terms, there are two basic ways of accomplishing the GHG mitigation: by increasing efficiency; or by switching to a fuel with lower carbon content. GHG mitigation options in the electricity and heat sector can be supply- or demand-side oriented. Supply-side oriented GHG mitigation options in the power sector include: improvement of combustion efficiency, re-powering, fuel switching, reduction of transmission and distribution losses, dispatch modifications; and others. The second GHG mitigation option is power system expansion with new generating technologies. There are many options for new generating technologies: advanced fossil fuel systems (combined cycle), non-fossil fuel systems (hydro, renewables, nuclear).

GHG mitigation options on the demand side are typically related to the introduction of CO_2 tax rates. Integrating environmentally related economic instruments into economic decision-making is a new concept in Lithuania, though pollution charges have been applied for years. During the initial stage of the new tax system preparation (implemented in 1999), the tax rate for CO_2 (as principal pollutant) emissions equal to 5 USD/t was introduced using the experience of foreign countries, but later during the consideration stage of the law this tax was eliminated from the environmental tax system. Taking into account the poor economic situation of the country, implementation of a high CO_2 tax is unrealistic for Lithuania. As business standards are raised, there are new opportunities for new instruments, like product charges and tradable permits in Lithuania.

Seeking to implement Kyoto requirements, some GHG mitigation options were prepared for the Lithuanian power sector in 2001 (LEI, 2001b) using the ENPEP model developed by the International Atomic Energy Agency, which is able to simulate energy markets and determine energy supply and demand balance over a long-term period:

- Switching from heavy fuel oil (HFO) to less polluting fuels by modernizing the largest thermal power plant and introducing additional gas turbines;

- Introduction of new generating technologies: combined cycle gas turbine (CCGT) and CHP;
- Small scale nuclear power plant.

For an analysis of the GHG mitigation options within the electricity and heat production sector, three GHG mitigation scenarios were designed. These were based on the power sector expansion plan (LEI, 2001b) obtained by running the IAEA's WASP-IV model during the preparation of the National Energy Strategy in 1999. The main assumptions for the scenarios were:

Scenario 1. It was assumed that the remaining lifetime of five not-earlier-refurbished units at the Lithuanian TPP would be approximately 5-8 years. It was assumed that after five years, the 300 MW units could be re-powered by installing additional gas-turbines. The total installed capacity of one unit would then be 400 MW. These re-powered units will be fired with natural gas (gas turbine) and gas or heavy fuel oil (i.e., steam boiler).

Vilnius CHP and Kaunas CHP can be operated until 2008 without additional investments, and after 2008 only flue gas desulfurization would be necessary. After 2005 the gasification of Mazeikiai CHP will be performed and it will operate on HFO and natural gas.

Of new generating capacities, 10 units (each 60 MW capacity) of new CCGT would enter into operation in 2005. After that, one unit each year (i.e., five units, each 50 MW) of new gas turbines (GT) would enter into operation by 2010. Modular CHP of 100 MW capacity will enter into operation in 2003.

Scenario 2. The main assumptions for this scenario are the same as for scenario 1, but it also includes additional new generating capacities: two units (each 350 MW capacity) of new CCGT.

Scenario 3. The main assumptions for this scenario are the same as for scenario 2, with additional new generating capacities: new small-scale modular nuclear power plant of 95 MW capacities.

In all these scenarios the structure of electricity generation will change significantly after the closure of the Ignalina NPP. In the case of scenario 1, the share of electricity generated by the Ignalina NPP will be replaced by electricity produced at modernized Lithuanian TPP. The share of electricity produced at Lithuanian TPP will make up to 50% in 2020 and the share of CCGT about 23%. In the case of scenario 2, the share of electricity generated at Lithuanian TPP will be about 30% in 2020, because its capacities will be replaced by CCGT of 350 MW. This new power plant would produce 27% of total electricity generated in 2020. In the case of scenario 3, the share of the closed Ignalina NPP will be replaced by electricity generated at new CCGTs at 50% and new small-scale modular nuclear power plant at about 10%. Modernization of Lithuanian TPP is not included in this scenario. In the cases of scenario 2 and scenario 3, gas turbines are used only for peak demand. In all these scenarios electricity generation at existing CHP would stay the same.

The fuel consumption structure will change significantly too, according to expected results in different scenarios. In 1999 the share of nuclear fuel in electricity generation was 67.5%, the share of natural gas was 16.8% and the share of HFO was 15%. In 2020, according to scenario 1, the share of natural gas will amount to 72%, and the share of HFO to 25%. In the case of scenario 2 the share of natural gas will be 77%. And in the case of scenario 3, natural gas would be 70%, HFO 17% and nuclear fuel about 10% of all fuel consumed for electricity generation.

The analysis of the GHG mitigation options in the electricity and heat production sector according to baseline and three mitigation scenarios on the supply side is presented in Figure 5.55. The sharp increase of CO_2 emissions is obvious in 2005 and 2010 because of the subsequent closure of two units at the Ignalina NPP.

According to scenario 1, in 2016 CO_2 emissions in the electricity and heat production sector will reach 16.1 Mt and the Kyoto target will not be met without additional GHG mitigation measures. In the case of scenario 2, CO_2 emissions at the end of the study period will reach 15.7 Mt. According to scenario 3, which includes additional new generating capacities (CCGT and new small scale modular nuclear power plant), CO_2 emissions will be 14.7 Mt in 2020. As one can see from Figure 5.55, only in the case of GHG mitigation scenario 2 and scenario 3 will Lithuania be able to fulfill the Kyoto commitments because CO_2 emissions values according to these two scenarios will be below the Kyoto target.

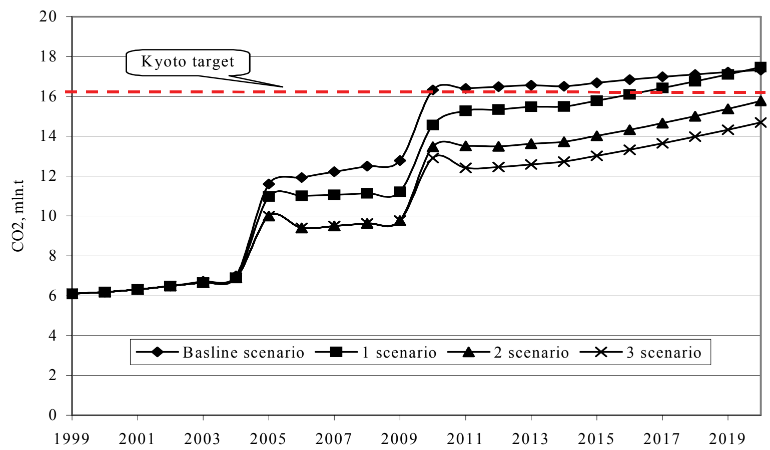

Figure 5.55 Forecast of CO_2 emissions in electricity and heat production sector according to three mitigation scenarios (scenarios 1, 2, 3)

Preparation for the implementation of flexible mechanisms under the Kyoto Protocol (as mentioned before) is necessary for Lithuania. International GHG emission reduction measures (i.e., the flexible mechanisms) and local GHG mitigation measures (i.e., green budget reform, which encompasses the introduction of a CO_2 tax) were presented in the previous section because these policies have an impact on energy prices, and affect GHG emission reductions through energy price increases (Lithuanian Ministry of Environment, 1996b).

5.7.5.2. Atmospheric pollution reduction

The closure of the Ignalina NPP could cause a significant increase of SO_2 and NOx emissions because its capacities will be replaced by capacities primarily burning fossil fuel. The increase of these pollutant emissions, however, is prevented by the implementation of stricter environmental standards. The implementation of these standards will be enforced by two EU directives.

The first directive - Directive 1999/32/EC relating to a reduction in the sulfur content of certain liquid fuels (Sulfur directive) - is to ensure that, as from 1 January 2004, the HFO used within territories of EU Member States does not exceed the sulfur content of 1.00 % by mass. This requirement shall not apply to HFO used in (large and small) combustion plants where the emissions of sulfur dioxide from the plant are less than or equal to 1,700 mg/Nm3, and for combustion in refineries, where the monthly average of emissions of SO_2 averaged over all plants in the refinery shall not exceed 1,700 mg/Nm3. According to the requirements of EU Directive 88/609/EEC, it is possible to burn HFO with a sulfur content exceeding 1% if it is co-combusted with either natural gas or with biomass. Thus, HFO having a sulfur content of 2.2% can be used by LCP's if it is co-combusted with at least 55% natural gas or 55% biomass (in terms of energy input). In this case, the concentration of SO_2 in the flue gas will be kept below 1,700 mg/Nm^3. Similarly, Orimulsion should be used with at least 75% natural gas.

In addition, after 2008 the new norms for SO_2 emissions will be established for large combustion plants (LCP) based on the second directive - Directive 2001/80/EC on the limitation of emissions of certain pollutants into the air from large combustion plants (LCP Directive). Therefore SO_2 emissions will not increase significantly in Lithuania because, in order to comply with the requirements of Sulfur and LCP directives, such emission abatement measures as flue gas desulphurization equipment will be installed in the biggest Lithuanian power plants. According to the requirements of Directive 2001/80/EC, after 1 January 2008 seven times more stringent standards for SO_2 emissions should be applied for combusting HFO in the biggest Lithuanian power plants. During negotiations with the EU, Lithuania succeeded in receiving a transitional period for Vilnius, Kaunas and Mazeikiai CHP until 2015 for the implementation of these requirements in order to have more time to prepare for such new

requirements. The smaller large combustion sources will switch to gas or wood in order to meet the sulfur and LCP directive requirements.

The analysis of increased emissions tax rates on SO_2 (from current rates of 85 EUR/t to 90 EUR/t) and NOx (from current rates of 140 EUR/t to 170 EUR/t) showed that, besides the increased price of electricity and heat and a clear shift to natural gas in the primary energy balance, such a reform will reduce oil refining activities and the export of oil products from Lithuania (LEI, 2003). Therefore the increase of these taxes is the least economically attractive option, as noted earlier.

5.8. Conclusions

In this case study the following priority areas were selected, based upon National Energy Strategy targets:

- Energy consumption;
- Energy intensities;
- Structure of economy;
- Energy prices;
- Energy security;
- Environmental energy situation.

Energy consumption. Final energy consumption per capita in Lithuania is less than half of that in the EU-15, and was continuously decreasing through 2000. Only since 2001 has this trend reversed. This is associated with the high rates of GDP growth since then (6.5% in 2001; 6.7% in 2002; and 6.8% in 2003). At the same time final energy consumption per capita has been slowly increasing in the EU-15. Thus, it will take some time before these indicators will converge. Low final energy and electricity consumption per capita rates reflect the low income and low living standards in Lithuania, and raise questions about energy affordability. Noting the quite low final energy consumption per capita in Lithuania, but comparable levels of TPES per capita in Lithuania and the EU-15, one can conclude that there is rather low energy conversion efficiency within the Lithuanian energy system.

Energy intensities. In the EU-15, positive trends decoupling final energy and electricity consumption per capita from final energy and electricity intensity can be observed. In Lithuania, final energy and electricity intensity of GDP is decreasing more slowly than final energy and electricity consumption per capita. Primary energy intensity of GDP is especially high (more than twice as high as the EU-15 average). In order to define the impact of changes in the structure of the economy on the decline in energy intensity, a less aggregated analysis of energy intensity was performed.

The structure of economy has dramatically changed in Lithuania since 1990. The share of value added from manufacturing decreased, while that from the commercial sector (which is the least energy intensive) increased. In general, energy intensity has decreased in all branches of the economy since 1990. All of these trends have an impact on the decline in final energy intensity of GDP in Lithuania. These trends should be maintained in the future by implementing energy efficiency policies in all sectors.

Energy prices. Household energy prices are very high in Lithuania when compared with income. Energy affordability can be considered a major social problem in Lithuania. The worst situation with energy affordability in Lithuania is in the heating sector, because district heat prices in Lithuania are very high (only about 14% lower than in EU-15 countries) compared with low disposable income of population (about 30 times lower than in EU-15). The amount of heat that could be consumed monthly at current consumer prices and income indicates that in Lithuania the heat which could be consumed by the average population is roughly one-ninth that in the EU-15. The amount of electricity and natural gas consumed monthly at current electricity and natural gas prices in Lithuania was only a third of the EU-15 average, and electricity prices were 2.3 times and natural gas prices 3 times higher in the EU-15. In order to ensure energy affordability, social support schemes to low-income population are necessary.

Security of supply. The net energy import dependency in Lithuania was 44% in 2002, and in 2010 when the Ignalina NPP will be closed, it will increase dramatically up to 90%. As the Lithuanian energy sector highly depends on energy imports, it is necessary to increase indigenous energy production and the utilization of renewable energy sources and increase the energy supply efficiency. Development and upgrading of energy infrastructure is also crucial. Opening the electricity market and successful competition in EU electricity and gas markets would help to increase the security of energy supplies. Though renewables will never be able to replace nuclear capacities, enhancement of the utilization of this energy source in Lithuania is among the priorities of energy policy. In 2002 indigenous or renewable energy sources in total primary energy mix amounted to 9.2%. The target for 2010 is to reach 12%. The share of indigenous electricity to total electricity production is very small in Lithuania, about 3%. Lithuania agreed with the EU to implement a 7% target by 2010. In order to achieve this target, additional policies promoting use of renewables in Lithuania are necessary.

Environmental energy situation. EU-15 CO_2 emissions per kWh are twice as high as those in Lithuania, and electricity consumption per capita is also more than twice as high. A trend of declining CO_2 emissions along with increasing electricity consumption per capita can be observed in the EU-15. In Lithuania, other trends can be noticed: the decline in electricity consumption per capita also resulted in a decline in CO_2 emissions per kWh, but since 2001 this trend has changed. The Kyoto target of 230 g/kWh should not be surpassed with the expected increase in electricity consumption per capita level. Only in the case of implementation of appropriate GHG mitigation measures will Lithuania be able to fulfill the Kyoto commitments after the closure of the Ignalina NPP. SO_2 and NO_x emissions will also tend to increase, but implementation of stringent NO_x and SO_2 emission standards for large combustion plants after 2008, imposed by the EU directives, should mitigate these trends. The smaller power plants have also switched to less polluting fuels because of the sulfur directive requirement since 2004.

In general, positive trends in relation to sustainable development can be noticed in the Lithuanian energy sector; although, compared with the EU-15, some issues require additional attention. These include energy intensity, renewable energy sources and energy affordability. New policies to address these problems should be implemented, such as: new support schemes for the low income population to increase energy affordability, new measures to enhance utilization of renewable energy sources, reduction of energy transformation losses in the system, and local and international climate change mitigation measures.

Though energy statistics capabilities are adequate to conduct energy policy analysis, some information on environmental issues related to the energy sector is lacking. This information (wastewater discharges, land area taken by energy facilities, intensity of use of forest resources, etc.) needs to be addressed in energy statistics.

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ANNEX 5.1

Number	Indicators	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
#2	GDP/capita adjusted at PPP in USD'95	9,635.4		7,032.5	5,906.6	5,346.4	5,532.9	5,802.9	6,233.8	6,557.8	6,306.7	6,556.7	6,985.1	
#3	Current end-use energy prices, in USD'95													
	Electricity	0.0001	0.0002	0.001	0.014	0.02	0.04	0.05	0.05	0.0412	0.0412	0.052	0.035	0.053
	Heat	0.018	0.09	0.36	2.7	14.4	33.3	64.8	80.1	94.5	97.2	103.5	138	142.8
	Natural gas	0.003	0.007	0.099	2.2	3.6	4.8	5.7	5.8	5.6	5.6	8.8	11.1	11.1
#4	Shares of sectors GDP adjusted at PPP in USD'95 value added, %													
	Manufacturing	40	47	39	38	34	33	33	33	34	32	31	31	31
	Agriculture	15	16	13	14	11	12	13	13	12	11	11	7	7
	Commercial	37	30	39	38	46	46	45	45	45	47	47	50	49
	Transportation	8	8	9	10	10	9	10	10	9	10	11	12	13
#9	Final energy intensity of economic branches (GDP adjusted at PPP in USD'95), toe/thou USD													
	Manufacturing	0.284	0.198	0.274	0.153	0.169	0.159	0.142	0.132	0.121	0.113	0.109	0.104	0.117
	Agriculture	0.167	0.157	0.134	0.113	0.113	0.079	0.075	0.058	0.054	0.044	0.039	0.038	0.042
	Commercial	0.164	0.140	0.106	0.091	0.084	0.073	0.067	0.057	0.049	0.049	0.042	0.042	0.042
	Transportation	0.600	0.594	0.485	0.537	0.584	0.606	0.544	0.552	0.579	0.487	0.394	0.430	0.444
#11	Energy mix													
	TPES, %													
	Coal	5.9	4.9	4.4	5.2	4.5	3.2	2.5	2.1	1.7	1.8	1.4	1.1	1.8
	Oil	44.1	43.0	38.9	44.5	44.4	38.3	34.1	36.9	40.2	37.2	31.2	31.3	28.5
	Natural gas	28.3	29.3	24.8	15.9	21.5	23.1	23.3	22.7	19.0	23.2	29.0	26.6	25.2
	Nuclear	26.8	27.8	34.2	34.0	25.0	35.1	39.1	35.6	38.2	32.7	30.8	32.6	35.9
	Hydro	0.2	0.2	0.2	0.4	0.5	0.4	0.3	0.3	0.4	0.5	0.5	0.3	0.4
	CRW	1.0	1.0	1.5	2.5	2.9	2.6	5.5	5.9	6.2	7.5	8.7	8.1	8.2
	Electricity, %													
	Nuclear	60.0	57.9	78.9	88.0	79.0	87.4	85.8	83.6	79.0	75.4	75.7	77.1	79.8
	Fossil fuels	38.6	41.0	19.4	9.2	16.4	9.8	12.1	14.4	18.6	21.5	21.2	18.2	15.8
	Hydro	1.5	1.2	1.7	2.8	4.6	2.8	2.0	2.0	2.4	3.2	3.0	4.7	4.4
	Electricity net import													

Number	Indicators	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
#12	Energy supply efficiency, %	56	55	59	55.9	59.0	52.4	48.1	50.3	47.4	51.7	52.9	50.8	47.6
#14	Energy intensity of GDP (adjusted at PPP in USD'95	0.30	0.26	0.28	0.23	0.24	0.22	0.21	0.19	0.18	0.17	0.16	0.14	0.13
	TPES/GDP, toe/thou USD	0.46	0.51	0.42	0.43	0.40	0.43	0.43	0.38	0.38	0.34	0.31	0.27	0.27
	FEC/GDP, toe/thou USD													
#16	Energy consumption per capita	2.91	2.35	1.94	1.38	1.29	1.22	1.22	1.22	1.20	1.10	1.03	1.08	1.12
	FEC/capita, toe/capita	4.46	4.60	2.98	2.51	2.16	2.36	2.50	2.38	2.50	2.12	2.02	2.31	2.48
	TPES/capita, toe/capita													
#18	Net energy import dependence	71.65	72.74	64.7 1	59.31	68.91	58.60	54.52	56.99	55.01	58.15	58.33	52.0	
# 19	Income inequality, %							0.184	0.188	0.194	0.197	0.197	0.190	0.186
#20	1. Ratio of monthly disposable income per capita (in USD'95) of 20% poorest households to the prices of major energy sources													
	Electricity, kWh/month/capita							13.91	15.53	15.54	15.41	12.78	13.86	
	Natural gas, GJ/month/capita							0.054	0.059	0.056	0.056	0.037	0/040	
	District heat, GJ/month/capita							0.012	0.011	0.01	0.01	0.009	0/01	
	2. Ratio of monthly disposable income per capita (in USD'95) of average households to the prices of major energy sources													
	Electricity, kWh/month/capita							40.78	44.83	45.70	47.60	37.89	38.99	
	Natural gas, GJ/month/capita							0.158	0.169	0.166	0.173	0.109	0.112	
	District heat, GJ/month/capita							0.036	0.032	0.03	0.031	0.026	0.027	

Number	Indicators	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
#21	1. Fraction of disposable income per capita (in USD'95) spent on fuel by average population, %							8.16	8.35	8.37	8.74	9.19	9.42	
	2. Fraction of disposable income per capita (in USD'95) spent on fuel by 20% of poorest population, %							7.45	7.51	7.22	7.06	7.85	8.47	
#23	Quantities of SO2 and NOx emissions from power sector, kt	105	112	65	60	55	58	58	51	69	45	19.4	26.5	26.2
#26	Quantities of CO_2 emissions from power sector, Mt	47	46	28	25	24	19	19	17	20	15	11.2	8.0	9.6

6. MEXICO

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6.1. Introduction

The International Atomic Energy Agency (IAEA) issued an invitation in 2001 for countries to participate in a coordinated research project on Indicators for Sustainable Energy Development (ISED) for the period 2002-2005. In March 2002 the participation proposal submitted by Mexico's Secretariat of Energy (SENER) and the National Institute of Statistics, Geography and Informatics (INEGI) to the IAEA was approved.

This project was conducted by the IAEA with the cooperation of the United Nations Department of Economic and Social Affairs (UNDESA), the Statistical Office of the European Communities (Eurostat), the European Environmental Agency (EEA) and the International Energy Agency (IEA). Its main objective was to develop and test national energy indicators within the social, economic and environmental dimensions needed for the evaluation of current national policies, as well as for the analysis and formulation of sustainable development policies.

As part of the project work plan, participating countries had to submit a final report summarizing the results and findings of the corresponding national case studies. Participating Mexican institutions have prepared the present final report that provides a broad picture of the Mexican energy sector and its relationship with the three pillars of sustainable development. For SENER and INEGI, participation in this project represented a unique opportunity to assess data availability and the technical infrastructure for developing the ISED. For the final report, Mexico has implemented three-quarters of the indicators proposed, and has a clear idea about the information limitations/time frame for elaborating the remaining ones. More important, these indicators will provide an invaluable source of information for assessing current energy policies, and for proposing modifications, elaborations and/or implementation of new policies necessary to address gaps identified during the ISED analysis. This will be discussed in detail in a later section.

The chapter is structured in six sections: 1) an overview of the Mexican energy sector and development; 2) a review of the energy statistical data capabilities of the two national institutions involved in the ISED project, as well as a brief description of data compilation processes for the elaboration of indicators; 3) the identification of selected energy priority areas to be assessed by using the ISED system, and policy measures derived from indicator interpretation; 4) the ISED implementation process; 5) the presentation of all information on each indicator; and 6) an overview of conclusions and perspectives for future work.

6.2. Overview of the Mexican Energy Sector

6.2.1. Structure of the Mexican Energy Sector

Public enterprises of the energy sector, coordinated by the Secretariat of Energy, have a special importance in Mexico. Besides their contributions to the society in economic terms and the services they provide, they include three of the largest businesses of the country: Petróleos Mexicanos (Pemex) and subsidiary agencies, Comisión Federal de Electricidad (CFE) y Luz y Fuerza del Centro (LyFC). It must be said that Pemex is considered one of the ten largest businesses of the world in terms of assets and income.

The energy sector consists of two major subsectors: hydrocarbons and electricity. It includes other companies responsible for providing support and diverse services (Figure 6.1). The Instituto Mexicano del Petróleo (IMP), the Instituto de Investigaciones Eléctricas (IIE) and the Instituto Nacional de Investigaciones Nucleares (ININ) conduct activities in scientific research, providing innovative technological elements, so that Pemex, CFE and LyFC can enhance their competitiveness and offer better products and services. They also promote training of specialized human resources in order to support the national electric and petroleum industries.

Additionally, the activities of exploration and the services of high technological specialization carried out by Compañía Mexicana de Exploraciones, SA, have permitted Pemex to identify hydrocarbon reserves with potential for future exploitation. With regard to the enterprise III Servicios, S.A. de CV, the administrative services and real estate operations provided to Pemex have promoted an increase in the aggregate value of properties and facilitated the operating tasks of the company.

Finally, the commercialization of hydrocarbons, carried out at the international level by PMI Comercio Internacional, SA de CV, is a determinant factor for the generation of foreign exchange and of important fiscal contributions for the federal government.

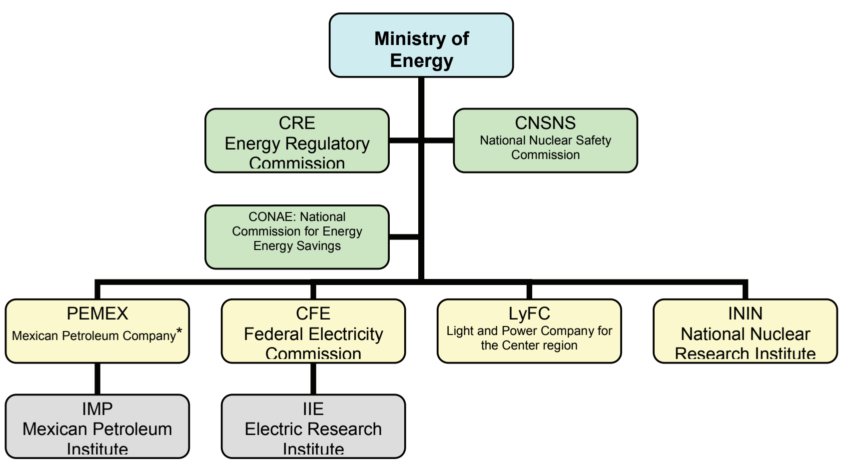

Figure 6.1 Structure of the Mexican Energy Sector
** It comprises the following four subsidiary companies: Pemex Exploration and Production, Pemex Refining, Pemex Gas and Basic Petrochemical, and Pemex Petrochemical.*
Source: Secretaría de Energía (www.energia.gob.mx)

6.2.2. Energy Sector Program 2001-2006

The most important national general plan in Mexico is the National Development Plan 2001-2006 (NDP), which specifies the country's national objectives and priorities. The three essential axes of the NDP are: social and human development, growth with quality, and order and respect.

For the energy sector, one of the specific development strategies stated by the NDP is that this "… sector should include a transparent and modern regulation that guarantees quality in service, as well as competitive prices. Therefore, it is necessary to ensure resources so that the public businesses of the sector can comply with their objectives, to facilitate competitiveness and investment and to promote the participation of Mexican companies in energy infrastructure projects. The public businesses will establish development plans for national suppliers of the goods and services that they require for their management and development"[1]

The Energy Sector Program 2001-2006 (ESP) was created following the principles established in the NDP, which is of federal jurisdiction, and is designed as a strategic tool to prompt the sustainable development of the country. It contains the background, policies, priorities, strategies, specific actions and goals of the energy sector, which serve as reference and guidance for the compliance of commitments made by the Mexican government on energy issues.

Among other strategies of the ESP, natural gas will become a primary source of energy. For power generation, the best alternative will be natural gas due to its high efficiency in combined cycle power utilities, as well as its cleaner combustion compared to petroleum or coal. In addition, the ESP established the necessity of diversifying energy sources, and considered liquefied natural gas to be an important source in the coming years for reaching that goal.

6.2.3. Overall picture of energy production and consumption

The aim of this section is to present a brief summary of Mexico's energy resources related to production and current energy consumption of hydrocarbons and electric power, both by sectors and fuels.

The development of Mexico and many other developing countries has been characterized by the predominance of hydrocarbons in the productive processes. In many countries oil does not surpass 40-50% of the primary energy productive structure, but in some Latin American countries that proportion reaches around 60-70%, Mexico included.

However, the socio-economic development pattern followed by Mexico in the last decades has in general evolved to less energy intensive consumption, with emissions showing a tendency to decrease.

6.2.4. Relevance of the energy sector in Mexico

Mexico supports a considerable extent of its social and economic development through the use of energy. The energy sector has a decisive role in the national life: it generates electricity and hydrocarbons as supplies for the economy and the provision of public utilities; it contributes 3% of the GDP (1.7% coming from hydrocarbons and 1.3% from electricity); oil represents 8% of total exports and oil-related taxes contribute 37% of the Federal Budget; and nearly 40% of public investment is directed to energy projects. Public companies in the oil and power sectors provide employment to approximately 250,000 workers.

Mexico is ranked 9th worldwide in crude oil reserves, 4th in natural gas reserves in the Americas (after the United States, Venezuela and Canada), 7th in crude oil production, and 8th in natural gas production. The national petroleum company (Pemex) is the 7th largest petroleum company by crude oil output worldwide, and one of the most profitable before taxes. In terms of electricity generation, Mexico ranks 16th worldwide, and the national electricity company (CFE) is the 6th largest power

[1] Poder Ejecutivo Federal, *Plan Nacional de Desarrollo 2001-2006*, México, 2001, p. 110.

company in the world. In terms of electricity coverage, 95% of the national population is connected to the grid, which represents one of the most comprehensive coverage ratios in Latin America.

From the environmental perspective, this sector releases 75% of the total of national inventory emissions. Mexico is one of the 13 largest producers of CO_2 emissions in the world (1.3 % of the world). The ecological depletion and degradation costs represent around 10% of total GDP.

6.2.5. Energy sector challenges

During the 2001-2006 presidential period, 120 billion dollars (20 billion per year) were required to expand and modernize Mexico's energy infrastructure; 48 billion in exploration and production, 18 billion in refining, 20 billion in natural gas, and 34 billion in electricity. Resources from the public sector are insufficient to fulfill these requirements, and thus complementary investments from the private sector are necessary.

The main challenges regarding energy are to: 1) guarantee the coverage of future energy demand derived from the economic and demographic growth of the next years, 2) transform the national energy enterprises into internationally competitive entities, and 3) maximize the profits of the energy sector for the benefit of the population in general.

According to forecasts developed in 2002, the energy demand in the following 10 years was expected to increase by 70% for electricity, by 35% for LPG, by 120% for natural gas and by 45% for liquid fuels.

6.2.6. Long term vision of the energy sector

- The population must have full access to energy at competitive prices.
- The public and private energy companies must be competitive at the international level. They must:
  - operate within an adequate legal and regulatory framework;
  - protect the environment and improve efficiency;
  - foster the efficient use of energy and promote the use of renewable energies;
  - promote R&D to maintain an energy sector updated with the most advanced available technologies.

6.2.7. Strategic Objectives of the Energy Sector

- Guarantee a reliable energy supply, according to international quality standards, and competitive prices.
- Provide adequate legislation as an instrument for the development of the energy sector.
- Enhance the participation of Mexican enterprises in energy infrastructure.
- Improve energy efficiency programs and development of renewable energies.
- Foster a safe and reliable use of nuclear energy, maintaining the highest international safety standards.
- Ensure leadership in risk prevention of the productive operations of the energy sector.
- Ensure leadership in the protection of the environment.
- Promote the development and application of advanced science and technology.
- Expand and foster international cooperation on energy matters.
- Improve the service quality of the national energy companies.

6.3. Energy Statistical Data Capability of SENER and INEGI

For several years, SENER has been elaborating a national energy balance that includes indicators on energy production and consumption nationally and by economic sectors: agriculture, industry, transport, and residential-commercial-public service.

SENER has also developed information systems for long-term analysis and research in priority areas such as energy savings/energy efficiency, local/regional and global environmental impacts, safety, and technological development. Information is collected through several networks within the energy sector that have been set in place, so information comes from groups that develop their own programs, policies, and prospective and energy balance studies. Information ranges from the more technical and specific data to the more general of public interest. Additionally, since 1990 SENER has produced several annual prospective studies for the energy sector (electricity, natural gas and liquefied petroleum gas), as well as the annual National Energy Balance.

Institutions within the energy sector -- including the Mexican Petroleum Institute (IMP), the Electric Research Institute (IIE), and the Nuclear Research Institute (ININ) -- participate in modelling efforts on energy, economy and the environment, including diverse topics such as: gas and oil supply/demand (IMP), electricity demand/supply and renewable energies (IIE), and energy efficiency and savings, emissions reductions and renewable energy regulatory frameworks through the National Commission for Energy Savings (CONAE). Additionally, the National Autonomous University of Mexico (UNAM) has modelled the electrical sector expansion, including long-term national energy supply and demand and long-term planning scenarios.

Information generated in multiple research projects must be adequately handled, processed and disseminated. Thus SENER is developing a Centre for Energy Research and Information that coordinates research networks and promotes cooperation agreements between SENER, the research institutes of the energy sector, and (eventually) other national and international institutions, research centres and multilateral agencies.

The IIE together with SENER is currently developing a geographical information system (SIGER), which will include a detailed inventory of renewable energies in the country in terms of installed capacity and resources. The system has already completed its information database for Oaxaca, one of the states with the highest wind resources in Mexico.

The National Institute of Statistics, Geography and Informatics (INEGI) is responsible for producing the Nation's basic statistical information by means of national censuses, sample surveys and administrative records. The Population and Housing Census and the Economic Census are conducted every five years and the Agriculture and Livestock Census is conducted every ten years.

Household surveys are also regularly undertaken to gather information on social, demographic and economic issues, as well as surveys of industrial, commercial and service establishments. A variety of administrative records are used extensively. These records include information on foreign trade flows and demographic events, to mention only a few.

In addition, INEGI integrates and generates derived statistics on social and economic aspects of the country, such as the System of National Accounts, which includes the quarterly Gross Domestic Product, the Integrated System of Economic and Ecological Accounts, which include an estimation of ecological depletion and degradation costs.

INEGI also generates information on the physical milieu, natural resources, infrastructure and territory. Aerial photography and satellite imagery are used and several field activities are carried out, as well as special projects of interpretation and analysis.

INEGI, together with the Secretariat of Environment and Natural Resources (SEMARNAT) and within the environmental sector's Technical Committee, develops and implements conceptual, methodological and normative infrastructure that addresses the production and integration of statistics and geographic information on natural resources, environment and sustainable development under national and international comparability criteria.

Other activities of INEGI include:

- Increasing and improving the availability and quality of natural resources, environment and sustainable development information, as well as obtaining and disseminating new environmental information on strategic areas or sectors for public administration planning and management.
- Working intra- and inter-institutionally for the conceptual and methodological development and production of environmental and sustainability indicators, in order to provide decision-makers with diagnosis and assessment reports on environmental performance according to national and international commitments.
- Producing, in collaboration with national agencies and province governments, publications on environmental statistics and indicators both at the national level and for metropolitan zones.

In summary, SENER and INEGI, having considerable experience and a sound database, have developed the ability for elaborating the proposed indicators on sustainable energy development. The joint project with IAEA contributes to creating an awareness of the need to expand the energy statistics capability, as well as to incorporate the ISED package into national databases, and improve them accordingly.

6.4. Selected Energy Priority Areas to be Assessed by using the ISED System

In order to pave the way for development towards sustainability, Mexico must account for strategic sectors with a national system of indicators. Energy and environment are clearly strategic issues, due to their complexity and the magnitude of impacts on the society at local, regional, national, and global levels.

The ISED package provides a good platform for constructing relevant indicators that allow the adoption of response actions and policy measures. In working within this framework, it has been necessary to identify the selected energy priority areas that need to be assessed through the core indicators. These will allow decision-makers to devise and analyze the driving forces, trends and impacts of current energy policies.

In light of the ten goals of the ESP, the selected national priority areas and corresponding strategies which could be assessed using the ISED system are shown in Box 6.1. Under this scheme, a total of 41 indicators proposed by the IAEA were distributed according to the main topics addressing the socio-economic and environmental dimensions related to energy. These dimensions were broken down into four categories corresponding to the list of indicators and basically keeping in mind the goals of the Mexican energy sector. Response actions and policy measures were identified for each category and targeted indicator.

Eight of the ten ESP Mexican energy sector goals were addressed by the ISED package, as shown in Box 6.1.

BOX 6.1: MEXICAN ENERGY SECTOR GOALS, RELEVANT ACTIONS AND POLICY MEASURES ON TARGETED ISED			
Energy policy issues and goals of Mexican energy sector	**ISED Core Set**	**Response Actions on Targeted Indicator**	**Policy Measures on Targeted Indicator**
I Socio-economic aspects			
Context indicators	1, 2, 4, 7, 19	Monitor macro energy-related socio-economic tendencies and assess current energy policies.	· Implement or adjust energy policies. · Link energy policies to socio-economic concerns. · Eliminate or relocate energy subsidies in order to assist poorest population segments. · Strengthen wealth distribution policies.
II Energy Supply			
Goal 1: "Guarantee a reliable energy supply, according to international quality standards, and competitive prices"	3, 11, 15, 17, 18, 22, 36, 37	Allow decision-making in energy investment, taxes, energy supply, and import policies. Establish a relationship between generation sources and fuel types (development planning and forecasts).	· Increase share of natural gas in fuel mix. · Increase the use of pollution abatement technologies to use existing national energy sources. · Increase the share of renewable sources of energy in fuel mix. · Increase private participation in the Energy Sector, including oil exploration and production.
Goal 2: "Adequate legislation as an instrument for the development of the Energy Sector"	11, 17, 18, 36, 37	Promote an increasing participation of private companies in energy infrastructure.	
Goal 3: "Enhance the participation of Mexican enterprises in energy infrastructure"	17, 18, 36, 37	Contribute to national economic growth.	. Encourage Mexican enterprises by adequate policies that give certain fiscal incentives.
Goal 4: "Improve energy efficiency programs and development of renewable energies"	22	Enhance population access to energy from renewable sources, such as mini-hydro, PV systems, etc.	· Promote sustainable development of poor population by access to (renewable and grid) energy, for households as well as for productive activities.
Goal 10: "Improve service quality of the National energy companies"	22	Increase access of population to the grid.	
III Energy Production and Consumption Patterns			
Goal 4: "Improve energy efficiency programs and development of renewable energies"	5, 6, 8, 9, 10, 12, 14, 16, 20, 21, 35, 40	Evaluate the evolution of the efficiency and energy saving policies, to establish energy supply and renewable energy policies.	· Integrate environmental concerns into energy policies. · Target existing and new energy savings and efficiency programs in the most energy intensive sector. · Optimise economic activity levels through reducing shares of energy intensive areas. · Decrease energy intensities through end-use energy efficiency improvement. · Increase efficiency of energy supply, in particular for electricity generation. · Integrate energy efficiency in sectoral policies. · Implement advanced, environmentally sound technologies with lower specific fuel consumption. · Switch to more environmentally benign fossil

BOX 6.1: MEXICAN ENERGY SECTOR GOALS, RELEVANT ACTIONS AND POLICY MEASURES ON TARGETED ISED			
			fuels, such as natural gas.
IV Environmental protection and safety policies			
Goal 7: "Leadership in the protection of the environment" *Goal 4: "Improve energy efficiency programs and development of renewable energies"* *Goal 2: "Adequate legislation as an instrument for the development of the Energy Sector"*	13, 23, 24, 25, 26, 29, 30, 33, 41	Establish a relationship between emissions and control-mitigation policies to reduce environmental impact. Use cleaner fossil fuels and renewable energy. Measure land efficiency use by energy sector.	· Include externalities in full costs of energy. · Implement legal and regulatory frameworks and enabling environment favouring energy conservation and efficiency. · Promote and increase the use of renewables. · Improve material intensities across sectors.
Goal 6: "Leadership in risk prevention of the productive operations of the energy sector"	34	Risk evaluation and control policies.	
Goal 5: "Foster a safe and reliable use of nuclear energy maintaining the highest international safety standards"	27, 28, 31, 32, 38, 39	Environmental and safety policies. Policies for radioactive waste. Uranium supply.	

Notes: Column 1: Goals 8 and 9 are not addressed because they correspond to international cooperation on energy and improving service quality, respectively. For these matters ISED framework does not provide indicators.
Column 2: Numbers are in correspondence with the 41 original ISED list.
Column 3: Indicates potential and/or concrete response actions on the targeted indicators.
Column 4: Presents more specific policies to follow the issues represented by the ISED.
Source: Adapted from Secretariat de Energía. *Programa sectorial de energía, 2001-2006*, México, 2001, and International Atomic Energy Agency / International Energy Agency. *Indicators for Sustainable Energy Development: A Collaborative Project*, Vienna, 2001.

6.5. ISED implementation

SENER and INEGI have designed a matrix (Box 6.2) for presenting and assessing the results of the indicators implementation process (i.e., information on the state of each indicator; indicator availability; data availability and/or conceptual difficulty; elaboration feasibility; as well as information sources and institution responsible for its development).

Based on the selected energy priority areas mentioned above, the review of energy statistical data capabilities, as well as the analysis and adequacy of methodological sheets for the ISED framework, SENER and INEGI have already constructed an important number of indicators and consider that there is an enormous potential for developing the remaining ones.

According to this assessment, from a total of 41 proposed indicators (ISED package), 33 are now developed in correspondence with the proposed definition (number 7 was an exception, for which an alternative indicator was constructed). Five indicators would be feasible in the medium term (numbers 10, 25, 30, 33, and 41); and the other three might be feasible in the long term (numbers 12, 13, and 39). (See Box 6.2).

The results and information for all indicators are presented according to a thematic structure of four categories, which synthesizes the energy-related environment scope and allows the grouping of indicators in the following manner:

a) *Socio-economic:* a total of five proposed indicators, all fully developed.

b) *Energy Supply:* a total of eight proposed indicators, all fully developed.

c) *Energy Production and Consumption Patterns:* a total of twelve proposed indicators, ten of them developed.

d) *Environmental protection and safety policies:* a total of sixteen proposed indicators, ten of which have been developed.

For some indicators, which have not yet been elaborated, Box 6.2 also provides some explanations about data availability or feasibility of constructing such indicators.

BOX 6.2: ISED FOR MEXICO: ASSESSMENT OF FEATURES AND WORK PROCESS FOR EACH INDICATOR					
No.	IAEA Indicators List[1]	Not available	Data availability and/or conceptual difficulty	Elaborated/ Feasibility	Responsible Institution
1	Population: Total and percentage in urban areas 1950-2000			Elaborated	INEGI
2	Gross domestic product (GDP) per capita			Elaborated	INEGI
3	End-use energy prices with and without tax/subsidy			Elaborated	SENER
4	Shares of sectors in GDP value added			Elaborated	INEGI
5	Distance travelled: Total and by urban transport			Elaborated	SCT, INEGI, CITY GOVERNMENTS
6	Freight transport activity: Total, by mode			Elaborated	SCT, INEGI
7	Floor area per capita (Housing and occupation characteristics - alternative indicator-) 1950-2000			Elaborated	INEGI-SENER
8	Manufacturing value added by selected energy intensive industries			Elaborated	INEGI, SENER
9.1	Energy intensity in Manufacturing			Elaborated	SENER-INEGI
9.2	Energy intensity in Agriculture			Elaborated	SENER-INEGI
9.3	Energy intensity in Commercial and service sector			Elaborated	SENER-INEGI
9.4	Energy intensity in Transportation			Elaborated	SENER-INEGI
9.5	Energy intensity in Residential sector			Elaborated	SENER-INEGI
10	Energy intensity of selected energy intensive products	X	Need to define intensive products more precisely; data not sufficient.	Medium	SENER
11	Energy mix			Elaborated	SENER and others
12	Energy supply efficiency	X	Data not sufficient; it requires estimation exercise.	Long	CFE, LyFC, PEMEX
13	Status of deployment of pollution abatement technologies	X	Data not sufficient; it requires estimation exercise.	Long	SENER, CFE, PEMEX, LyFC
14	Energy use per unit of GDP			Elaborated	SENER-INEGI
15	Expenditure on energy sector			Elaborated	PEMEX, CFE, LyFC, INEGI
16	Energy consumption per capita			Elaborated	SENER, INEGI
17	Indigenous energy production			Elaborated	SENER
18	Energy net import dependency			Elaborated	SENER
19	Income inequality			Elaborated	INEGI
20	Ratio of daily disposable income/ private consumption per capita of 20% poorest population to the prices of electricity and major household			Elaborated	INEGI

BOX 6.2: ISED FOR MEXICO: ASSESSMENT OF FEATURES AND WORK PROCESS FOR EACH INDICATOR					
No.	IAEA Indicators List[1]	Not available	Data availability and/or conceptual difficulty	Elaborated/ Feasibility	Responsible Institution
	fuels				
21	Fraction of disposable income/ private consumption spent on fuel and electricity			Elaborated	INEGI
22	Fraction of households heavily dependent on non-commercial energy and without electricity			Elaborated	INEGI
23	Quantities of air pollutant emissions			Elaborated	SENER (CFE)
24	Ambient concentration of pollutants in urban areas			Elaborated	SEMARNAT
25	Land area where the acidification exceeds critical load	X	There is no information on acidified land area caused by air pollution (acid rain). The available data corresponds to general specifications of the acid rain and to the natural acidification of soil.	Medium	SEMARNAT
26	Quantities of greenhouse gases emissions			Elaborated	SEMARNAT
27	Radionuclides in atmospheric radioactive discharges			Elaborated	CNSNS, ININ, CFE
28.1	Discharges into water basins: Oil into coastal waters			Elaborated	CNSNS, ININ, CFE
28.2	Discharges into water basin: Radionuclides in liquid radioactive discharges			Elaborated	CNSNS, ININ, CFE
29	Generation of solid wastes			Elaborated	PEMEX, CFE, LyFC
30	Accumulated quantity of solid waste to be managed	X	According to the General Law for Prevention and Integral Management of Residues, the control and handling of residues generated inside the country, including waste related to energy, corresponds to the Secretary of Environment and Natural Resources. Aggregated data is available at national level but not by source.	Medium	PEMEX, CFE, LyFC
31	Generation of radioactive waste from nuclear power fuel cycle chain			Elaborated	CNSNS, ININ, CFE
32	Accumulated quantity of radioactive waste awaiting disposal			Elaborated	CNSNS, ININ,
33	Land area taken up by energy facilities/infrastructure	X	There are only available data on linear kilometres of pipelines and electrical lines. Land area taken up by energy facilities is not available.	Medium	PEMEX, CFE, LyFC
34	Fatalities due to accidents with breakdown by fuel chain			Elaborated	SENER, PEMEX
35	Fraction of technically exploitable capability of hydro power currently not in use			Elaborated	SENER (CFE)
36	Proven recoverable fossil fuel reserves			Elaborated	SENER
37	Lifetime of proven fossil fuel reserves			Elaborated	PEMEX
38	Proved uranium reserves			Elaborated	CNSNS, ININ, CFE
39	Lifetime of proved uranium reserves	X	Because no exploitation has occurred in Mexico for over a decade, it is not	Long	CNSNS,

BOX 6.2: ISED FOR MEXICO: ASSESSMENT OF FEATURES AND WORK PROCESS FOR EACH INDICATOR					
No.	IAEA Indicators List[1]	Not available	Data availability and/or conceptual difficulty	Elaborated/ Feasibility	Responsible Institution
			possible to calculate the lifetime.		ININ, CFE
40	Intensity of use of forest resources as fuelwood			Elaborated	SENER
41	Rate of deforestation	X	The available information does not consider specific data of the forest area that has changed as a result of the wood extracted to be used as fuelwood. This practice, considered minimal, does not substantially affect the deforestation phenomenon.	Medium	PEMEX, CFE, LyFC, SEMARNAT

Medium: Medium term feasibility.
Long: Long term feasibility.
[1] IAEA, "Methodology Sheets for Elaborating Indicators of Sustainable Energy Development", Workshop on Indicators for Sustainable Energy Development Project, International Centre for Theoretical Physics (ICTP), May 13 - 17, 2002, Trieste, Italy.
Source: SENER and INEGI.

6.6. Information on Indicators

All of the indicators elaborated by Mexico have been constructed using the conceptual framework and the methodology sheet of the IAEA's Indicators for Sustainable Energy Development project, which was presented and discussed in the first Workshop carried out in the International Centre for Theoretical Physics (Trieste, Italy, 2002).

The statistical information for the 33 indicators implemented is presented in four basic areas of the energy sector: 1) Socio-economic, 2) Energy Supply, 3) Energy Production and Consumption Patterns, and 4) Environmental Protection and Safety Policies.

6.6.1. Socio-economic Indicators

The socio-economic indicators developed in this study are:

- 1. Population: Total and percentage in urban areas, 1950-2000
- 2. Gross domestic product (GDP) per capita
- 4. Shares of sectors in GDP value added
- 7. Housings and occupation
- 7. Housings and occupation characteristics, 1950-2000
- 19. Income inequality

6.6.1.1. INDICATOR 1

Population: Total and percentage in urban areas, 1950-2000 (%)

Definition: The whole number of people or inhabitants in a country or region; and the ratio of population living in defined urban areas to total country population.

Purpose: The indicator is a basic socio-economic indicator and measures the size of population in a country or region. Knowing the size of a country's population, its changing rate, and share of urban population is important for evaluating the welfare of the country's citizens, assessing the productive capacity of its economy, and estimating the quantity of goods and services produced per each inhabitant. Thus governments, businesses, and anyone interested in analyzing economic performance

must have accurate population estimates; and in particular its share in urban areas, which measures the size of formal and informal urban settlements by their population.

TABLE 6.1 POPULATION: TOTAL AND PERCENTAGE IN URBAN AREAS, 1950-2000

	Population					Growth Rate (%)			
	1950	1970	1990	1995	2000	1950-70	1970-90	1990-95	1995-2000
Total Population (Thousands of inhabitants)	25,779	49,050	81,249	91,158	97,483	3.3	2.5	2	1.6
Semi-urban Population (Cities with 2,500 to 14,999 inhabitants)	3,940	7,407	11,284	12,370	13,341	3.2	2.1	1.6	1.8
Urban Population (Cities with more than 15,000 inhabitants)	7,209	22,004	46,675	54,633	59,419	5.7	3.7	2.8	2

Source: For 1950 and 1970, Luis Unikel, El desarrollo urbano de México: Diagnóstico e implicaciones futuras, México, 1976; for 1990 and 1995, INEGI, XI Censo General de Población y Vivienda 1990, Conteo de Población y Vivienda 1995, México, 1996. INEGI, XII Censo General de Población y Vivienda 2000, México 2001.

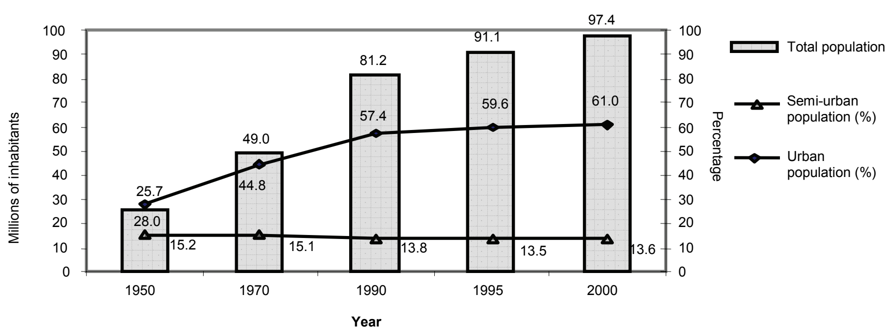

Figure 6.2 Population: total and percentage in urban areas, 1950-2000

Trends: The total population of Mexico increased during the 1950-1970 period at an annual growth rate of 3.3%, and slowed down in the past 32 years to reach an annual growth rate of 1.6% between 1995 and 2000. In 1950, the semi-urban and urban population of Mexico represented 43.2% of the total, while by 2000 it accounted for more than 64% of total population. The percentage of urban population has grown steadily between 1950 and 1990, but importantly slowed down over the last decade. On the other hand, the percentage of the semi-urban population decreased slightly between 1970 and 1990, remaining almost constant for the next 10 years. Statistics show that immigration has preferentially occurred from rural areas to large cities. For instance, the total population of Mexico City's Metropolitan Area was 2.95 million inhabitants in 1950, and by the year 2000 it reached 17.8 million. Official estimates project that Mexico City will reach a population of 20.3 million by 2010, according the Consejo Nacional de Población.

Indicator construction and limitations: The indicator provides only a general scope and some implications for the environment if the current tendency of population growth patterns continues, which is concentrating in the largest and middle size cities. In general, it provides some signals about the demographic tendencies and pressures on the environment.

A limitation of the indicator is that it is not directly tied to environmental impacts. Data should be updated more frequently in order to present a general comparison with data on natural and environmental performance.

6.6.1.2. INDICATOR 2

Gross domestic product (GDP) per capita (USD of the base 1990 year per capita)

Definition: Levels of GDP per capita are obtained by dividing annual or period GDP both at current market prices and/or prices based on purchasing power parity by population. A variation of the indicator could be the growth of real GDP per capita which is derived by computing the annual or period growth rate of GDP in constant basic producers' or purchasers' prices divided by corresponding population.

Purpose: The indicator is a basic economic growth indicator and measures the level and extent of total economic output. It reflects changes in total production of goods and services.

TABLE 6.2 GDP PER CAPITA 1980-2004

Year	GDP per capita. constant prices (1993-MEX)	GDP per capita constant prices 1993-USD
1980	13,614.83	4,371.15
1981	14,458.43	4,642.00
1982	14,118.89	4,532.98
1983	13,227.56	4,246.82
1984	13,410.54	4,305.56
1985	13,470.58	4,324.84
1986	12,709.29	4,080.42
1987	12,670.52	4,067.97
1988	12,579.26	4,038.67
1989	12,851.40	4,126.05
1990	13,242.58	4,251.64
1991	13,536.18	4,345.90
1992	13,767.18	4,420.07
1993	14,282.48	4,585.51
1994	14,647.94	4,702.84
1995	13,501.47	4,334.76
1996	13,981.59	4,488.90
1997	14,714.95	4,724.36
1998	15,241.71	4,893.48
1999	15,575.25	5,000.56
2000	16,439.13	5,277.92
2001	16,089.09	5,165.53
2002	15,969.02	5,126.99
2003	15,962.57	5,124.91
2004	16,271.80	5,224.20

Source: International Monetary Fund, World Economic Outlook Database, September 2003.
OCDE. 2004. Purchasing Power Parities (PPP) Statistics.

Trends: Measured in 1993 market prices, Mexico's GDP per capita has grown 19.5% in the period 1980-2000 and dropped four times (1982-83, 1986-88, 1994-95 and 2000-2003). Three of these episodes coincide with the end of presidential terms, where economic crises due to political instability have had a negative effect on the economy. It is important to mention that even though an increase of GDP per capita is observed, the wealth distribution has not improved (as will be observed later). Thus wealth distribution policies, access to energy, education, services and jobs must all be improved.

Indicator construction and limitations: Construction of this indicator was accomplished with IMF/OECD information in order to maintain consistency of data and international comparability.

6.6.1.3. INDICATOR 4

Shares of sectors in GDP value added (%)

Definition: This indicator measures the contribution of the various economic sectors to total production. It is obtained by dividing the value added in a specific sector by the total GDP value-added at constant 1990 prices.

Purpose: The relative size of sectors is a significant indicator of the state of the economy. The relative size of manufacturing also hints at basic driving forces associated with sustainable development.

TABLE 6.3 SHARES OF SECTORS IN GDP[a] (1988-2002)

Year	Agriculture[b]	Manufacturing[c]	Commerce and Services[d]	Transportation[e]
1988	8.1	19.8	56.3	9.2
1989	7.8	20.5	56.1	9.2
1990	7.8	20.8	55.8	9.1
1991	7.7	20.6	56.3	9.0
1992	7.4	20.7	56.3	9.2
1993	7.4	20.2	56.7	9.4
1994	7.1	20.1	56.6	9.7
1995	7.8	20.4	56.3	9.9
1996	7.7	21.5	54.7	10.1
1997	7.2	22.1	54.3	10.4
1998	7.0	22.6	54.0	10.6
1999	6.9	22.8	53.6	11.0
2000	6.5	22.8	53.8	11.3
2001	6.9	22.0	54.2	11.7
2002	6.8	21.7	54.6	11.9

[a] GDP at 1990 prices and purchasing power parity.
[b-e] International Standard Industrial Classification (ISIC) revision 3.
Source: INEGI. Sistema de Cuentas Nacionales de México (SCNM), 1988-1999 y 1996-2002. Aguascalientes, México 2000 y 2003.

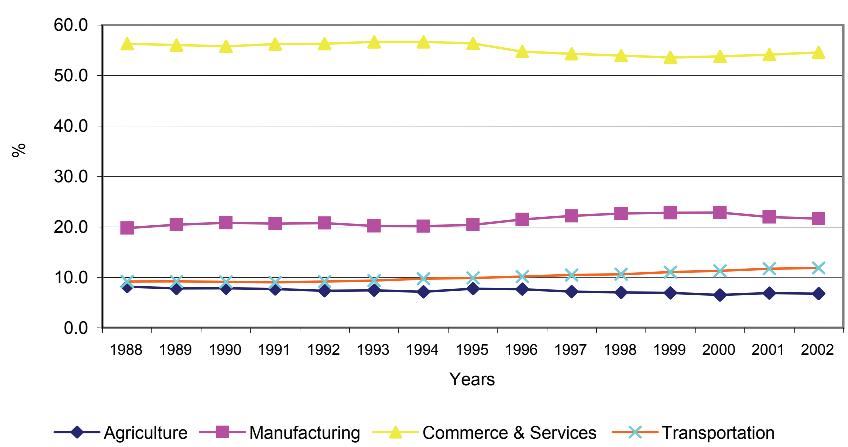

Figure 6.3 Shares of sectors in GDP at PPP, 1988-2002

Trends: In the 1980s, Mexico started an economic policy of openness towards international trading directed to displace the existing mono-export model based on hydrocarbons. The objective was to try to diversify the national productive base, and was accompanied by a strategy of deregulating the decentralized entities (including those of the energy sector) of the economy and the governmental system. Mexico's economic and social development in the years to come will have to rely on sectors and industries of greater dynamism in international trade, a trend that was strengthened in 1994 with the signing of the North American Free Trade Agreement.

A consequence of this scheme of commercial openness has been the greater interrelation of the Mexican economy with that of the United States, which has implied, among other things, the reduction of agricultural subsidies, the insertion of foreign industries in activities basically directed towards exports, a growing flow of commodities and persons (fundamentally to the United States), and in general greater competition between national and northern (i.e., foreign) firms.

In this context, during the 1988-2002 period, the Commerce and Service sector has maintained a share higher than 50%, followed by Manufacturing (which accounts for around 21%), Transportation (with approximately 10.5%) and, in last place, Agriculture (with 6.8 per cent).

Taking the sectoral structure as a whole, Transportation increased its share, from 9.2% in 1988 to 11.9% in 2002; on the contrary, Agriculture displays an almost steady decrease, passing from 8.1% to 6.8%. The remainder of the sectors has shown erratic performances.

In the future, the trends in the Mexican economy point to a greater diversification of its productive base regarding international markets.

Indicator construction and limitations: The historical series could only be constructed from 1988, since the methodology used by INEGI is similar to the one shown until 2002. That is, before 1988 the data published by the Institute does not exist with the required detail for this indicator (by sector).

This construction included only the categories and sectors noted in the methodology sheet (ISED Methodology Sheet).

For the manufacturing sector, divisions 15 to 37 were included, in order to visualize the sector as a whole.

For the conversion to the purchase parity power (PPP), numbers for basic values in current prices were taken and turned into 1990 constant prices, since the official numbers are in 1993 constant prices.

The official numbers of the commerce and services sector presented for this indicator do not include the participation of the informal sector in the economy. This is an important component that, in agreement with official estimations of the INEGI in the matter, represents about 10% of the national GDP.

6.6.1.4. INDICATOR 7

Housing and occupation characteristics, 1950-2000 (sq. m per person)

Definition: Defined as the median usable living space per person.

Purpose: This is a key indicator of housing quality, which measures the adequacy of living space in dwellings. A low value for the indicator is a sign of overcrowding.

TABLE 6.4 HOUSING AND OCCUPATION CHARACTERISTICS, 1950-2000

	1950	1960	1970	1990	1995	2000
Housings (millions)1	5.3	6.4	8.3	16.2	19.4	21.9
Occupants (millions)	25.8	34.9	48.2	80.9	90.9	97
Average occupants per housing	4.9	5.4	5.8	5	4.7	4.4
Average occupants per room2	NA	2.9	2.5	1.9	1.6	1.6
Average occupants per bedroom	NA	NA	NA	2.7	2.3	2.2

NA: Not available.
[1] For 1990, 1995 and 2000, information is of particular housings.
[2] Kitchen room is not considered as bedroom in dwellings.
Source: INEGI, Indicadores sociodemográficos de México, 1930-2000, México, 2001.

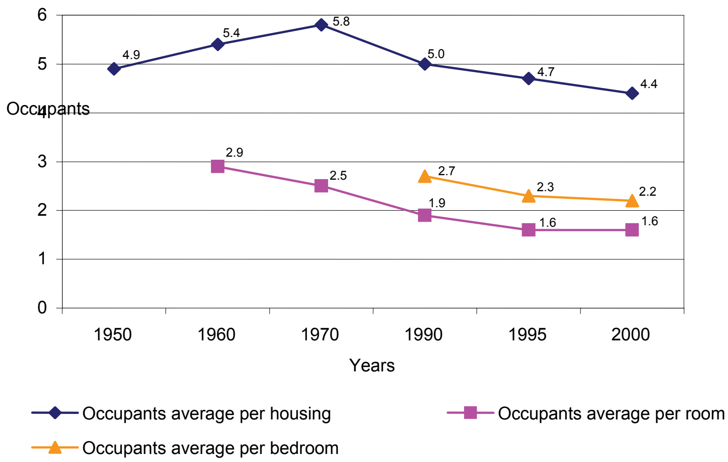

Figure 6.4 Housings and occupation characteristics, 1950-2000

Trend: This is an alternative indicator to the one proposed by the methodology sheet. It shows that there is a general tendency for the average occupants per housing, room and bedroom to drop between 1960 and 2000. In turn, the population growth rate also diminished between 1970 and 2000 (see indicator # 1) from 2.5% (1970-1990) to 1.6% (1995-2000), while the number of houses grew more than 180% between 1970 and 2000.

Indicator construction and limitations: The data in which this indicator is based was only updated to the year 2000, since the last National Census was done in that year.

6.6.1.5. INDICATOR 19

Income inequality

Definition: Ratio of disposable income (after allowing for taxes and social security transfers) or private consumption in terms of individual (per capita) available to the groups of poorest 20% and richest 20% of the population.

Purpose: This indicator provides a measure of income or resources inequality within a population highlighting the picture of how levels of economic welfare are evolving in a society.

TABLE 6.5 NATIONAL INCOME DISTRIBUTION, 1996-2002

Year	Poorest 20% households[1]	Richest 20% households[2]
1996	3.8	55.28
1998	3.14	56.61
2000	3.51	56.51
2002	3.69	53.86

1 Referred to 20% of households (stratums I y II) with least quarterly monetary current income.
2 Referred to 20% of households (stratums IX y X) with highest quarterly monetary current income.
Source: Encuesta Nacional de Ingreso-Gasto de los Hogares (ENIGH), 1996, 1998, 2000, 2002. Aguascalientes, México 1998, 2000, 2001, 2003.

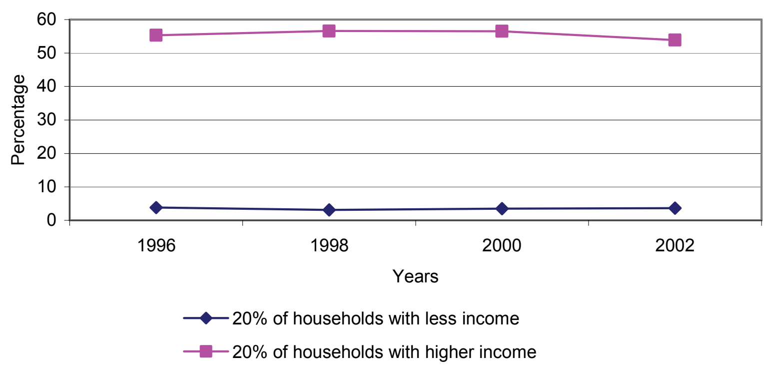

Figure 6.5 National income distribution, 1996-2002

Trends: In the last two decades, governmental policies successfully accomplished macroeconomic stability, moderating public investment, containing inflation and adjusting wage rises.

These policies resulted in restricted purchasing power and led to an increase in the social strata with lower income.

In the period 1989-2002, the 20% of the population in households with the least income absorbed between 3.14% and 3.85% of the national income, whereas the 20% with the highest income obtained between 51.26% and 57.54%. Except during 1984, in all other years the difference between these groups of households was always above 50%, reaching in 1994 the highest value, 54.26 percent.

The greatest distance (or inequality) in income between these two groups occurred in 1998: the quintile of population with the highest purchasing power received 18 times more income than the poorest quintile, a proportion that was reduced to 14.6 times in 2002.

Indicator construction and limitations: For this indicator, the principal source provides, among other advantages, stability and conceptual and methodological coherence over time. The National Income-Expenditure in Households Survey (ENIGH) groups the distribution of population by household according to their income.

The deciles I and II contain the 20% of the population with the lowest income (i.e., it is assumed that these deciles represent the poorest segment), while deciles IX and X contain to the richest 20 percent.

More detailed studies (i.e., those considering well-being levels or the poverty line) were not considered, since they are not available for the levels needed by this indicator. For the calculation of this indicator, the current monetary quarterly household income (which corresponds to the deciles mentioned above and defined by INEGI) was taken, since it is the most recommended and suitable source to establish income concentration.

6.6.2. Energy Supply Indicators

This section groups eight indicators covering different aspects of the energy supply sector. They should show the extent to which secure, diverse and sustainable supplies of energy to consumers at competitive prices are ensured. The trends shown by these indicators might address measures and policies on important energy development fields, such as: energy efficiency, conservation, intensity, and environmental problems.

6.6.2.1. INDICATOR 3

End-use energy prices with and without tax/subsidy (USD in PPP/Toe)

Definition: Actual prices paid for energy by final consumers.

Purpose: This indicator reflects the extent to which energy becomes more or less expensive over time. In the developed world this should measure the disincentive to increase consumption, but for the developing world it would be a measure of affordability of energy, on the one hand, and of incentive for energy conservation and efficiency improvement, on the other.

Consumption of fossil fuels is a major contributor to global warming and air pollution. Fossil fuel resources should also be conserved to support long-term development. Energy prices can be regulated to internalize environmental and social costs, to manage demand, and to encourage development of alternative renewable energy sources.

For developing countries there is a need to increase energy availability and affordability, in particular for the lower income groups of the population, so as to improve social and economic development. At the same time, the energy use practices in the developing countries are generally less efficient and often wasteful. Appropriate pricing mechanisms may be used to overcome these deficiencies.

TABLE 6.6 END-USE ELECTRICITY PRICES (USD/KWH)

Year	Industrial	Agricultural	Residential	Public service
1980	0.045497097	0.023945840	0.064653769	0.044898451
1981	0.046776541	0.023945840	0.068085854	0.044697583
1982	0.043828379	0.007533003	0.060606430	0.038349832
1983	0.039204054	0.003733719	0.050405212	0.033603475
1984	0.059771394	0.013634208	0.073283868	0.056241108
1985	0.061265050	0.015075693	0.069444415	0.058298025
1986	0.076303386	0.015817843	0.085510787	0.076020082
1987	0.071467925	0.014212601	0.066102769	0.073087594
1988	0.083133310	0.023134573	0.075365803	0.090480951
1989	0.087357498	0.019382176	0.071693395	0.108271657
1990	0.082988415	0.021192522	0.078098863	0.126190616
1991	0.091496079	0.039974584	0.093840630	0.142138368
1992	0.092032961	0.051813090	0.101519274	0.155973856
1993	0.086817268	0.061389063	0.099107811	0.157965316
1994	0.078181335	0.058929239	0.098777245	0.155854699
1995	0.068123929	0.046028943	0.067323096	0.142007457
1996	0.074036756	0.044677812	0.084959775	0.146608230
1997	0.082333537	0.045170691	0.086222404	0.150722378
1998	0.077823411	0.045576810	0.088209277	0.166234355
1999	0.078048597	0.045689581	0.087403068	0.168078727
2000	0.084894380	0.046391873	0.090380877	0.170573006
2001	0.084422411	0.049003166	0.095081190	0.177626504

Source: SENER.2003. Statistical Compendium of the Energy Sector.

TABLE 6.7 END-USE ENERGY PRICES OF VARIOUS FUELS

Year	LPG Residential use USD/L	Motor LPG USD/L	Residential NG USD/m3	Industrial rest of the country NG USD PPP/m^3	Industrial Border Zones NG USD/m^3
1980	0.05986460	0.05986460	0.05986460		
1981	0.10394787	0.10394787	0.05197393	0.05197393	0.05197393
1982	0.13696368	0.13696368	0.03424092	0.06848184	0.06848184
1983	0.11201158	0.11201158	0.11201158	0.11201158	0.11201158
1984	0.08521380	0.08521380	0.15825419	0.15825419	0.15825419
1985	0.12830377	0.22453160	0.24858855	0.24858855	0.24858855
1986	0.26913942	0.56660930	0.23608721		
1987	0.36442568	0.77136769			
1988	0.18893935	0.39992161			
1989	0.16618583	0.32806633			
1990	0.16054361	0.26594399			
1991	0.14125915	0.26669259			
1992	0.16981025	0.37473558	0.18605752	0.15199065	0.15199065
1993	0.21349313	0.38438557	0.26931473	0.13171939	0.13171939
1994	0.24567318	0.38005456	0.26414485	0.12098942	0.10436492
1995	0.25841287	0.47170604	0.32404154	0.18218791	0.16065351
1996	0.34900380	0.47688305	0.42093588	0.31490266	0.22991624
1997	0.39647100	0.39647100	0.30603971	0.19029687	0.18408404
1998	0.36501779	0.36501779		0.17424054	0.17262720
1999	0.40328951	0.40328951		0.14360089	0.14661846

TABLE 6.8 END-USE ENERGY PRICES OF VARIOUS FUELS

Year	86 Octane Unleaded Fuel Border Zones USD /L	86 Octane Unleaded fuel rest of the country USD/L	93 octane unleaded fuel US-Mex border USD/L	93 octane unleaded fuel Rest of the country USD/L	Jet Fuel Mexico City USD/L
1980	0.41905221	0.41905221	-	-	0.35918761
1981	0.51973934	0.59864601	-	-	0.36381754
1982	1.02722762	1.02722762	-	-	0.68481841
1983	0.76541246	1.40387775	-	-	0.80274965
1984	0.65736358	0.65736358	-	-	0.63301678
1985	0.84199349	1.27820695	-	-	0.32877841
1986	0.84991395	0.84991395	-	-	0.42495698
1987	1.16008841	2.70555942	-	-	0.53651558
1988	0.60145692	0.60145692	-	-	0.28655801
1989	0.53213909	0.64869175	-	-	0.34442660
1990	0.69801571	0.69801571	-	-	0.45929434
1991	0.52283471	0.87251964	-	-	0.28310445
1992	0.53563603	0.63940896	-	-	0.26257696
1993	0.48623550	0.68657847	-	-	0.25070753
1994	0.52182461	0.62341878	-	-	0.24382601
1995	0.73148617	1.03441339	-	-	0.39103747
1996	0.73530571	0.76727552	0.80990194	0.80990194	0.44970871

1997	0.74784141	0.90314723	0.82837817	0.82837817	0.30557950
1998	0.82078587	0.85708598	0.90346946	0.90346946	0.21659067
1999	0.81296917	0.96598632	0.89462109	0.89462109	0.39228425
2000	0.81497043	0.85216154	0.91360772	0.91360772	0.38969816
2001	0.84000063	0.90713970	0.94167668	0.94167668	0.24402253
2002	0.82418046	0.86130570	0.92367612	0.92367612	0.37719250

Trends: In general, prices for all fuels have increased between 1980 and 2001. Differences in electricity prices are due to subsidies; agricultural tariffs have the highest ones, while public services (e.g. municipalities) and general services receive the lowest subsidies. In the case of municipalities, different options are being considered (such as self supply schemes) to prevent increases in existing debt. For companies providing services, the promotion of energy efficiency programs is an important option.

Heavy taxation is applied to fuels in Mexico, which makes them an important source of income for the government. In the case of some fuels, prices in the northern and southern border regions differ from prices in the rest of the country (e.g. 86 octane gasoline). That policy is designed to prevent Mexican nationals from crossing into the U.S. or Central America in search of cheaper gasoline. Data on domestic NG stopped being reported in 1998 because private companies began its distribution at that time.

In terms of price increases (especially of gasoline), another important factor has also played a key role—the improvement of quality. In fact, there are plans regarding further improvements in order to comply with national and international regulations and market demands.

Indicator construction and limitations: Complications regarding data management for this indicator include: changes in price calculation methodologies for some fuels (e.g., LPG); privatization in distribution (i.e., domestic NG); improvement/changes in fuel quality, such as the disappearance of leaded gasoline; initiation of production and distribution in 1996 of high octane gasoline; and differentiated prices in border zones vs. rest of the country.

6.6.2.2. INDICATOR 11

Energy mix

Definition: The structure of energy supply in terms of shares of energy sources in final energy consumption, primary energy supply, and electricity generation.

Purpose: This indicator measures the structure of energy consumption, the proportion of energy mix between fossil fuels, renewables, and nuclear energy sources. Regarding the economic dimension, energy supply mix is a key determinant of energy security. This implies that the "right energy mix" relies on a well-diversified portfolio of domestic, or imported, or regionally traded fuels and sources of energy. Also, the energy supply mix has a major effect on environmental performance because the environmental impact of each energy source differs greatly.

TABLE 6.9 ENERGY CONSUMPTION BY SECTORS (PJ) 1965-2002

Year	Agriculture	Transportation	Residential, Commercial and Public	Industrial	Energy sector
1965	41.27	275.11	302.89	326.36	401.27
1966	42.97	297.43	312.97	360.82	433.86
1967	43.88	323.85	320.13	390.55	400.14
1968	45.93	356.54	331.02	410.63	453.00
1969	47.28	381.94	339.10	456.58	555.83
1970	48.67	409.75	351.02	475.23	514.35
1971	47.91	431.86	358.49	486.78	532.90
1972	51.61	480.96	373.87	526.49	635.28

1973	53.94	525.15	389.29	566.18	751.16
1974	61.58	576.76	396.79	618.90	767.27
1975	70.08	613.59	430.99	661.15	747.15
1976	73.11	669.57	448.39	711.61	782.19
1977	76.39	711.28	455.65	712.03	923.14
1978	81.38	773.47	475.81	816.84	1,039.80
1979	88.27	876.03	495.37	874.41	1,194.28
1980	95.80	981.51	542.73	890.00	1,447.07
1981	98.40	1,091.16	560.37	982.23	1,459.89
1982	104.70	1,085.71	593.58	1,025.73	1,719.99
1983	90.46	975.23	588.07	1,074.61	1,510.85
1984	90.06	1,029.30	604.29	1,036.27	1,512.33
1985	92.38	1,040.42	622.11	1,089.83	1,498.19
1986	91.8	1,033.92	624.34	989.85	1,475.37
1987	98.33	1,059.71	643.08	1,068.22	1,551.95
1988	102.79	1,072.33	651.81	1,021.22	1,607.85
1989	96.21	1,183.66	665.05	1,031.13	1,740.70
1990	92.58	1,275.31	702.60	1,100.46	1,626.04
1991	93.87	1,360.49	726.10	1,120.66	1,670.45
1992	91.21	1,372.60	769.45	1,117.07	1,671.97
1993	92.56	1,403.33	795.89	1,139.23	1,644.71
1994	91.05	1,471.73	823.03	1,203.92	1,669.17
1995	93.54	1,399.08	816.35	1,255.45	1,647.24
1996	101.4	1,418.83	838.02	1,282.54	1,869.69
1997	106.92	1,478.14	841.22	1,288.47	1,987.51
1998	106.56	1,527.26	869.44	1,320.65	2,034.83
1999	116.88	1,548.04	803.30	1,242.10	2,206.86
2000	115.52	1,614.33	833.58	1,274.03	2,359.14
2001	110.33	1,611.12	838.63	1,206.46	2, 978.60
2002	106.41	1,634.32	850.00	1,238.16	2,225.75

TABLE 6.10 FUEL CONSUMPTION FOR ELECTRICITY GENERATION (PJ)

Year	Natural gas	Heavy fuel oil	Diesel	Coal
1965	48.53	31.09	3.95	0.16
1966	48.95	31.17	4.41	0.18
1967	52.28	37.34	4.12	0.62
1968	52.81	49.92	3.99	1.50
1969	58.87	61.63	8.47	1.98
1970	58.52	80.71	10.37	2.21
1971	69.67	107.98	7.82	1.63
1972	66.70	130.51	11.77	2.27
1973	67.27	147.75	17.76	2.10
1974	62.62	176.32	27.09	2.27
1975	88.34	192.77	49.81	1.98
1976	71.87	227.42	44.97	2.21
1977	69.10	254.56	35.10	2.21
1978	91.42	301.97	46.56	0.00
1979	128.01	297.36	47.18	0.00
1980	118.80	363.80	45.83	0.00
1981	107.36	355.46	44.24	0.15
1982	118.25	407.03	33.36	11.96

1983	97.45	463.33	12.62	23.86
1984	78.14	497.96	16.27	30.90
1985	81.93	515.96	10.69	37.29
1986	106.68	551.53	8.94	61.50
1987	115.11	604.47	13.17	70.42
1988	107.07	634.67	7.67	77.15
1989	113.04	668.21	12.02	78.13
1990	143.70	659.38	15.61	76.05
1991	168.89	665.75	17.20	78.47
1992	156.62	656.44	12.31	81.39
1993	153.37	665.61	11.73	103.30
1994	180.06	794.10	13.30	128.26
1995	185.38	696.54	10.45	140.12
1996	191.37	718.91	9.53	170.54
1997	207.93	823.13	13.27	171.55
1998	246.21	903.74	19.36	176.11
1999	272.97	887.53	17.54	178.69
2000	333.38	954.59	25.15	183.06
2001	400.38	915.19	18.57	226.99
2002	529.03	787.56	15.18	264.10
2003	611.66	677.95	29.59	307.98

Source: SENER. 2003. National Energy Balance.

TABLE 6.11 PRIMARY ENERGY SUPPLY (PJ)

Year	Total	Coal	Crude oil	Condensates	Non associated gas	Associated gas	Hydro power	Geo thermal power	Nuclear	Cane bagasse	Wood	Wind
1965	1,483.98	28.88	679.53	0.12	397.16	33.35	118.97	0.0	0.0	46.46	179.51	0.0
1966	1,580.98	30.81	733.15	0.52	409.89	38.74	135.84	0.0	0.0	49.70	182.33	0.0
1967	1,635.20	37.80	799.52	0.53	364.48	45.12	144.66	0.0	0.0	57.90	185.20	0.0
1968	1,741.49	39.62	852.83	0.45	377.78	51.63	176.43	0.0	0.0	54.64	188.12	0.0
1969	1,895.21	40.17	895.90	0.86	468.10	61.77	178.44	0.0	0.0	58.88	191.10	0.0
1970	1,965.55	45.05	945.05	0.25	453.65	71.75	200.23	0.0	0.0	55.45	194.12	0.0
1971	1,947.75	56.55	941.52	0.15	480.99	26.21	187.82	0.0	0.0	57.73	196.78	0.0
1972	2,099.28	62.50	1,040.03	0.17	447.23	95.71	197.74	0.0	0.0	56.40	199.49	0.0
1973	2,275.88	67.01	1,139.01	0.12	457.39	130.99	209.82	2.10	0.0	67.21	202.23	0.0
1974	2,438.22	74.03	1,261.45	0.12	448.31	161.84	212.69	5.93	0.0	68.82	205.03	0.0
1975	2,523.89	85.03	1,307.50	0.22	412.42	242.06	197.23	6.80	0.0	64.78	207.87	0.0
1976	2,693.20	65.25	1,482.49	0.15	374.55	271.09	219.54	7.44	0.0	61.94	210.76	0.0
1977	2,983.85	93.85	1,693.59	0.46	305.29	371.83	234.37	7.29	0.0	63.47	213.70	0.0
1978	3,283.84	97.85	1,843.54	5.45	335.39	509.56	194.65	7.25	0.0	73.47	216.69	0.0
1979	3,678.77	96.13	1,983.18	15.56	254.12	803.28	214.98	12.28	0.0	79.51	219.73	0.0
1980	4,331.57	97.34	2,425.76	0.60	349.27	948.71	200.07	10.94	0.0	76.06	222.83	0.0
1981	4,691.29	86.04	2,598.56	1.34	370.98	1,037.19	291.95	11.51	0.0	69.87	223.84	0.0
1982	4,912.81	103.04	2,565.69	30.05	345.83	1,290.17	263.60	15.03	0.0	74.54	224.87	0.0
1983	4,768.35	117.30	2,410.28	74.71	308.21	1,304.89	232.41	15.28	0.0	79.36	225.91	0.0
1984	4,869.25	117.64	2,570.69	167.63	263.22	1,155.68	267.49	16.25	0.0	83.70	226.95	0.0
1985	4,936.28	127.52	2,631.56	172.21	208.98	1,173.52	292.40	18.39	0.0	83.70	228.01	0.0
1986	4,714.67	140.61	2,502.37	155.37	197.04	1,139.03	219.06	37.41	0.0	94.71	229.08	0.0
1987	4,889.13	135.98	2,660.64	160.07	184.97	1,175.14	198.36	48.15	0.0	95.64	230.17	0.0
1988	4,945.31	128.70	2,664.62	177.05	174.94	1,208.15	224.60	50.38	0.0	85.61	231.26	0.0
1989	5,100.83	142.46	2,725.87	179.38	188.44	1,236.31	260.79	50.38	3.94	80.90	232.37	0.0
1990	5,122.98	141.27	2,758.32	141.64	243.68	1,187.56	251.80	55.30	31.05	78.88	233.49	0.0

1991	5,214.46	136.64	2,850.56	188.31	232.10	1,147.83	232.72	58.19	45.93	86.73	235.46	0.0
1992	5,193.73	138.18	2,822.02	185.80	219.16	1,131.50	275.80	61.34	41.86	80.61	237.46	0.0
1993	5,349.40	155.85	2,906.86	139.86	188.27	1,241.72	274.17	61.42	53.07	88.69	239.49	0.0
1994	5,382.12	188.35	2,946.91	140.79	202.53	1,273.86	208.51	58.22	47.78	73.60	241.54	0.04
1995	5,308.08	209.73	2,764.81	148.02	217.44	1,202.66	283.87	58.46	92.99	86.43	243.61	0.06
1996	5,544.10	240.48	2,756.98	148.26	285.86	1,314.97	322.32	58.73	85.58	85.82	245.07	0.05
1997	5,532.40	240.71	2,765.51	148.31	281.18	1,315.95	271.15	56.08	112.50	94.44	246.54	0.04
1998	5,600.40	246.05	2,852.71	145.91	362.86	1,235.05	252.96	58.13	100.47	98.19	248.02	0.05
1999	5,765.72	250.37	2,863.99	124.87	422.17	1,259.20	336.15	57.78	108.26	90.98	251.90	0.06
2000	5,663.87	257.58	2,829.35	130.70	434.80	1,176.99	342.07	61.03	90.33	87.08	253.87	0.08
2001	5,691.78	293.94	2,869.87	137.65	430.62	1,168.56	291.82	57.13	96.70	91.98	253.44	0.07
2002	5,647.00	316.28	2,842.74	121.02	445.65	1,156.21	259.05	56.25	106.97	87.68	255.09	0.07

Source: SENER, 2003, National Energy Balance

Trends: Total energy consumption has increased 4.5 times in the 1965-2002 period, with the Energy Sector (oil and electricity) assuming the largest share, followed by the Transport Sector and the Industrial Sector (including manufacturing). All sectors have shown dramatic increases in the period considered.

In terms of primary energy supply, crude oil is by far the highest source of energy, even though many other sources of energy are supplied. It is important to note that in the period considered, associated gas showed the highest increase. This is due to the fact that PEMEX, recognizing its value for productive uses, stopped flaring it in oil fields. Hydropower refers mainly to large hydro, even though large potentials for mini hydropower have been estimated by CONAE in several states of the country, such as Puebla and Veracruz. Other sources of renewable energy such as wind are still marginal, thus further efforts must be made in order to comply with what has been proposed in the energy sector forecast.

In terms of energy consumption for electricity generation, various sources of energy are used, the two most important being heavy fuel oil and natural gas. As can be observed, natural gas used in combined cycle power plants is continuing to grow, even though Mexico is not self-sufficient in this fuel. Heavy fuel oil use for this purpose is decreasing, even though oil extracted in Mexico presents a higher amount of heavy fractions. Other alternatives such as efficient emission control equipment should be contemplated, in order to use what is being produced in the country. Further exploration and production of NG is required.

Indicator construction and limitations: Data generated by SENER is readily available so construction of this indicator presented no difficulties. Fuelwood data still needs to be accounted for.

6.6.2.3. INDICATOR 15

Expenditure on energy sector

Definition: Expenditure on energy sector refers to economic resources spent by public sector and industry in forms of investments and current expenditures to secure national energy supply in an environmentally benign manner.

Purpose: The indicator provides an indication of a level of the efforts undertaken by a country to secure national energy supply. Alternatively, it can be interpreted as a measure of the economic cost or financial overburden imposed by a society to match its energy demand in short and long terms.

TABLE 6.12 FEDERAL PUBLIC INVESTMENT TOTAL DISCHARGED, ON ENERGY SECTOR AND OIL AND ELECTRICITY INDUSTRIES 1997 - 2002 (MILLIONS OF PESOS)

Year	Total (1)	Energy sector (2)	Oil industry (3)	Oil Share in total %	Oil Share in energy sector %	Electricity industry	Share of electricity in total %	Share of electricity in energy sector %
1997	102,445	42,280	28,675	28.0	67.8	13,605	13.3	32.2

1998	106,870	46,317	30,561	28.6	66.0	15,755	14.7	34.0
1999	118,916	43,332	25,136	21.1	58.0	18,196	15.3	42.0
2000	142,721	51,707	31,304	21.9	60.5	20,403	14.3	39.5
2001	144.548	49,208	31,389	21.7	63.8	17,819	12.3	36.2
2002	152,616	56,353	32,739	21.5	58.1	23,614	15.5	41.9

Source: SHCP.Cuenta de la Hacienda Pública Federal, 1997-2002. México

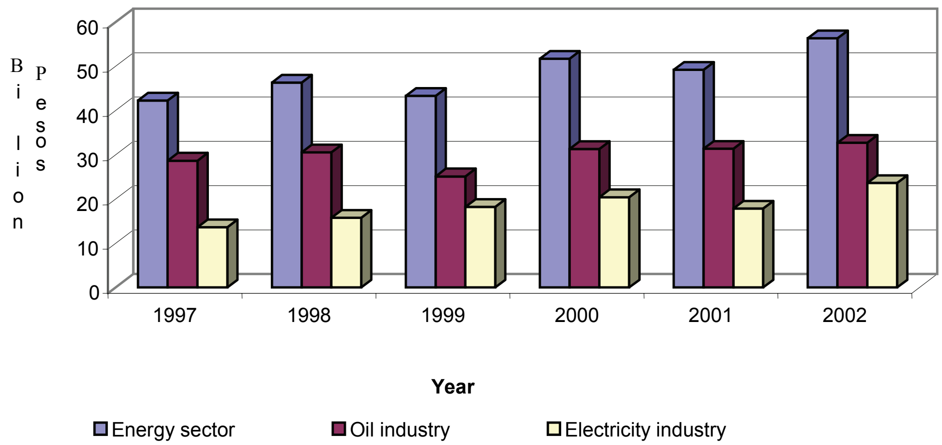

Figure 6.6 Investments in energy sector and oil and electricity industries, 1997 - 2002

TABLE 6.13 EXPENDITURE: SAFETY AND ENVIRONMENTAL PROTECTION, 1999-2003 (MILLION PESOS)

Year	Operation				Investment			
	Industrial safety	Environmental protection	Clean products	Total	Industrial safety	Environmental protection	Clean products	Total
1999	3,379	2,062	102	5,543	2,671	2,520	104	5,295
2000	3,689	1,421	75	5,185	5,406	6,525	92	12,023
2001	5,232	2,598	19	7,849	4,942	5,200	201	10,343
2002	6,330	3,433	507	10,270	4,327	2,907	228	7,462
2003	7,120	3,634	1,464	12,218	3,263	2,732	353	6,348
Total	25,750	13,148	2,167	41,065	20,609	19,884	978	41,471

Note: These allotted values include both direct and indirect expenses.
Source: PEMEX. Informe de Gastos en Seguridad y Protección Ambiental, años 1999-2003

TABLE 6.14 ENVIRONMENTAL PROTECTION EXPENDITURE AND GDP, 1997-2002 (MILLION PESOS)

Year	GDP	Oil			Electricity, Gas and Water	
		GDP (Oil sector)	Current expenditure	Fixed expenditure	Current expenditure	Fixed expenditure
1997	3,174,275	25,956	2,318	330	147	9
1998	3,846,350	28,624	2,900	210	163	916
1999	4,593,685	39,902	2,719	2,298	64	827
2000	5,490,757	48,162	1,528	5,053	64	1,941
2001	5,811,346	51,638	2,810	4,432	78	1,237
2002	6,256,382	55,619	4,033	2,907	131	1,364

Note: Expenditures carried out by the Federal Government and Federal District, as well as companies of direct control.
Source: INEGI. Sistema de Cuentas Económicas y Ecológicas de México 1997-2002, México, 2004

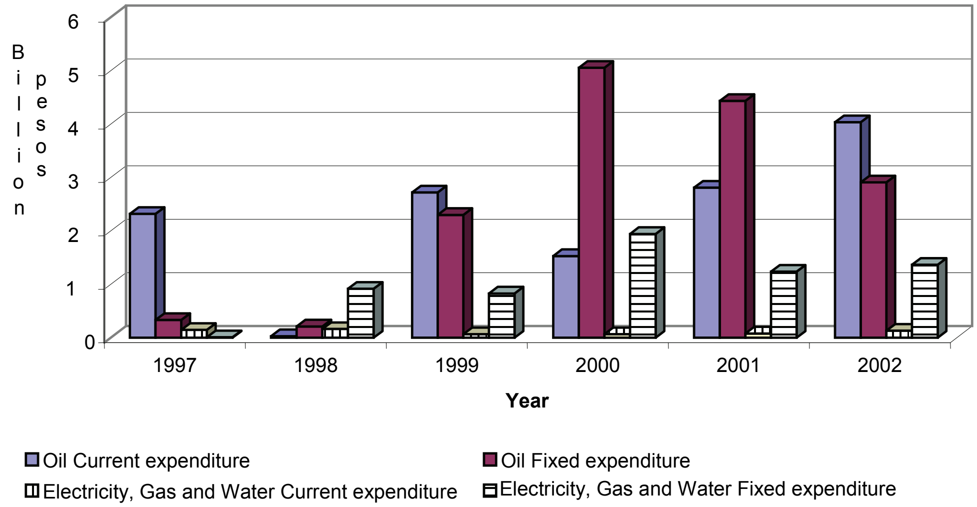

Figure 6.7 Environmental Protection Expenditure

Trends: The Energy Sector Program 2001-2006 has the strategic objective—in addition to guaranteeing energy in a timely manner and of high quality—of being a sector leader in the protection of the environment.

The environmental politics of the sector has direct implications for the quality of the air, on a local, regional and global basis. Additionally, companies in the sector carry out actions with regards to water and soil, the handling of dangerous residuals, and protection of biodiversity.

Environmental management carried out by companies in the sector has two main objectives: to minimize the impacts generated by the companies, and to prevent new impacts.

Since 1993 Petróleos Mexicanos has been carrying out environmental audits whose main objective is to ensure the execution of environmental legislation. In 1997 it developed a system to quantify the costs from the relative activities of industrial safety, environmental protection and clean products.

Indicator construction and limitations: Data availability is scarce and dispersed. Companies in the sector are working on the implementation of their environmental management systems, and three of the main ones (Pemex, CFE and LyFC) undertook environmental administrative activities beginning in the mid-1990s. However, obtaining figures related to expenses made in investment for safety and environmental protection is complicated. Adequate statistics concerning economic resources and work guided towards protection of the environment within the energy sector are still lacking.

6.6.2.4. INDICATOR 17

Indigenous energy production and electricity generation

Definition: Amount of indigenous primary energy produced nationally in a given year in total and by fuel types, such as: coal, oil, natural gas, nuclear, hydro, all converted into oil equivalent, and combustible renewables & waste (CWR) all converted into oil equivalent; and amount of total electricity produced domestically from all primary energy sources.

Purpose: The indicator is a widely used measure of extent to which indigenous energy production is economically and environmentally competitive with imported energy in an increasingly global energy market.

TABLE 6.15 GROSS INDIGENOUS ENERGY PRODUCTION (PJ) 1965-2002

Year	Coal	Crude oil	Condensates	Non Associated gas	Associated gas	Hydro	Geothermal	Nuclear	Cane bagasse	Wood	Wind
1965	24.684	710.48	0.119	422.783	88.879	118.967	0	0	48.647	179.509	0
1966	25.388	729.221	0.521	442.249	108.458	135.841	0	0	51.763	182.329	0
1967	29.091	800.441	0.533	462.94	135.43	144.662	0	0	59.758	185.199	0
1968	31.259	855.295	0.449	473.649	127.92	176.429	0	0	56.444	188.12	0
1969	33.689	899.066	0.863	494.34	141.463	178.439	0	0	60.951	191.095	0
1970	41.195	948.255	0.247	529.79	165.925	200.226	0	0	57.528	194.123	0
1971	47.952	939.355	0.147	531.049	139.172	187.823	0	0	59.444	196.783	0
1972	49.897	976.867	0.167	469.813	233.262	197.739	0	0	58.15	199.486	0
1973	58.318	996.977	0.123	479.459	241.182	209.819	2.101	0	69.115	202.234	0
1974	70.401	1,261.04	0.123	468.848	332.02	212.693	5.932	0	70.287	205.028	0
1975	69.832	1,550.93	0.215	430.01	424.629	197.227	6.804	0	66.179	207.87	0
1976	59.379	1,749.68	0.151	389.774	453.139	219.538	7.439	0	63.382	210.76	0
1977	70.282	2,132.51	0.457	317.302	507.253	234.368	7.289	0	64.865	213.7	0
1978	72.131	2,629.071	5.449	348.122	691.292	194.645	7.245	0	74.987	216.69	0
1979	73.074	3,168.128	15.564	263.633	940.952	214.975	12.28	0	81.179	219.733	0
1980	72.235	4,301.425	0.601	361.027	1,110.096	200.074	10.936	0	77.833	222.829	0
1981	71.145	5,129.298	1.336	382.653	1,309.184	291.953	11.513	0	71.236	223.844	0
1982	85.547	6,065.357	30.051	348.238	1,602.11	263.598	15.03	0	75.991	224.869	0
1983	108.636	5,871.447	74.714	310.614	1,511.992	232.411	15.277	0	80.886	225.906	0
1984	118.361	5,938.347	181.006	265.487	1,286.553	267.491	16.245	0	85.339	226.954	0
1985	121.44	5,793.614	185.421	211.158	1,269.367	292.395	18.393	0	85.264	228.013	0
1986	131.527	5,371.927	167.288	199.028	1,211.217	219.06	37.407	0	96.463	229.083	0
1987	145.985	5,651.436	172.121	186.842	1,253.831	198.362	48.152	0	97.429	230.166	0
1988	130.337	5,592.41	182.892	176.71	1,253.28	224.6	50.383	0	87.153	231.26	0
1989	140.023	5,594.783	185.954	190.343	1,272.279	260.786	50.379	3.936	82.33	232.367	0

1990	141.757	5,573.458	227.789	244.152	1,232.918	251.804	55.297	31.054	80.259	233.486	0
1991	128.723	5,854.583	256.98	233.201	1,188.458	232.717	58.187	45.925	88.229	235.463	0
1992	119.562	5,844.317	268.22	220.559	1,176.727	275.798	61.342	41.855	81.991	237.463	0
1993	129.415	5,861.197	151.585	190.045	1,302.149	274.165	61.417	53.072	90.174	239.487	0
1994	175	5,755.278	141.47	203.475	1,333.956	208.505	58.221	47.781	74.826	241.536	0.042
1995	172.707	5,554.085	148.713	238.07	1,275.606	283.872	58.459	92.986	87.858	243.609	0.062
1996	191.191	6,079.177	148.4	286.903	1,432.514	322.316	58.729	85.581	87.211	245.068	0.051
1997	189.709	6,463.785	148.303	281.251	1,489.9	271.153	56.075	112.495	95.971	246.538	0.041
1998	199.411	6,562.912	145.902	362.929	1,490.161	252.956	58.132	100.471	99.277	248.021	0.051
1999	203.846	6,351.474	124.917	422.171	1,456.595	336.146	57.778	108.26	91.979	251.898	0.062
2000	226.702	6,619.787	130.705	434.83	1,371.203	342.066	61.03	90.331	88.037	253.868	0.083
2001	223.201	6,811.686	137.659	430.619	1,317.402	291.822	57.132	96.699	92.996	253.444	0.071
2002	220.268	6,798.976	121.988	445.646	1,271.959	259.054	56.246	106.972	88.646	255.087	0.072

Source: SENER. 2003. National Energy Balance

TABLE 6.16 NATIONAL GROSS ELECTRIC GENERATION (GWH) 1980-2003

Year	Total	Private and mix production	Geo-thermal	Coal	Nuclear	Wind	Hydroelectric	Dual	Internal combustion	Combined Cycle	Vapor	Turbogas
1980	66,956	5,088	915				16,740		310	3,267	37,012	3,624
1981	73,490	5,611	964	33			24,446		251	3,456	35,527	3,202
1982	80,578	7,353	1,296	1,278			22,729		187	5,272	40,025	2,438
1983	82,272	7,441	1,353	2,424			20,583		107	4,281	44,822	1,261
1984	86,971	7,464	1,424	3,132			23,448		100	4,122	46,342	939
1985	93,404	8,052	1,641	3,852			26,087		43	4,554	48,322	853
1986	97,241	7,858	3,394	6,337			19,876		63	5,866	53,247	600
1987	104,002	7,692	4,418	7,289			18,200		63	7,440	58,298	602
1988	109,862	7,957	4,661	8,035			20,778		73	7,046	60,838	474
1989	117,744	7,643	4,675	7,890	372		24,200		98	7,150	65,087	629
1990	122,757	8,432	5,124	7,774	2,937		23,338		80	7,487	66,916	669
1991	126,962	8,550	5,435	8,077	4,242		21,737		186	7,748	70,328	659
1992	130,342	8,586	5,804	8,318	3,919		26,095	59	237	7,214	69,829	281
1993	135,316	8,750	5,877	10,500	4,931		26,235	2,148	277	7,981	68,339	277
1994	146,722	9,200	5,598	13,037	4,239	4	20,048	7,770	249	9,099	77,023	456
1995	150,638	8,294	5,669	14,479	8,443	6	27,528	6,053	455	10,399	68,948	364
1996	160,494	8,605	5,729	17,735	7,878	5	31,442	2,775	419	10,661	74,805	440
1997	170,519	9,134	5,466	17,575	10,456	4	26,430	7,001	460	11,233	82,102	657
1998	180,491	9,509	5,657	17,956	9,265	5	24,616	12,692	314	13,184	86,206	1,088
1999	192,234	11,317	5,623	18,251	10,002	6	32,714	11,234	382	15,526	85,104	2,077
2000	205,631	12,910	5,901	18,696	8,221	8	33,075	13,569	419	17,712	89,891	5,229
2001		ND	5,567	18,567	8,726	6.51	28,465	14,109	466	25,377	90,395	5,457
2002		ND	5,398	16,152	9,747	6.67	24,862	13,879	555	44,765	79,300	6,395
2003		ND	6,282	16,681	10,502	5.37	19,753	13,859	755	55,047	73,743	6,929

Source: SENER,2003, Statistical Summary of the Energy Sector

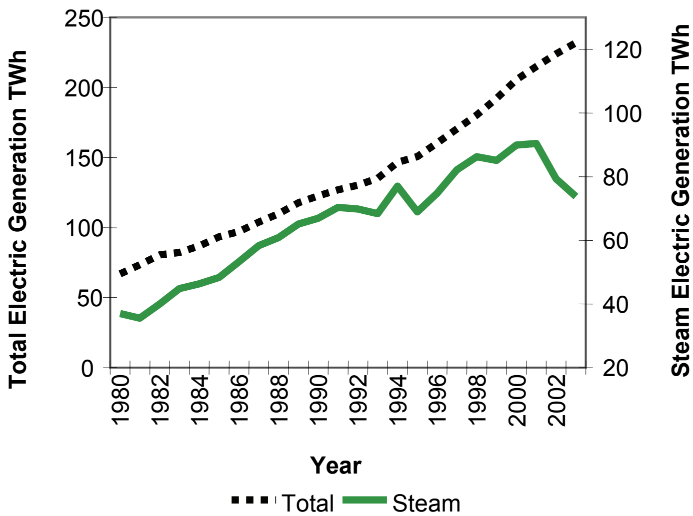

Figure 6.8 National Gross Electric Generation 1980-2002

Trends: Gross indigenous energy production has increased 6 times in the 1965-2002 period, hydrocarbons representing the main source of production contributing 89.7% of the total in 2002.

Electricity generation has gone from 66,956 GWh in 1980 to 205,631 GWh in 2000, which represents a three-fold increase, with thermal representing 40% of the total. Other significant technologies for electricity generation are coal-based, hydroelectric and combined-cycle. Nuclear technology's contribution will not change since there is only one nuclear plant in Mexico and there are no further expansions being considered. For the year 2000, geothermal electricity represents 3% of total generation. Mexico is the third largest geothermal producer of electricity, after the U.S. and the Philippines. Renewable sources of energy (i.e., principally hydro and geothermal) represented 19% of total generation in 2000, which is a significant contribution. Other sources such as biogas, wind and mini hydro, need further encouragement in order to promote more energy diversification and security, reduce pollutant emissions, and promote local development (among others).

Indicator construction and limitations: Data generated by SENER are readily available, so construction of this indicator presented no difficulties.

6.6.2.5. INDICATOR 18

Energy net import dependency (%) or net energy imports and exports

Definition: The ratio of net import (imports minus exports) to consumption of primary energy in a given year in total and by fuel types such as: oil & petroleum products, gas, coal; and electricity in particular. The indicator can also be represented in terms of net energy imports and exports.

Purpose: This indicator measures the extent to which a country relies on imports to meet its energy needs. Mexico is a major exporter of crude oil but several petroleum products including natural gas, gasoline, LPG, etc., are important.

TABLE 6.17 ENERGY NET IMPORTS AND EXPORTS (PJ) 1965-2002

Year	Coal	Crude oil	NG	LPG	Gasoline	Diesel	Heavy fuel oil	Gross Electr. generation
1965	6.348	-4.070	-9.133	NA	NA	NA	NA	NA
1966	7.098	0	-8.036	NA	NA	NA	NA	NA
1967	5.947	0	-7.806	NA	NA	NA	NA	NA
1968	6.513	0	-7.057	NA	NA	NA	NA	NA
1969	9.600	0	-6.598	NA	NA	NA	NA	NA
1970	10.746	0	-5.500	NA	NA	NA	NA	NA
1971	15.801	0	-3.001	NA	NA	NA	NA	NA
1972	22.057	0	-1.383	NA	NA	NA	NA	NA
1973	11.758	0	-0.280	NA	NA	NA	NA	NA
1974	15.057	-2.766	-0.052	NA	NA	NA	NA	NA
1975	23.409	-13.146	0	NA	NA	NA	NA	NA
1976	4.448	-11.761	0	NA	NA	NA	NA	NA
1977	25.823	-20.598	-0.286	NA	NA	NA	NA	NA
1978	22.746	-30.191	0.000	NA	NA	NA	NA	NA
1979	29.251	-36.466	0.000	NA	NA	NA	NA	NA
1980	32.768	-42.763	-6.885	NA	NA	NA	NA	0.092
1981	27.534	-47.489	-6.126	NA	NA	NA	NA	0.046
1982	21.727	-54.329	-4.939	NA	NA	NA	NA	0.001
1983	7.382	-57.662	-4.200	6.709	-6.749	-10.922	-8.610	-0.009
1984	5.683	-56.793	-3.317	18.413	-11.058	-4.638	-13.373	-0.010
1985	13.976	-54.527	0.100	20.182	-7.793	-6.103	-14.456	-0.010
1986	5.316	-53.121	0.130	13.398	-6.996	-10.259	-3.062	-0.140
1987	-0.569	-52.943	0.142	8.344	-4.413	-4.708	2.834	-0.185
1988	0.372	-52.129	0.156	8.886	-6.107	-3.644	4.252	-0.166
1989	-0.225	-50.837	1.102	9.312	6.609	-4.897	10.454	-0.112
1990	3.763	-50.121	1.047	8.550	7.064	-12.045	10.140	-0.112
1991	0.547	-51.150	4.115	8.339	15.765	-8.206	9.382	-0.110
1992	15.257	-51.272	6.519	12.181	18.090	-13.569	7.566	-0.081
1993	1.749	-50.015	2.236	11.870	14.673	-16.429	3.267	-0.082
1994	4.769	-48.676	2.377	11.974	9.941	-7.150	18.459	-0.057
1995	19.650	-49.862	3.455	14.499	11.236	-6.069	3.819	-0.052
1996	20.454	-54.011	0.933	21.621	9.481	-2.134	9.540	0.006
1997	28.216	-56.942	1.373	34.193	15.372	3.010	18.784	0.086
1998	28.566	-56.709	2.154	35.026	15.443	3.877	20.137	0.079
1999	29.436	-53.457	0.557	40.404	8.084	6.791	10.384	0.027
2000	28.581	-54.852	5.082	52.801	5.304	8.750	22.637	0.043
2001	39.089	-54.693	7.144	42.772	16.416	-1.094	17.338	0.003
2002	69.573	-52.389	13.694	42.715	6.089	3.354	-8.211	ND

Source. SENER. 2003. National Energy Balance

Trends: Mexico exports more than 50% of its crude production, and it is self-sufficient in terms of electricity. Import dependence on coal, LPG, NG, and gasoline has grown in recent years. This is due to lack of investment in the sector, as mentioned before; even though there are significant gas and oil reserves, the necessary infrastructure to process them does not exist. Demand for gas both by the electric sector and the private sector has increased significantly in recent years.

Indicator construction and limitations: Data generated by SENER are readily available so construction of this indicator presented no difficulties.

6.6.2.6. INDICATOR 22

Fraction of households heavily dependent on non commercial energy and without electricity (%)

Definition: Proportions of households with lack of access to commercial energy sources, in particular to electricity, and heavily dependent on "traditional" non-commercial energy sources, such as fuel-wood, crop wastes and animal dung.

Purpose: To monitor progress in the access of the population to commercial fuel and electricity as an important prerogative for alleviating poverty.

TABLE 6.18 SHARES OF HOUSEHOLDS DEPENDING ON TRADITIONAL ENERGY AND WITHOUT ELECTRICITY 1960-2000 (%)

Year	Without electricity	Dependent on non commercial energy	Non commercial energy and without electricity
1960	65.70	64.20	NA
1970	41.10	44.20	NA
1980	21.80	28.60	NA
1990	12.40	21.10	9
2000	4.50	17.10	3.5

NA. Not available.
Source: VIII, IX, X, XI, y XII Censo General de Población y Vivienda 1960, 1970, 1980, 1990, 2000. México 1962, 1972, 1986, 1991, 2001.

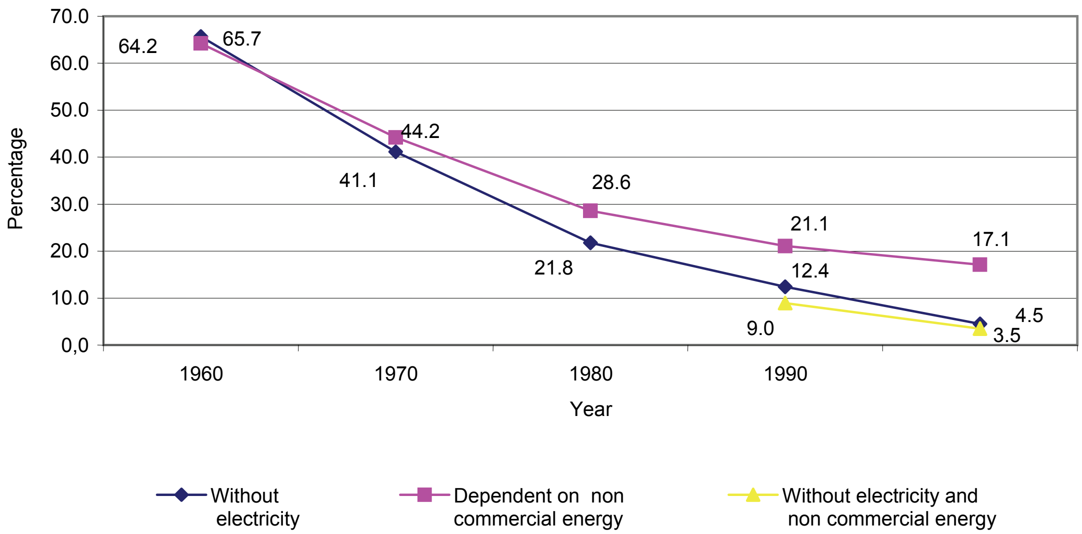

Figure 6.9 Households dependent on traditional energy and without electricity 1960-2000

Trends: In 1960, 65.7% of households, belonging mostly to the rural sector, didn't have electric power, a proportion that decreased to 4.5% in 2000. This is a result of the adoption of a governmental policy of electrification of the country.

It is equally important (although not in the same proportion as the case for electricity) that there was a decrease in the proportion of households dependent on non-commercial fuels (e.g., fuelwood, charcoal), from 64.2% to 17.1%.

The proportion of households without electricity access and that use non-commercial energy decreased significantly.

These tendencies reflect in general a modification in consumption patterns, which benefits the population and is a less degradable use of forest resources.

Since 2000, resources allotted to electrification, previously managed by the Federal Commission of Electricity, have been transferred directly to municipalities to be managed in development programs they considere appropriate. The results of this program remain to be seen.

It is expected that in upcoming years, as public and private companies coexist in the electric sector operating inside an appropriate regulatory framework, electricity coverage to the population will increase, with better conditions of quality and price. In this context, the federal government is aware that 5% of the population, for the most part indigenous and rural, still lives without access to electrical services.

A goal for the 2001-2006 period is to reach 97% of total national coverage for electricity. Electric generation from renewable sources (i.e., photovoltaic systems, wind, mini-hydro and biomass) will also be promoted in those isolated communities.

Indicator construction and limitations: Households that use electricity and consume coal and wood for cooking have been excluded from the analysis; thus, to know the real consumption of such non-commercial energies, 17% of the country's total households should be considered in addition to that included in the indicator. To be more precise, the Census of Population and Housing inquires into the type of fuel for cooking, with wood and coal being the only two non-commercial energy options specified there.

For some censuses, one obstacle is that the information was not at the household level, and therefore refers to the general population. Also, the 1960 data are estimated.

6.6.2.7. INDICATOR 36

Proven recoverable fossil fuel reserves (Million metric tonnes for coal and oil; billion cubic m for natural gas)

Definition: Proven recoverable fossil fuel reserves are generally defined as those quantities which geologic and engineering information indicate can be recovered with reasonable certainty in the future from known energy resources under existing economic and technical conditions. The indicator consists of such fossil fuels as: oil, natural gas, and coal.

Purpose: The purpose of the indicator is to measure availability of various fossil fuel energy resources.

TABLE 6.19 PROVEN FOSSIL FUEL RESERVES 1980-2003

Year	Total (Mbl) a/	Crude oil (Mbl) b/	Condensates (Mbl) c/	Dry gas crude equivalent (Mbl) b/
1980	45,803	30,616	2,944	12,243
1981	60,126	44,161	3,063	12,902
1982	72,008	48,084	8,914	15,010
1983	72,008	48,084	8,914	15,010
1984	72,500	49,911	7,185	15,404
1985	71,750	49,260	7,150	15,340
1986	70,900	48,612	6,981	15,307
1987	70,000	48,041	6,839	15,120
1988	69,000	47,176	6,934	14,890
1989	67,600	46,191	6,821	14,588
1990	66,450	45,250	6,733	14,467
1991	65,000	44,292	6,633	14,075
1992	65,050	44,439	6,786	13,825
1993	64,516	44,043	6,733	13,740
1994	63,220	43,127	6,648	13,445
1995	62,058	42,146	6,650	13,262
1996	60,900	42,072	6,400	12,428
1997	60,160	41,392	6,430	12,338
1998	57,741	41,064	5,875	10,803
1999	58,204	41,495	6,036	10,673
2000	56,154	39,918	5,574	10,662
2001	52,951	38,286	4,927	9,738
2002	50,032	36,266	4,384	9,382
2003	48,041	34,389	4,229	9,423

a/ Information from the beginning of each year. Includes condensate and raw natural gas. Staring on 1 Jan. 1995, reserves are expressed according to definitions, methods and procedures accepted by international oil companies and include proven, probable and possible reserves; therefore, starting in that year data cannot be compared to prior information.
b/ For 2002 data are estimates based on real data up to September.
c/ Includes liquids from processing plants.
Source. SENER. 2003. Statistical compendium of the Energy Sector.

Trends: It is not possible to interpret trends for the overall 1980-2003 period. For the time period starting in 1995, a decreasing trend is observed in the proven fossil fuel reserves. Nevertheless reserves are still sufficient for at least two decades.

Indicator construction and limitations: Changes in ways for estimating reserves make it difficult to compare numbers.

6.6.2.8. INDICATOR 37

Lifetime of proven fossil fuel reserves (Years)

Definition: Lifetime of proven energy reserves, known as the production life index, is the ratio of energy reserves remaining at the end of any year to the production of energy in that year.

Purpose: This indicator provides an indication of the length of time that proven reserves would last if production were to continue at current levels.

TABLE 6.20 LIFETIME OF PROVEN FOSSIL FUEL RESERVES (NG AND PETROLEUM) 1980-2003

Crude oil, condensates, Dry gas	
Year	Coefficient Reserves/ production (years) a/
1980	58
1981	59
1982	60
1983	52
1984	54
1985	54
1986	54
1987	55
1988	52
1989	54
1990	53
1991	50
1992	50
1993	49
1994	48
1995	48
1996	43
1997	39
1998	39
1999	41
2000	38
2001	35
2002	33
2003	30

a/ For 2002 data are estimates based on real data up to September.
Source. SENER. 2003. Statistical compendium of the Energy Sector.

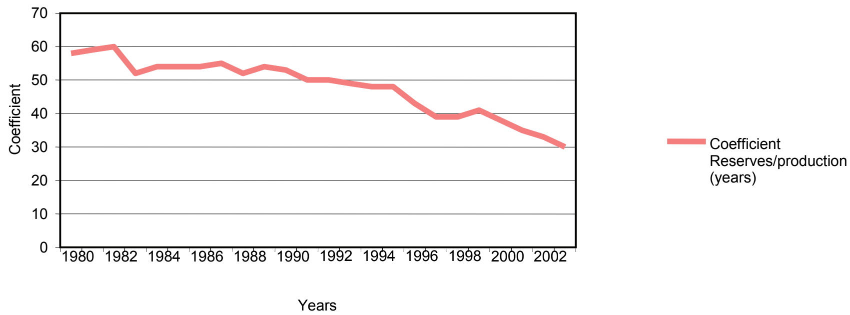

Figure 6.10 Coefficient Reserves/production 1980-2003

Trends: Proven reserves dropped 20 years from 1980 to 2002 due to a lack of investment in oil exploration. It is a result of the economic dependence of PEMEX on the national budget. This is a negative trend and needs to be reversed by adequate national energy policies.

Indicator construction and limitations: Data generated by SENER are readily available so construction of this indicator presented no difficulties. Crude oil, condensates and gas are the fuels considered in the index.

6.6.3. Energy Production and Consumption Patterns

The indicators on energy production and consumption patterns are:

- 5. Distance travelled: total and by urban transport
- 6. Freight transport activity: total, by mode
- 8. Manufacturing value added by selected energy intensive industries
- 9.1 Energy intensity in manufacturing
- 9.2 Energy intensity in agriculture
- 9.3 Energy intensity in commercial and service sector
- 9.4 Energy intensity in transportation
- 9.5 Energy intensity in the residential sector
- 14. Energy use per unit of GDP
- 16. Energy consumption per capita
- 20. Ratio of daily disposable income per capita of 20% poorest population to the prices of electricity and major household fuels, 1996-2002
- 21. Fraction of disposable income/private consumption spent on fuel and electricity
- 35. Fraction of technically exploitable capability of hydropower currently not in use
- 40. Intensity of use of forest resources as fuelwood

6.6.3.1. INDICATOR 5

Distance travelled per capita: total and by urban transport

Definition: The number of kilometres travelled per person in a given year in total and by urban transport, and in particular by electrically driven vehicles in urban public transport.

Purpose: This indicator can contribute to monitoring fuel consumption for travelling and the environmental impact of the systems for personal mobility in a particular country or area.

TABLE 6.21 DISTANCE TRAVELLED PER CAPITA: METRO, 1995-2004

Year	Distance travelled (Thousands of kilometres)		Passenger transport (Thousands of passengers)		Kilometres per year per capita	
	Metro Mexico City[a]	Metrorey Monterrey	Metro Mexico City[b]	Metrorey Monterrey	Metro Mexico City	Metrorey Monterrey
1995	1,159.0	3,065	48,456.4	36,934	23.92	82.99
1996	1,158.6	3,035	46,740.3	31,372	24.79	96.74
1997	1,172.1	2,872	44,774.6	34,606	26.18	82.99
1998	1,171.9	2,649	44,173.9	32,935	26.53	80.43
1999	1,204.0	2,640	41,864.8	36,077	28.76	73.18
2000	1,264.4	2,750	45,665.6	40,047	27.69	68.67
2000	1,312.8	2,615	47,131.8	45,456	27.85	57.53
2001	1,288.6	2,991	45,899.8	47,764	28.07	62.62
2002	1,246.6	6,985	45,237.1	51,678	27.56	135.16
2003	1,279.3	6,435	47,267.9	52,420	27.06	122.76

[a] average number of kilometres travelled daily.
[b] average number of passengers moving daily by Metro.
Source: INEGI. Banco de Información Económica (BIE), www.inegi.gob.mx.

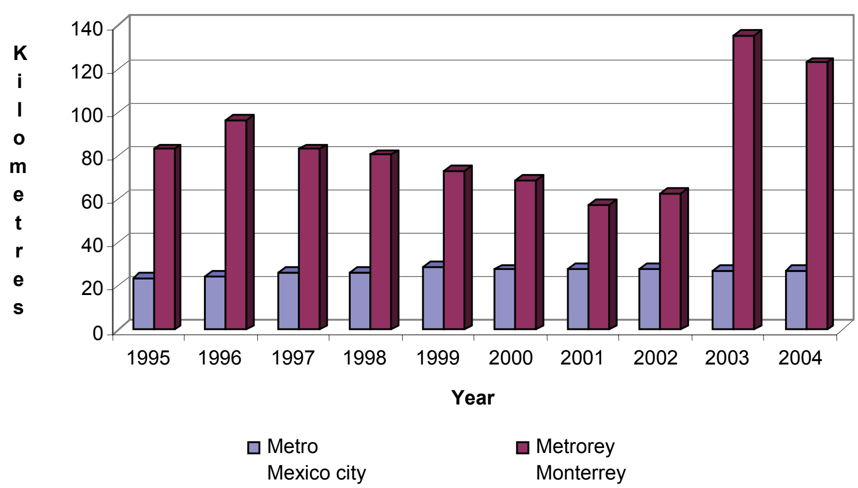

Figure 6.11 Distance travelled per capita: metro, 1995-2004

TABLE 6.22 DISTANCE TRAVELLED PER CAPITA: TROLLEYBUS, 1995-2004

Year	Distance travelled (Thousands of kilometres)		Passenger transport (Thousands of passengers)		Kilometres per year per capita	
	Trolleybus Mexico City[a]	Trolleybus Guadalajara	Trolleybus Mexico City[b]	Trolleybus Guadalajara	Trolleybus Mexico City	Trolleybus Guadalajara
1995	21,017	NA	142,589	NA	147.40	NA
1996	21,814	NA	143,932	NA	151.56	NA
1997	22,369	3,671	79,347	13,828	281.91	265.48
1998	20,252	3,609	62,528	13,288	323.89	271.60
1999	19,981	3,126	64,470	12,299	309.93	254.17
2000	22,089	3,516	81,434	12,594	271.25	279.18
2001	20,504	3,516	82,490	12,184	248.56	288.58
2002	20,465	3,516	66,380	10,380	308.30	338.73
2003	22,878	3,516	63,613	9,708	359.64	362.18
2004	23,403	3,516	68,713	7,755	340.59	453.38

Source: INEGI. Banco de Informacion Economica (BIE), www.inegi.gob.mx.

TABLE 6.23 DISTANCE TRAVELLED PER CAPITA: ELECTRIC TRAIN, 1995-2004

Year	Distance travelled (Thousands of kilometres)		Passenger transport (Thousands of passengers)		Kilometres per year capita	
	Electric train Mexico City[a]	Electric train Guadalajara	Electric train Mexico City[b]	Electric train Guadalajara	Electric train Mexico City	Electric train Guadalajara
1995	1,404	NA	25,796	NA	54.43	NA
1996	1,634	NA	32,399	NA	50.43	NA
1997	1,697	4,705	19,678	47,098	86.24	99.90
1998	1,649	4,725	15,730	48,969	104.83	96.49
1999	1,754	4,739	17,121	46,865	102.45	101.12
2000	1,732	4,757	17,877	48,488	96.88	98.11
2001	1,480	4,958	16,438	51,621	90.04	96.05
2002	1,387	5,306	15,139	51,623	91.62	102.78
2003	1,444	5,476	15,749	53,577	91.69	102.21
2004	1,506	5,372	17,498	57,036	86.07	94.19

Source: INEGI. Banco de Informacion Economica (BIE), www.inegi.gob.mx.

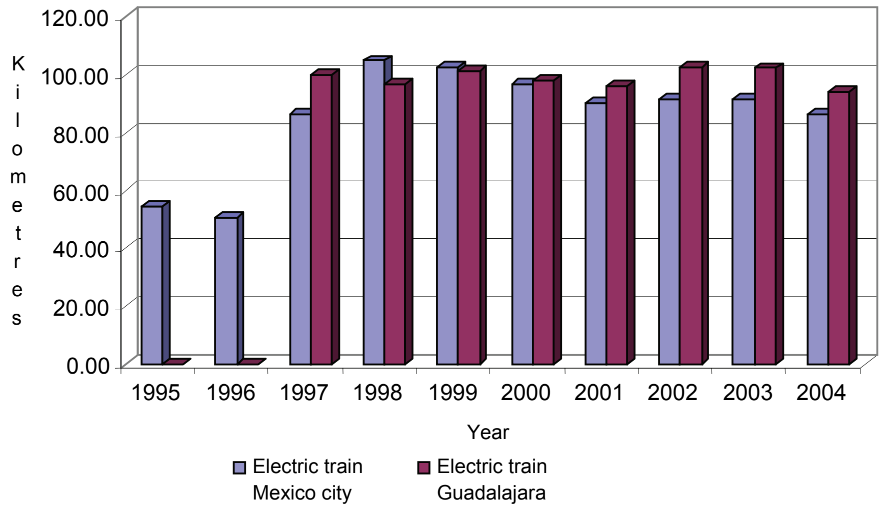

Figure 6.12 Distance travelled per capita: electrically train, 1995-2004

Trends: Electric transport systems (metro) for Mexico City and Monterrey show a sustained growth from 1994 to 2004, both in terms of the average travelled kilometres per day and the average number of passengers transported daily. In contrast, the trolleybus of Mexico City and Guadalajara present an important decrease in the number of transported passengers, and lower growth is registered for the low speed train.

Indicator construction and limitations: The information for the total urban transport does not allow for type and modal analysis in order to have an overall picture.

6.6.3.2. INDICATOR 6

Freight transport activity: total, by mode (Billion tonne-km per year for total freight activity, and percentage for share of different modes)

Definition: The indicator reflects production aspects of transportation and is defined as the number of tonnes of freight transport multiplied by the distance transported, by different modes of transport, such as truck, train, inland water, and pipelines.

Purpose: This indicator can contribute to monitoring fuel consumption for freight transport and the environmental impact of the systems for freight activity in a particular country or area.

TABLE 6.24 FREIGHT TRANSPORT ACTIVITY: TOTAL BY MODE 1995-2002

(Millions of tonnes) Transportation mode	1995	1996	1997	1998	1999	2000	2001	2002[4]
Total	606.1	650.7	613.7	694.7	702.9	734.7	727.4	734.7
Road	419.5	441.8	393.7	456.9	471.1	490.1	483.0	485.7
Road Motor Vehicles[1]	367.0	383.0	332.0	381.0	394.0	413.0	409.0	411[4]
Rail[2]	52.5	58.8	61.7	75.9	77.1	77.1	74.0	74.7[4]
Air	0.3	0.3	0.3	0.4	0.4	0.4	0.3[5]	0.3[5]
Maritime[3]	186.3	208.6	219.7	237.4	231.4	244.2	244.4	248.7

[1] Including general and special freight.
[2] Including national movement, export and import.
[3] Including coastal and height movement.
[4] Estimated.
[5] Preliminary.
Source: Gobierno de los Estados Unidos Mexicanos, 2º Informe de Gobierno, 1º de septiembre 2002, México, 2002.

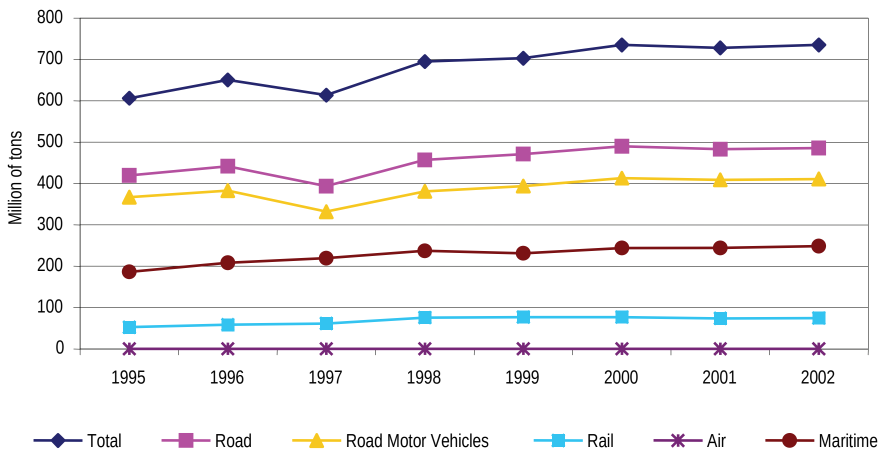

Figure 6.13 Freight transport activity: Total, by mode 1995-2002

Trends: Transportation activity has grown more than 20% between 1995-2002, with road motor representing 56%, railway 10%, and maritime 33.6% in the year 2001. Maritime is the transportation mode which experienced the largest growth (33.5%) between 1995-2002.

Indicator construction and limitations: Data availability limited the disaggregating of the indicator to the desired level. And measurement and interpretation became complicated by differences among products within category, such as size, utilization, etc.

6.6.3.3. INDICATOR 8

Manufacturing Value Added by Selected Energy Intensive Industries (%)

Definition: This indicator measures the contribution of the various manufacturing energy intensive industries in total manufacturing output. It is obtained by dividing the value added in a specific manufacturing branch by the total net value-added in manufacturing at constant 1990 prices.

Purpose: The indicator is designed to monitor the relative size of energy intensive industries in manufacturing. The relative size of energy intensive industries also hints at basic driving forces associated with level of energy use per unit of GDP.

TABLE 6.25 SHARES OF MANUFACTURING VALUE ADDED OF ENERGY INTENSIVE INDUSTRIES IN TOTAL GDP 1988-2002

Year	Iron and steel	Non-ferrous metals	Basic chemicals	Non-metallic minerals	Paper and pulp	Refined petroleum products
1988	4.85	1.59	4.45	2.10	1.02	3.58
1989	4.60	1.51	4.33	1.98	1.08	3.62
1990	4.73	1.45	4.26	1.91	1.11	3.72
1991	4.35	1.32	4.25	1.92	1.15	3.45
1992	4.25	1.33	4.17	1.98	1.12	3.35
1993	4.51	1.26	4.12	2.05	1.15	3.30
1994	4.72	1.21	4.09	2.15	1.15	3.37
1995	5.51	1.13	4.34	1.90	1.28	3.41
1996	5.72	1.31	4.18	1.89	1.24	3.06
1997	5.80	1.27	4.05	1.80	1.17	2.65
1998	5.51	1.30	4.08	1.71	1.11	2.46
1999	5.34	1.20	4.08	1.68	1.14	2.32
2000	5.15	1.16	3.83	1.16	1.09	2.15
2001	4.84	1.23	3.82	1.65	1.09	2.14
2002	4.99	1.21	3.83	1.70	1.13	2.13

Source: INEGI. Sistema de Cuentas Nacionales de México (SCNM), 1988-1999 y 1996-2002. Aguascalientes, México 2000 y 2003.

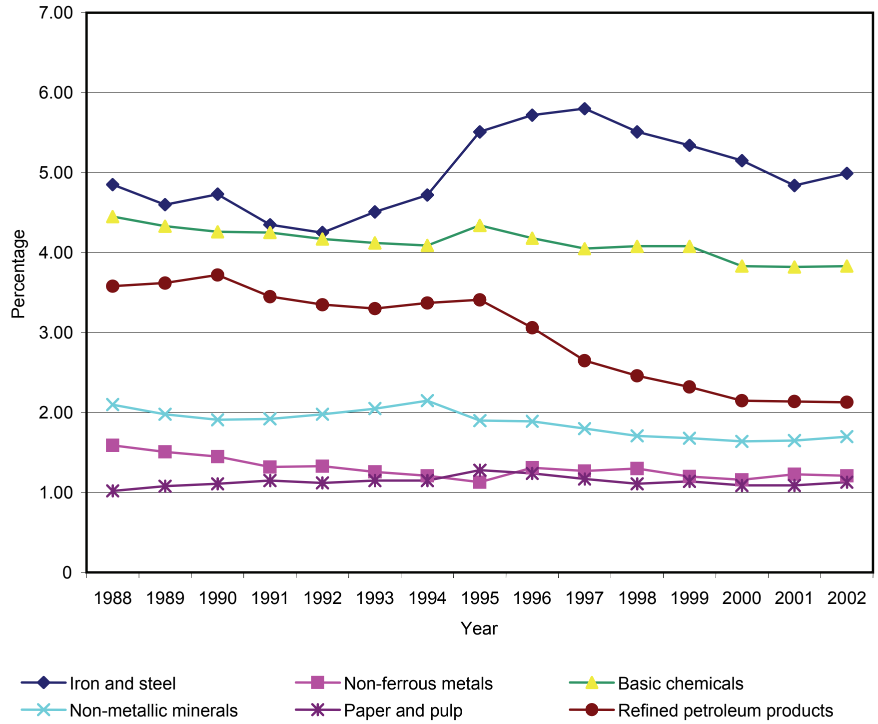

Figure 6.14 Shares of sectors in manufacturing GDP at PPP 1988-2002

Trends: In the period 1988-2002, most of the primarily energy intensive industries displayed a progressive reduction in their fraction of value added in total GDP and in the Manufacturing sector.

This tendency is observed mainly in the following cases: Basic Chemicals from 4.45% to 3.83%; Iron and Steel, after reaching a value of 5.80% in 1997, dropped to 4.99% in 2002; and Refined Petroleum from 3.58% to 2.13 %.

Accordingly, a decrease in the share of the value added of these industries brought about a decrease in the quantity of energy used by these selected industries.

Indicator construction and limitations: For comparison purposes, the historical series is available starting from 1988; information prior to this year is not available with the required detail of the indicator.

For the construction of this indicator, the categories and divisions mentioned in the methodological sheet (ISED Methodology sheet) were included.

The percentage share of the industries is calculated in relation to the total value added of the manufacturing sector.

6.6.3.4. INDICATOR 9.1

Energy Intensity in Manufacturing

Definition: Energy consumption per unit of manufacturing output.

Purpose: The manufacturing sector is a major consumer of energy. This indicator is a measure of the efficiency of energy use in the sector and can be used for analysing trends and making international comparisons in energy efficiency, particularly when the indicator can be disaggregated to specific branches of manufacturing.

TABLE 6.26 ENERGY INTENSITY IN THE MANUFACTURING SECTOR 1980-2002

Year	(TOE/1,000 USD)	(KWh/ USD 2,000)
1980	0.20	0.26
1981	0.19	0.26
1982	0.20	0.30
1983	0.21	0.32
1984	0.19	0.32
1985	0.17	0.32
1986	0.17	0.33
1987	0.16	0.32
1988	0.15	0.32
1989	0.16	0.35
1990	0.16	0.37
1991	0.15	0.38
1992	0.15	0.38
1993	0.15	0.41
1994	0.15	0.43
1995	0.14	0.44
1996	0.13	0.46
1997	0.12	0.48
1998	0.11	0.48
1999	0.11	0.50
2000	0.10	0.53
2001	0.11	0.55
2002	0.11	0.59

Source: INEGI. 2003. National Accounting System
SENER. 2003. National Energy Balance.

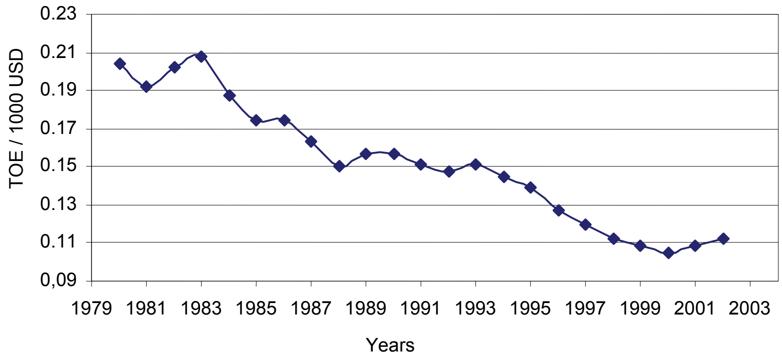

Figure 6.15 Energy intensity in the Manufacturing Sector 1980-2002

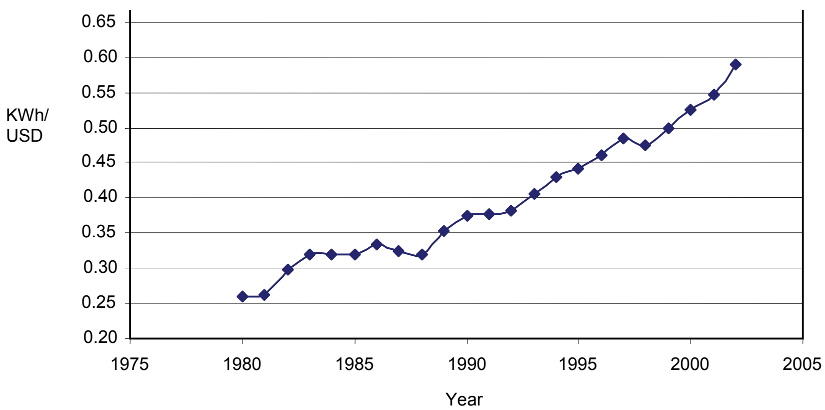

Figure 6.16 Energy Intensity in the Manufacturing Sector: electricity consumption per GDP

Trends: Energy intensities have dropped for total energy consumption. In the last 13 years the paper and cellulose pulp industry has decreased its intensity by 6%, aluminum by 5% and sugar by 3.7%. During the same period, the tobacco industry increased its intensity by 1%. The transformation sector (specifically refineries) has increased operations, thus increasing energy demand. A good approach could be to segregate private and public energy intensities.

Electricity use per GDP follows an increasing trend due to reduced electricity prices in real terms.

Indicator construction and limitations: Some slight changes have occurred regarding the way SENER aggregates sub sectors within the Manufacturing Sector, and the way INEGI estimates value added. Thus SENER provides its own estimates that may not be completely concurrent with INEGI´s official system of national accounts. Efforts have been made to harmonize criteria; unfortunately, no resources have been allocated for this matter.

6.6.3.5. INDICATOR 9.2

Energy intensity in Agriculture

Definition: Energy consumption per unit of agricultural output.

Purpose: The agriculture sector is an important consumer of energy. The purpose of the indicator is to provide a measure of the efficiency of energy use in the sector that can be used for analyzing trends, particularly in non-commercial energy consumption, and making international comparisons in energy efficiency.

TABLE 6.27 ENERGY INTENSITY IN AGRICULTURAL SECTOR 1980-2002

Year	(TOE/1,000 USD)	(KWh/USD)
1980	0.059	0.112
1981	0.054	0.105
1982	0.061	0.155
1983	0.059	0.138
1984	0.052	0.128
1985	0.049	0.130
1986	0.049	0.144
1987	0.049	0.165
1988	0.047	0.171
1989	0.043	0.186
1990	0.041	0.159
1991	0.041	0.152
1992	0.044	0.138
1993	0.044	0.147
1994	0.043	0.163
1995	0.048	0.188
1996	0.040	0.184
1997	0.041	0.193
1998	0.042	0.199
1999	0.044	0.221
2000	0.048	0.235
2001	0.050	0.224
2002	0.052	0.222

Source: INEGI. 2003. National Accounting System
SENER. 2003. National Energy Balance.

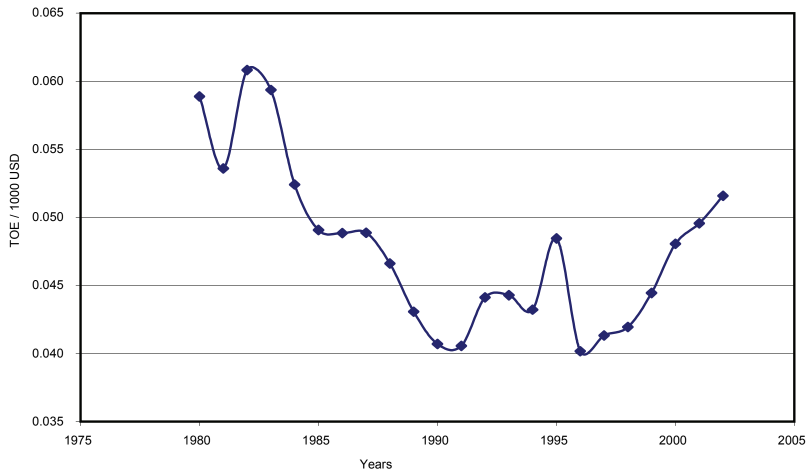

Figure 6.17 Energy intensity agricultural sector 1980-2002

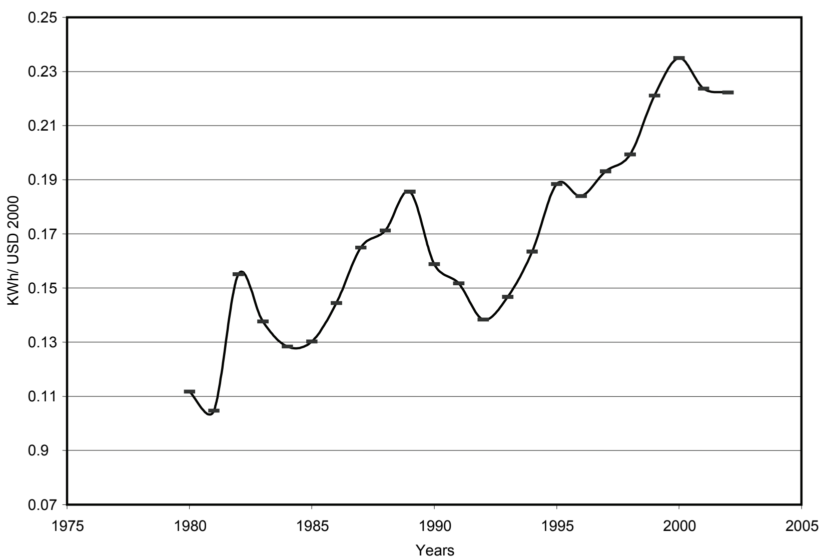

Figure 6.18 Electricity Intensity Agricultural Sector 1980-2002

Trends: Total energy intensity dropped during the 1980s, except for an increase in 1982 (associated with that year's crisis due to political and economic changes in the country). From 1990 to 2002, intensity has grown due to increases in consumption coupled with declining in growth of the sector. A considerable increase was observed in 1995 consistent with that year's crisis. Energy intensity in terms of electricity consumption has doubled during the considered period, basically due to lower real prices for electricity. On the other hand, the price of diesel fuel, which is consumed in large quantities in this sector, has considerably increased because its price is governed by international pricing.

Indicator construction and limitations: Even though information and data are available, the variation in agricultural production due to climate, availability of other inputs, among other factors, also needs to be taken into account.

Energy efficiency in agricultural production needs to be improved at a national level. Policies promoting renewable energy sources need improvement as well, since among many benefits, they will

contribute considerably to increased labour efficiency and diversified economic activities in rural areas.

6.6.3.6. INDICATOR 9.3

Energy Intensity in Commercial and Service Sector (toe/1,000$ and kWh/$)

Definition: Energy consumption per unit of commercial and service sector (value added) output.

Purpose: This indicator is used to monitor trends in energy consumption in the commercial/service sector, which is the largest sector of most economies.

TABLE 6.28 ENERGY INTENSITY IN COMMERCIAL SECTOR. 1990-2000

Year	Toe/1,000 USD	kWh/ USD
1990	0.02	0.10
1991	0.03	0.11
1992	0.03	0.11
1993	0.03	0.12
1994	0.04	0.12
1995	0.08	0.27
1996	0.09	0.30
1997	0.09	0.30
1998	0.10	0.35
1999	0.08	0.37
2000	0.08	0.34

Source: INEGI, Sistema de Cuentas Nacionales de México (SCNM), 1988-1999 y 1996-2001.

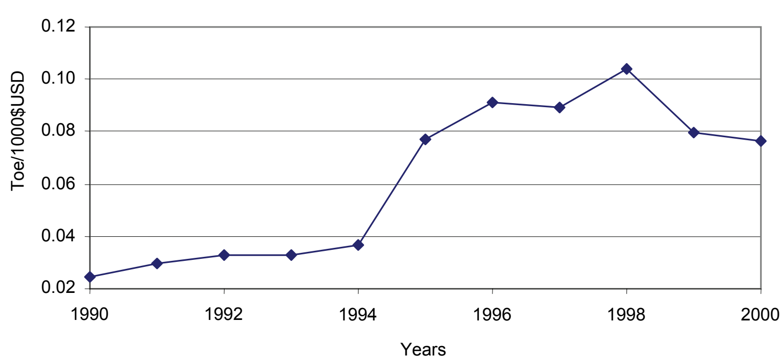

Figure 6.19 Energy Intensity in Commercial Sector 1990-2000

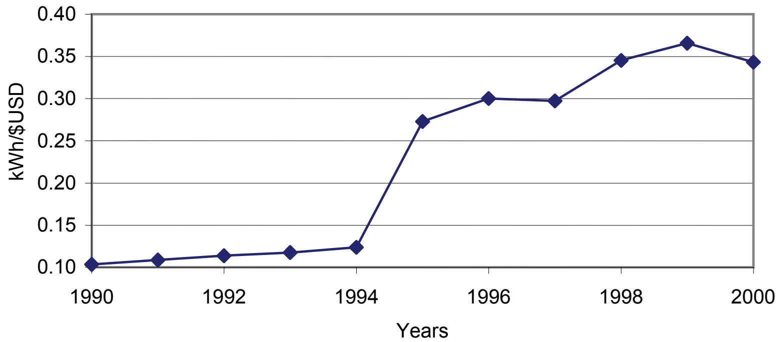

Figure 6.20 Electricity Intensity in Commercial Sector 1990-2000

Trends: The service/commercial sector is a large consumer of electricity. In general, it requires increases in energy efficiency in order to reduce overall energy use. Energy and electricity intensity increased in 1995, in part as a result of a drop in GDP at that time, but the high levels of intensity remained even after the GDP recovered.

Indicator construction and limitations: Time series in this indicator cannot be expanded because of differences in the way SENER and the National Accounts System categorize economic groups.

6.6.3.7. INDICATOR 9.4

Energy Intensity in transportation

Definition: Energy consumption for transportation per unit of transportation sector output and relative to the amount of freight or passengers carried and the distance travelled.

Purpose: Transportation is a major consumer of energy, mostly in the form of fossil fuels, and the share of transportation in energy consumption is generally increasing. The indicator is a measure of how efficiently energy is used for moving goods and people. The indicator can be used to monitor trends in energy consumption for transportation and for international comparisons. Separation of freight and passenger travel is essential.

TABLE 6.29 ENERGY INTENSITY TRANSPORTATION 1990-2000

Year	Toe/1,000 USD	kWh/ USD
1990	1.15	2.35
1991	1.29	2.82
1992	1.32	3.45
1993	1.34	4.15
1994	1.43	5.64
1995	2.79	9.40
1996	3.15	35.70
1997	3.09	16.31
1998	3.50	21.29
1999	3.54	21.37
2000	3.39	22.28

Source: INEGI, Sistema de Cuentas Nacionales de México (SCNM), 1988-1999 y 1996-2001.

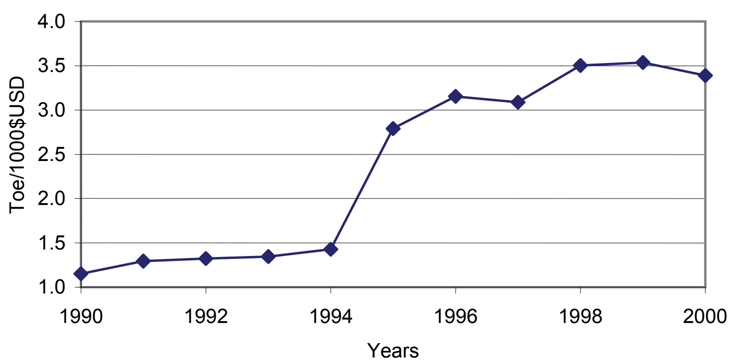

Figure 6.21 Energy Intensity in Transportation 1990-2000

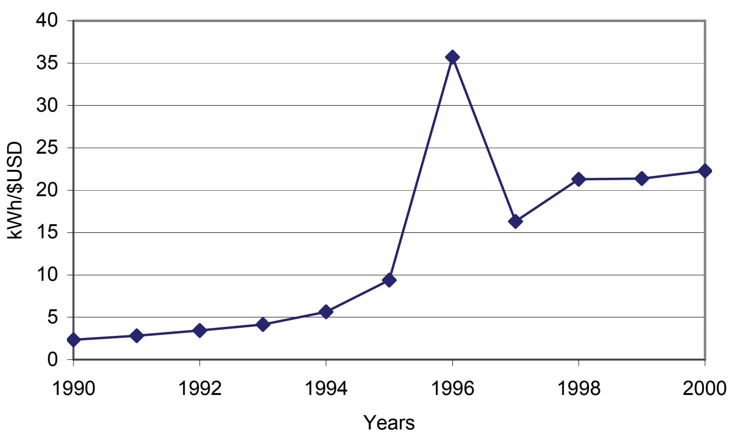

Figure 6.22 Electricity Intensity in Transportation 1990-2000

Trends: Energy intensity in transportation has dramatically increased in the last decade, mainly due to population growth in urban areas and insufficient public transportation systems.

Population growth in urban areas has not been matched by efficient transportation systems. Mexico needs more public transport and a culture of less personal vehicle use, as well as street planning in urban design.

Until major changes in the urban public transportation systems occur, the energy intensity in this sector will continue to increase and result in negative impacts on the environment and human health.

Indicator construction and limitations: Time series in this indicator cannot be expanded because of differences in the way SENER and the National Accounts System categorize economic groups.

6.6.3.8. INDICATOR 9.5

Energy Intensity in the Residential Sector (toe of final energy and kWh of electricity per capita or per household; toe of energy used for space heating per unit of home area)

Definition: Amount of energy or electricity used per person or household and for space heating per unit of home area in the residential sector.

Purpose: The indicator is used to monitor energy consumption in the residential sector.

TABLE 6.30 ENERGY INTENSITY RESIDENTIAL SECTOR 1993-2000

Year	kWh/USD	Toe/1,000$USD
1993	0.20	0.12
1994	0.21	0.12
1995	0.31	0.18
1996	0.27	0.16
1997	0.23	0.13
1998	0.24	0.13
1999	0.23	0.11
2000	0.20	0.09

Source: INEGI, Sistema de Cuentas Nacionales de México (SCNM), 1988-1999 y 1996-2001.

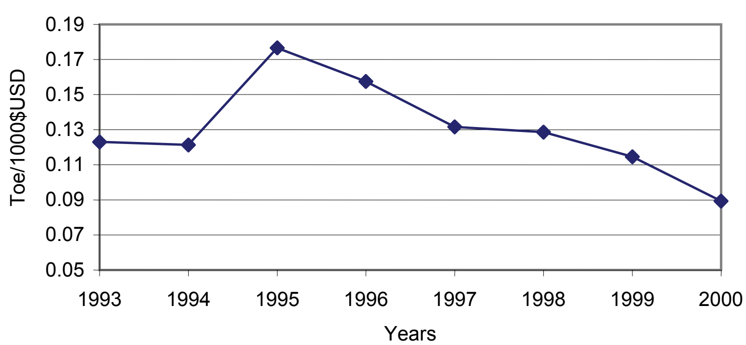

Figure 6.23 Energy Intensity Residential Sector 1993-2000

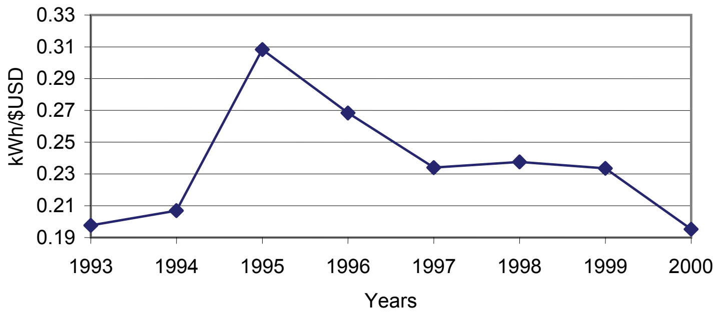

Figure 6.24 Electricity Intensity Residential Sector 1993-2000
Note: The data available cover only the period from1993 to 2000. The exchange rate for dollars is based on Bank of Mexico data for each year.

Trends: The residential energy intensity index has generally trended downward by an average of 8% since 1995, with the greatest declines observed in the mid 1990s (due to the economic crisis of 1994). Other than that, residential energy use appears to grow in lockstep with increases in households.

Indicator construction and limitations: Time series in this indicator cannot be expanded because of differences in the way SENER and the National Accounts System categorize economic groups.

The improvement of energy efficiencies in this sector is an important priority for Mexico. Many policies addressing these issues are being formulated for this sector, in order to balance energy consumption increases due to the industrialization of rural areas.

6.6.3.9. INDICATOR 14

Energy use per unit of GDP

Definition: Ratio of energy consumption to GDP in real US dollars.

Purpose: Trends in overall energy use relative to GDP indicate the general relationship of energy consumption to economic development and provide a rough basis for projecting energy consumption and its environmental impacts with economic growth. For energy policy-making, however, sector or sub-sector energy intensities should be used.

TABLE 6.31 ENERGY USE PER UNIT OF GDP 1980-2002

Year	TOE/1,000 USD /a	KWh / USD /a
1980	0.182	0.172
1981	0.182	0.172
1982	0.187	0.186
1983	0.189	0.196
1984	0.183	0.201
1985	0.184	0.209
1986	0.182	0.224
1987	0.187	0.234

1988	0.182	0.245
1989	0.182	0.254
1990	0.185	0.252
1991	0.185	0.248
1992	0.181	0.247
1993	0.182	0.251
1994	0.181	0.260
1995	0.191	0.287
1996	0.184	0.293
1997	0.175	0.294
1998	0.171	0.294
1999	0.158	0.300
2000	0.152	0.303
2001	0.149	0.308
2002	0.150	0.313

a/ National Accounts base year: 2003.
Source: International Monetary Fund, *World Economic Outlook Database*, September 2003.
SENER. 2003. National Energy Balance.

Trends: Total energy use per unit of GDP remained more or less constant from 1980 until the mid 1990s, and from then on has continuously dropped due to higher shares of non-energy intensive sectors (e.g. services). Peaks are observed and can be explained due to recurrent economic crises, sometimes associated with political change. Electricity consumption has continuously increased (particularly after 1994-1995, due to the economic crisis), yet no sign of recovery is observed.

Indicator construction and limitations: It is important to supplement the energy use of GDP indicator with energy intensities disaggregated by sector, since these are a better representation of energy efficiency developments. This could not be done with the information available.

6.6.3.10. INDICATOR 16

Energy consumption per capita

Definition: The per capita amount of energy – coal, oil, petroleum products, gas, combustible energy & waste, electricity, and heat converted into oil equivalent - available in a given year in a given country or geographical area.

Purpose: This indicator measures the level of energy use on a per capita basis and reflects the energy use patterns and aggregate energy intensity of a society.

TABLE 6.32 ENERGY CONSUMPTION PER CAPITA

Year	TOE per capita /a	KWh per capita/a
1980	0.759	716.232
1981	0.808	763.944
1982	0.810	805.360
1983	0.768	797.095
1984	0.757	831.256
1985	0.762	866.703
1986	0.714	879.141
1987	0.732	916.664
1988	0.708	950.493
1989	0.723	1,007.934
1990	0.758	1,029.308
1991	0.804	1,077.477
1992	0.800	1,089.610
1993	0.803	1,111.001
1994	0.825	1,183.318
1995	0.803	1,207.203
1996	0.803	1,276.728
1997	0.803	1,348.969
1998	0.816	1,407.521
1999	0.766	1,458.236
2000	0.775	1,547.008
2001	0.746	1,543.024
2002	0.746	1,558.067

a/ Estimated population data were used since official data are presented every 10 years
Source: International Monetary Fund, *World* Economic Outlook Database, September 2003.
SENER. 2003. National Energy Balance.

Trends: Electricity consumption per capita grew by 217% between 1980 and 2002, reflecting a considerable growth in the quality of life. Considering Indicator 19, however, there remains an important income inequality, and while energy consumption has significantly increased and per capita consumption levels also have increased, energy consumption remains concentrated in the 20th percentile of households with higher income, according to indicators #19 and #22.

Indicator construction and limitations: The actual value of the indicator is strongly influenced by a multitude of economic, social and geographical factors.

6.6.3.11. INDICATOR 20

Ratio of daily disposable income/private consumption per capita of 20% poorest population to the prices of electricity and major household fuels

Definition: Amount of household energy (electricity; the main fuels used for heating and cooking; and kerosene used for lighting) that a person in the 20% poorest population group could consume per day based on daily disposable income and the actual prices of energy commodities.

Purpose: This indicator provides a measure of energy affordability by poorest households. The indicator is an assessment of the amount of electricity and fuel that could be consumed daily according to current consumer energy prices and available disposal income.

TABLE 6.33 RATIO OF DAILY DISPOSABLE INCOME[1]PER CAPITA OF 20% POOREST[2] POPULATION TO THE PRICES OF ELECTRICITY[3] AND MAJOR HOUSEHOLD FUELS[4]

Year	Electricity kWh/capita/day	Liquefied gas (LP) Gj/capita/day
1989	11.01	0.15
1992	12.13	0.19
1994	16.24	0.14
1996	12.35	0.10
1998	11.50	0.07
2000	15.46	0.09
2002	12.78	0.09

[1] Available income equals annual monetary income based on quarterly income.
[2] Corresponds to households with lowest incomes (stratum I y II).
[3] Unit price of electricity equals annual average based on bi monthly price.
[4] Annual unit price of liquefied gas based on monthly price.
Source: INEGI. Encuesta Nacional de Ingreso-Gasto de los Hogares, 1989, 1992, 1994, 1996, 1998, 2000, 2002. México 1992, 1993, 1995, 1998, 2000, 2001, 2003.
SENER. Balance Nacional de Energía 2002. México, 2003.
www.energia.gob.mx (10 octubre 2004).

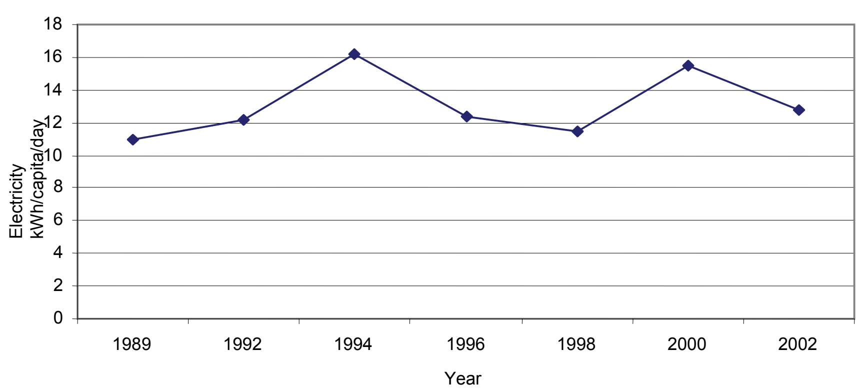

Figure 6.25 Ratio of daily disposable income/private consumption per capita 20% poorest to prices of electricity 1989-2002

Trends: In 1989, the 20% of the population with the lowest income could purchase 11 kWh/day per capita, whereas in 1994 this increased to 16 kWh/day per capita. In 1996 and 1998, as a result of the economic crisis (precipitated at the end of 1994), and because the price per kWh/day was increased from 0.15 pesos in 1994 to 0.43 pesos in 1998, the purchasing power of the poorest declined in its capacity to buy electricity. It recovered again in 2000, at 15.46 kWh/day, and then again decreased in 2002 to 12.78 kWh/day.

If the average consumption in the typical house is 5 to 6 kWh/day, it can be inferred that in 1989 the population with lowest incomes could acquire electricity for a period of approximately 45 days; 13 years later, in 2002, the amount of electricity that could be acquired for this population is for more than 50 days.

An important factor that could explain this performance is the governmental subsidy that homes have received for a considerable period of time, until 2001 when it became selective to those homes that had not exceeded a basic limit of electricity consumption. This means that the lowest income population level was not usually affected, which explains the slight improvement in its level of purchase.

In the case of liquefied gas, there was a decreasing trend in affordability. Whereas in 1989 the population with lowest income could buy 0.15 Gj/day per capita, in 2002 the amount was reduced to 0.09 Gj/day per capita.

The amount of this type of fuel purchased by the poorest segment of the population has decreased due to the constant increase of its price in these past 13 years, which went from 7.41 pesos in 1989 to 106.19 in 2002. Unlike the electric sector, a subsidy policy does not exist in this case.

Indicator construction and limitations: For the year 1989 electricity and gas prices were not available, so the calculations were done with prices from the year 1990 published by Secretariat of Energy (SENER). The household survey data corresponds to l989.

The electricity and Liquefied Gas of Petroleum prices correspond to the residential rate.

Kerosene data are not included because consumption is not significant and is declining.

6.6.3.12. INDICATOR 21

Fraction of disposable income/private consumption spent on fuel and electricity (%)

Definition: The expenditure spent on household fuel and electricity as a percentage of total private consumption per capita by average population and by a group of 20% poorest population.

Purpose: This indicator provides a measure of energy affordability by average population and by poorest households. The indicator is the fraction of household final consumption expenditure that the average population and in particular the group of 20 % poorest population actually spent on household fuel and electricity according to current consumer energy prices and actual consumption level.

TABLE 6.34 FRACTION OF PRIVATE CONSUMPTION[1] SPENT ON FUEL AND ELECTRICITY 1984-2002

Year	% of average expenditure per person on electricity and gas of average population	% of average expenditure per person on electricity and gas of the population with least income[2]
1984	2.98	2.87
1989	3.08	3.28
1992	3.68	4.11
1994	4.29	5.45
1996	4.80	6.00
1998	4.63	5.22
2000	4.63	6.00
2002	5.17	6.00

[1] Available expenditure available equals annual monetary expenditure based on quarterly expenditure.
[2] Poorest 20% of households.
Source: Encuesta Nacional de Ingreso-Gasto de los Hogares, 1984, 1989, 1992, 1994, 1996, 1998, 2000, 2002. México 1985, 1989, 1993, 1995, 1997, 1999, 2001, 2003.
SENER. Balance Nacional de Energía 2002. México 2003.

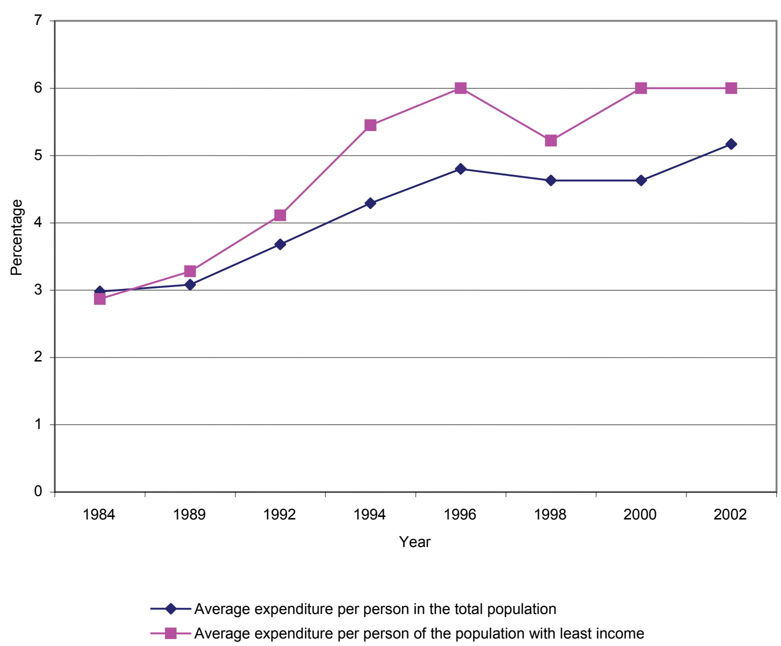

Figure 6.26 Fraction of private consumption spent on fuel and electricity 1984-2002

Trends: Disposable income spent on fuel and electricity grew at a faster pace for the population with least income than for the average population. The share of income required for the purchase of electricity and gas, between 1984 and 2002, grew at an average annual growth rate of 4% for the average population, whereas it grew at 6% for the quintile of lowest incomes.

A factor explaining this situation is the increase of prices for power: the price of a kWh was raised from $0.10 in 1989 to $0.77 in 2002, i.e., a 670% increase, whereas the price for gas was increased

1,433% (from $7.41 to $106) over the same years. Another factor is that the average population had a higher percentage increase in its income than did the poorest quintile.

The tendencies observed for both segments of the population are the following: in the case of the poorest quintile, consumption of gas and electricity in 1989 were 1.8 Gj per capita and 120.77 kWh per capita, respectively; in 2002 the per capita consumption was 1.04 Gj for gas and 209.9 kWh for electricity; thus gas consumption decreased by 11.9%, as a result of the greater increase in its price, while electricity registered an increase of 73%. In the case of the average population, gas and electricity consumption passed from 2.89 Gj and 368.2 kWh per inhabitant in 1989 to 3.09 Gj and 702.7 kWh per inhabitant in 2002.

The differences in the proportions between both groups are the following: for electricity consumption, it was close to 200% in 1989 and 250% in 2002; for gas, the amounts in both years were, respectively, 150% and 200%.

The previous variations could also be seen in the context of the comments for indicator 21: the cancellation of the subsidy for electricity affected the average population but not the poor population. For gas, there has been no subsidy and therefore the price increments have affected both strata.

In recent years, Mexico has followed a policy to ensure economic development while simultaneously diminishing the impact on the environment, through the implementation of energy efficiency, energy savings and diversification of energy sources.

The National Plan of Development also has implications in state policies that define and direct subsidies to the users who need it most and that give support of the public sector to generators that respect environmental regulations and to projects that bring electricity to the excluded areas, as well as foster the use of renewable energy.

Indicator construction and limitations: As regards to incomes for population's strata, the official source is the National Survey of Household’s Income-Expenditure (ENIGH), whose available data only correspond to the period included for this indicator. For gas and electricity, the data are much more readily available.

This indicator includes two calculations: one for the average population and the other for the poorest 20% of the population.

For both groups the numerator refers to the expenditure of those households that consumed electric power and the denominator includes all households, even those that did not report expenses for electricity consumption.

Total expenditures spent only by households that consumed electrical energy is required, so that the percentage of private consumption spent on fuel and electricity is more exact.

A comparable situation exists for the case of Liquefied Petroleum gas.

6.6.3.13. INDICATOR 35

Fraction of technically exploitable capability of hydropower currently not in use (%)

Definition: It is defined as one minus the ratio of total rated capacities of hydroelectric generating units that are installed at all sites, which are generating, to the amount of the gross theoretical capability that can be exploited within the limits of current technology.

Purpose: The purpose of the indicator is to measure availability of technically exploitable capability of hydropower.

This indicator provides a basis for estimating future hydroelectricity supplies, enabling proactive decision making to ensure the efficient use of technical potential of hydroelectricity over the longer term.

Availability of domestic technical hydropower potential allows an increase in renewable energy production, consequently decreasing atmospheric pollution, and increasing energy availability, in particular for the poor in the developing world that have no access to electricity. Small, mini and micro plants (usually defined as plants less than 100MW, 10MW and 20 kW, respectively) play a key role in many countries, often being a mainstay of rural electrification.

TABLE 6.35 FRACTION OF TECHNICALLY EXPLOITABLE CAPABILITY OF HYDRO POWER CURRENTLY NOT IN USE 1980-2004

Year	1- (Installed capacity / potential) * 100
1980	85.49
1981	84.14
1982	84.14
1983	84.18
1984	84.18
1985	84.18
1986	84.18
1987	81.73
1988	81.24
1989	81.21
1990	81.10
1991	80.80
1992	80.80
1993	80.21
1994	77.91
1995	77.41
1996	75.70
1997	75.70
1998	76.51
1999	76.71
2000	76.71
2001	76.71
2002	76.72
2003	76.72
2004	76.75

Source: SENER. 2003. Statistical Compendium of the Energy Sector

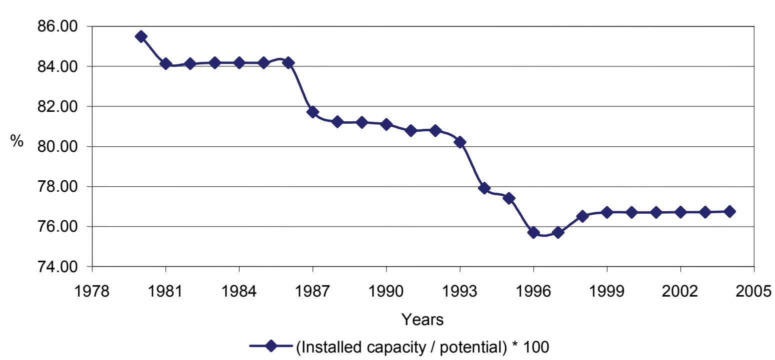

Figure 6.27 Fraction of technically exploitable capability of hydro power currently not in use 1980-2004

Trends: The estimated natural hydropower potential for Mexico amounts to almost 42,000 MW, according to official studies from the CFE. The installed capacity of hydroelectricity grew 21% in recent years.

In 2004 hydroelectricity represented 23% of total hydropower potential. New hydroelectric projects starting in 2003 will increase hydro capacity by more than 1,700 MW.

The potential included both large and small hydro projects. It would be better to subdivide this indicator into large hydro installed capacity/potential and small hydro installed capacity/ potential.

Indicator construction and limitations: Data generated by SENER and CFE are readily available so construction of this indicator presented no difficulties.

6.6.3.14. INDICATOR 40

Intensity of use of forest resources as fuelwood (%)

Definition: The indicator compares the amount of harvested wood to be used for energy needs as a percentage of the Net Annual Increment (NAI) for the national forest, defined as the average annual volume of gross increment less natural losses. If the annual increment is not known, the allowable cut can be used as a surrogate.

Purpose: The indicator aims at assessing whether actual forest harvest to be used for energy needs is compensated for by new growth within the nation's forests. If the indicator is greater than 100, it implies that a country for its energy needs alone is over-harvesting its stock of forest.

This indicator is a proxy, which is relevant for assessing the sustainability of forest stocks management when interpreted over a long time period. The indicator relates sustained yield to actual harvest of fuelwood in terms of a relative balance between forest growth and harvest. The total harvest rate set by a country is a function of the size of its forests, proportion of the forest area dedicated to timber production, the productivity of the forest and its age class structure, and the management objectives and sustained yield policies of the country.

For this study, the data available are for consumption of fuelwood.

TABLE 6.36 USE OF FOREST RESOURCES AS FUELWOOD 1960-2000

Year	Population[1]	National consumption Fuelwood[2] PJ	National consumption Fuelwood[2] Toe	Consumption per capita Toe per capita
1960	34,923,129	316	7,545,381	0.22
1970	48,225,238	342	8,178,084	0.17
1980	66,846,833	341	8,155,632	0.12
1990	81,249,645	340	8,109,296	0.10
2000	9,.483,412	338	8,075,857	0.08

[1] INEGI, 2002 www.inegi.gob.mx
[2] Balance Nacional de Energía 2001 (SENER, 2002)

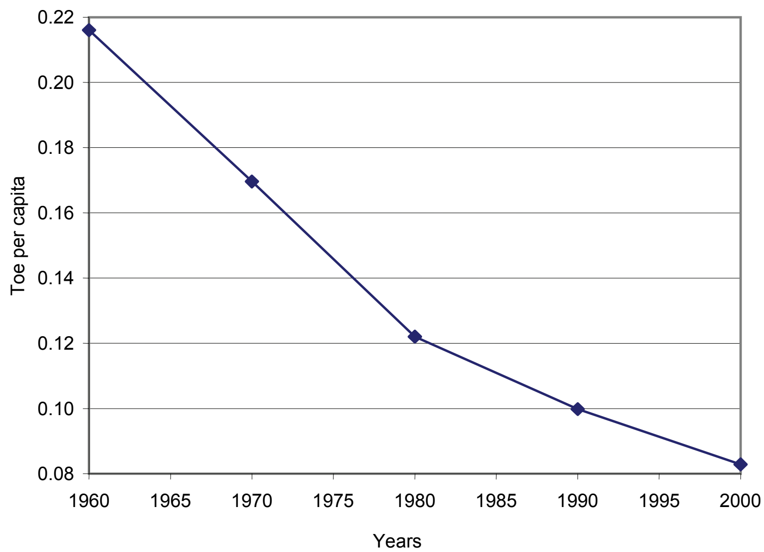

Figure 6.28 Intensity of use of forest resources as fuelwood 1960-2000

Trends: Lately 90% of fuelwood is consumed for household purposes (mainly for cooking and heating), and the remaining 10% is consumed by small-scale industry. Between 1960 and 1970, fuelwood consumption grew by 8.4%, but starting from 1970 consumption has decreased 0.5% annually, due to greater access of the rural population to alternative fossil fuels, and to immigration of the rural population to urban areas (see Indicator #1). On a per capita basis, fuelwood consumption decreased 20% between 1990 and 2000. The southern states of Veracruz (11%), Chiapas (10%), and Oaxaca (9%) exhibit the largest consumption of fuelwood.

Indicator construction and limitations: Accurate data on Mexico's forest area are readily available, as it has been used as a basic indicator for forest resources. It is an essential requirement for forest policy making and planning.

It is worth noting that the indicator does not measure the total rate of deforestation but focuses on deforestation caused by the harvesting of fuelwood.

6.6.4. Environmental protection and safety policies

The indicators on environmental protection and safety policies are:

- 23. Quantities of air pollutant emissions
- 24. Ambient concentration of pollutants in urban areas
- 26. Quantities of greenhouse gas (GHG) emissions from energy related activities
- 27. Radionuclides in atmospheric radioactive discharges
- 28.1 Discharges into water basin: Oil into coastal waters
- 28.2 Discharges into water basin: Radionuclides in liquid radioactive discharges
- 29. Generation of solid wastes
- 31. Generation of radioactive waste from nuclear power fuel cycle chain
- 32. Accumulated quantity of radioactive waste awaiting disposal

- 34. Fatalities due to accidents with breakdown by fuel chain
- 38. Proven uranium reserves

6.6.4.1. INDICATOR 23

Quantities of Air Pollutant Emissions (Tonnes or 1,000 tonnes)

Definition(s): Emissions of air pollutants, which are artificially introduced into the air from all energy-related activities and from both electricity production and transportation in particular. From human health and ecosystem perspectives, main causes of growing concerns are emissions of acidifying substances, such as sulphur oxide (SOx) and nitrogen oxides (NOx); ozone forming gases (ozone precursors), such as volatile organic compounds (VOC), nitrogen oxides, fine particulates and carbon monoxide (CO).

Purpose: The purpose of this indicator is to track the release of air pollutants into the atmosphere. The indicator is used to evaluate the environmental performance of national policies and to describe the environmental pressure in relation to air pollution abatement in energy related activities, and in power generation and in transportation in particular.

The indicator can be used to assess the environmental pressure in relation to energy production and consumption and to evaluate the environmental performance of national policies designed to address four major impacts of air pollutants on human health and the ecosystem:

- the acidification of soil and water by pollutants such as sulphur oxides and nitrogen oxides;
- the damage to buildings sensitive to the same acidifying substances;
- the formation of tropospheric ozone from so-called ozone precursors, e.g. volatile organic compounds, nitrogen oxides and carbon monoxide which indirectly affect human and animal health and vegetation;
- direct effects on human health and ecosystems e.g. through high atmospheric concentrations of particulates, and VOCs.

TABLE 6.37 POLLUTANT EMISSIONS FROM ELECTRIC GENERATION 1995-2001

Year	Generation from Thermal (GWH)	CO2* (tons)	NOx* (tons)	SO2* (tons)	Particles* (TSP) (tons)
1995	100,686	72,175,029	194,990	1,246,175	78,782
1996	106,833	75,642,535	214,291	1,295,413	81,516
1997	119,017	84,783,563	229,393	1,485,541	93,902
1998	131,376	93,596,258	250,042	1,623,374	102,800
1999	132,517	93,851,596	253,806	1,592,876	100,937
2000	143,865	102,626,660	275,873	1,709,404	108,701
2001	152,818	105,197,280	297,309	1,666,711	106,625

Source: CFE.2002.

TABLE 6.38 QUANTITIES OF AIR POLLUTANT EMISSIONS PER GWH 1995-2001

Year	CO2 Ton/GWh	NOx Ton/GWh	SO2 Ton/GWh	Particles (TSP) Ton/GWh
1995	716,833	1,937	12,377	0.782
1996	708,045	2,006	12,126	0.763
1997	712,365	1,927	12,482	0.789
1998	712,430	1,903	12,357	0.782
1999	708,223	1,915	12,020	0.762
2000	713,354	1,918	11,882	0.756
2001	688,383	1,946	10,907	0.698

Source: CFE. 2002.

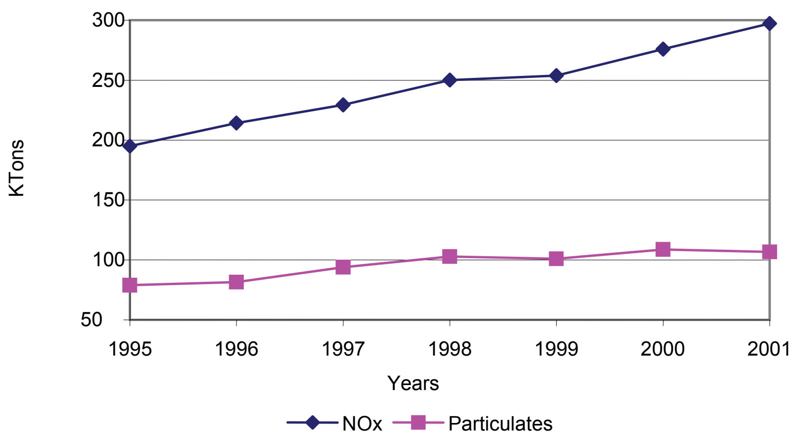

Figure 6.29 NOx and particulates Emissions from electric utilities 1995-2001

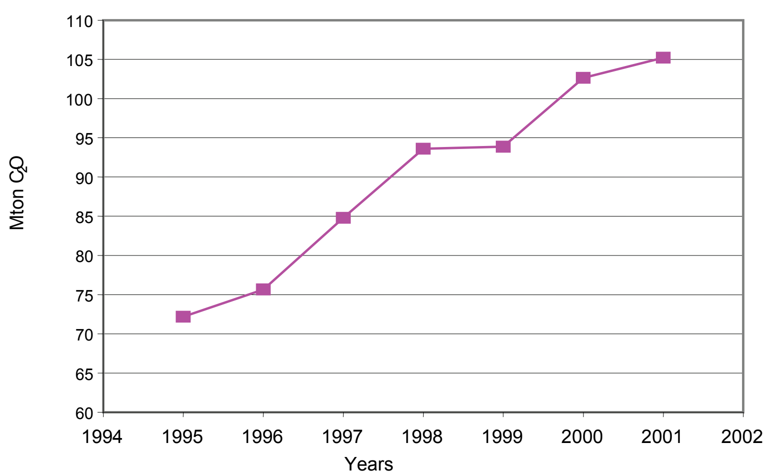

Figure 6.30 CO2 Emissions from electric utilities 1995-2001

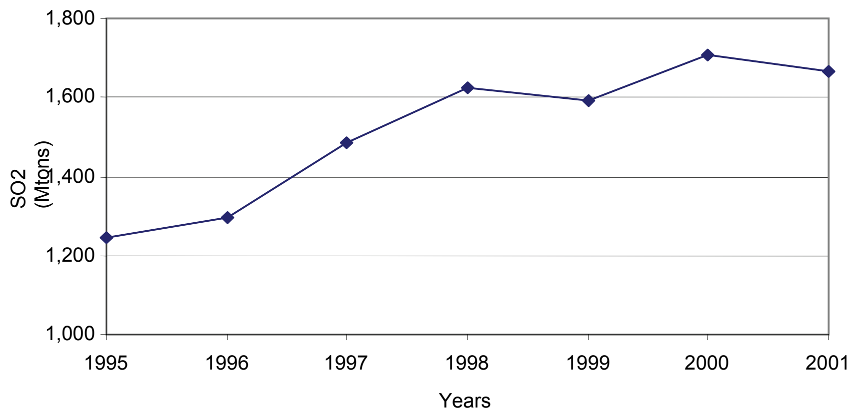

Figure 6.31 SO2 Emissions from electric utilities 1995-2001

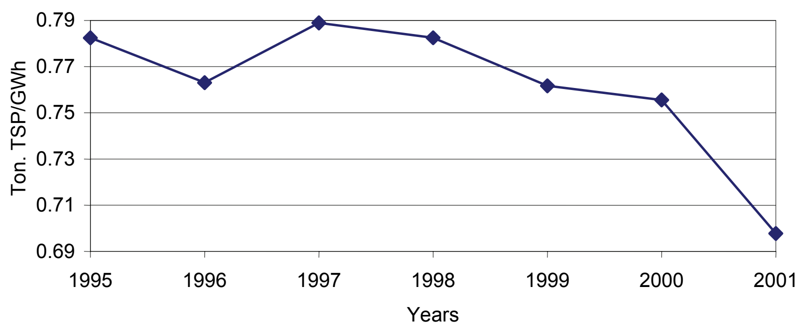

Figure 6.32 TSP emissions per GWh 1995-2001

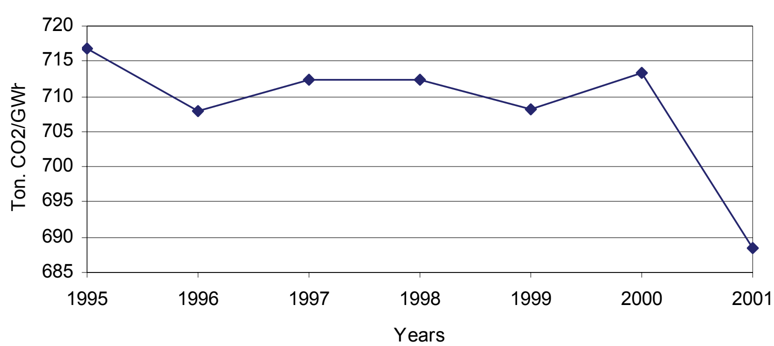

Figure 6.33 CO2 emissions per GWh 1995-2001

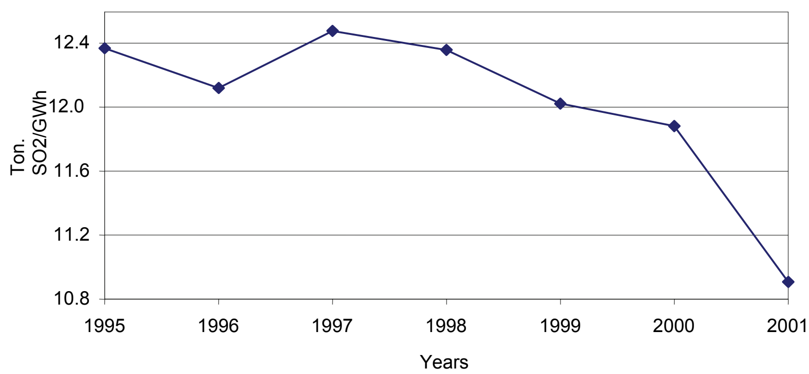

Figure 6.34 SO2 emissions per GWh 1995-2001

TABLE 6.39 AIR POLLUTANT EMISSIONS FROM PEMEX (TON) 1999-2003

Year	SOx	NOx	Total suspended particles	Total organic compounds
1999	685,801	131,533	17,962	179,401
2000	641,535	126,840	16,818	193,320
2001	687,690	86,823	82,832	83,086
2002	496,648	90,163	76,204	78,162
2003	602,930	101,285	86,546	81,895

Source: PEMEX. 1999-2003. Report 1999-2003. Safety, health and environment.

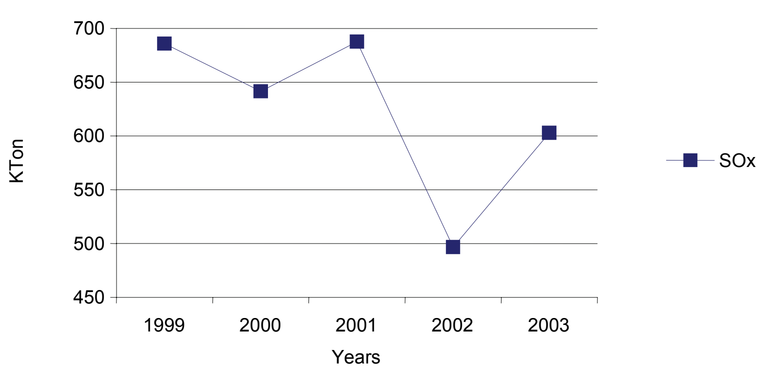

Figure 6.35 PEMEX Air pollutant emissions 1999-2003 SO_x

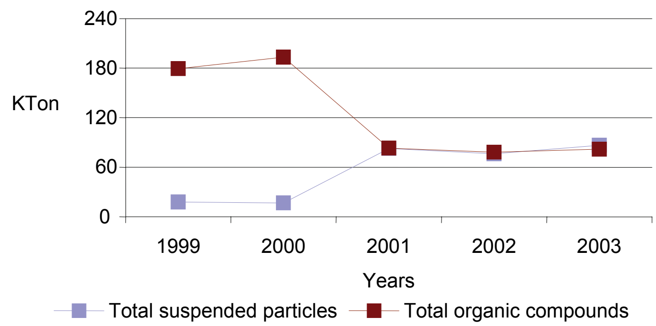

Figure 6.36 PEMEX Air pollutant emissions 1999-2003 TSP; TOC

Trends: The emission intensities for all the pollutants considered have decreased over the last 5 years, due to the increased use of cleaner fuels for electricity generation and improved efficiency in generation.

Power generation grew almost 52% between 1995-2001, and absolute emissions grew during that period, but emission intensity dropped 3.9% for CO2, 12% for SO2, and 10.8% for total suspended particles (TSP). Emission intensity for NOx increased slightly (0.46%). This is the result of a technological switch of the Mexican thermal power capacity from conventional power plants to more efficient combined cycle plants. As result of this transformation, the power sector has doubled its consumption of natural gas between 1995 (5,226 Bm3) and 2001 (11,328 Bm3), and began dropping the consumption of high sulfur fuel oil by almost 900 Mm3 between 2000-2001.

Regarding PEMEX, its oil production increased from 3,012 thousand bl/day in 2000 to 3,317 thousand bl/day in 2003, and this also led to increases in oil processing in the four subsidiaries of the company. During 2002 a major reconfiguration occurred in the National Refinery System (note: PEMEX manages the entire Refinery System of the country), increasing operations in 2003. All these events led to reported emission increases.

Indicator construction and limitations: Data for PEMEX and CFE are available for recent years, since both companies began implementation of sound environmental programs in the past decade. Data from previous years might not be available or consistent.

Another important aspect is that the level of detail required for various combustion processes (particularly data related to machinery characteristics) is not readily available for certain activities. Emission factors from existing sources of inventory compilation guidance were used to obtain estimates of the pollution emissions released into the atmosphere.

Concrete actions relating pollution control technologies and policies are needed in order to maintain favourable emission intensity indexes.

6.6.4.2. INDICATOR 24

Ambient concentration of pollutants in urban areas (µg/m3 or mg/m3, as appropriate)

Definition: Ambient air pollution concentrations of ozone, carbon monoxide, particulate matter (PM10, PM2.5, SPM, black smoke), sulphur dioxide, nitrogen dioxide, nitrogen monoxide, volatile organic compounds (VOCs) including benzene and lead.

Purpose: The indicator provides a measure of the state of the environment in terms of air quality and an indirect measure of population exposure to air pollution which is a health concern in urban areas.

TABLE 6.40 MEAN ANNUAL CO CONCENTRATION 1988-2002 (PPM)

Year	MCMA	MMA	GMA	TMA	Cd. Juarez
1988	4.067				
1989	4.447				
1990	5.889				
1991	6.270				
1992	5.689				
1993	3.694	1.101			
1994	3.455	0.977		1.911	
1995	2.560	1.002		1.710	
1996	2.665	1.006	2.041	1.652	1.438
1997	2.445	1.023	2.203	1.524	1.136
1998	2.377	1.048	2.141	1.616	1.301
1999	2.164	0.991	2.026	1.595	1.357
2000	2.261	0.995	2.001	1.442	1.164
2001	1.960	0.863	1.945	1.398	0.961
2002	1.707	0.938	2.129	1.188	3.314

	Decrease	Decrease	Increase	Decrease	Increase
Subtraction (1^{st} year-last year)	2.4	0.2	0.1	0.7	1.9
% of decrease or increase	58.0	14.8	4.3	37.8	130.4

MCMA : Mexico City Metropolitan Area
MMA : Monterrey MetropoIitan Area
GMA : GuadaIajara Metropolitan Area
TMA : Toluca MetropoIitan Area

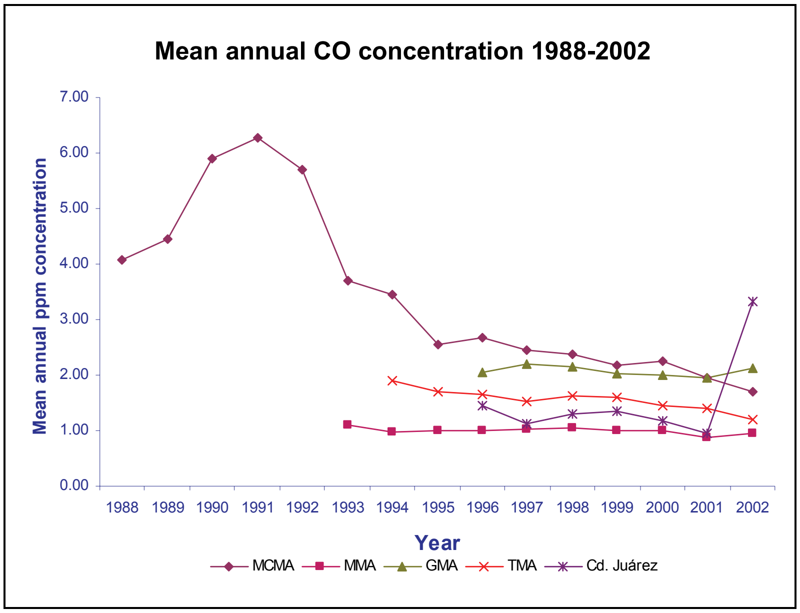

Figure 6.37 Mean annual CO concentration 1988-2002

TABLE 6.41 MEAN ANNUAL NO_2 CONCENTRATION 1988-2002 (PPM)

Year	MCMA	MMA	GMA	TMA
1988	0.038			
1989	0.041			
1990	0.042			
1991	0.041			
1992	0.046			
1993	0.042	0.019		
1994	0.037	0.019		0.024
1995	0.031	0.019		0.018
1996	0.037	0.019	0.044	0.021
1997	0.032	0.019	0.038	0.018
1998	0.029	0.017	0.044	0.022
1999	0.027	0.013	0.038	0.022
2000	0.030	0.015	0.037	0.021
2001	0.026	0.017	0.033	0.021
2002	0.028	0.011	0.039	0.021

	Decrease	Decrease	Decrease	Decrease
Subtraction (1st year-last year)	0.010	0.008	0.005	0.003
% of decrease or increase	26.4	43.3	11.6	13.0

MCMA : Mexico City Metropolitan Area
MMA : Monterrey MetropoIitan Area
GMA : GuadaIajara Metropolitan Area
TMA : Toluca MetropoIitan Area

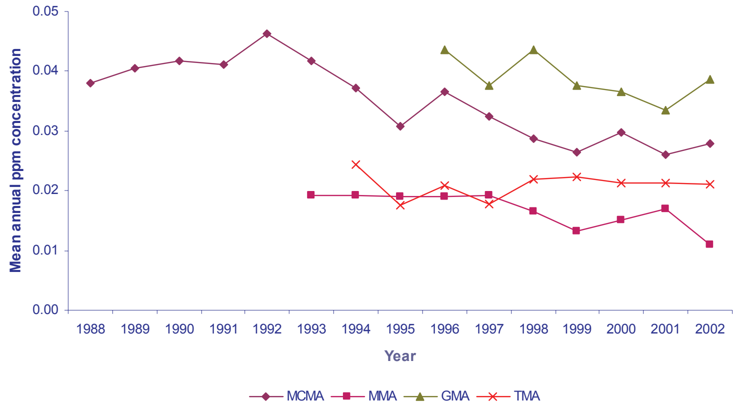

Figure 6.38 Mean annual NO_2 concentration 1988-2002

TABLE 6.42 MEAN ANNUAL PM_{10} CONCENTRATION 1993-2002 (µG/M3)

Year	MCMA	MMA	GMA	TMA	Cd. Juarez
1993		54.4			
1994		62.1			
1995	61.2	51.2			
1996	73.1	55.0	68.5		56.1
1997	73.9	42.3	52.8		48.5
1998	71.1	57.3	74.0	60.0	55.7
1999	51.4	68.3	61.1	59.4	64.9
2000	52.4	59.6	59.1	45.0	68.3
2001	51.2	84.8	56.0	42.7	65.1
2002	50.9	87.0	55.1	51.5	71.0

	Decrease	Increase	Decrease	Decrease	Increase
Subtraction (1st year-last year)	10.3	32.7	13.4	8.5	14.9
% of decrease or increase	16.8	60.1	19.6	14.1	26.6

MCMA : Mexico City Metropolitan Area
MMA : Monterrey Metropolitan Area
GMA : Guadalajara Metropolitan Area
TMA : Toluca Metropolitan Area

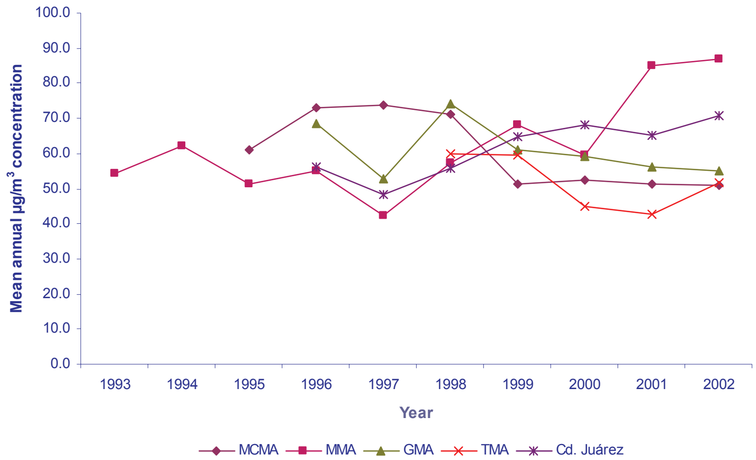

Figure 6.39 Mean annual PM10 concentration 1993-2002

TABLE 6.43 MEAN ANNUAL SO_2 CONCENTRATION 1988-2002 (PPM)

Year	MCMA	MMA	GMA	TMA
1988	0.048			
1989	0.048			
1990	0.052			
1991	0.055			
1992	0.046			
1993	0.021	0.012		
1994	0.020	0.011		
1995	0.017	0.010		0.007
1996	0.016	0.009	0.013	0.011
1997	0.014	0.010	0.011	0.009
1998	0.014	0.010	0.009	0.010
1999	0.013	0.010	0.010	0.011
2000	0.018	0.011	0.009	0.009
2001	0.016	0.011	0.008	0.010
2002	0.012	0.009	0.010	0.009

	Decrease	Decrease	Decrease	Increase
Subtraction (1st year-last year)	0.036	0.003	0.003	0.002
% of decrease or increase	74.4	27.1	24.5	29.6

MCMA : Mexico City Metropolitan Area
MMA : Monterrey Metropolitan Area
GMA : Guadalajara Metropolitan Area
TMA : Toluca Metropolitan Area

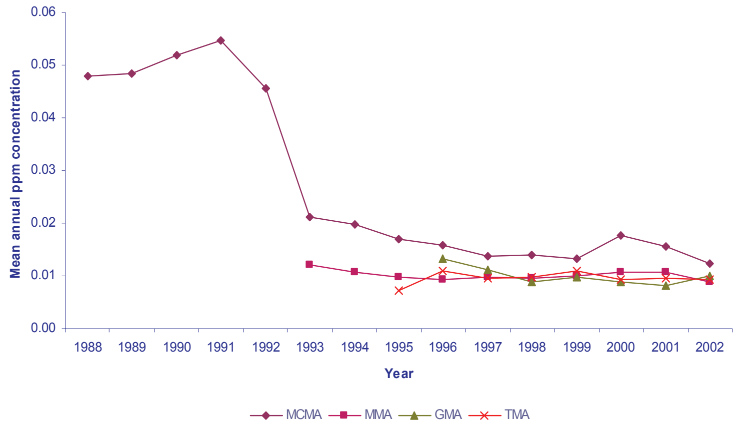

Figure 6.40 Mean annual SO_2 concentration 1988-2002

TABLE 6.44 ANNUAL PEAK OF O_3 HOURLY DATA 1988-2002 (PPM)

Year	MCMA	MMA	GMA	TMA	Cd. Juarez
1988	0.405				
1989	0.493				
1990	0.496				
1991	0.404				
1992	0.475				
1993	0.370	0.141			
1994	0.312	0.152		0.137	
1995	0.349	0.130		0.134	
1996	0.323	0.174	0.336	0.220	0.189
1997	0.318	0.186	0.299	0.167	0.148
1998	0.309	0.137	0.313	0.144	0.262
1999	0.321	0.157	0.228	0.140	0.169
2000	0.282	0.141	0.219	0.180	0.139
2001	0.271	0.224	0.194	0.144	0.141
2002	0.284	0.144	0.233	0.136	0.128
	Decrease starting from 1991	Increase	Decrease	Decrease	Decrease
Subtraction (1st year-last year)	0.121	0.003	0.103	0.001	0.061
% of decrease or increase	29.9	1.8	30.7	0.7	35.8

MCMA : Mexico City Metropolitan Area
MMA : Monterrey MetropoIitan Area
GMA : GuadaIajara Metropolitan Area
TMA : Toluca MetropoIitan Area

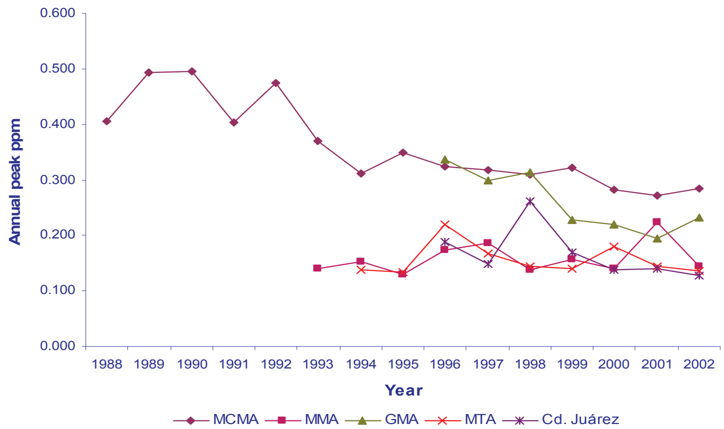

Figure 6.41 Annual Peak of O_3 hourly data 1988-2002

Trends: Air quality levels for most pollutants show a reducing tendency and remain relatively steady in the major cities.

Some trends shown by graphs may be due to the adoption of environmental protection measures for the emissions reduction of Carbon Monoxide (CO), Sulphur Dioxide (SO2), Ozone Concentration (O3), Nitrogen Dioxide (NO2), and Particles smaller than 10 µm (PM10).

For MCMA:

The "Hoy no Circula" ("Not circulating today") and Vehicle Monitoring Programs started in 1988, which means that cars with certain license plates cannot circulate one day of the week.

1989: The surfactant-type additive was replaced by one of the surfactant-dispersant types at a national level, reducing the accumulation of deposits in automobile motors. An oxygenated ingredient was added to gasoline in MCMA aimed at reducing carbon monoxide and hydrocarbons.

1992: The Industrial Emissions Control Program began, aimed at reducing NOx and HC emissions.

1993: Automobiles with a three-way catalytic converter were launched, which required the distribution of Magna Sin gasoline. National Diesel was replaced by non-sulphur Diesel (0.5% sulphur) throughout the country.

1994: The Standards NOM 085 and NOM 086 came into force, setting emission limits for industry and fuel quality. Non-sulphur Diesel was replaced by Pemex Diesel (0.05% sulphur) at the national level.

1997: The distribution of PEMEX's reformulated magna gasoline started as part of the ongoing fuel environmental-improvement program. The Vehicle Monitoring Program became modernized through the use of BAR 97 equipment.

For MMA:

1993: Automobiles with a three-way catalytic converter were launched, which required the distribution of Magna Sin gasoline.

1994: The Standards NOM 085 and NOM 086 came into force, setting emission limits for industry and fuel quality.

Indicator construction and limitations: As a complement of this indicator, the creation of indicator 24A is proposed, which should define the origin of pollutants in urban areas, so different sector contributions could be identified.

6.6.4.3. INDICATOR 26

Quantities of greenhouse gas (GHG) emissions from energy related activities (Annual GHG emissions in megatonnes (Mt); Emissions of CH4 and N2O are to be converted to CO2 equivalents using 100 year global warming potentials (GWPs) provided in the IPCC Second Assessment Report, 1995)

Definition: Emissions related to energy use, less removal by sinks, of the greenhouse gases carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O).

Purpose: This indicator measures the quantities of the three main GHGs emitted from energy sources and which have a direct impact on climate change, less the removal of the main GHG CO2 through sequestration as a result of land-use change, ocean sink and forestry.

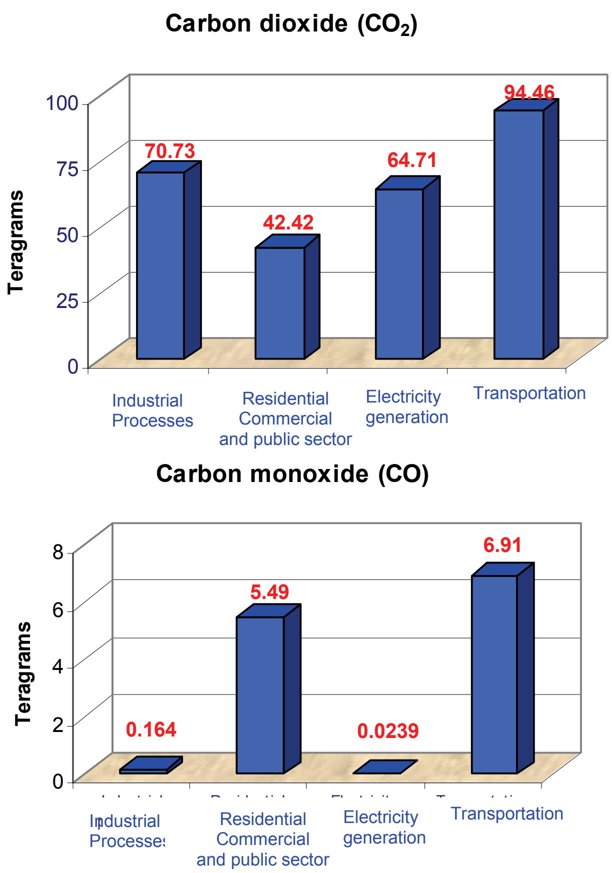

Figure 6.42 CO2 and CO Emissions
Source: SEMARNAP, INE, et al. 1995. Preliminary National Inventory of Greenhouse Gas: Mexico.

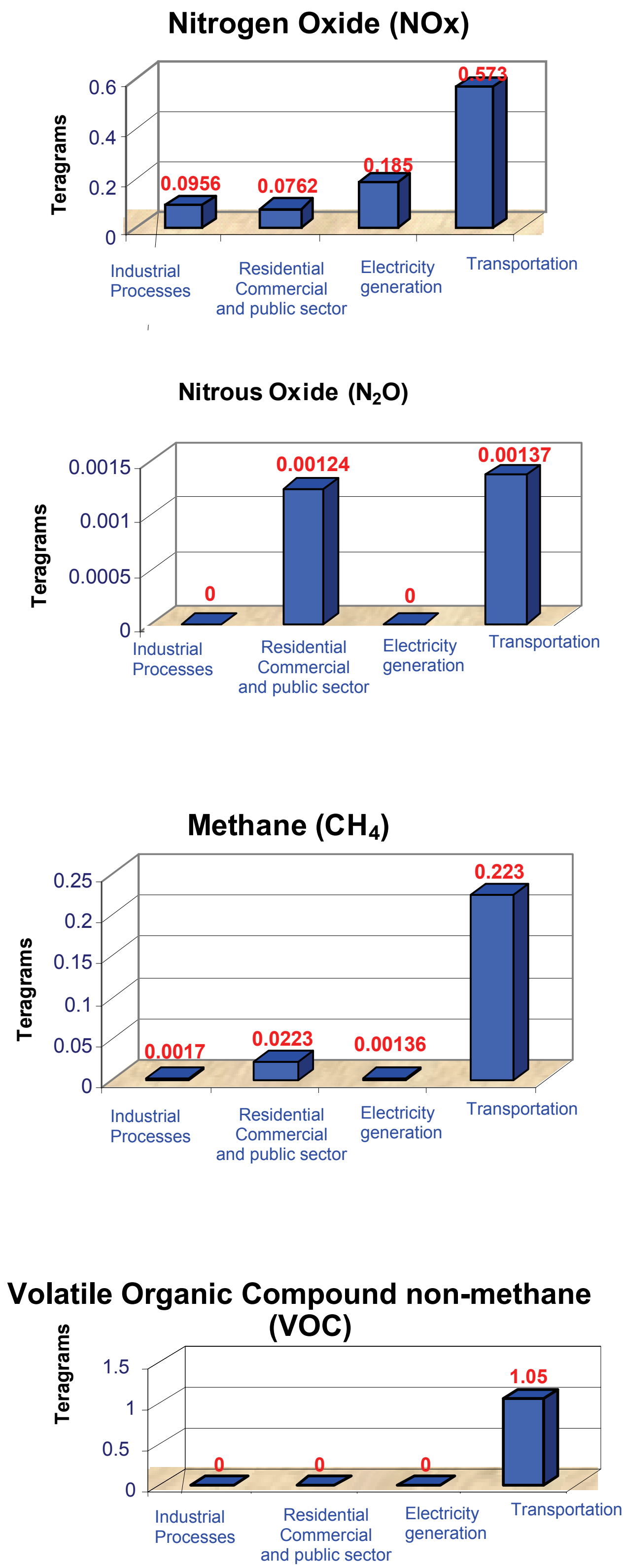

Figure 6.43 NOx, N2O, CH4 and VOC Emissions
Source: SEMARNAP, INE, et al. 1995. Preliminary National Inventory of Greenhouse Gas: Mexico.

Trends: The transport sector is responsible for 34% of the Total CO_2 emissions accounted for. Mexico has developed an important set of actions and policies for climate change mitigation, although all of them cannot be quantified accurately. During the 1990s, the Mexican economy grew under cleaner productive patterns than in the past. Inter-institutional mechanisms were established to contribute to the objectives of the Framework Convention on Climate Change of the United Nations, and by doing so the country avoided significant amounts of GHG emissions during the past decade.

Mexico is committed to continuing to require such actions in due course, independently of multilateral international negotiations. In the present circumstances, the country cannot assume additional commitments to those already accepted. Nevertheless, the establishment of flexible mechanisms derived from the Convention (and in particular the Clean Development Mechanism) will be able to complement the national effort.

Indicator construction and limitations: This indicator shows the quantity of GHGs emitted to the atmosphere from energy use only; it is relevant to note that non-energy sources can also produce significant levels of emissions. It also does not show how the climate will be affected by the increased accumulation of GHGs.

Data were not available for all GHG sources, and it is for 1995, since the last National Communication from Mexico to the Convention was done in 1998. In 2006, Mexico will present a second report.

6.6.4.4. INDICATOR 27

Radionuclides in atmospheric radioactive discharges

Definition: This indicator refers to radionuclides present in planned and controlled aerial discharges into the atmosphere from nuclear fuel cycle facilities in the country and specified by those radionuclides that contribute greater than 5% of the collective dose from discharges (noble gases, tritium, carbon-14, iodine and Cs-137).

Purpose: The purpose of this indicator is to assist in quantifying the pressures on the environment by identifying the aerial radionuclide discharges that contribute most to the collective dose. Whilst not directly related to the impact, the indicator provides a simple tool from which trends and achievements can be gauged.

TABLE 6.45 ANNUAL LIBERATED ACTIVITY IN ATMOSPHERIC DISCHARGES, GIGA BECQUEREL PER YEAR (GBQ/YR)

Isotope	1990	1999	2000	2001	2002	2003
H-3	2.16E+03	1.34E+03	5.83E+02	7.11E+02	6.80E+02	2.91E+02
I-131	4.03E-02	2.22E-02	9.97E-02	9.42E.-3	1.83E-02	8.16E-02
Cs-137	6.25E-04	1.50E-03	2.53E-03	7.37E.-4	1.24E-04	2.77E-03
AR-41	<LLD	4.95E+00	<LLD	<LLD	1.25E-02	<LLD
KR-85	<LLD	<LLD	<LLD	<LLD	<LLD	<LLD
KR-85m	6.71E+01	4.84E+02	1.10E+02	<LLD	2.97E+01	2.60E+01
KR-87	3.39E+01	5.67E+01	4.01E+00	<LLD	3.21E+01	2.00E+01
KR-88	2.01E+00	2.09E+02	1.73E+01	<LLD	2.36E+01	<LLD
XE-133	1.40E+01	1.70E+03	7.64E+02	<LLD	1.12E+00	<LLD
XE-133m	<LLD	<LLD	<LLD	<LLD	<.LLD	<LLD
XE-135	1.58E+01	3.21E+02	6.18E+01	<LLD	1.51E+01	2.78E+01
XE-135m	1.60E+01	3.91E+01	1.40E+01	<LLD	3.27E+00	<LLD
XE-138	<LLD	2.46E+01	<LLD	<LLD	3.83E+01	<LLD
Electricity generation (TWh)	9.3	9.6	7.9	8.5	NA	NA

NA: Not available
LLD: Low Line Drive
Source: Comision Federal de Electricidad Gerencia de Generacion Nucleoelectrica 2003.

Trends: For most of these elements a significant increase was observed in 1999 due to a change of the catalyst used in the only nuclear plant in Mexico. An increase in the process efficiency can also be observed, causing a reduction of tritium used.

Indicator construction and limitations: Mexico has only one nuclear power plant, which has a strict control of its emissions. This facilitates the data collection effort.

6.6.4.5. INDICATOR 28.1

Discharges into water basins: Oil into coastal waters

Definition: Total accidental, licensed and illegal discharges of mineral oil to the coastal and marine environment.

Purpose: This indicator shows the amount of oil discharges into coastal waters and has the potential to illustrate the effectiveness of measures designed to reduce these discharges over time in accordance with Regional Seas Conventions and Action Plans.

TABLE 6.46 DISCHARGES INTO MARINE REGION OF CAMPECHE SOUND, DURING OIL PRODUCTION, 2001-2002

Year	Marine region	Oil discharges		
		Total (Number)	Total (Tons)	CO_2 Emissions (tons/10^6)
2001	northeast	28	69	6.09
	southeast	1	369	1.57
2002	northeast	25	8	4.47
	southeast	2	261	1.46

Source: J. Ángel García-Cuéllar et al., Impacto ecológico de la industria petrolera en la Sonda de Campeche, México, tras tres décadas de actividad: una revisión. www.scielo.org.ve

TABLE 6.47 SEVERAL DISCHARGES OF HYDROCARBONS REGISTERED IN PEMEX REPORTS, 1999-2005

Year	Event	Cause	Loss	Site or region
1999	Oil pipeline	Valve leak	113 b crude oil	Rio Sarabia, San Juan Guichicovi, Oax.
2000	Oil pipeline	Pipeline fissure	6,300 b crude oil	Poza Rica-Madero
	Pipeline	Accident by land settle	12,000 b crude oil	Poza Rica-Madero
2001	Oil pipeline 30"	Accident by land settle	14,500 b crude oil	Minatitlán
	Pipeline 12"	Fuel intake clandestine	4,423 b crude oil	Nuevo Teapa. Poza Rica
		Fuel intake clandestine	5,371 b of gasoline	Bajío
	Oil pipeline 48" in Dos Bocas (RMSO)		2,706 b crude oil	
2002	several	Different causes	9,570 tons of hydrocarbons	Different sites
2003	Oil pipeline and gas pipeline 30 "	River avalanche		Nogales y Rio Blanco, Ver.
2004	Oil pipeline 30 "	Oil pipeline break down		Right side of Río Coatzacoalcos
2005	pipeline 4 "	Labor accident in Dam		Poza Rica, Ver.

Source: www.pemex.gob.mx

Trends: The oil intensive activity of Pemex implies pressures on the environment caused by activities and processes related to exploration, production, refining, shipment operations and storage, and accidents (break down of the submarine pipelines, ship-tank accidents, spills and explosions of platforms).

The main areas of hydrocarbons in Mexico are in the Gulf of Mexico and continental platforms, which are: Campeche basin, Veracruz, Macuspana, Chiapas-Tabasco, Sabinas, and Salina. Important natural gas deposits are in Burgos, Gulf of California, in the country's northwest.

Between January and February of 2004, Campeche basin increased its contribution of crude oil by 2.7%, in comparison to the same months of 2003. This amount, that represented 83.6 percent of the national total production, is a feature of the importance of this region. Considering the extraction of big volumes of crude oil, it is of important to note that the number of spills of hydrocarbons and the spilled quantity have diminished considerably.

Indicator construction and limitations: Information about this indicator is still lacking and mainly is related to monitoring activity, which allows distinction between the impacts due to natural factors and those due to anthropogenic factors.

6.6.4.6. *INDICATOR 28.2*

Discharges into water basin: Radionuclides in liquid radioactive discharges

Definition: This indicator shows radionuclides present in planned and controlled discharges into liquid; discharges into the water basin from nuclear fuel cycle facilities; and those radionuclides that contribute greater than 5% of the collective dose from discharges (noble gases, tritium, carbon-14, iodine and Cs-137).

Purpose: The purpose of this indicator is to assist in quantifying the pressures on the environment by identifying the radionuclides in liquid discharges that contribute most to the collective dose. Whilst not directly related to the impact, the indicator provides a simple tool from which trends and achievements can be gauged.

TABLE 6.48 ANNUAL DISCHARGES INTO WATER BASINS (GBQ/YR)

Isotope	1998	1999	2000	2001	2002	2003
H-3	1.12E+03	1.42E+03	5.59E+02	1.01E+03	1.82E+02	1.85E+02
C-14	<LLD	<LLD	<LLD	<LLD	<LLD	<LLD
I-131	<LLD	<LLD	<LLD	<LLD	<LLD	<LLD
Cs-137	1.32E-01	2.33E-03	1.71E-02	6.53E-03	1.41E-02	6.91E-03
AR-41	4.47E-03	<LLD	<LLD	<LLD	<LLD	<LLD
KR-85	<LLD	<LLD	<.LLD	<LLD	<LLD	<LLD
KR-85m	<LLD	<LLD	<LLD	<LLD	<LLD	<LLD
KR-87	<LLD	<LLD	<LLD	<LLD	<LLD	<LLD
KR-88	<LLD	<LLD	<LLD	<LLD	<LLD	<LLD
XE-133	<LLD	7.02E-03	3.85E-04	<LLD	<LLD	1.82E-03
XE-133m	<LLD	<LLD	<LLD	<LLD	<LLD	<LLD
XE-135	1.97E-03	3.75E-03	2.92E-02	3.71E-03	8.24E-04	8.31E-03
XE-135m	<LDD	<LLD	<LLD	<LLD	<LLD	<LLD
XE-138	<LDD	<LLD	<LLD	<LLD	<LLD	<LLD
Electricity generation (TWh)	9.3	9.6	7.9	8.5	NA	NA

NA: Not available
LLD: Low Line Drive
Source: Comision Federal de Electricidad (Gerencia de Generacion Nucleoelectrica, 2003)

Trends: The indicator represents the planned and controlled liquid discharges from nuclear fuel cycle facilities by type of discharge. This table shows data since 1998, including 2003 for the main discharge.Discharges have been controlled and stable for the past decade.

Indicator construction and limitations: Mexico has only one nuclear power plant, which has a strict control of its emissions. This facilitates the data collection effort.

6.6.4.7. *INDICATOR 29*

Generation of solid wastes

Definition: Amounts of waste produced from all energy related activities and from thermal power plants in particular on a weight basis at the point of production.

Purpose: The main purpose is to represent the production of solid waste produced from activities related to various fuel chains of energy use.

For this case, within the energy sector PEMEX presents information on the inventories of hazardous residues generated by its four subsidiary companies as the result of their production activities. This information is published in PEMEX's sustainable development reports.

In accordance with the General Law for the Prevention and Integral Management of the Residues, wastes originating from PEMEX's activities are considered to be hazardous residues, which are formed principally of muds and clippings from perforation, and oily muds and worn out oils from refineries and petrochemical complexes.

TABLE 6.49 HAZARDOUS RESIDUES GENERATED BY PEMEX`S OPERATIONS, 1999 – 2003 (TONS)

		PEP	PR	PGPB	PPQ
Initial inventory 1999	344,554	46,067	285,255	199	13,033
Generation	185,001	134,556	32,812	1,085	16,548
Disposal	305,758	135,281	149,011	1,197	20,269
Final inventory 1999	223,799	45,343	169,056	88	9,312
Initial inventory 2000	223,799	45,343	169,056	88	9,312
Generation	185,303	150,443	15,023	1,064	18,773
Disposal	313,014	195,609	95,335	1,056	21,014
Final inventory 2000	96,088	177	88,744	96	7,071
Initial inventory 2001	125,550	101	118,005	1,411	6,033
Generation	278,523	217,758	40,277	1,219	19,269
Reception	11,634	11,481	153	0	0
Treated in situ	68,908	7,078	45,811	167	15,852
Treated by a third party	244,498	206,478	35,629	451	1,940
Transferred intra Pemex	6,556	6,187	87	282	0
Final inventory 2001	95,745	9,597	76,908	1,730	7,510
Initial inventory 2002	95,677	9,585	76,846	1,736	7,510
Generation	384,352	249,032	115,693	1,517	18,110
Reception	20,640	15,805	4,812	23	0
Treated in situ	138,004	15,346	107,998	29	14,631
Treated by a third party	260,775	238,422	19,935	950	1,468
Transferred intra Pemex	25,971	16,114	7,959	1,898	0
Final inventory 2002	75,919	4,540	61,459	399	9,521
Initial inventory 2003	75,859	4,507	61,432	399	9,521
Generation	481,596	381,980	85,959	1,662	11,995
Reception	20,187	19,461	376	0	350
Treated in situ	52,018	2,531	40,068	53	9,366
Treated by a third party	417,873	383,772	31,018	1,144	1,939
Transferred intra Pemex	21,530	13,608	6,960	560	402
Final inventory 2003	86,221	6,037	69,721	304	10,159

PEP: Pemex Exploración y Producción.
PR: Pemex Refining
PGPB: Pemex Gas y Petroquímica Básica.
PPQ: Pemex Petroquímica.
Source: Pemex.Informe de Desarrollo Sustentable, varios años. México, D. F., 2004.

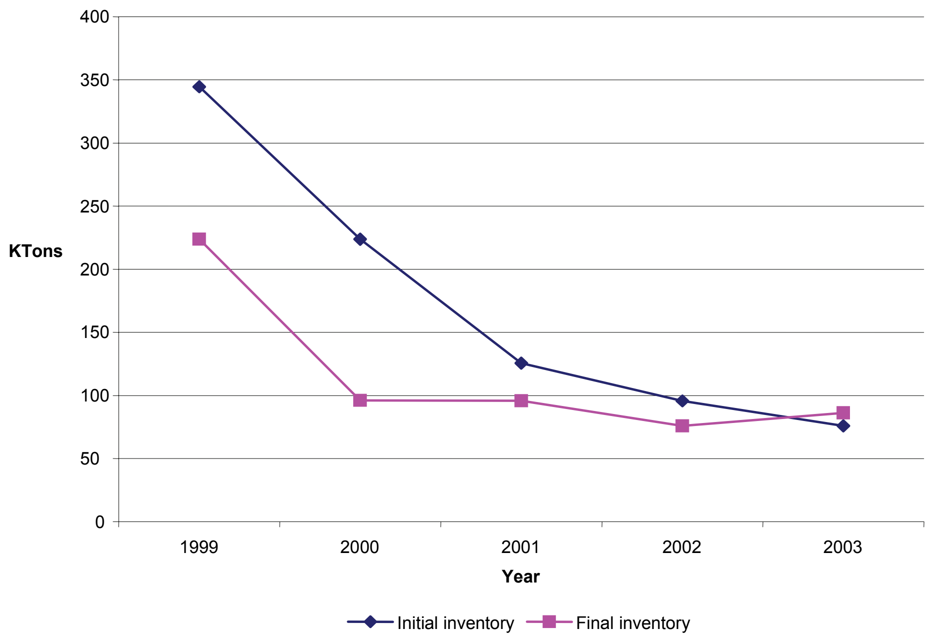

Figure 6.44 Hazardous residues generated by PEMEX´s operations, 1999 - 2003

Trends: The entire inventory of hazardous residues dropped 57%, from 223,799 tons in 1999 to 96,087 in 2000; in 2001, continuing with the efforts of inventories elimination, the disposal of most of the remaining inventory was achieved, obtaining a final inventory of 95,745 tons.

From 2002 the entire inventory increased 13.6%, from 75,919 to 86,221 tons in 2003 as a consequence of an increase in production. This increase in waste generation is principally due to the clippings and muds of perforation in Pemex Exploración and Producción, given the rising operations in the fields of development and exploration; the increase of oily muds in refineries was due to the maintenance programmed in tanks, and the increase of worn out oils was because of lubricant changes in the operation equipment.

Indicator construction and limitations: From the information that PEMEX generates based on its sustainable development reports for several years, it was possible to construct the historical series of the generation of solid hazardous residues resulting from PEMEX's operation.

In the case of the electric sector, data are scattered and not organized on the basis of consistent historical series.

The Comisión Federal de Electricidad (CFE) and Luz y Fuerza del Centro (LFC) consider the worn out lubricants and the Polychlorinated Biphenyls (PCBs) among other hazardous wastes generated in the electric sector. PCB is one of the twelve organic compounds (POCs) considered to be persistent by the Stockholm Convention.

In 2002 the Secretary of the Environment and Natural Resources authorized the incineration of 32,800 liters per year of wornout oils generated in two thermal power plants. This amount, added to the one authorized in the 1999 – 2001 period for other power plants, represents a total accumulated amount of 5,032,800 liters per year.

Since 1980 the purchase of equipment with PCBs has been banned and the removal of such equipment started, in compliance with the Mexican Official Standard NOM-133-ECOL-2000.

6.6.4.8. INDICATOR 31

Generation of Radioactive Waste from Nuclear Power Fuel Cycle Chain (Cubic metre (m3) per annum for arisings destined for disposal in solid form; and tonnes of heavy metal (tU) per annum for spent fuel)

Definition: Radioactive waste arisings from nuclear power generation and other nuclear fuel cycle related activities, in forms of arisings destined for disposal in solid form, split into three different categories (high level radioactive waste; low and intermediate level radioactive waste, long-lived; low and intermediate level radioactive waste, short-lived); and spent fuel arisings.

Purpose: The purpose is to represent the annual amounts of various radioactive waste streams that arise from the nuclear fuel cycle. Quantitative values are required so that appropriate resources (e. g., financial, human, etc.) for the proper management of these types of waste can be allocated.

TABLE 6.50 SPENT FUEL ARISINGS (TONS HEAVY METAL) 1998-2003

Isotope	1998	1999	2000	2001	2002	2003a
Spent fuel arisings	22	22	22	39	20	20
Electricity generation (TWh)	9.3	9.6	7.9	8.5	NA	NA

[a] Estimated
NA: Not available.
Source: Laguna Verde Power Plant.

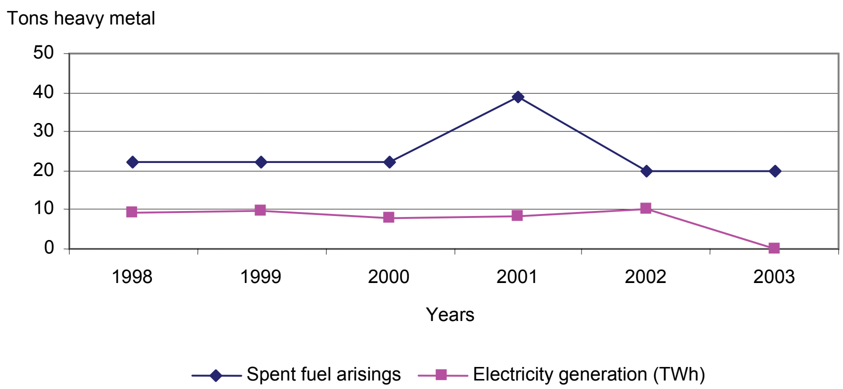

Figure 6.45 Spent fuel arisings 1998-2003

Trends: Data are presented beginning in 1998, when the nuclear plant facility started full operation. No explanation was available for the 2001 increases. Spent fuel is deposited in reactor pools.

Indicator construction and limitations: Mexico has only one nuclear power plant, which has a strict control of its emissions. This facilitates the data collection effort.

Nevertheless, defining the indicator at the overall fuel cycle level requires an elaborated methodology that is not yet fully developed.

6.6.4.9. *INDICATOR 32*

Accumulated quantity of radioactive waste awaiting disposal (Cubic metre (m3) broken down into the different categories as outlined in the related Driving Force Indicator "Generation of Radioactive Waste from Nuclear Power Fuel Cycle Chain", and tonne of heavy metal (tU) for spent fuel)

Definition: The indicator is a measure, at the national level, of the accumulated quantities of radioactive waste still awaiting near surface or geological disposal. These quantities include all radioactive wastes originating from a full nuclear power chain, including uranium mining, milling, and power generation, split into different categories, such as High Level radioactive Waste (HLW), Low and Intermediate Level radioactive Waste, long-lived (LILW-LL), Low and Intermediate Level radioactive Waste, short-lived (LILW-SL), and Spent fuel.

Purpose: It is recognised that near surface or geological disposal in a safe and environmentally sound manner is the most sustainable solution to the problem of radioactive waste. By giving a measure of the quantities of radioactive waste still awaiting disposal, this indicator shows the sustainable status of the existing radioactive waste management infrastructure. Increasing quantities of radioactive waste awaiting disposal over time would indicate a trend towards a less sustainable situation, thus implying a need to take actions to favour the near surface or geological disposal option.

TABLE 6.51 ACCUMULATED QUANTITY OF RADIOACTIVE WASTE AWAITING DISPOSAL (TEMPORARILY STOCKED RADIOACTIVE WASTE IN THE LAGUNA VERDE NUCLEAR PLANT) 1998-2003

Waste type description	1998	1999	2000	2001	2002	2003
Humid waste						
	BIDONS					
HUMID WASTE VOLUME (CEMENTED)	43.02	0	0	0.19	0	0
TOTAL VOLUME (CEMENTED)	48.2			0.22		
HUMID WASTE VOLUME (ASPHALTED)	249.57	11.87	7.79	1.95	0	0
TOTAL VOLUME (ASPHALTED)	279.62	13.3	8.72	2.18		
	HIC's					
HUMID WASTE VOLUME (MUDS)	240.87	34.47	19.16	22.99	3.82	26.77
TOTAL VOLUME (MUDS)	261.24	38.31	21.28	25.54	4.26	29.79
HUMID WASTE VOLUME (RESINS)	437.69	73.68	45.90	34.42	61.17	49.70
TOTAL VOLUME (RESINS)	480.46	80.88	51.08	38.31	68.10	55.33
Dry Waste						
	BIDONS					
NOT COMPACTABLE DRY WASTE VOLUME	89.65	20.80	7.90	17.06	7.49	8.74
NOT COMPACTABLE DRY WASTE TOTAL VOLUME	94	218.11	8.29	17.88	7.85	9.16
COMPACTABLE DRY WASTE VOLUME	791.02	80.70	79.46	83.62	69.26	13.10
COMPACTABLE DRY WASTE TOTAL VOLUME	829.46	84.63	83.32	87.68	72.63	13.74
	Boxes					
METALLIC WASTE TOTAL VOLUME	2.08	0	0	0	0	151.56
COMPACTABLE DRY WASTE TOTAL VOLUME	2.18					

HIC's: High Integrity Containers
BIDONS : Thermoplastic recipients
Source: Comisión FederaI de EIectricidad. Gerencia de Generación Nucleoeléctrica, Data from 2003.

Trends: The radioactive waste awaiting disposal has been decreasing over the past 5 years. This is due in part to waste minimization and the systematic management of the storage and disposal of such waste.

Indicator construction and limitations: There is an inevitable time lag between the moment that the waste arises and its disposal. In some cases this time lag can be on the order of decades, and therefore trends should be interpreted carefully.

6.6.4.10. INDICATOR 34

Fatalities due to accidents with breakdown by fuel chain

Definition: This indicator measures the number of annual fatalities in the energy sector as a total and broken down by coal, oil, gas, nuclear and hydro fuel chains. Additionally, fatalities in power generation sectors with breakdown by thermal, nuclear, and hydro power plants are to be specified.

Purpose: The indicator shows the number of fatalities in energy-related severe accidents. The indicator is used to assess the risk to human health derived from energy systems, and in particular by various fuel chains as a basis for their comparative risk assessment.

TABLE 6.52 WORKER FATALITIES DUE TO LABOR ACCIDENTS 2001 - 2003

Subsidiary of PEMEX	2001	2002	2003
Exploration and production PEP	NA	NA	3
Refining PR	NA	NA	2
Gas and basic petrochemicals PGPB	NA	NA	0
Petrochemicals PPQ	NA	NA	1
Corporate	NA	NA	0
Contractors	NA	NA	16
Total	5	13	22

Source: PEMEX. Informe de Desarrollo Sustentable, 2003. México, D. F., 2004.
NA: Not available

TABLE 6.53 ACCIDENT INDEX NUMBER, 1997 - 2003

Area	Frequency							Graveness						
	1997	1998	1999	2000	2001	2002	2003	1997	1998	1999	2000	2001	2002	2003
Pemex	3.96	2.68	1.19	1.19	1.00	1.17	1.09	307	325	180	170	124	132	125
Exploration and production	7.48	4.66	1.66	1.66	1.26	1.14	NA	572	436	180	277	191	154	NA
Refining	2.59	1.92	0.72	0.72	0.69	1.10	0.63	229	350	253	126	85	138	121
Gas and basic petrochemicals	1.04	0.50	0.90	0.90	0.50	1.01	0.92	224	327	118	109	88	114	110
Petrochemicals	2.31	1.48	1.06	1.06	0.53	0.88	1.07	152	175	173	170	139	156	199
Corporate	2.05	1.84	1.49	1.49	1.86	1.79	1.54	38	69	21	32	53	40	52

NA Not available.
Source: PEMEX. Informe de Desarrollo Sustentable, 2003. México, D. F., 2004.

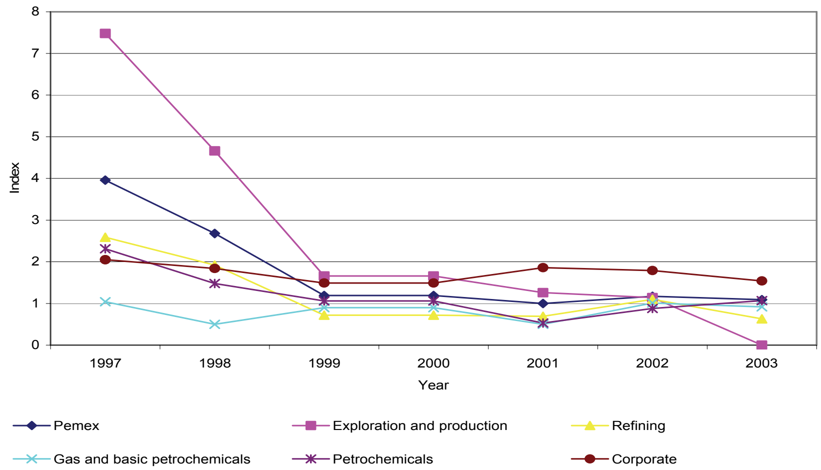

Figure 6.46 Frequency of accident index number, 1997 - 2003

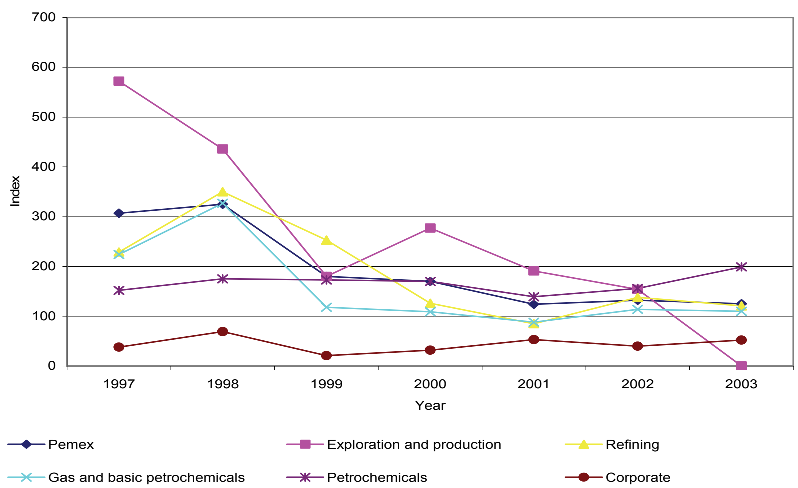

Figure 6.47 Gravity of accident index number, 1997 - 2003

Trends: PEMEX uses indices to evaluate safety performance. These indices, of frequency and gravity, reflect information on the accidents that happened by non-accomplishment of the procedures or because of the company's lack of preparedness. Even when it has advanced in fomenting the habit of reporting any accident in a systematic way, the results of the index just reflect a few accidents. In order to ensure that all accidents are reported, internal controls have been improved. Since March 2000 the information from different sources has been compared to corroborate its consistency.

In 1997, after one of the worst accidents (an explosion in a gas processing plant –Cactus- where six workers died), the Program of Security, Health and Environment Protection of PEMEX was reevaluated and reformulated.

Starting from 1998 the evaluation of the accident frequency for the contractors became evaluated with an index that takes into account the number of accident occurrences per million of man-hours worked in a certain period. This index was 2.7 in 1998, 1.9 in 1999 and 1.8 in 2000.

Indicator construction and limitations: Accidents have not been registered in nuclear energy generation, although evaluations of risk or vulnerability can exist in the facilities of the Laguna Verde plant. That information is not available.

Actually there is a wide source of information about work illness but not those fatalities due to accidents with breakdown by fuel chain.

Number of fatalities in the energy sector represents a considerable matter, although the information to incorporate into this indicator is not enough, as there are no records regarding the differentiated kind of fatalities.

6.6.4.11. INDICATOR 38

Proven Uranium reserves

Definition: Uranium ore bodies or deposits that could be produced competitively in an expanding market.

Purpose: The purpose of the indicator is to measure availability of nuclear fuel resources.

This indicator provides a basis for estimating future nuclear energy supplies, enabling proactive decision making to ensure the efficient use of these resources over the long term. Proven energy reserves represent a basic stock that governments can use to attain higher levels of sustainable development. Availability of domestic energy reserves is a necessary prerequisite to increase indigenous energy production and decrease energy import dependency.

TABLE 6.54 PROVEN URANIUM RESERVES 2003 (CONVENTIONAL RESOURCES RECOVERABLE AT UP TO USD130/KG)

Country	Recoverable at				Total recoverable at up to USD130/kg
	< USD40/kg	USD40-80/kg	< USD80/kg	USD80-130/kg	
	Thousand tonnes of uranium				
Mexico[a b c]	0	0	0	1,275	1,275
Canada	297,264	41,900	333,834	0	333,834
United States	NA	NA	102,000	243,000	345,000
Total North America	397,264	41,900	435,834	244,275	680,109
Total World[d]			2,471,600	809,900	3,281,500

[a] Data for 2001.
[b] Assessment not made for the last 5 years.
[c] *In situ* resources were adjusted by the Secretariat to estimate recoverable resources using recovery factors provided by countries or estimated by the Secretariat according to the expected production method.
[d] It includes 43 countries of a total of 50.
NA Not available.
Source: Nuclear Energy Agency. *Uranium 2003: Resources, Production and Demand.* OECD. France, 2004.
Figures for total world: World Energy Council. *Survey of Energy Resources 1999.* London, 2001.

TABLE 6.55 GEOGRAPHIC DISTRIBUTION OF URANIUM RESERVES OF MEXICO 1981

State	Reserves (tons)
Total	10,600.0
Chihuahua	2,078.1
Sonora	889.6
Durango	258.8
Nuevo León	3,477.0
Others	3,896.5

Source: UNAM-PUE. Compendium of information of the Mexican energy sector 1999. México, 1999.

Trends: Within 43 countries reporting Reasonably Assured Resources (RAR), Mexico contributes 1.25 thousand tonnes, corresponding to 0.19% of the USD 80-130/kgU cost category, and 0.04% of the <USD 130/kgU one.

In accordance with the Survey of Energy Resources 1999, uranium exploration activities in Mexico came to an end in 1983. At that point, known resources totalled 2,400 tonnes recoverable at USD 80-130/kgU, comprising 1,275 tonnes of Reasonable Assured Resources (RAR) and 525 tonnes of Estimated Additional Resources (EAR-I).

Additional undiscovered resources amounted to 12,700 tonnes, the bulk of which (10,000 tonnes) were speculative.

In 1981 there were about 14,500 tons of uranium in Mexico, of which only 10,600 tons is thought to have any possibility of being extracted. This was in the states of Nuevo León and Chihuahua, which have major volumes of 3,477.0 and 2,078.1 tons respectively.

However, currently there is no planned exploration activity, nor any development program of explored uranium reserves in Mexico.

The National Commission to Save Energy through the Federal Commission of Electricity, in a publication from 1997, considers that these reserves would ensure the necessary fuel for reactors of the nuclear electric power station at Laguna Verde during all of its life.

Actually, nuclear fuel used at Laguna Verde is purchased from a foreign firm, because this is cheaper than exploiting Mexican uranium reserves, which could only be done by a state-owned firm.

Today, Mexico follows standardized procedures to ensure that the nuclear and radioactivity industry works with the highest levels of security for the population and the environment. At the same time, Mexico is a member of the Nuclear Energy Agency (NEA) of the OECD and the International Atomic Energy Agency (IAEA). Gross nuclear electric energy generation increased from 8,220.9 GWh during 2002 to 10,501.5 GWh in 2003 (4th Annual Government Report).

Indicator construction and limitations: No exploration has occurred in Mexico for over a decade, and thus the data available comes from relatively old estimates.

6.7. Conclusions and Perspectives

Energy is essential to improving social and economic well-being, and is indispensable to most industrial and commercial wealth generation. Nevertheless, energy is a means to an end, the end being improved human welfare, improved living standards, good social health, a sustainable economy and a clean environment. Accordingly it is important to consider the fact that no form of energy can be tagged as good or bad, per se. All are valuable as an integrated and diversified energy portfolio in the search to deliver this end.

In its quest towards sustainable economic development, Mexico will require the design and implementation of an integrated strategy of resources, technology, appropriate economic incentives and strategic policy planning. An essential tool for this task is standardized monitoring of the impacts of selected policies and strategies measuring Mexico's development. It is crucial to understand the current status concerning energy and economic sustainability, in order to identify what needs to be improved and how it can be achieved.

Methods and indicators for measuring and assessing the current and future effects of energy use are needed, as well as a determination whether current energy use is sustainable—and if not, how it might be changed so that it does become sustainable. This chapter represents the first approach to such a set of tools needed for future policy development towards sustainability. In this respect, the indicators developed by SENER and INEGI (80 percent of ISED total) constitute an excellent starting point.

During recent years the population has increased considerably, reaching a rate of 1.6% per year. This in turn has raised the need for an important increase in additional services, which has a direct impact on Mexico's sustainable development.

Because of an increase in energy efficiency programs, the energy sector has been able to lower energy intensity. From 1993 to 2003, it has decreased by 14%.

Sulphur dioxide emissions (in tons), which are the principal emissions problem within the energy sector (for both CFE and PEMEX) resulting from the fossil fuels used, decreased by 16.5% from 2000 to 2003.

Mexico has been fostering the use of renewable sources of energy, particularly hydro and geothermal electricity, and hydropower represents 23% of the nation's total installed capacity. Mexico is ranked third in the world in terms of installed capacity for geothermal energy.

Nonetheless, a major push is needed for other sources of renewable energy. In 2003, renewable energy accounted for only 6.1% of the national production of primary energy.

Current electricity planning foresees an increase in the dependence on (imported) natural gas. Another potential problem is the increase in vulnerability to price volatility for energy-related services, due to dependence on hydrocarbons (oil and gas).

6.7.1. Potential Strategies for the Future

6.7.1.1. Promotion of renewable energies in Mexico

The Goal #4 of the programme PROSENER is to "Improve energy efficiency programs and development of renewable energies." Further, it stipulates that 1,000 MW (additional to CFE´s expansion program) will be installed by 2006 based on renewable sources such as solar, wind, mini hydro, geothermal and biomass. As presented earlier in this document, there is an enormous potential for energy generation based on renewable sources. By doing so there would be a diversification of the energy supply, an attenuation of impacts on the environment, the possible promotion of specific activities within the manufacturing sector, and an important enhancement of a national technology area that has been working in the country for more than 25 years. Additionally, promotion of renewable energies would increase employment and local development, and would benefit isolated populations.

Based on some ISED indicators, it can be concluded that the 1,000 MW goal has not been accomplished, but some of the factors/actions that have been identified that would help install such renewable capacity are to:

- Consider environmental externalities in electricity prices;
- Establish national and regional policies and programs in accordance with changes in the structure of the energy sector;
- Establish a regulatory base for the promotion of renewable energies and cogeneration;
- Create a National System for the assessment, registration and diffusion of renewable resources in the country;
- Create a financial mechanism to promote renewable energies;
- Allocate resources for research and technological development;
- Maintain and improve cooperation of Mexican institutions with academic, bilateral and multilateral bodies.

Several actions are currently taking place in Mexico towards these purposes; they include:

- Private, public and mixed project development to increase installed capacity for energy and electricity generation.
- Promotion of projects to increase installed capacity for electricity generation (primarily wind), design of a financial mechanism, and capacity building (among others) in the "Large Scale Renewable Energy Development Project" financed by the Global Environment Facility (GEF) – the World Bank.

- Construction of a wind technology research centre with a grant given by GEF – United Nations Development Programme for the development of the "Action Plan for Removing Barriers to the Full-scale Implementation of Wind Power."
- Participation of different sectors in initiatives, forums, and meetings intended to profile a draft document in order to conceive a law entitled: Law for the Promotion of Renewable Energies and Cogeneration.

6.7.1.2. Clean fuels

Based upon environmental criteria, and specifically the Mexican Official Norm "NOM-086-ECOL-1994" that deals with environmental criteria for fossil fuels (liquid and gaseous) used in stationary and mobile emission sources, PEMEX has made changes regarding gasoline quality. In the 1990s, the most remarkable were the phase-out of leaded gasoline, and the introduction of a low sulphur diesel and a high octane (93) gasoline in the Mexican market. These represented investments of 1,700 million USD.

Due to technological advances and existing regulations (that force Official Norms to be reviewed), the sulphur in gasoline and diesel is expected to diminish.

Further, delays in the introduction of cleaner fuels to the market will have negative impacts on health (morbidity and mortality), the environment (acid rain, global warming, etc.), the economy (agricultural impacts, damages to infrastructure, etc.), as well as to the auto industry. The latter impact would affect the exportation of this sector because new American and European technologies are readily available, and some of them cannot operate with existing levels of sulphur, since this element "poisons" pollution control equipment installed in automobiles (for reducing pollutants in exhaust: organic compounds, nitrogen oxides, carbon monoxide and dioxide, etc.).

PEMEX estimates that over 2,380 million USD are needed to make the necessary changes in the National System of Refineries so cleaner fuels can be produced (and not imported, preventing further energy import dependency): for gasoline, 1,300 million USD; diesel, 750 million USD; and for the adequate management of residual gases containing sulphur, 330 million USD (costs are calculated for a five-year period).

Two options are currently being considered for financing this project: budget allocation by the Ministry of Finance and approval by the Legislative Branch, as well as charging investment to consumption.

Analyses regarding the most suitable investment scenario are still being developed, but what is clear is that this improvement has to be made as soon as possible.

Some perspectives on sustainable energy development

The complex interrelationships among changes in population, economic development, and energy consumption appear to reveal some important trends about these three broad factors. How significantly does the size and growth of the Mexican population and economic growth levels affect the demand for energy?

The average annual growth of the total population has been constantly reduced over the past fifty years: 3.3% in 1950-1970, 2.5% in 1970-1990, and 1.6% in 1990-2000. Over the past few decades, Mexico has experienced rapid economic growth; however, in recent years, despite several serious economic crises, this growth has stabilized around 2%. The real GDP per capita (1993 price level and PPP's - $US) had an average annual growth of 1.79% in 1990-2001. Average annual growth of toe energy consumption per capita dropped -0.74% from 1990 to 2001.

From a demographic point of view Mexico experienced unparalleled transformations during the twentieth century. First, it went through cycles of intense population growth and, more recently, of a marked deceleration. Thus, in accordance with the Census figures, the Mexican population went from almost 17 to nearly 26 million people between 1930 and 1950; in the next twenty years, the number of inhabitants almost doubled, and then only required three decades to be doubled again. At the present time, with around 100 million inhabitants, Mexico occupies eleventh place among the most populated

nations in the world. It is forecasted that it will maintain that same position for the next several decades.

In recent times, economic growth has not been sufficient to assimilate the reality of the demographic growth throughout the country; the informal economy, underemployment and poverty persist.

Public policies designed to address the above-stated facts are based on the following approaches:

- A. To increase fiscal coverage, starting from a higher base of taxpayers. Mexico is today one of the countries with the lowest fiscal coverage. This prevents the country from having enough resources to deepen social programs, including a primary focus on decreasing poverty. On the other hand, the spread of the application of the value added tax to all products would already allow a larger tax collection for such purposes.
- B. To achieve approval of the structural reforms addressing the standing laws on energy, fiscal management and the labor sector. Another government strategy seeks to achieve the approval of changes in standing legislation that allows private capital to participate in the energy sector (PEMEX, CFE), in order to raise its profitability and to boost this decisive sector in the country's development. In the labor sector, changes are being considered in legislation to encourage the participation of foreign investment, as well as to encourage further domestic investment.
- C. To encourage self-management through credit support for micro and small companies. This would allow the employment of all those who did not have room within the formal economy, as well as provide technical support to impel productive projects.

While Mexican economic performance has been stable, some social conditions for Mexico's growing population need to be improved. It is necessary to pay attention not only to the welfare of society, but also to pollution controls and infrastructure considerations in order to reduce or reverse environmental degradation.

People in rural areas of Mexico gather and use energy, often inefficiently, in the form of fuelwood or dung for cooking and heating. But this consumption pattern is contributing to erosion and the loss of soil fertility and, due to poor combustion, to a widespread incidence of air pollution. While poverty is the primary cause of this practice, limited access to information and the absence or lax enforcement of property rights are factors as well.

Energy use in Mexico's densely populated urban areas shows some positive characteristics. Greater density improves the economics of public transport systems, thereby achieving lower energy use per passenger-kilometer of travel in some cities. Multi-family housing, another attribute of high population density, allows for more efficient energy use than single-family homes.

Though there have been public health elements in previous pieces of legislation, Mexico only began to seriously address environmental protection in the late 1980s and 1990s. The first comprehensive environmental bill, the General Law of Ecological Balance and Environmental Protection (LGEEPA), enacted in 1988, was amended in 1996 to make sustainable development an explicit concern of the federal government.

In summary, social programs, the creation of employment and productive efficiency are the big challenges to tackle in ensuring sustainable development. The resulting efforts should result in a reduction of the inequity of the existing income distribution, decreases in poverty, improvements in the environment, and, ultimately, a better quality of life.

Public policies that raise the agricultural sector's participation in the GDP (which currently has the smallest share of all sectors) under the North America Free Trade Agreement are required. This could be done mainly by promoting policies decreasing cost inputs, to elevate levels of competitiveness and production; promoting and supporting peasant economic organizations; and strengthening their capacity of self-organization in access to markets.

In order to achieve competitive economic development, at the same time it is also necessary to have a balanced regional development. This could be done by strengthening the regional economies; by supporting plans for urban development and territorial regulation; by guaranteeing that ecological

sustainability and economic development are addressed in all regions of the country; and by fostering the creation of nuclei of development that discourage regional migration.

Future tasks and proposals

Seeing that the ISED methodology package does not provide institutional dimension indicators or response indicators according to the DSR framework, Mexico should consider the development of some response indicators, such as:

- Quality of fuels by type of main pollutant
- Official ecological standards for regulating environmental pollution from energy
- Conventions ratified
- Energy consumption per capita in urban areas or cities

Other strategic indicators to be developed in Mexico on a long-term basis might include those related to energy production and consumption patterns (mainly in urban areas); the decoupling of energy and the environment; renewable sources; energy consumption in households; energy eco-efficiency; rural energy use; and the energy-poverty relationship, among others.

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ANNEX 6.1: Acronyms and Abbreviations

Acronyms

CONAE = Comisión Nacional para el Ahorro de Energía.

IEA = International Energy Agency.

IIE = Instituto de Investigaciones Eléctricas.

IMP = Instituto Mexicano del Petróleo.

INE = Instituto Nacional de Ecología.

INEGI = Instituto Nacional de Estadística, Geografía e Informática.

ININ = Instituto Nacional de Investigaciones Nucleares.

IPCC = Intergovernmental Panel on Climate Change.

OECD = Organisation of Economic Co-operation and Development.

PEMEX = Petróleos Mexicanos.

CFE = Comisión Federal de Electricidad.

CONASENUSA = Comisión Nacional de Seguridad Nuclear y Salvaguardias.

LFC = Compañía de Luz y Fuerza del Centro.

SCT = Secretaría de Comunicaciones y Transportes.

SEMARNAT = Secretaría de Medio Ambiente y Recursos Naturales.

SENER = Secretaría de Energía.

MCMA = Mexico City Metropolitan Area

MMA = Monterrey Metropolitan Area

GMA = Guadalajara Metropolitan Area

TMA = Toluca Metropolitan Area

WEC = World Energy Council.

Abbreviations

CH_4 = methane – a greenhouse gas.

CHP = Combined heat and power.

CO_2 = Carbon dioxide – a greenhouse gas.

DPSIR = Driving forces, Pressures, State, Impact and Responses.

EAR – I = Estimated Additional Resources I.

EAR-II = Estimated Additional Resources II.

FCCC= Framework Convention on Climate Change (UN).

GBq = Giga Becquerel.

GDP = Gross Domestic Product.

GJ = Gigajoule.

HFCs = Hydrofluorocarbons.

Km = Kilometre.

Ktonnes = Thousand tonnes.

kWh = Kilowatt hour.

Mt = Million tonnes.

Mtoe = Million tonnes of oil equivalent.

NH_4 = ammonia.

N_2O = Nitrous oxide.

NMVOC = Non-methane volatile organic compounds.

NO_X = Nitrogen oxides, including nitric oxide (NO) and nitrogen dioxide (NO_2).

Peta joule (PJ) unit = 10^{15} joules.

PM = Particulate matter.

RAR = Reasonably Assured Resources.

SO_2 = Sulphur dioxide.

Toe = Tonnes of oil equivalent.

tU = Tonnes of recoverable uranium (= approximately 1.3 short tons of uranium oxide).

Short ton U_3O_8 = Tonnes of uranium oxide (= 0.769 tU).

US$ 1 per pound of uranium oxide = US$ 2.6 per kilogram of uranium.

TWh = Terawatt hour.

UNFCCC = United Nations Framework Convention on Climate Change.

7. THE RUSSIAN FEDERATION

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7.1. Introduction

This research project, entitled "Initial analysis of different indicators for sustainable energy development on the basis of analysis of existing economic, energy and environmental trends in Russia," began in 2002 and was conducted by a research team representing the Centre for Energy Policy and the Ministry of Industry and Energy of the Russian Federation (RF). Its principal objectives were to evaluate the current status and prospects for energy policy in the Russian Federation, to identify its major priorities, and to examine their correlation with the main principles and indicators for sustainable energy development. This project was implemented under the patronage of the International Atomic Energy Agency (IAEA) within the Agency's work programme on Sustainable Energy Development.

The following components are included in the final version of the study:

Overview of the energy sector

The main trends and indicators of the current state (1992-2001) and prospects (up to 2020) for development of the energy resource base, primary energy and electricity production, international trade and consumption by fuels and branches of economy are analyzed. A brief analysis of energy from the standpoint of the three dimensions of sustainability (i.e., social, environmental, and economic) as well as the institutional dimension is performed.

The situation in the domestic energy sector is also analyzed with respect to accessibility, security, efficiency, and the environment, as well as institutional and infrastructure problems associated with its functioning.

Review of the energy statistical data capability

The main problems the research team faced during the project implementation are described and discussed. The problem of statistical data collection for sufficient time series, as well as ensuring needed quality and comparability of collected data, are emphasized. It is emphasized in this section that statistical data on ISED were collected from a variety of sources, including governmental decrees, information published by the State Committee for Statistics, Ministry of Economy, Ministry of Industry and Energy, etc.

Identification of major energy priority area

On the basis of detailed analysis of the main governmental decrees on energy policy problems, as well as Energy Strategy of Russia to 2020[1] (hereafter "Strategy"), the major priorities of the national energy policy are identified, and explanations for these priorities are outlined.

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[1] Energy Strategy of Russia to 2020 (Strategy) was prepared by the Ministry of Energy of the Russian Federation in cooperation with a number of leading scientific and research institutions and approved by Government in 2003.

Implementation of ISED framework

The indicators of the ISED package related to selected energy policy priorities (including state indicators, and direct and indirect driving forces) are identified. The ISED database constructed with collected statistical data and classifications based upon the dimensions of sustainability to be analysed, is discussed.

Assessment of current energy policies in priority areas

A critical overview of the current status and prospects for energy policy priorities is outlined. A critical analysis of the effects and effectiveness of the country's energy policy in selected areas is discussed.

Strategy for improvements in priority areas

The principal strategies and measures aimed at making improvements in priority areas of the country's energy policy over the long-term are given.

Conclusions and recommendations

The main results of implemented research are listed. A brief evaluation of the current state and prospects of energy policy in priority areas from the standpoint of sustainability is given. Recommendations on improving energy policy are elaborated.

7.2. Overview of the Energy Sector

7.2.1. Current state and prospects of economic development

The period of economic reforms in the Russian Federation can be divided into a phase of depression and a period of recovery. In 1992-1996, the total amount of GDP, calculated in billion US$ at 1995 prices and PPPs had declined by 26% (Table 7.1). By comparison with the 1992 level, the indicator of GDP per capita had fallen almost US$ 1900 per person.

Continuation of such negative economic trends was finally halted in 1997, when some economic growth took place (1% in comparison with 1996). However, the economic crisis of 1998 resulted in another GDP decline of 5.4%.

The country's economic performance since August 1998 has been impressive. In 1998-2001, GDP grew by 20.6% (GDP growth peaked at 9% in 2000). Inflation has been tamed, with consumer prices rising by less than 13% in 2003, compared to 84% in 1998. Unemployment has fallen steadily, down to a little over 8% of the workforce by the end of 2003 (OECD, 2004). The general government budget, which ran deficits of over 3% of GDP in 2000 and 2001, moved into surplus in 2003. Capital investments finally started to pick up, growing by 12.5% in 2003.

Prudent fiscal policy, including a broadening of the tax base and a general reduction in taxes, coupled with tight controls on government spending, has fuelled consumption and helped to sustain economic growth. Political stability over the past five years has encouraged both investors and consumers.

Nevertheless, positive trends in the country's economy in recent years must be considered a consequence of surging oil production and exports, buoyed by very high oil prices. The oil and gas sectors in particular contributed more than half of the increase in GDP growth in the past few years.

The year 1999 was a landmark, demonstrating (at least according to official statistics) real economic growth (5.4%), and the dynamism of the domestic economy's development has given political leaders grounds for optimism. Economic growth continued in 2000-2001 (Table 7.1), as well as in 2002 and 2003.

Economic problems in the first years of the economic reforms influenced the output of the industrial and transportation sectors. Industrial output in 2000 was only equal to 60% of the level of 1990. Activity in freight transport in 1992-2000 declined by 28% (Table 7.2), and distance travelled per capita by passenger transport by 27% (Table 7.3). According to preliminary evaluations, both the

industrial and transportation sectors demonstrated growing activity in 2001-2003, which reflected positive trends in the domestic economy.

The Russian Federation has made considerable progress in its transition to a market economy, but many legacies of the old centrally planned system are still evident and many serious problems remain. A number of institutional, regulatory and legal reforms still need to be implemented. The restructuring of key sectors of the economy, including energy, has yet to be completed. There are various projections for future economic growth.

President Putin set an ambitious goal in his State-of-the-Nation Address in May 2003. He noted: "We should at least double the gross domestic product in a decade. The doubling of the GDP is of course a large-scale task. It will call for a profound analysis and adjustment of the existing approaches to economic policy."

According to the Strategy document noted earlier, the two main scenarios for economic development are considered moderate and optimistic.

A broad range of conditions including the main forecasting trends for the world's economy, needed payments in accordance with the external debt of the country, continuation of economic reforms, expected inflation rates, as well as the transformation of GDP structure were taken into account in the above scenarios.

In the optimistic scenario, higher intensity and effectiveness of economic, fiscal and price reforms are planned. According to this scenario, the level of GDP in 2020 will increase by a factor of 3.3 in comparison with 2000. This scenario assumes a high (world) price level for oil (USD30 per barrel) and natural gas (USD138 per 1,000 m^3) in 2020.

In its moderate scenario, the Strategy assumes a GDP growth rate of 5% to 6% per year to 2020. The total amount of GDP produced in 2020 will increase by a factor of 2.3 in comparison with the level in 2000. Oil prices within the forecasting period were assumed to be constant (at USD18.5 per barrel). Natural gas in this scenario would cost USD119 per 1,000 m^3.

The dynamics of the main macroeconomic indicators in the optimistic and moderate scenarios are given in Table 7.4. It follows from the figures given in Table 7.4 that a relatively high rate of economic, industrial and investment growth are expected during the next two decades, under either scenario. If the country is to meet these ambitious goals over the forecasting period, the Russian fuel and energy complex (FEC) will face the challenge of meeting rapidly growing domestic energy demand.

7.2.2. Current state and prospects of the Fuel and Energy Complex

7.2.2.1. Energy resource base

The Russian Federation has one of the largest, most highly developed and widely diversified energy systems in the world. Holding abundant, large proven recoverable reserves of fossil fuels, as well as technically-exploitable hydro potential, the country cannot only fully satisfy its internal energy needs, but also can act as one of the major energy suppliers in the world market.

During the 1990s, the size of the energy resource base remained relatively stable (WEC, 1998, 2001). Table 7.5 provides data on the available volume of proven recoverable reserves of fossil fuels and uranium, as well as the fraction of technically exploitable capabilities for hydropower not currently in use. Table 7.6 presents the energy potential of renewable energy sources.

TABLE 7.1 MAIN MACROECONOMIC AND ENERGY INDICATORS IN RUSSIA IN 1992-2001

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
GDP (billion US$ at 1995 prices and ex. rates)	441.203	402.957	352.307	337.709	326.227	329.163	313.034	329.938	359.632	377.613
GDP (billion US$ at 1995 prices and PPPs)	1,089.617	995.163	870.074	834.022	805.665	812.916	773.083	814.829	888.164	932.573
Population (millions)	148.689	148.52	148.336	148.141	147.739	147.304	146.899	146.309	145.555	144.752
Share of urban population, %	73.7	73.3	73.1	73.0	73.1	73.1	73.1	73.1	73.1	73.1
GDP per capita (1,000 US$ at 1995 prices and ex. rates)	2.967	2.713	2.375	2.280	2.208	2.235	2.131	2.255	2.471	2.609
GDP per capita (1,000 US$ at 1995 prices and PPPs)	7.328	6.7000	5.866	5.630	5.453	5.519	5.263	5.569	6.102	6.443
Energy Production/TPES	1.444	1.401	1.504	1.518	1.536	1.549	1.597	1.576	1.574	1.603
TPES/GDP (toe per thousand 1995 US$ PPP)	0.711	0.75	0.749	0.753	0.765	0.732	0.752	0.74	0.691	0.666
TPES/Population (toe per capita)	5.211	5.015	4.392	4.242	4.174	4.04	3.958	4.122	4.218	4.293
Electricity consumption/GDP (kWh per 1995 US$ PPP)	0.833	0.854	0.885	0.907	0.922	0.898	0.926	0.903	0.859	0.801
Electricity Consumption/Population (kWh per capita)	6107.479	5724.091	5190.729	5109.639	5030.743	4956.104	5029.773	5235.615	5235.615	5318.98
Floor area per capita, m^2/person	16.8	17.4	17.7	18.1	18.3	18.6	18.9	19.1	19.3	19.5

Sources: OECD/IEA (2003), Ministry of Industry and Energy (MIE) of the Russian Federation (2003a)

TABLE 7.2 FREIGHT TRANSPORT ACTIVITY IN RUSSIA IN 1992-2000, BILLION TONNES -KM

Transportation mode	1992	1993	1994	1995	1996	1997	1998	1999	2000
Total	4,697.8	4,157.6	3,566.5	3,532.6	3,370.1	3,255.5	3,147.0	3,256.1	3,367.3
Rail	1,967	1,608	1,195	1,214	1,131	1,100	1,020	1,078	1,145
Road	42	53	36	31	26	25	21	24	28
Pipeline transport	2,146	2,019	1,936	1,899	1,913	1,844	1,888	1,904	1,916
International navigation	541	476	398	387	298	284	216	248	276
Air	1.8	1.6	1.5	1.6	2.1	2.5	2.0	2.1	2.3

Source: MIE (2003b), State Committee for Statistics (SCS) of the Russian Federation (2003)

TABLE 7.3 DISTANCE TRAVELED PER CAPITA BY TRANSPORTATION MODE IN RUSSIA IN 1992-2000, KM/PERSON[1]

Transportation mode	1992	1993	1994	1995	1996	1997	1998	1999	2000
Total transport	4,581	4,451	4,019	3,732	3,572	3,472	3,276	3,295	3,351
Rail	1,703	1,833	1,531	1,297	1,226	1,156	1,045	1,012	1,025
Air	792	560	487	484	437	417	378	403	425
International navigation	20	13	10	9	7	6	5	4	2
Bus	1,428	1,349	1,306	1,270	1,227	1,217	1,220	1,223	1,225
Road (taxi)[2]	26	13	9	7	4	3	2	2	2
Tram	175	177	175	171	171	170	174	172	173
Trolleybus	176	191	183	182	185	189	192	190	191
Metro	261	315	318	312	315	314	260	289	308
Urban transport, total	1,414	1,442	1,432	1,405	1,396	1,403	1,385	1,358	1,383
Bus	771	745	747	733	713	726	700	705	709
Urban navigation	1	1	1	0.5	.5	0.5	0.5	0.5	0.5
Road (taxi)	26	13	9	7	4	3	2	2	2
Tram	175	177	175	171	171	170	174	172	173
Trolleybus	176	191	183	182	185	189	192	190	191
Metro	261	315	318	312	315	314	260	289	308

Source: MIE (2003b), SCS (2003)
1 Ratio of travelled distance/population
2 Excluding private cars

TABLE 7.4 MAIN MACROECONOMIC INDICATOR FORECASTS[3]

Indicator	2000	2005		2010		2015		2020	
		(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
GDP	100	127	125	173	157	242	192	334	231
Industrial production	100	125	123	165	153	220	186	288	222
Investment	100	142	139	227	200	408	271	699	360
GDP per capita	100	131	128	181	165	257	207	356	255
Real income of the population	100	150	147	247	196	316	248	441	301
Expenditures on energy use per capita	100	169	169	194	192	215	206	235	233
Energy intensity of GDP	100	82	82	72	74	55	64	42	56

Source: MIE (2003b)
Values for the year 2000 = 100
(1) – optimistic scenario
(2) – moderate scenario

TABLE 7.5 CURRENT STATE OF ENERGY RESOURCE BASE

Indicator	Unit of measure	Value
Fraction of technically exploitable capability of hydropower not currently in use	%	90.7
Proven recoverable fossil fuel reserves		
Coal	Mt	157,000
Oil	Mt	6,700
Gas	Bm^3	48,000
Lifetime of proven recoverable fossil fuel[2] reserves		
Coal	Years	600
Oil	Years	36
Gas	Years	80
Proven uranium reserves	Kt	145
Lifetime of proven uranium reserves	years	56

Source: MIE (2003a), World Energy Council (WEC) (1998), WEC (2001)

TABLE 7.6 POTENTIAL OF RENEWABLE ENERGY SOURCES IN RUSSIA, MTOE/YEAR

	Gross potential	Technical potential	Economic potential
Small Hydro	252	87	46
Geothermal	N.a	N.a	80
Biomass	7,000	37	25
Wind	18,200	1,400	7
Solar	1.6×10^6	1,600	9
Low Potential Heat	367	80	25
Total	1.63×10^6	3,204	192

Source: IEA (2003b)

TABLE 7.7 GROWTH AND EXTRACTION OF PROVEN RECOVERABLE FOSSIL FUEL RESERVES

Energy carrier	1996	1997	1998	1999	2000
Oil and condensate					
annual growth of reserves, Mt	216.7	276	232	200	295
percentage of production, %	71.9	92	76.6	65	91
Natural gas					
annual growth of reserves, Bm^3	180	398.5	128	210	450
percentage of production, %	29.9	69.8	21.7	35.6	77
Coal					
annual growth of reserves, Mt	590.3	255	252	250	N.a
percentage of production, %	229	104.2	108.6	100	N.a

Source: MIE (2003a), MIE (2003b)

[2] Ratio: proven recoverable reserves/ current overall production including exports

The Russian Federation owns 45% of the world's natural gas reserves; 13% of the oil reserves; 23% of the coal reserves; and 14% of the uranium reserves (Strategy, 2003). The lifetime of proven recoverable reserves of hydrocarbons will allow the country's energy carriers to continue to play an important role in world trade.

However, the state of the energy resource base for the past 8-10 years has exhibited significant deterioration and exhaustion. More than 50% of the estimated oil resources, and 80% of the natural gas resources, lie in remote areas (i.e., East Siberia, continental shelf of the Arctic seas, etc.). The share of difficult-to-recover oil and gas reserves is still growing, and this will make it inevitable that large-scale investment for exploration and exploitation of these new oil and gas fields will be required.

Similarly, the volume of the most economically effective proven recoverable reserves of oil and gas has substantially declined (see Table 7.7). It follows from the figures given in this Table that the annual growth of proven recoverable oil and gas reserves will only partly compensate for annual production. This negative trend continued in 2000-2002.

During this 2000-2002 period, proven recoverable oil reserves grew by 849 Mt. For the same period, oil production accounted for 1,052 Mt. Therefore the correlation between proven recoverable reserves growth and production in the oil industry for the past three years was about 80%. As far as natural gas is concerned, this percentage was about 85-87%. The most economically efficient fields have gradually been depleted, especially those large oil fields with initial recoverable reserves over 100 Mt. The share of these major oil fields in the total structure of oil production in Russia now stands at 57% (in 1990 this share was about 70%). Oil production in these oil fields has been constantly declining. There is a lack of investment for exploring and exploiting the new oil fields. This has been especially evident in the effort to open up valuable oil and gas fields in the northern European part of the Russian Federation and Western Siberia – the Timan-Pechora basin, the Barents Sea shelf, and the Yamal peninsula, where the energy resources produced will be of importance primarily for export. The Strategy estimates resources of oil at 44 Bt; natural gas at 127,000 Bcm; and geological resources of coal at 4,450 Bt (i.e., 30% of the world's resources of this category).

Depletion of the most economically effective part of the energy resource base and deterioration of its condition have not yet noticeably affected either the volume of proven reserves (and thus self-sufficiency in fossil fuels), nor energy export opportunities. However, if urgent measures are not undertaken, it will become a serious obstacle to energy and economic development. Developing the country's huge energy resources requires massive investment. According to the Strategy, US$ 40-50 billion should be invested in the energy resource base before the year 2020 in order to ensure reliable fuel supplies in the domestic market, as well as economically justified export. A set of legislative measures aimed at creating a favourable investment climate for domestic and foreign investors is to be introduced.

7.2.2.2. The role of the FEC in Russia's economy

The FEC has traditionally played an important role in the economy due to national climatic conditions (i.e., more than 60% of Russian territory is located in the permanent frost zone), as well as socio-economic and historical factors. The FEC supplies energy to all the sectors of the economy, and plays a decisive role in the main financial and economic indicators of the country. During recent years of reform, its role in accomplishing social and economic progress has increased significantly.

Currently the FEC accounts for 20.2% of GDP; 30% of industrial production (against 11.6% in 1991); 54.5% of exports; and 16.5% of the personnel involved in industrial production. The FEC enterprises supply 39% of the tax collected in the budget (Table 7.8).

Despite existing economic problems, the Russian FEC has retained the bulk of its production potential and keeps high standards in providing the economy with energy and currency resources. During the years of reform, the FEC became a unique contributor, almost at the cost of weakening itself. It facilitated, to a large extent, the functioning of market forces during the transition period. As a result of the non-payment of energy services and relatively low tariffs for energy carriers regulated by government, its joint stock societies and companies subsidized hundreds of millions of dollars every year for other sectors of the economy.

According to the optimistic scenario of the Strategy, the share of the FEC in domestic industry will decrease in 2020 to 19.8% (moderate scenario assumes 18.7%).

TABLE 7.8 THE ROLE OF THE FEC IN DOMESTIC ECONOMY IN 2001, %

Economic structure	Energy Industries				
	Oil[1]	Gas	Electricity production	Coal	FEC, total
GDP	49.4	32.7	14.3	3.6	20.2
Export	64.1	33.2	0.5	2.2	54.5
Tax, collected in the budget	58.8	30.3	9.2	1.7	38.5

Source: MIE (2003b)

[1] Share of each particular sector in the FEC

7.2.2.3. Energy production

The collapse of the Soviet Union and the ensuing economic crisis had a negative impact on the country's fuel and energy complex. By 2001, primary energy production in the Russian Federation had fallen almost 11% in comparison with the level of 1992; the output of coal had fallen about 15%; of oil, almost 13%; and of natural gas, more than 9% (Annex 7.1). For the same period, electricity production had decreased by 119 BkWh, or by 11.8% (Table 7.9).

The principal reasons for the declining output in the FEC included:

- A decline in the paying capacity of consumers;
- A reduction in the GDP;
- A decline in industrial production (i.e., industry is the largest energy consumer among the sectors of the domestic economy).

The decline in energy production mostly took place between 1992 and 1997, the lowest year of energy production during the period of economic reform. The period from 1998 through the present time can be characterized as a recovery period for the domestic FEC. The average annual growth rates of primary energy production in 1998-2001 were 2.4%, the same growth rates exhibited by electricity generation. Production of oil has rebounded strongly since 1999, in response to higher world prices and the devaluation of the ruble after the 1998 financial crisis. At the same time, however, gas production volumes have declined.

At the beginning of 2001, the production potential of the FEC comprised almost 142,000 oil wells, 6,400 gas wells, and 25 oil refineries with a total capacity of 257 million tonnes. The installed capacity of power stations amounted to 215 million kW (at the beginning of 2002), and the length of transmission lines exceeded 2.5 million km. There were 151 coal mines and 75 open-pit mines, with a total capacity of 313 million t/year (Ministry of Industry and Energy, 2003).

Fuel and energy supply in the country is provided by a system of pipelines: 47,300 km of oil pipelines, 149,000 km of gas pipelines, and about 20,000 km of petroleum product pipelines, numerous oil tank farms, fuel yards, etc.

Natural gas is a leading source of primary energy in the Russian Federation. For the period 1992-2001, the share of natural gas in primary energy production mix increased from 46.2% to 47%. At the same time, the share of other fossil fuels (oil and coal) had declined. In general, fossil fuels dominate in primary energy production, covering over 94% of its total volume.

Natural gas also dominates in the structure of electricity production (Table 7.9). However, in 1992-2001, both the physical amounts of electricity produced by gas-based power plants and the share of natural gas as a source of electricity generation had a tendency to decline.

TABLE 7.9 ELECTRICITY GENERATION IN RUSSIA IN 1992-2001

	Years	Coal	Petroleum Products	Gas	Nuclear	Hydro	Geothermal, Solar. etc.	CRW	Total
BkWh	1992	154.273	100.157	460.67	119.626	171.843	0.029	1.852	1,008.45
	1993	148.591	82.998	429.744	119.186	173.399	0.028	1.756	955.702
	1994	162.741	73.387	364.315	97.82	174.978	0.031	1.609	874.881
	1995	160.528	67.889	354.057	99.532	175.411	0.03	1.579	859.026
	1996	160.901	56.603	364.724	109.026	153.328	0.028	1.556	846.166
	1997	157.258	51.869	357.404	108.498	156.584	0.029	1.532	833.174
	1998	162.51	52.793	345.52	105.32	158.497	0.03	1.519	826.189
	1999	161.341	40.901	358.634	121.874	160.492	0.028	2.075	845.347
	2000	175.615	33.091	370.372	130.715	164.077	0.058	2.538	876.468
	2001	168.773	30.02	376.744	136.935	173.899	0.091	2.868	889.333
% of total	1992	15.3	9.93	45.68	11.86	17.04	0.01	0.18	100
	1993	15.55	8.68	44.97	12.47	18.14	0.01	0.18	100
	1994	18.6	98.39	41.64	11.18	20.0	0.01	0.18	100
	1995	18.69	7.9	41.22	11.59	20.41	0.01	0.18	100
	1996	19.02	6.69	43.1	12.88	18.12	0.01	0.18	100
	1997	18.87	6.23	42.9	13.02	18.79	0.01	0.18	100
	1998	19.67	6.39	41.82	12.75	19.18	0.01	0.18	100
	1999	19.09	4.84	42.42	14.41	18.98	0.01	0.25	100
	2000	20.0	3.78	42.26	14.91	18.72	0.04	0.29	100
	2001	18.97	3.38	42.32	15.4	19.55	0.06	0.32	100

Source: MIE (2003b)

Petroleum products had consequently decreased their share in the fuel balance of electricity generation (from almost 10% in 1992 to 3.4% in 2001). Coal, nuclear and hydropower had demonstrated an increase of the physical amount of electricity generated as well as definite growth within the electricity generation mix.

The total share of non-fossil fuels and energy resources in the electricity generation mix is much higher than in the primary energy production mix. For 2001, it was equal to 35.33%.

The technical and economic state of the FEC's enterprises is far from perfect. A high share of exhausted, old and inefficient equipment remains in place (Table 7.10). This negative situation has not been addressed to date.

Distribution losses of electricity, 84.1 TWh in 1992, increased by an additional 19.3 TWh in 2001, and their share of total electricity generation increased from 8.3% in 1992 to 11.6% in 2001. The capacity factor of domestic electric power plants declined from 54.8 % in 1992 to 48% in 2001 (Table 7.11).

The economic crisis which accompanied the transition to a market–driven economy, the ineffective state policies in energy prices and taxes, and non- payments for energy carriers in the first years of reforms all affected the financial state of the FEC's branches. The distinct evidence is a high share of unprofitable enterprises in Russia's fuel and energy complex (Table 7.12). In the FEC, this share in 2000 was 39.5% (8.7% in 1992); in the electric power industry, 40.7% (compared to 6.6%); and in the coal industry, 54.3% (compared to 20.8%).

The Strategy assumes that an essential growth of primary energy production will occur within the forecasting period. It will affect both total primary energy and all energy sources (Table 7.13). Total primary energy production growth rates in 2000-2020 will be 1.2 % per year in the moderate scenario and 1.8% in the optimistic scenario. Electricity production growth rates will be higher (i.e., 1.65% per year in the moderate and 2.3% in the optimistic scenarios).

TABLE 7.10 DYNAMICS OF WEAR OF EQUIPMENT IN THE FUEL AND ENERGY COMPLEX IN 1995-1998, IN %

Branch	1995	1996	1997	1998
Electric power industry	58	58	61	64
Oil industry	51	53	56	59
Oil refining industry	75	74	79	81
Gas industry	59	62	67	70
Coal industry	52	57	58	60

Source: MIE (2003b)

TABLE 7.11 GENERATING CAPACITIES AND THEIR TECHNICAL CHARACTERISTICS

	Unit of measures	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Installed capacities: Total	GW	212.0	213.4	214.9	215.0	214.5	214.2	214.1	205.4	214.0	214.7
Plants using:											
Fossil fuels		148.4	148.8	149.7	149.7	149.1	149.0	148.7	140.0	148.9	148.2
Hydro		43.4	43.4	44.0	44.0	44.1	43.9	44.1	44.1	43.9	44.3
Nuclear		20.2	21.2	21.2	21.3	21.3	21.3	21.3	21.3	21.2	22.1
Hours of used installed capacity: Total	Hours	4,810	4,545	4,209	4,079	4,078	4,008	3,968	4,056	4,217	4,159
Plants using:											
Fossil fuels		5,085	4,714	4,254	4,092	4,089	3,964	3,935	3,934	4,080	3,897

Hydro		4,043	4,097	4,126	4,113	3,596	3,672	3,692	3,720	3,803	3,970
Nuclear		n.a.	n.a.	n.a.	n.a.	n.a.	5,098	4,872	5,650	6,067	6,240
Capacity factor	%	54.8	51.9	45.8	46.6	47.3	45.8	44.1	48.5	48.2	48.0
Distribution losses	TWh	84.1	80.6	79.0	83.5	84.5	84.4	93.2	96.8	101.6	103.4
	% of total generation	8.3	8.4	9.0	9.7	10.0	10.1	11.3	11.5	11.6	11.6

Source: MIE (2003b)

TABLE 7.12 SHARE OF UNPROFITABLE ENTERPRISES IN THE FUEL AND ENERGY COMPLEX, IN %

Years	Total industry	Total FEC	Coal industry	Oil industry	Oil refining industry	Gas industry	Electric power industry
1992	7.2	8.7	20.8	8.0	n.a	17.9	6.6
1993	7.8	26.0	30.5	10.4	n.a	27.6	5.2
1994	22.6	20.6	49.4	15.8	2.7	30.8	7.5
1995	26.4	21.9	44.9	24.5	1.9	10.7	13.6
1996	43.5	29.8	53.9	18.7	13.7	13.3	20.9
1997	46.9	34.2	60.8	28.2	23.3	32.2	23.2
1998	49.2	39.8	63.7	40.4	31.1	51.5	30.9
1999	39.2	42.3	60.0	27.1	22.7	35.1	40.7
2000	38.7	39.5	54.3	14.4	17.1	32.5	40.7

Source: MIE (2003b)

TABLE 7.13 PRIMARY ENERGY PRODUCTION FORECASTS

	Unit of measure	2000	2002	2010		2020	
				Moderate scenario	Optimistic scenario	Moderate scenario	Optimistic scenario
Total primary energy	Mtoe	996.5	1,060	1,190	1,270	1,265	1,420
Electricity generation	TWh	876	892	1,015	1,070	1,215	1,365
Oil production	Mt	324	379	445	490	450	520
Motor fuels production	Mt	83	88	100	110	115	135
Natural gas production	Bcm	584	595	635	665	680	730
Coal production	Mt	258	253	310	330	375	430
Centralized heat production	MGcal	1,452	1,437	1,570	1,625	1,720	1,820

Source: MIE (2003a)

Oil production will increase by 126-196 Mt (39-60%) within 2000-2020, gas production by 96-146 Bm^3 (16-25%), and coal production by 117-172 Mt (45-67%).

It is anticipated that 25,000-35,000 km of electricity transmission lines over 330 kV will be put in operation before 2020. New generation capacities will be needed to ensure forecasted levels of electricity and heat production. Taking into account the modernization of existing and replacement of exhausted capacities, 121-177 GW of generating capacities should be created in 2003-2020, including 7-11.2 GW of hydropower plants, 17-23 GW of nuclear power plants, and 97-143 GW of thermal power plants.

7.2.2.4. The role of energy exports

In the Russian Federation, explored and prospective reserves of fossil fuels allow both domestic demand to be met for years ahead and its role in the world arena to be maintained and strengthened. As an example, the country accounts for 11-12% of the world trade in energy resources, and in particular, 3%-3.5% of the trade in liquid fuels and 35% of the trade in natural gas. Available statistical data on energy export revenue within the period 1995-2000 are given in Table 7.14.

Since the Russian Federation is primarily oriented towards raw materials export (including energy carriers), export revenue depends upon world energy prices. A comparative analysis of net oil and gas export volumes and energy export revenues for 1998 and 2000 illustrates this fact.

According to available statistics, the total volume of crude oil net export in 1998 was equal to 132.3 Mtoe, while in 2000 it was 139.2 Mtoe, an increase of 5.2 %. Oil export revenues during the same period rose by a factor of 2.6, however. For natural gas, the volume of its net export decreased in 1998-2000 by 9.8%; however, the gas net export revenue indicator for this period had a completely opposite trend: +27.4%.

According to UNECE, a change in world oil prices by one dollar is likely to be associated with a 0.4 to 0.6 percentage change in GDP, with a change in fiscal revenue amounting to $0.8-$0.9 billion/year.

Crude oil plays a leading role in the structure of the country's net energy export. The total volume of net energy export had increased its share from 40.3% in 1992 to 43% in 2001.

TABLE 7.14 ENERGY EXPORT REVENUE OF THE RUSSIAN FEDERATION[1] IN 1995-2000, MLN USD[2]

Energy carrier	1995	1996	1997	1998	1999	2000
Crude oil	11,005	14,063	13,002	8,768	12,823	22,911
Coal	735	810	702	491	432	972
Petroleum products	4,137	7,146	6,939	3,886	4,628	10,151
Natural gas	8,541	9,653	10,707	9,024	10,950	11,500
Electricity	18,303	206.14	152.1	170	146	101.95
Total energy export	24,601.3	31,878.14	31,502.1	23,339	28,979	45,635.95

Source: MIE (2003b)
1 Excluding CIS countries
2 In current dollars

A decline in the natural gas share also occurred over the same period (i.e., from 46.3 to 39%).

Almost half of the net energy export revenue is captured by crude oil. The export of energy resources satisfies almost 80% of the demand of the Baltic countries and Eastern Europe, and essential volumes of gas and oil are delivered to Western European countries.

One important geographical feature of the Russian Federation energy export is worth noting— the share of CIS countries as a final destination for energy carriers dramatically declined over the period 1992-2001 (Figure 7.1).

This can be explained primarily in terms of economic and financial reasons—especially the low purchasing power of consumers in CIS countries, non-payments for energy carriers, and the decrease in energy demand in CIS countries due to economic development problems.

The indicator "Energy net import dependency" is included within the ISED indicator listing. As a large-scale energy exporter, Russia has a negative energy net import dependency (Figure 7.2), or the share of energy net imports in the total amount of energy supply. In 1992-2001, the share of net export in TPES in Russia increased from 42.2% to 59.1%; in conventional energy consumption, from 43.1% to 59.7 %; in crude oil consumption, from 50.5% to 83.5%; and in natural gas consumption, from 42.9% to 54.4%.

Over the long term, the Russian Federation will remain one of the largest players on the world energy scene. The country's importance in global energy supply and trade will grow over the outlook period (i.e. through 2020), with major implications for world supply security. The country is planning to increase the volume of its energy exports. According to the Strategy, the total volume of energy exports will increase from 383 Mtoe in 2000 to 556 Mtoe in 2020 under the moderate scenario, and to 626 Mtoe under the optimistic scenario (Figure 7.3). The volume of energy exports in considering such prospects will depend mostly on energy prices in world markets. In the case of world oil prices in the 18-20 USD/barrel range during the forecasting period, the total volume of primary energy exports will increase in 2010 by 23-25% in comparison with 2000, and by 25-30% in 2020.

In the case of oil prices rising to 30 USD/barrel by 2020, economically justified energy exports in 2010 will be more than in 2002 by 30-35%, and in 2020 by 45-50%.

In the short term, real revenues from energy exports are likely to remain sufficiently high to stimulate economic growth. But over the long term, the Russian Federation will need to reduce its reliance on energy exports by developing other industries. To diminish its excessive dependency on energy export revenues, the country urgently needs to improve the quality and diversity of other manufacturing industries and internationally traded services. Such improvements will depend to a large extent on the country's completing and fully implementing its ambitious programme of market reforms.

7.2.3. Primary energy supply

In 1992-2001, the total consumption of primary energy in the Russian Federation declined by 20% or by 153.5 Mtoe (Annex 7.1). Coal consumption for this period dropped by 19%, oil consumption by 28%, and natural gas consumption by 8%.

As noted above, the principal factor explaining declining consumption (as well as production) of fuel and energy in the country was the economic downturn, which reduced solvent demand for energy.

Natural gas accounts for more than half of the total primary energy supply mix. For the period 1992-2001, its share increased from 47% to 52.3%. Oil kept a second place in that structure, with a 28.5% share in 1992 declining to 21.4% in 2001. The relative growth of the share of nuclear power (from 4.1% to 5.8%) should also be noted.

The indicator of energy self-sufficiency (i.e., the ratio primary energy production/TPES) is traditionally high, taking into account the country's status as a large net energy exporter. The ratio increased from 1.44 in 1992 to 1.6 in 2001.

Available data on the per capita consumption of primary energy and electricity exhibited a declining trend in 1992-1998, but some growth in 1998-2001 (Table 7.1 and Figure 7.4). A comparative quantitative analysis of this indicator shows that the Russian Federation is at a level comparable to leading industrially developed countries (e.g., European Union countries). Statistical data on motor fuels and combustible renewables and waste (CRW) per capita are given in Figure 7.5.

However, the problem is that EU countries having comparable indicators of per capita primary energy and electricity consumption can boast of much higher levels of GDP per capita (22,218 USD/person in 2001 in the EU, versus 6,442 USD/person in the Russian Federation). In other words, relatively high indicators of per capita primary energy and electricity consumption alone cannot provide evidence of sustainability in energy development. How efficiently primary energy and electricity are used remains an important question.

It is interesting to evaluate per capita energy consumption in the residential sector. Table 7.15 provides information on per capita consumption of fossil fuels, electricity, heat and CRW in the residential sector in 1992 and 2001.

Comparison of GDP energy and electricity intensities in the Russian Federation and in EU countries is given in Figure 7.6. According to available statistics, in 1992 the Russia/EU ratio in GDP primary energy intensity was 3.66, but in 2001 it was 3.76; as far as electricity intensity is concerned, the ratio between the Russian and EU relevant indicators was 2.77, in both 1992 and 2001.

The energy supply efficiency is low, mostly because of the technical state of equipment in FEC's branches. The share of distribution losses in TPES is 2.8 times higher than in the EU. A huge difference in electricity supply efficiency also exists. In terms of gas supply efficiency, 17 Bcm of natural gas were lost in pipelines in 2001—a figure comparable to annual natural gas consumption in Poland, or annual natural gas production in Italy.

"Fossil fuel efficiency for electricity generation" is included in the list of ISED indicators, and along with distribution losses, this indicator shows the level of energy supply efficiency in the country. Local statistics give some information on specific fuel consumption for electricity and heat generation produced by thermal power plants (including CHP) (Table 7.16).

As is well known, utilizing CHP contributes to an improvement in the efficiency of heat and electricity generation. The combined method of heat and electricity production is widely-used in the Russian Federation. About 65% of total electricity and 50% of heat were produced by CHPs in 2001.

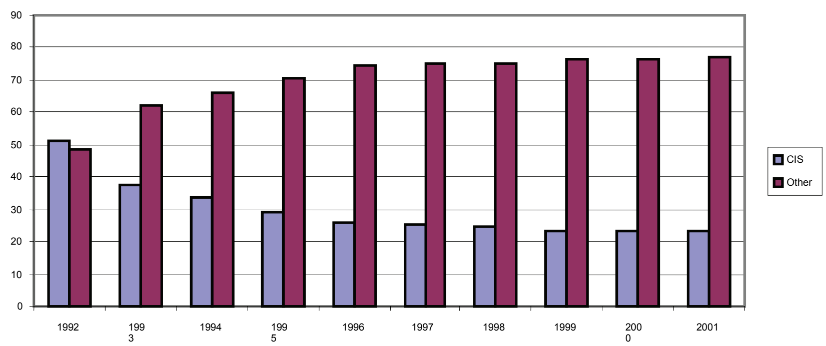

Figure 7.1 Geographic structure of Russia's energy export, %

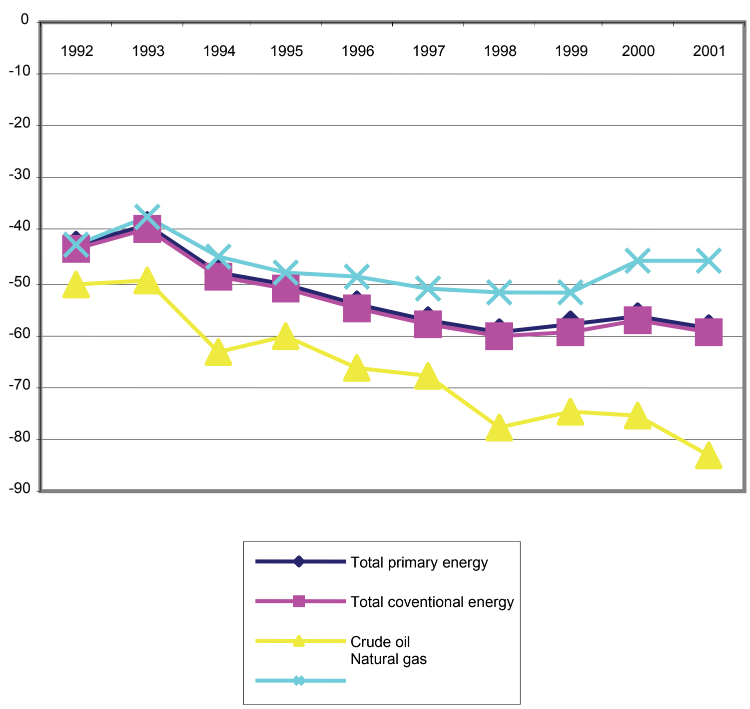

Figure 7.2 Russia's energy import dependency, %

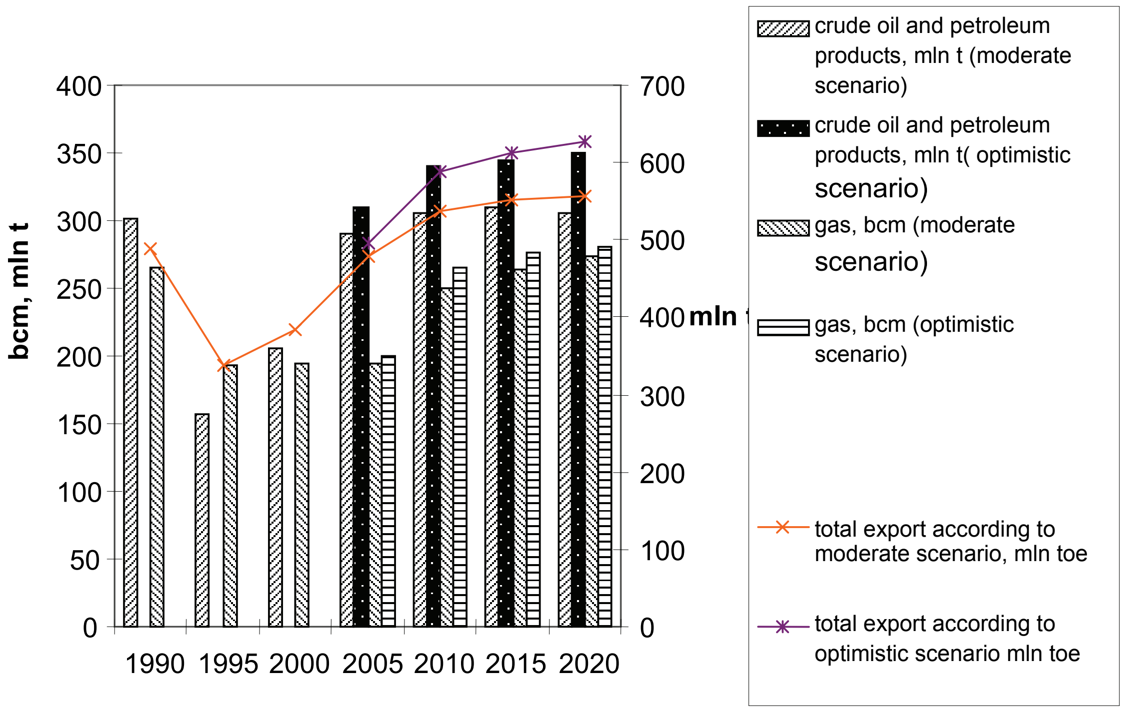

Figure 7.3 Energy export from Russia

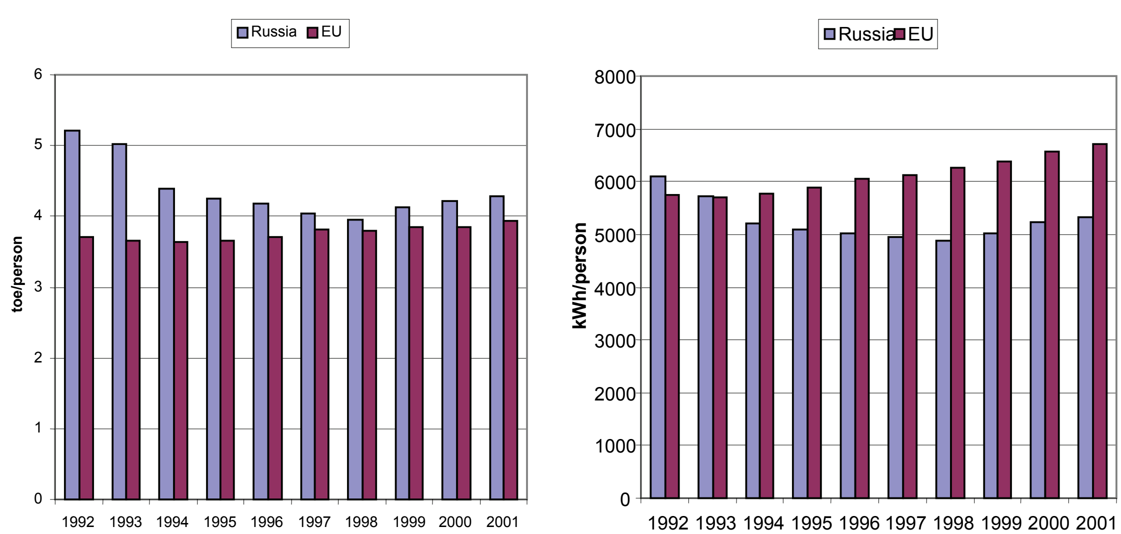

Figure 7.4 Per capita primary energy and electricity consumption in Russia and EU countries.

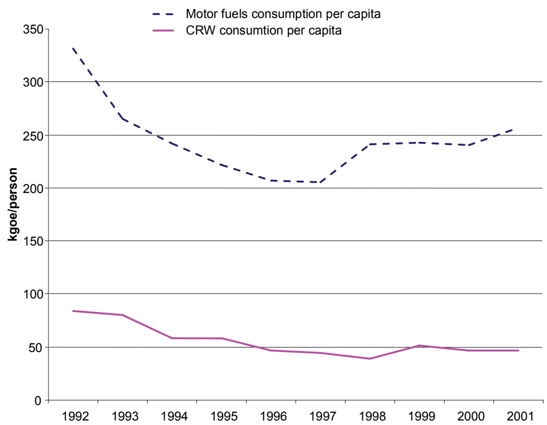

Figure 7.5 Motor fuels and CRW consumption per capita in Russia, kgoe/person

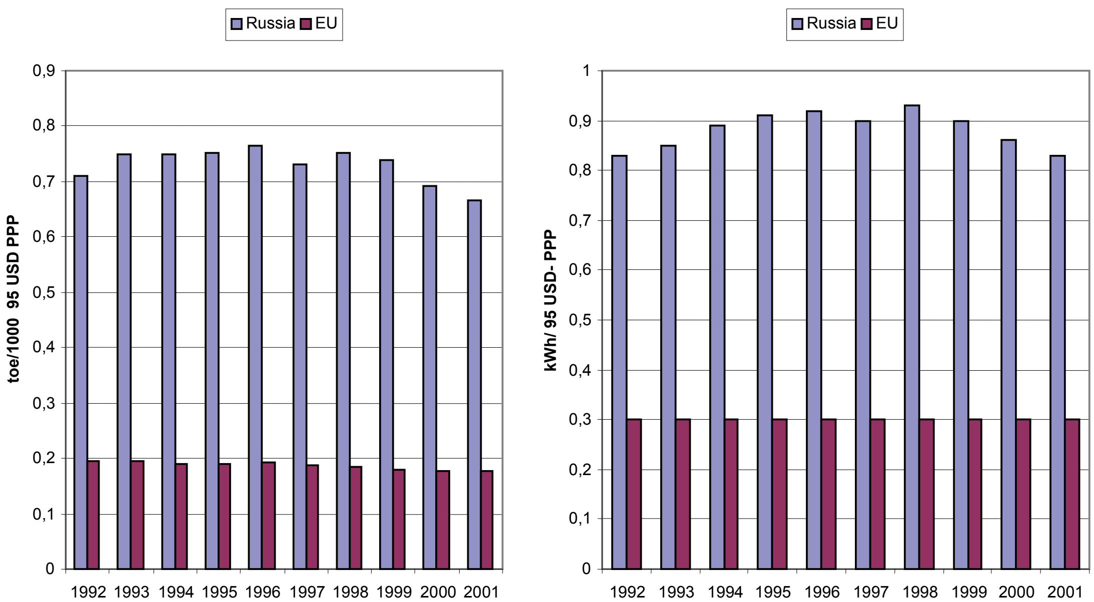

Figure 7.6 Energy and electricity intensities of GDP in Russia and EU

TABLE 7.15 PER CAPITA ENERGY CONSUMPTION IN RESIDENTIAL SECTOR

Energy carrier	Unit of measure	1992	2001
Fossil fuels	toe/ person	0.395	0.408
Electricity	KWh/ person	905	958
Heat	toe/ person	0.58	0.49
CRW	toe/ person	0.04	0.01

Source: OECD/IEA (2003)

7.2.3.1. *Energy demand forecasts*

Expected economic growth in the Russian Federation during the next two decades will require an additional consumption of primary energy. The Strategy gives the following forecasting estimations for the prospects of 2020 (Table 7.17). According to the moderate scenario, total primary energy demand in 2002-2020 will grow by 1.25% per year, while the optimistic scenario assumes 1.8% per year.

Natural gas will remain a basic fuel in the structure of internal primary energy demand. Its share in the TPES mix will decline from 50% in 2002 to 45-46% in 2020 (Table 7.18). Crude oil and petroleum products will represent 22% of primary energy demand, and solid fuels about 20%. The share of TPES from heat and electricity produced by nuclear and hydropower plants, as well as renewables, will remain relatively stable.

Motor fuels consumption will grow faster than the consumption of other energy carriers. In comparison with the year 2000 levels, motor fuel consumption will rise by 20-22% in 2010 and by 33-55% in 2020.

Electricity demand in 2000-2020 will grow at higher rates than total primary energy demand because of the high intensity of electrification in industry, agriculture and the residential sector. Moderate growth of centralized heat demand is expected, with an increase of 18-25% by 2020 (in comparison with 2000). This growth will be connected with structural change in the domestic economy, implementation of heat conservation potentials, and decentralized source development.

TABLE 7.16 ENERGY SUPPLY EFFICIENCY IN RUSSIA

	1992	1995	1997	1999	2001
Distribution losses as percentage of TPES, %	3.2/1.3 [1]	4.2/1.3	3.9/1.3	4.1/1.3	3.6/1.3
Distribution losses as percentage of total electricity generation, %	8.3/6.0[1]	9.7/6.0	10.1/5.0	11.4/5.8	12.3/5.7
Own use and losses in gas pipelines as percentage of total gas production, %	9.3/7.1 [1]	9.1/6.1	8.4/6.6	8.6/6.8	8.1/7.1
Specific fossil fuel consumption for electricity generation, kgoe/kWh	0.217	0.218	0.24	0.24	0.241
Specific fossil fuel consumption for heat generation, kgoe/kWh	0.121	0.122	0.103	0.102	0.102
Share of CHP's in total electricity generation, %	70.6	67.5	67.7	66.2	64.7
Share of CHP's in total heat generation,%	56.3	48.4	51.3	47.6	49.6

Source: MIE (2003b)
1 Numerator : Russia; denominator: EU

TABLE 7.17 ENERGY DEMAND FORECASTS IN RUSSIA, MTOE

	Natural gas	Crude oil and petroleum products	Solid fuel	Other[1]	Total
2002	324	127	120	69	640
2005	326[2]-336[3]	136-143	126-129	72-73	660-681
2010	348-371	150-180	134-149	82-86	714-765
2015	357-390	165-180	150-157	90-98	762-825
2020	367-406	176-198	162-178	96-106	801-888

Source: MIE (2003a)
1 Nuclear, hydro and renewables
2 Moderate scenario
3 Optimistic scenario

TABLE 7.18 ENERGY DEMAND FORECASTING STRUCTURE IN RUSSIA, %

	Natural gas	Crude oil and petroleum products	Solid fuel	Other[1]	Total
2002	50.6	19.8	18.8	10.8	100
2005	49.4[2]-49.3[3]	20.6-21.0	19.1-18.9	10.9-10.8	100
2010	48.7-48.5	21.0-20.8	18.8-19.5	11.5-11.2	100
2015	46.8-47.3	21.7-21.8	19.7-19.0	11.8-11.9	100
2020	45.8-45.7	22.0-22.2	20.2-20.0	12.0-12.1	100

Source: MIE (2003a)
1 Nuclear, hydro and renewables
2 Moderate scenario
3 Optimistic scenario

7.2.3.2. Energy demand structure

The heat and electricity production sector is one of the largest consumers of primary energy. In 1992, this sector consumed 119 Mtoe, or 15.4% of the total volume of primary energy resources used by the domestic economy; in 2001, the quantity of primary energy used for heat and electricity generation purposes was 116 Mtoe (Annex 7.1), or 18.6% of TPES.

In 1992-2001, total final energy consumption declined by 159 Mtoe, or by 27%. For the same period, petroleum products demand by final consumers decreased by 33.4%; for natural gas, by 12%; for electricity, by 18.3%; and for heat, by 34.2%. The ratio of total final energy consumption/ TPES fell from 76% in 1992 to 69% in 2001.

Heat is a leading energy resource in the final energy mix. Its share in 2001 accounted for about one-third of the total final energy consumption. The share of natural gas increased from 23.1% in 1992 to 28% in 2001 .

TABLE 7.19 THE MAIN SECTORS OF RUSSIA’S GDP PRODUCTION IN 1998

Sector of GDP production	Share in total GDP, %
Industry	26.8
Agriculture	5.4
Construction	6.6
Transport	8.8
Trade (wholesale and retail)	18.5
Residential sector	2.6
Communication	1.8
Financial sector (credits, insurance)	0.35
Science	0.75
Education, culture and art	3.5
Defense	1.7
Management	3.3
Real estate activities	3.0
Net taxes on products (excluding subsidies)	8.0
Other sectors	8.9
Total GDP	100.0

Source: SCS (2003)

The industry and residential sectors are the largest consumers of final energy. Over three-quarters of energy consumption in industry today is covered by the four most energy intensive branches: iron and

steel (21.4% in 2001), chemical and petrochemical (31.3%), non-ferrous metals (12.6%) and machinery (11%).

The share of industry in the aggregated structure of GDP has declined during recent years (Figure 7.7) according to official statistics. A more detailed structure of GDP (available for 1998 only) is given in Table 7.19.

Within industrial energy consumption, heat has the highest share. In 2001, for example, it was about 34%. The transportation sector mostly uses petroleum products, including motor fuels (56.5% in total energy consumption in this sector in 2001) and natural gas (used mostly for ensuring the functioning of gas pipelines). The most actively consumed energy resource in agriculture is petroleum products (46%), while the commercial/public services and residential sectors have 50% and 49% dependence on heat, respectively.

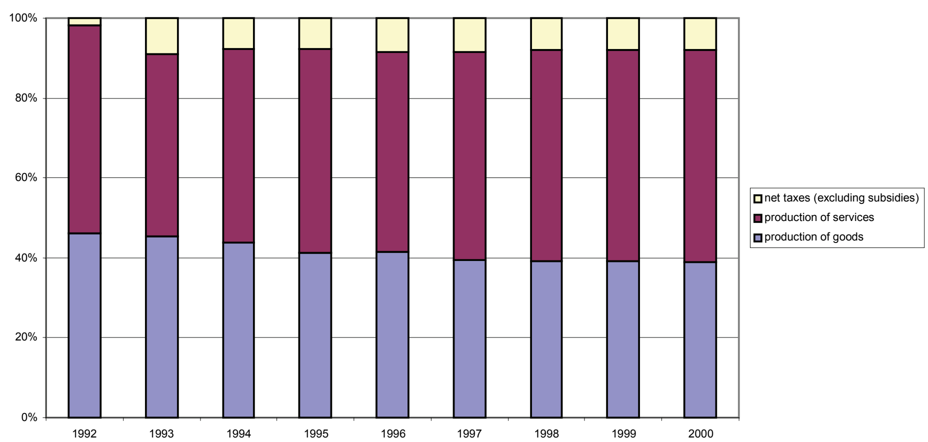

Figure 7.7 Aggregated structure of Russia's GDP in 1992-2000, %

The heat and electricity generation sector is the largest consumer of solid fuel. Fully 74% of coal used by the domestic economy in 2001 was consumed by CHP's, heat and electric power plants. The transportation sector consumed about 38% of the total liquid fuel supply, while 58% of total natural gas consumption was aimed at heat and electricity generation. The largest fraction of final electricity is used by industry (52% in 2001), while the residential sector is the largest consumer of heat (53% in 2001).

7.2.3.3. Investment problems of Russia's FEC

One of the most serious problems for sustainable energy development in the Russian Federation is a lack of investment.

According to the Ministry of Energy, a negative trend of investment took place in the FEC in 1992-1998 (Table 7.20). Some growth of investment activity, strongest in the oil industry, occurred in 1999 and 2000 (as well as in 2001-2002).

The contribution of various sources of financing for domestic energy has dramatically changed during recent years (Figure 7.8).

Internal (i.e., "own") financial resources of FEC enterprises is now the main source of investment for domestic energy. At the same time, central budgetary funding has sharply declined.

Despite the high potential attractiveness of Russia's energy for foreign investment, their share in total investment in the FEC's branches is relatively low—about 13% of the total investment in energy, of which 95% is directed at the oil industry alone. The principal reason for the low investment activity of foreign investors is an unfavourable investment climate.

Some figures are available addressing investment forecasts in the country's energy sector.

Investment forecasts developed by the IEA are outlined in Table 7.21. In 2001-2010, the gas industry will have the highest share of total investment in energy (38%). In 2011-2020 and 2021-2030, the electricity sector will become the most capital-intensive branch of domestic FEC (40.7% and 39%, respectively). IEA economic forecasts would require a total amount of investment of about 1,050 billion dollars in 2001-2030, or 35 billion dollars annually.

The Strategy gives the following forecasts (Table 7.22): 660 to 770 billion dollars (according to moderate and optimistic scenarios, respectively) will be needed in 2001-2020 in order to meet forecasted economic growth in the country and to ensure economically justified energy exports in external markets. It will account for 33-38.5 billion dollars per year (i.e., quite close to the IEA forecasts).

In the optimistic scenario, the total investment in energy in 2020 will increase by a factor of 7 in comparison with 2000; the moderate scenario assumes an increase by a factor of 3 to 6.

TABLE 7.20 INDICES OF EXPENDITURE ON ENERGY USE (PERCENTAGE OF PREVIOUS YEAR IN COMPARABLE PRICES)

Branches of the fuel and energy complex	1992	1993	1994	1995	1996	1997	1998	1999	2000
Total expenditures	60.3	88.0	76.0	87.0	82.0	95.0	93.3	104.5	117.7
Power engineering	66.7	84.0	66.7	103.6	88.7	97.3	72.0	90.1	83.8
Oil industry	66.6	53.4	79.5	93.5	74.3	96.6	72.7	125.1	173.1
Petroleum refining	66.6	180.0	102.2	81.5	82.0	56.2	81.0	74.0	201.6
"Gazprom"	55.2	75.7	135.7	78.9	94.5	101.5	66.3	135.2	88.4
Coal industry	58.8	73.3	60.0	76.5	79.0	82.3	64.9	95.1	67.0

Source: MIE (2003b)

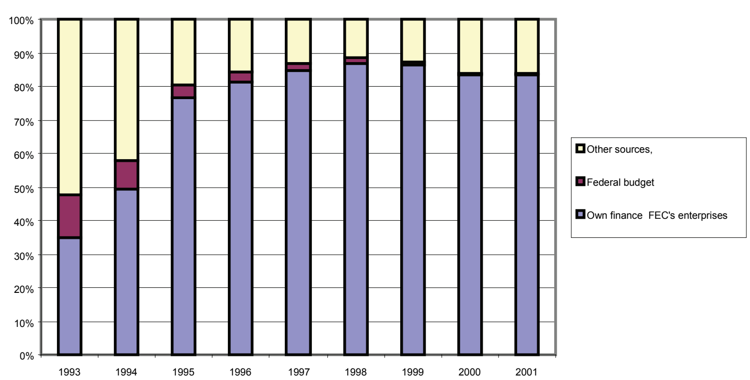

Figure 7.8 The main sources of investment in Russia's energy

TABLE 7.21 INVESTMENT FORECAST IN RUSSIA'S ENERGY SECTOR.

Investment (billion dollars)		2001-2010	2011-2020	2021-2030	2001-2030
	Total Country Investment	269	391	389	1,050
Oil	Total	97	111	120	328
	Exploration and development	90	104	114	308
	Non-conventional oil	-	-	-	-
	Refining	7	7	6	20
Gas	Total	103	117	111	332
	Exploration and development	52	65	70	187
	LNG liquefaction	2	1	0	4
	LNG degasification	-	-	-	-
	Transmission	33	34	24	92
	Distribution	7	11	14	32
	Underground storage	8	7	2	17
Coal	Total	6	4	6	13
	Total mining	5	4	4	13
	new mining capacity	3	1	2	7
	sustaining mining capacity	2	2	2	6
	Ports	0.2	0.0	0.0	0.3
Electricity	Total	64	159	153	377
	Generating capacity	15	69	72	157
	of which renewables	7	15	8	30
	Refurbishment	5	9	7	21
	Transmission	10	20	15	45
	Distribution	34	61	59	154

Source: IEA (2003a)

TABLE 7.22 ENERGY STRATEGY EVALUATIONS OF INVESTMENT IN ENERGY SECTOR [1, 2]

FEC's branch	Needed investment in 2001-2020, billion USD
Total	660-770
Gas industry	170-200
Oil industry	230-240
Electricity industry	120-170
Coal industry	20
Heat supply sector	70
Energy conservation	50-70

Source: MIE (2003a)
1 Investment in reconstruction and development
2 Including own financial means of fuel and power supplying companies and enterprises, budget and out-of budget investment, foreign investment and other sources.

The largest potential investment projects include: construction of nuclear power plants in European parts of the country; oil and gas pipeline construction; the installation of new electricity transmission lines; and oil field exploration and exploitation in East Siberia, and in the Far East. Large-scale investment will be needed for modernizing existing production and generation capacities, as well as development of infrastructure.

Options available to accumulate needed investment capital into the FEC include improving the investment legislation which would allow the creation of favourable conditions for domestic and foreign investors, and optimizing an energy pricing and fiscal policy, which would enable fuel and power supply companies to accumulate their own investment capital. Another important measure would be to improve the functioning efficiency of FEC enterprises.

Investment activity in other sectors of the domestic economy is going to be high in coming decades. Thus the share of the FEC in total investment in the domestic economy, currently at 33-35% in the 2001-2005 period, will decline to 31-33% in 2006 – 2010, and to 20-24% by 2020.

The Strategy assumes that investment growth in the FEC will contribute to enhancing investment activity in the other economic sectors, in particular within manufacturing industry.

7.2.3.4. End-use energy prices, taxation, and subsidies

Financial and investment problems of the FEC are closely linked with end-use energy prices and taxation policy, as well as energy subsidy levels. A problem of paramount importance for the Russian Federation is determining how to optimize the energy pricing and taxation mechanisms, taking into account the interests of all affected participants (including state, regional and local budgets, FEC enterprises and final consumers), and developing a reasonable approach to eliminating energy subsidies. The approach must aim at introducing the proper end-use energy prices, while simultaneously protecting the poorest part of the population.

In the early 1990s the government artificially kept down end-use energy prices, which increased much more slowly than the prices of industrial products. However, in recent years they have been constantly and rapidly growing (Table 7.23). Coal and petroleum product prices are already free from state control; however, end-use electricity, heat and natural gas prices are still state-controlled.

Statistical data on end-use energy prices and subsidies are very limited and fragmentary.

End-use prices as well as payments for energy bills vary among the different regions of the country. In some northern regions of the Russian Federation, end-use energy prices (especially for heat and electricity) are much higher than in the European part of the country. There are also considerable differences because of climate distinctions; the duration of the heating season in the Komi Republic, for example, is about 300 days annually.

In this connection, the financial burden to pay for energy resources and to maintain the energy supply systems becomes onerous for consumers (in particular, for regional budgets). Some regions spend up to 40% of their budgets on energy, mostly for electricity and heat supply systems.

As far as the general population is concerned, the fraction of disposable income spent on fuel and electricity has increased significantly in recent years, and is still growing.

Energy prices for the general population are still subsidized. Unfortunately, official statistics on energy subsidies and end-use energy prices are not available. An attempt to research this problem was undertaken by IEA in a study on energy subsidies, published in 1999 (IEA, 1999). It conducted a detailed analysis of energy prices and subsidies in the Russian Federation (and some other countries), and made certain conclusions concerning the current rate of energy subsidy in the country, the potential energy and financial savings due to energy subsidy removals, and also on the level of right (reference) prices (i.e., without subsidy) for electricity and natural gas for industry and households in 1997 (Table 7.24).

According to their results, the subsidy share of electricity and natural gas in the Russian Federation in 1997 was more than 40%. The estimated average level of the right price of natural gas for households should be about 10 times higher than the current price.

IEA estimated that actual electricity prices for households in 1997 were about 2.5 times lower than the right price. Unfortunately, recommendations addressing how to protect the poorest part of population from end-use energy prices growth were not provided.

TABLE 7.23 END-USE ENERGY PRICE INCREASES FOR INDUSTRIAL ENTERPRISES (PERCENTAGE OF PREVIOUS YEAR).

Energy carriers	1994	1995	1996	1997	1998	1999	2000
Electricity	251	322	139	103.8	100.8	121	142.9
Heat	412	383	133	100	98.6	115.1	136.6
Natural Gas	349.7	366.7	107	102.1	102.2	131.4	126.1

Source: MIE (2003b)

TABLE 7.24 NATURAL GAS AND ELECTRICITY SUBSIDIES AND END-USE PRICES IN 1997

	Natural gas	Electricity
Estimated rate of subsidy (% of reference price)	46.1	42.0
Potential primary energy saving from subsidy removal, %	36.6	24.3
Estimated annual economic-efficiency cost, due to subsidy removal (mln USD)	5,298	1,501
Estimated budget cost, (mln USD)	21,055	10,854
Natural gas end-use price (USD per 1,000m^3):		
Households	21.4/246.6[1]	
Industry	57.9/125.6	
Power generation	61.1/95.3	
Electricity end-use price (USD per kWh):		
Households		0.028/0.067
Industry		0.041/0.06

Source: OECD/IEA (1999)
1 Numerator: current price (with subsidy)
Denominator: reference price (without subsidy)

The problem of energy subsidy elimination has been actively discussed by domestic and foreign experts. Energy subsidies hamper the accumulation of investment potential of the FEC and, therefore, decrease reliability of the energy supply system. Cross-subsidization is a serious barrier for accelerating industrial and economic development in the country.

On the other hand, it makes energy services more affordable for the poorest (very essential) part of the population. In other words, the question concerning the future of energy subsidies is: "to be or not to be." The most popular opinion is that energy subsidies should be saved, but only for the poorest part of the population. Other categories of consumers should pay 100% for energy services.

One more problem in the field of end-use energy prices is the difference between internal and export prices. For example, the difference between the average price for imported (from Russia) gas in Germany and the price for natural gas for industrial consumers in 2001 was more than a factor of nine (Table 7.25). This difference makes foreign markets much more attractive for domestic fuel and energy supplying companies than internal ones.

Regional energy commissions (i.e., RECs, special governmental bodies) are responsible for electricity, heat and natural gas prices regulation. Each Russian region (totalling 89) has its own REC. Table 7.26 provides statistical data on electricity and gas tariffs for the population in the Moscow region introduced since the beginning of 2004 by the local REC.

On average, electricity tariffs for the population in Russia are 3.5-4 times less than in OECD countries (*Energy Prices and Taxes*, OECD/ IEA, 2003). Multi-tariff electricity meters allow residential consumers to pay four times less for 1 kWh of electricity in the period from 23.00-7.00 than during other parts of the day. These meters are mostly available in the new residential buildings, which have been put into operation during the last 5-10 years.

The unit of measure "ruble per person" is used in the system of residential payments for natural gas consumption. This is a fixed price for natural gas within the residential sector, regardless of consumption.

Residential consumers pay for electricity and natural gas in accordance with the set of equipment installed in the dwelling. Thus, electricity tariffs for households with gas and electricity stoves are different. A similar situation exists in the system of gas payment.

The tax policies of the state have played (and will continue to play in the future) an important role in stabilizing the financial position of FEC enterprises. The Ministry of Industry and Energy and the joint stock companies of the FEC have made considerable efforts for rationalizing the tax burden, and developing an appropriate approach to taxation on the various sectors. The government's position on this is clear: taxes have to be collected not where it is easy to collect, but rather where value is added.

For Russia, as for any other country, optimization of end-use energy prices and taxation, as well as a successful solution of the problem of removing energy subsidies, means:

- regular and stable payments in the budgets of different levels from the FEC's enterprises;
- reimbursement of expenditures and reasonable income of FEC's enterprises which will allow them to improve sustainability of development;
- affordable energy carriers for the consumers;

It also means:

- stimulation of energy conservation activity of consumers; and
- mitigating negative influence of the FEC on the environment.

TABLE 7.25 NATURAL GAS PRICES IN RUSSIA IN 1991-2001

	Export prices[1] $/1,000 m^3	End-use prices		
		Industry		Population
		Ruble/1,000 m^3	$/1,000 m^3	ruble/month [2]
1992	89.7	1,100	2.7	3.4
1993	88.3	21,875	17.6	29
1994	83.0	73,773	21.6	65
1995	95.0	257,151	55.7	951
1996	93.5	289,176	52.2	1,184
1997	99.5	327,000	54.9	2,449
1998	82.2	338[3]	16.4	3.18
1999	62.1	371	13.7	3.74
2000	116	390	13.7	4.3
2001	136	460	14.5	5.38

Source: IEA (2002)
1 Average prices for imported gas in Germany
2 Per person
3 After devaluation of Russian currency in August 1998

TABLE 7.26 END-USE ELECTRICITY AND NATURAL GAS PRICES FOR HOUSEHOLDS (BY 01.01.2004) IN MOSCOW REGION

End-use electricity prices			End-use natural gas prices		
Households with gas stoves	per kWh	1.22[1]/4.3 [2]	Households with gas stoves and centralized hot water supply system	per person	9.9[1]/34.7[2]
Households with electric stoves		0.86/3.0			
Households with gas stoves equipped with multi-tariff electricity meters (23.00-7.00)	per kWh	0.3/1.05	Households with gas stoves and gas water heater (without centralized hot water supply system)	per person	24.2/84.9
Households with electric stoves equipped with multi-tariff electricity meters (23.00-7.00)	per kWh	0.22/0.8	Households with gas stoves only (gas water heater and centralized hot water supply system are not available)	per person	13.3/46.6
Households in rural areas	per kWh	0.86/3.0	Households heated by gas heaters	per m^2 of heated space	4.4/15.0
			Households equipped with gas meters	per m^3	1.18/4.1

Source: Regional Energy Commission of Moscow (RECM) region (2000-2003)
1 Russian rubles
2 US cents using current exchange rates (1 USD=28.5 rubles)

7.3. Review of the energy statistical data capability

During project implementation, the research team was faced with the problem of statistical data collection. There are several main aspects of this problem:

- Availability;
- Accessibility; and
- Quality of statistics.

Statistical data related to some ISED indicators could not be obtained from official sources of information. The main difficulties in the construction of these indicators are associated with necessity to collect information from 89 regions (indicators 20 and 21) and various branches of the FEC (indicators 33 and 34). There are some evaluations made by independent experts or governmental officials, but it was not possible to use these evaluations in order to construct indicators in any event (especially for time series). The list of such indicators is given in the Table 7.27.

Nevertheless it was possible to obtain some information on the structure of consumption in PPP terms for 1998, related to indicator 21.

One other part of the needed statistical database on ISED can be considered inaccessible (at the moment) (Table 7.28). There is confidence that this information exists, but there is no access to a relevant database. Moreover, statistics for certain indicators are only partially available.

The main problem in collecting these statistics is that needed data are concentrated in various governmental structures, including:

- State Committee for Statistics;
- Ministry of Industry and Energy;
- Ministry of Science and Education;
- Ministry of Nuclear Energy;
- State Committee on Hydrometeorology, etc.

This makes the process of collecting information a very time consuming and complex task.

Another problem is the regional breakdown of the country. For example, end-use energy prices in Moscow and the Komi Republic (one of the northern regions of the country) are completely different. It thus becomes a significant problem to summarize the fragmentary information from 89 regions of the country, as well as to obtain the information itself. There are also several kinds of energy subsidies. For example, in Moscow disabled people and some other categories of the population are only required to pay 50% of their energy bills. Transforming such information into statistical data is extremely difficult.

It is also very difficult to obtain needed information about the energy intensity of the main economic sectors. Data on energy consumption is available. The problem is to find reliable statistics on GDP produced in these sectors, or the physical volumes of production. There is also no access to data for some environmental indicators.

The problem of ensuring necessary data quality (first of all, comparability) for the statistical data which is obtained is very real, particularly for recent data. This is a concern in certain macroeconomic indicators as well as information on energy production and supply in 2002-2003. For example, information on GDP growth in 2002 and even 2003 (preliminary) data are available in some publications, including official ones (note that the data are presented in terms of a percentage of the previous year). But there is no confidence that the data on GDP for 2001 given in the Table 7.1 and in the above publications are the same.

That is why the time series of macroeconomic and energy indicators are limited through 2001.

The main information sources for this project were the database of the IEA and Russia's Energy Strategy. Some parts of needed statistical data have been obtained through periodical issues and surveys available in the scientific and technical literature. An essential part of the statistics was obtained through personal contacts in the Ministry of Industry and Energy and the Ministry of Science and Education.

Given the relatively short history of the Russian Federation as an independent state, a short time series for ISED has been employed in the project (1992-2001), but it is nonetheless enough to evaluate the main trends and developments in the economy and the FEC of the country.

There is no doubt that active steps aimed at incorporating the ISED package into national databases should be undertaken. Moreover, it would be useful if comparable statistics within the ISED package were collected with the intellectual and statistical resources of the State Committee for Statistics, and that ISED were employed for constant monitoring of Russia's energy policy implementation.

TABLE 7.27 STATISTICAL ISED INFORMATION NOT AVAILABLE

N[31]	Indicator
20	Ratio of daily disposable income/private consumption per capita of 20% poorest population to the prices of electricity and major household fuels
21	Fraction of disposable income/private consumption spent on fuel and electricity by average population; group of 20% poorest population (partly)
33	Land area taken up by energy facilities and infrastructure
34	Fatalities due to accidents with breakdown by fuel chains

Source: IAEA/IEA (2003)
31-number in the list of ISED

TABLE 7.28 STATISTICAL ISED INFORMATION NOT ACCESSIBLE

N[32]	Indicator
3	End-use energy prices with and without tax/subsidy (partly)
8	Manufacturing value added by selected energy intensive industries
9	Energy intensity (partly)
15	Expenditure on energy use (partly)
24	Ambient concentration of pollutant in urban areas(partly)
25	Land area where acidification exceed critical load
27	Radionuclides in atmospheric radioactive discharges
28	Discharges into water basin (partly)
29	Generation of solid waste (partly)
30	Accumulated quantity of solid waste
31	Generation of radioactive waste
32	Accumulated quantity of radioactive waste

Source: IAEA/IEA (2003)
32 – number in the list of ISED

7.4. Identification of Major Energy Priority Areas

The FEC in Russia is one of the most important sectors of the economy, which determines the main parameters of its functioning. It is responsible for ensuring national security and strengthening the position of the Russian Federation in the international arena. Energy policy includes a broad range of measures designed to solve institutional, legislative, socioeconomic, scientific and technical as well as environmental problems of domestic energy development. Each of these areas is very important as a component of energy policy as a whole.

Nevertheless there are five aspects of national energy policy that can be considered as top priorities:

- Ensuring national energy security;
- Securing stable, uninterrupted and affordable energy supplies for the economy and households;
- Increasing the energy efficiency of the economy;
- Developing and improving the energy resource base;
- Decreasing the negative environmental impacts of the energy system.

These key priorities of energy policy are stated in the Energy Strategy of the Russian Federation. The main quantitative targets and benchmarks for each priority are already determined, clearly declared and widely presented.

7.4.1. Ensuring national energy security

The most important and dominating priority of energy policy is to ensure national energy security. National energy security is a state of society and a national energy system that would preserve the country's national security under external and internal threats and destabilizing factors caused by economic, socio-political or manmade origins. It would accomplish this by eliminating and compensating for the negative impacts of the above threats and factors by:

- Ensuring the reliable functioning of the energy system and securing guaranteed energy supplies to consumers;
- Creating necessary conditions for the development of the economic and social basis of society;
- Maintaining economically justified energy exports;

- Maintaining the technological and environmental safety of energy facilities;
- Assisting in strengthening the links that promote internal and external integration.

The paramount importance of energy for the system of economic and national security of the country makes ensuring national energy security the highest in the list of energy policy priorities.

Among the most serious economic threats to energy security, the following items deserve attention:

- A shortage of investment, limiting the possibility of compensating for the loss of productive capacity in the FEC, and modernizing and refurbishing the basic plant and equipment (most of which is worn out);
- The high level of energy intensity of the economy and, consequently, enormous non-productive losses of fuel and energy, which lead to additional expenditures for energy suppliers and consumers, as well as environmental hazards, measured in millions of dollars;
- A sharp decline in the amount of geological prospecting, and the associated deterioration of the raw-material base (in particular in the oil and gas sector).

Given that the bulk of the plant and equipment in the FEC is in a very poor state of repair, there is a high probability of major accidents or breakdowns at energy supply facilities, and with that an increased danger to industry and the environment.

The most important external destabilizing factors may be considered to include:

- Discriminatory actions by foreign countries (or their associations) in relation to the Russian Federation and its subjects in international energy markets;
- The dependence of some border areas of the Russian Federation on energy supplies from foreign States;
- Limitations on the transport of energy resources exported by the Russian Federation, the blockade of oil and gas pipelines in the territories of transit States, non-observance of the Convention on freedom of navigation through straits, etc.

Internal factors include possible socio-economic threats (associated primarily with conflicts on the grounds of nationality or religion), the manifestation of separatism in individual regions of the country, and strikes and labour disputes at companies of the FEC and related infrastructure. Industrial, social and political disputes may present a particularly serious threat, since, like natural or individual emergencies occurring in fuel-producing regions, they may close off the energy flows that are of vital importance in supplying both domestic and external consumers. Any serious worsening of the social situation may also exacerbate personnel problems, with a negative impact on the incidence of accidents and breakdowns in various energy branches. A rise in social tension may also be provoked by shortages of energy resources and the interruption of energy supplies to individual regions of the Russian Federation (e.g., the Far East, remote and northern regions).

The country's energy security is multi-sectoral in nature, and the internal and external links between the FEC and other branches of the economy must be taken into account.

When speaking about energy security as a priority of energy policy of the Russian Federation, its primacy can be considered as a priority of the macro-level, while the four other priorities can be considered as merely components.

7.4.2. Securing stable, uninterrupted and affordable energy supplies for the economy and households

Despite a large energy resource base and its status as a large energy net-exporter, the Russian Federation in recent years has been faced with the problem of ensuring internal energy requirements. The principal problem is that energy resources are unevenly spread throughout the country. Because of this, several regions are heavily dependent on energy imports from other regions. For the most part, regions produce less energy than they need, so they have to import it from the few energy-rich regions such as Western Siberia. Some of the fossil-fuel-deficient regions face frequent disruptions in fuel

supplies, due to rugged weather and transportation conditions and to the suppliers' preferences for export markets. Given the long distances between regions, transportation costs can dramatically increase the total cost of fuel. Some remote territories such as Kamchatka, Republic Tyva and Republic Altai spend more than half of their budget on fuel.

In this regard, an important aspect of realizing this priority is the need to have an effective system of administration and regulation for state-owned and private enterprises responsible for energy supplies for the regions. Weak administration and control was the reason for the energy crisis in the Kamchatka region in previous years.

Another problem is to keep energy systems in good technical repair. Technical accidents in heat supply systems during the winter season became a frequent phenomenon in Russia in recent years. The solution for the problem depends on administrative action and constant control, as well as investment in the modernization of equipment and pipelines, and associated new construction.

About ten million people in remote areas are not connected to the electricity grid and are currently served by stand-alone generation systems using either diesel fuel or gasoline. Nearly half of these diesel and gasoline systems are reported to be no longer operating because of fuel delivery problems and/or high fuel costs. Remote Northern and far Eastern areas get their fuel by rail or road, and even sometimes by helicopter. These suppliers are unreliable and expensive.

In principle, off-grid energy supply systems have proven to be very cost effective in many OECD and developing countries because electricity suppliers can avoid the cost of extending transmission and distribution systems. Because of the sheer size of the Russian Federation, wind or hybrid wind-diesel systems, biomass-fired steam boilers with turbine-generators and small-hydro power stations could be cost-competitive with traditional fossil fuel technologies in remote areas, and their use can and should contribute to improving the energy self-sufficiency of these regions.

The above analysis suggests that solutions for the problem of securing stable, uninterrupted and affordable energy supplies to all economic sectors and households will require serious administrative, technological and financial efforts.

7.4.3. Increasing the energy efficiency of the economy

According to the Strategy, the level of energy intensity of the country's GDP is 23 times higher than the world's average and 31 times higher than in the European Union. In the past 20 years in industrially developed countries, the annual growth rate of TPES was 0.4% per 1% growth of GDP. As a result, the level of GDP energy intensity in these countries has declined by 21-27%.

Table 7.1 shows that the situation in the Russian Federation was completely different, with constant or increasing energy intensity in many years of the analysis. However, in recent years (due to economic recovery, and in particular industrial output growth and an increase of the share of services in GDP value added), the level of energy intensity of GDP has declined by 2-3% annually.

Across the country, the economically viable potential for energy conservation currently stands at nearly 250-300 Mtoe, or 39%-47% of the overall primary energy use. Approximately one third of this potential is accumulated in the FEC, 35-37% in industry, and 25-27% in the residential sector.

About 20% of available energy conservation potential can be realized due to low-cost measures (i.e., less than 14 USD per toe). Fifteen percent of the evaluated potential can be realized for 35 USD and more per toe. The remaining two-thirds of considered potential require 14-35 USD per toe.

The Strategy assumes that economic restructuring and technological and organizational energy efficiency measures will decrease the level of GDP energy intensity by 26-27% by 2010 and by 45-55% by 2020 in comparison with 2000 (Figure 7.9).

About 50% of the forecasted economic growth is to occur due to restructuring, without increasing the energy demand.

The growth of energy use per unit of GDP (Table 7.1) was primarily caused by the growth of energy intensity in manufacturing industry, while in the services sector this indicator tended towards

reduction. Unfortunately, a sectoral breakdown of energy intensities measured in monetary or physical units is not available.

The increase in energy intensity in manufacturing industry was caused by:

- increasing levels of industrialization, accompanied by a decrease in low energy intensive industries and a growth in high energy intensive and resource-driven industries focusing on exports;

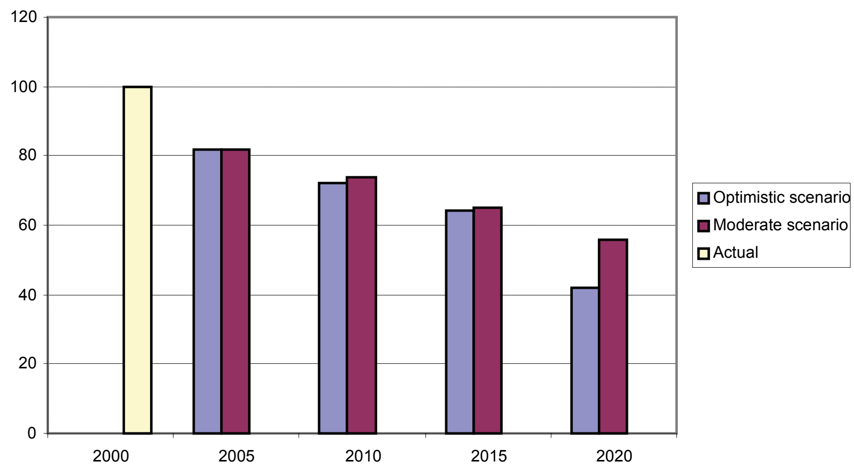

Figure 7.9 Energy use per unit of GDP in Russia in 2000-2020 (2000 = 100%)

- a two or threefold decrease in industrial capacity levels, which sharply increased the total energy intensity of the so-called "fixed energy" cost components, such as heating, lighting, etc.;
- a significant (up to 25%) "unaccounted-for" element of industrial production, mainly in the manufacturing sector, hidden from taxation and hence not reported by official statistics; and
- the use of outdated technologies.

Nevertheless, in some branches of the manufacturing industry there is progress towards decreasing energy intensity. One positive example is the iron and steel industry. For the period 1995-1999 alone, the level of specific energy consumption in this branch declined by 20%. However, the gap between specific energy consumption in steel production and leading foreign countries still remains (Table 7.29).

The reasons for the specific energy consumption decline in steel production can be explained by the following main factors:

- Many economically (and energy) inefficient steel-producing enterprises have been closed;
- Like oil or gas, steel is a very important export product. Its export allows steel-producing enterprises (almost all of them are already privatized) to accumulate the needed investment for modernization and energy efficiency improvements.

Some information on the final energy intensity of selected energy intensive products is provided in Table 7.30. Unfortunately, the statistical data available are not comprehensive and do not allow for definitive conclusions about the dynamics and regularities of final energy intensities over time.

Decreasing non-productive energy losses during transportation and distribution (which are higher than in developed countries) can and must contribute to increasing the energy efficiency of the economy. The implementation of energy saving measures would enable the country to prolong the lifetime of the

most efficient component of its energy resource base (i.e., proven recoverable reserves), to extend the energy export potential, and to mitigate negative environmental impacts.

Among the principal obstacles for increasing energy efficiency, the following topics deserve particular attention:

- Disadvantages of institutional structures;
- Weakness of legislative base;
- Lack of investment;
- Ineffective pricing and taxation policy (including existing energy subsidies);
- Deterioration of scientific and research base;
- Limited and inefficient information support.

TABLE 7.29 SPECIFIC ENERGY CONSUMPTION IN STEEL PRODUCTION IN THE RUSSIAN FEDERATION AND IN THE UNITED STATES.

	1995	1996	1997	1998	1999
RUSSIAN FEDERATION					
Primary energy consumption, Mtoe	38.6	35.3	31.6	29.8	30.8
Steel production, Mt	51.6	49.3	48.5	43.8	51.5
Specific energy consumption, toe/t	0.75	0.72	0.65	0.68	0.6
UNITED STATES OF AMERICA					
Primary energy consumption, Mtoe	25.0	24.9	26.7	27.0	2.61
Steel production, Mt	95.5	95.5	98.5	97.7	97.4
Specific energy consumption, toe/t	0.26	0.26	0.27	0.28	0.27

Source: IEA (2002)

TABLE 7.30 SPECIFIC FUEL AND ENERGY CONSUMPTION RUSSIA'S INDUSTRIAL BRANCHES, KGOE/T

Branch; Product / Energy use	1992	1993	1994	1995	1996	1997	1998	1999	2000
Iron and steel									
Pig iron									
fossil fuels	408.1	413.7	414.5	417.0	411.3	408.3	405.5	403.6	404.2
heat	5.69	5.78	5.82	5.76	6.09	5.56	5.88	5.77	5.78
Chemical and Petrochemical									
Synthetic Rubber									
fossil fuels	874.1	863.6	804.8	754.0	734.4	712.3	738.0	636.4	668.5
electricity	753.0	778.1	803.7	666.4	724.3	737.5	769.4	694.2	672.4
heat	2,709.2	2,909.8	2,693.9	2,398.2	2,400.1	2,441.2	2,433.0	2,217.0	2,166.9
Pulp and paper									
Pulp									
electricity	153.5	158.0	187.3	169.1	172.0	163.8	169.1	164.9	154.3
heat	503.0	519.7	558.7	515.31	513.1	464.2	481.0	453.2	429.9
Paper									
electricity	158.8	160.0	204.4	183.29	232.7	231.3	220.4	278.3	259.0
heat	219.7	217.9	274.9	226.3	282.9	258.63	245.4	230.1	212.32
Construction materials									
Cement (clinker)									
fossil fuels	144.1	148.4	149.5	150.2	154.0	159.7	154.8	149.2	150.8
electricity	27.2	27.4	29.9	29.9	31.0	30.2	32.4	31.1	31.4

Source: MIE (2003b)

7.4.4. Developing and improving the energy resource base

The economic potential of the Russian Federation depends heavily on the volume, structure and geography of its energy resource base. Energy resource availability, accessibility and the cost of extraction and delivery are the key factors that will define the future development and performance of FEC, which plays an important role in energy and hard currency supplies for the domestic economy.

To date, the extent of exploration in the European regions of the Russian Federation and West Siberia is as high as 70% for oil and 45% for gas, while East Siberia and the Far East have been explored only 6-8% onshore and 2% offshore. Importantly, the remote regions of the latter (including North Tyumen and Arkhangelsk provinces) have about 46% prospective energy resources of the country.

Eighty percent of total proven recoverable reserves of coal are concentrated in Siberia, and only 10% in the European part of the Russian Federation, the largest coal-consuming region.

According to the Strategy, about 1 Mt of predicted uranium resources are located in the Russian Federation's territory. Today, 55 uranium fields are registered in the country. The total uranium production from these fields in 2020 will account for 6,500 to 7,000 tonnes, in comparison with an expected national uranium demand of 10,000 to 12,000 tonnes. The difference will be covered by uranium stocks and nuclear fuel recovery, as well as by nuclear fuel production from fast breeder reactors (by the end of forecasting period).

An essential growth of proven recoverable reserves of hydrocarbons should be achieved by 2020; for oil by 7.5-10 Bt, for natural gas by 11,200-18,800 Bcm.

In order to realize such a programme of energy resource base expansion, serious efforts in institutional, legislative and investment, as well as improvements in scientific and technical policy in the field of exploration and exploitation of energy resources, should be made.

7.4.5. Decreasing the negative environmental impacts of the energy system

In 1999, the Head of the State Committee for Environmental Protection of the Russian Federation reported that 250,000 people die prematurely in Russia every year from health problems caused by the environmental situation.

Environmental policy is directed towards the reduction of the burden of the FEC on the environment, as that sector accounts for a high share of hazardous atmospheric emissions and effluents, and over 30% of solid wastes. It is also responsible for the bulk volume of radioactive wastes.

That is why reducing the negative environmental impact of energy is one of the key priorities of Russia's energy policy. The FEC must accomplish a reduction in the emission of pollutants, the dumping of wastes, and other risks to the environment and human health to levels that would not have negative environmental implication.

Because of economic and industrial output declines, the principal indicators characterizing the environmental situation have decreased in the last 10 to 12 years.

Unfortunately, a well-developed and strictly oriented environmental protection policy at federal and regional levels cannot be considered the reason for the above decline.

In accordance with the Kyoto Protocol, the Russian Federation will have to keep its GHG emissions during 2008-2012 at the level of 1990. The Strategy forecasts that GHG emission in 2010 will account for only 75-80% of 1990 levels, however. Even in 2020, taking into account the forecasted energy demand growth, the level of GHG emission will still not exceed the level of 1990.

A significant reduction of environmental pollution can be accomplished through optimization of the fuel and energy balance, by means of: maximum energy conservation, wide use of the most environmentally compliant fuels like natural gas, nuclear power and renewables; and rational content and allocation of industrial facilities, with provisions for regional environmental resources.

Achieving environmental targets will require enhancing activity in R&D in the field of environmentally sound technologies; constant monitoring of the environmental situation; improving the legislative base for environmental protection; developing financial incentives to accomplish environmental goals; and stimulating energy consumers to minimize the negative environmental consequences of their activities.

7.4.6. Review of data availability to perform the analysis using the ISED scheme

The above analysis identified which statistical data for ISED were available or not available. The majority of indicators from the ISED listing can be constructed and described by means of obtained statistical data.

Each of the selected energy policy priorities can be represented through the ISED framework.

7.5. Implementation of ISED Framework

Progress achieved in implementing key energy policy priorities can be monitored and measured through the ISED indicators.

Agenda 21, the Rio Declaration on Environment and Development, adopted by the United Nations Conference on Environment and Development (i.e., UNCED, commonly called the Earth Summit) in Rio de Janeiro, Brazil in 1992, is dedicated to implementing sustainable development. This is seen as a focus for addressing today's pressing problems, and preparing the world for the challenges of the next century. Agenda 21 covers all issues that have significant bearing on one or more of the three key dimensions of sustainability (i.e., social, economic, and environmental), as well as the institutional dimension necessary for implementation. One of the most significant issues is energy.

Energy is an essential factor of social and economic development. As noted earlier, energy development is an important factor of environmental degradation at the global, national and local levels.

Chapter 9 of the Agenda states:

"Energy is essential to economic and social development and improved quality of life. Much of the world's energy, however, is currently produced and consumed in ways that could not be sustained if technology were to remain constant and if overall quantities were to increase substantially. The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption, and on growing reliance on environmentally sound energy systems, particularly new and renewable sources of energy. All energy sources will need to be used in ways that respect the atmosphere, human health, and the environment as a whole."

7.5.1. The FEC and the dimensions of sustainability

The above dimensions of sustainability include the following 16 topics:

Social dimension:

- Energy disparities;
- Energy affordability and accessibility

Economic dimension:

- Economic activity levels
- Energy production, supply and consumption
- Energy pricing, taxation and subsidies

- End-use energy intensities
- Energy supply efficiency
- Energy security

Environmental dimension:

- Global climate change
- Air pollution
- Water pollution
- Wastes
- Energy resource depletion
- Land use
- Accident risks
- Deforestation

The institutional dimension must address all of the above issues taken individually, as well as collectively.

A brief analysis of the FEC in the context of sustainable development is provided below.

7.5.1.1. Social dimension

Energy disparities

According to available statistics, the richest 20% of the world's population uses 55% of primary energy, while the poorest 20% uses only 5%. As far as the Russian Federation is concerned, statistical data on such disparities are not available.

Energy disparities are, in any event, a consequence of economic disparities—different living standards for the richest and poorest parts of the population. Large flats (or individual cottages), numerous electrical appliances, air conditioning in summer, and comfortably warm temperatures inside the dwelling in winter are now inevitable features of life for the richest part of the population (i.e., the so-called "new" Russians).

A small flat (often just one room per household), limited quantities of electrical appliances, and a sole electric bulb in the ceiling are the main attributes of living standards for the poorest part of the population.

According to experts' evaluations, the gap in personal income between the richest 20% and the poorest 20% of population in 2000 was as high as a factor of 10.3.

Indeed, as elsewhere, the poorest part of the population in Russia consumes much less energy than the richest one. However, one cannot say that there is a shortage of energy for the poorest people because of excessive energy consumption by the richest part of country's population. It depends on both the quantity and quality of energy services that are affordable.

Energy affordability

Under the conditions of market reforms, the question of energy affordability for various categories of consumers is becoming more and more relevant.

A brief analysis of current levels of end-use energy prices has been provided above. The principal forecast is that end-use energy prices will continue to grow for all categories of domestic consumers, and accordingly, one major concern is: how affordable are these prices for industry, the transportation sector, the service sector, and households?

In the case of end-use energy price growth, industrial enterprises and enterprises and companies in the transportation and services sectors will normally just include this growth in the cost (and thus

consumer's price) of industrial products, tickets for transportation means, or various services. In turn, this contributes to increased inflation rates.

As far as population is concerned, the financial burden associated with energy use (i.e., payments for energy bills) is consuming a higher and higher fraction of disposable income of domestic households.

Table 7.31 demonstrates a structure of consumption in PPP terms (including the share of expenditures of households on fuel and power) in the Russian Federation and several OECD countries. It can be seen that the Russian Federation has the highest share of fuel and power expenditures within the structure of household consumption. This is linked to the current low level of income in households, because end-use energy prices for the population in the country are actually lower than in OECD countries.

It is also very important to mention once again that the ordinary population not only pays for end-use energy prices growth directly in energy bills, but also for the general price growth in the country associated with rising end-use prices.

The Strategy provides some forecasts of energy affordability for the population.

It is emphasized in the Strategy that one of the main tasks of the state's energy policy is to ensure affordable energy supplies for the general population as well as socially and strategically important entities (i.e., within the budgetary sphere and the military-industrial complex). It also notes that the fraction of disposable income spent on fuel and electricity by the poorest part of the population is relatively high. However, the level of social support for this part of the population is not sufficient.

TABLE 7.31 STRUCTURE OF HOUSEHOLDS' CONSUMPTION IN 1998, % (BASED ON PPP VALUES)

Household Consumption	Russia	USA	Japan	UK	Germany
Food	28	13	12	14	14
Clothing and footwear	11	9	7	7	6
Fuel and power	16	9	7	9	7
Health care	7	4	2	3	2
Education	15	6	22	3	10
Transport and communications	8	8	13	6	7
Other consumption	16	51	37	58	53

Source: World Bank (2000)

In such a case, the problem is to minimize the negative economic effects of end-use energy price growth. As shown in Table 7.4, total expenditures (or payments) on energy use per capita in 2020 will be 233-235% of those in 2000. At the same time, the Strategy assumes that the real income of the population in 2020 will be 300-440% of the level in 2000. Thus, according to the Strategy, the more rapid growth of disposable income will compensate for the end-use energy price growth.

One additional problem of paramount importance is to ensure an effective social protection system for the poorest part of the population. This system should be transparent and operate in the least bureaucratic manner possible. Existing systems of social protection (e.g., energy subsidies, as well as those for other services such as waste management, maintenance and telephone) are very time consuming, complex, and bureaucratic.

Energy accessibility

According to official statistics, the FEC meets the entire energy requirements of the domestic economy and population.

The fraction of households heavily dependent on non-commercial energy is about 1-2%, and probably comparable with the share of CRW in the final energy mix in the residential sector (i.e., 1.3% in 2001). Officially, the fraction of households without electricity is 0%.

Nevertheless there are some problems in ensuring 100% access for the population to energy carriers.

Although the Russian Federation is a large net energy exporter, certain energy-limited regions depend on energy imports to a level of 70-80%, or more. At the same time, local energy resources including renewables are only weakly used. If this situation continues in the future, it is going to be a very serious social and political problem for the Russian Federation.

Interruptions in energy supplies, both in energy-limited and other regions of the country, are often caused by non-payments by energy consumers because of a reduction of their paying capacity, and problems in the financial interrelations between fuel and energy companies.

Another element influencing energy accessibility is the technical state of energy supply systems. Technical accidents in heat supply systems, for example, have been a frequent phenomenon in Russia in recent years. The solution to this problem depends upon administration activity and constant organization and technical control, as well as investment in the modernization of equipment and infrastructure.

One can thus say that the problem of energy accessibility is not a problem of energy resources or relevant infrastructure availability. It is not even connected with geographical distinctions of the country. Energy accessibility is an organizational, institutional and financial problem.

Regional leaders, federal officials, and the heads and owners of the fuel and energy supplying companies must ultimately take responsibility for ensuring reliable energy supplies for all categories of energy consumers throughout the Russian Federation.

7.5.1.2. Economic dimension

The level of energy development as well as its sustainability in any country is closely linked with the economic state of its energy system, and the situation in the national economy as a whole.

In Russia the state of the FEC reflects the main trends of economic development in the country.

The collapse of the centrally planned system, economic crisis, and the transition to a market-driven economy have negatively affected the economic state and functioning of the FEC.

The level of the country's GDP as well as the GDP per capita have tended to decrease, associated with the general decline in economic activity levels (in particular in industrial output, passenger and freight transport activities). Correspondingly, there was a decline in energy demand from economic sectors, and an essential reduction of internal energy production. At the same time, the decrease in internal energy consumption contributed to increasing the net energy export share in TPES (Figure 7.2).

In the past 2-3 years, economic growth has resumed, as well as growth in energy production and consumption (Table 7.1).

One of the most serious problems the FEC faced in recent years is a lack of investment. This concerns virtually all sectors of domestic energy, including production, transmission, distribution, consumption, R&D, environmental protection, etc. As shown in Table 7.32 the total amount of private investment in the energy sector is lower than in some developing countries.

As mentioned above, the FEC today relies mostly on internal financial resources.

TABLE 7.32 INVESTMENT IN ENERGY PROJECTS WITH PRIVATE PARTICIPATION, MLN USD

Country	1990-1995	1996-2002
Russia	1,100	2,295
Argentina	12,035	13,470
India	2,889	9,680
Indonesia	3,202	7,544
Philippines	6,831	7,031
Morocco	2,300	4,820

Source: World Bank (2000)

At the same time, ineffective pricing and taxation policy in energy carriers and the unresolved problem of energy subsidy removal do not allow domestic energy enterprises to create the needed investment potential.

Because of that, the technical state of the FEC has substantially deteriorated. In turn, the low technical level of equipment is the main reason for low energy supply efficiencies, the relatively high level of end-use energy intensity, and the increasing risk of potential technological accidents.

In recent years, some positive trends in energy efficiency improvements have taken place (especially in some branches of the manufacturing industry). This was mostly connected with growing industrial output, and closing non-profitable and economically uncompetitive enterprises; it was only partly related to the direct implementation of available energy conservation potential.

The material and energy intensive structure of the GDP (with traditionally large shares of heavy industries) has been reformed during recent decades. In 1992-2000, there was some decline in the industrial share of the country's GDP value added, and simultaneously growth of the share of services and taxes.

The concluding analysis of the FEC with respect to its economic dimension suggests that the economic and financial framework for domestic energy in the country needs serious improvements, and cannot be considered sustainable.

7.5.1.3. Environmental dimension

The FEC's functioning and development is an important reason for the environmental problems faced in the country in recent years. Global climate change, air and water pollution, waste generation, existing risks (sometimes very high) of technical accidents in various energy industries, the large areas of lands used for energy purposes, and non-renewable energy resource depletion are the principal negative consequences of the FEC's influence on the environment.

According to official statistics, most categories of air pollutant emissions for the years of economic reforms have essentially declined (Table 7.33). This decline was mostly associated with the diminishing internal demand for energy resources. Power engineering is a leader in the industrial structure of air pollutant emissions (Figure 7.10). Its share is more than the share of the oil, coal and gas industries all combined.

TABLE 7.33 QUANTITIES OF AIR POLLUTANT EMISSIONS IN RUSSIA IN 1993-1999 (THOUSAND TONS)

	1993	1994	1995	1996	1997	1998	1999	1993-99
Oil sector	962	796	758	770	828	951	877	-9%
SOx	16	15	19	20	23	23	23	46%
CO	618	497	438	490	541	657	627	2%
NO_x	17	16	17	18	21	22	24	39%
VOCs	275	236	254	210	202	189	143	-48%
Particulates	36	32	30	32	41	60	60	64%
Oil production, Mt	352	316	307	301	306	303	305	-13%
Natural gas sector	497	511	304	293	306	292	314	-37%
SOx	47	47	47	48	48	51	61	30%
CO	248	241	206	200	216	204	213	-14%
NO_x	62	51	28	24	24	24	25	-60%
VOCs	136	168	18	17	13	5	7	-95%
Particulates	4	4	5	4	5	8	8	93%
Natural gas production, Bm^3	618	604	595	601	571	591	591	-4%
Coal sector	243	243	216	197	166	140	118	-51%
SOx	56	55	50	42	33	26	20	-63%
CO	63	67	64	62	50	42	34	-45%
NO_x	15	16	16	16	14	11	10	-33%
VOCs	N.a	N.a	N.a	N.a	N.a	N.a	N.a	N.a
Particulates	109	105	86	77	69	61	54	-50%
Coal production, Mt	285	273	263	257	245	232	249	-13%
Petroleum Refineries	906	770	691	671	731	683	637	-30%
SOx	197	181	159	144	148	134	136	-31%
CO	87	64	59	59	49	50	47	-46%
NO_x	22	21	21	21	22	21	20	-9%
VOCs	589	494	441	438	502	469	427	-27%
Particulates	11	10	11	9	10	9	7	-34%
Petroleum products production	219	181	180	176	178	163	169	-23%
Power engineering	5.887	5.231	4.973	4.705	4.382	4.297	3.887	-34%
SOx	2.498	2.255	2.134	2.006	1.833	1.818	1.618	-35%
CO	191	219	248	259	254	238	242	27%
NO_x	1.384	1.200	1.137	1.109	1.055	1.021	961	-31%
VOCs	1	1	1	1	1	1	1	39%
Particulates	1.813	1.556	1.453	1.330	1.239	1.219	1.065	-41%
Electricity generation, TWh	957	876	860	847	834	827	846	-12%
Total energy	8.590	7.551	6.939	6.635	6.411	6.364	5.836	-31%
SOx	2.813	2.553	2.408	2.259	2.084	2.051	1.858	-34%
CO	1.206	1.088	1.015	1.070	1.110	1.191	1.163	-4%
NO_x	1.501	1.304	1.218	1.187	1.135	1.100	1.041	31%
VOCs	1.097	899	713	666	718	665	579	-47%
Particulates	1.973	1.707	1.585	1.453	1.364	1.357	1.195	-39%

Source: State Committee on Environmental Protection (SCEP) (2003)

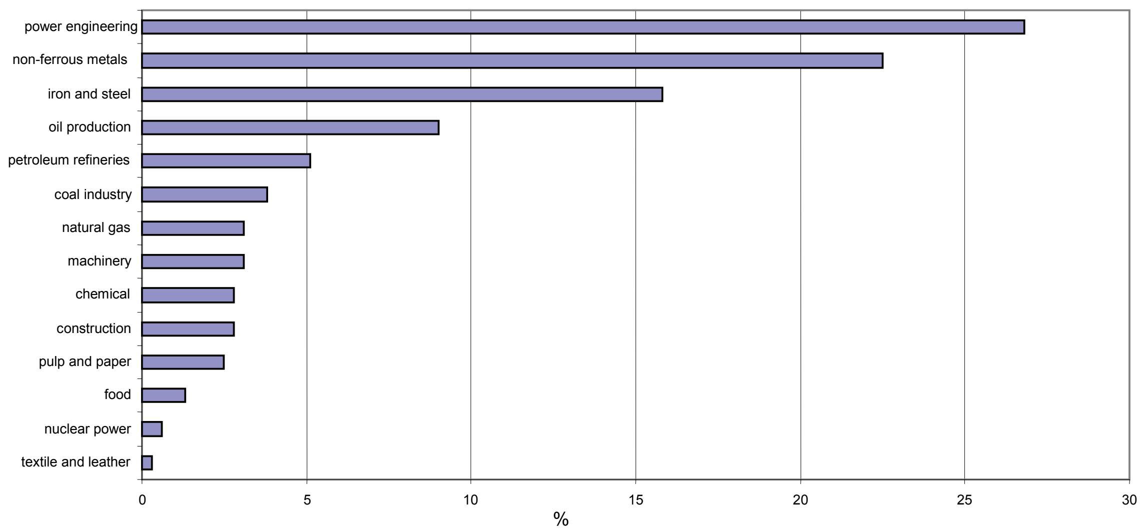

Figure 7.10 Industrial structure of air pollutant emissions (including SOx, CO, NOx, VOC and Particulates) in 1999, %

The same situation took place with respect to CO_2 emissions (Table 7.34). The level of primary energy consumption in Russia in 1992-1998 declined by 19.8%, and CO_2 emissions by 28.6%.

The structure of the main sources of CO_2 emissions in 1998 is given in Figure 7.11. This proportional share has been more or less constant in recent years.

Some information on ambient concentrations of pollutants in urban areas (for Moscow and Omsk) has been obtained (Table 7.35). Comparison with foreign cities shows that the environmental situation in urban areas is not the worst in the world, but far from being perfect.

Statistical data in Table 7.36 show definite activities in introducing technologies aimed at decreasing the negative influence of the FEC on the environment, as well as investment growth in environmental protection measures taking place. However, according to some experts' evaluations, both the introduction of new environmentally sound technologies and the investment in environmental protection measures undertaken in Russia do not meet the current requirements of the country.

As mentioned above, the lack of investment does not allow the FEC enterprises to ensure the needed refurbishment and modernization of their technological base. That is why the risk of technological accidents leading to fatalities and environmental damage is relatively high. Official statistics (e.g., time series) on the fatalities due to accidents in the energy sector throughout the country are not available. Nevertheless, such fatalities do take place, especially in the coal industry.

The Russian Federation has more than 20% of the world's forests. It is the most forested country in the world. They publish the forestry statistics every 5 years. In 1998, forested land was estimated to be 881.97 million hectares. The annual net growth in forested areas is nearly 1 billion cubic meters, above the allowable cut (according to official statistics) of 540 million m^3 (Table 7.37). However, some parts (probably, very essential) of deforestation in the country is uncontrollable.

Five million households in the country use forest resources as a fuel, and the annual consumption of woods for fuel purposes is about 50 Mm^3. These figures have been more or less constant for the most recent 10-12 years. It is emphasized in the Strategy that local energy sources, including fuelwood and residential and agricultural wastes, should be included in national and regional fuel and energy balances, and should contribute to the diversification of energy supplies and the solution of environmental problems.

TABLE 7.34 CO_2 EMISSIONS IN RUSSIA IN 1992-1998

		1992	1993	1994	1995	1996	1997	1998	1998/ 1992[1]
Total CO_2 emissions[2]	Mt CO_2	1,983.33	1,822.54	1,569.94	1,531.67	1,513.02	1,461.62	1,415.78	-28.6
CO_2 emissions/TPES	tCO_2 /toe	2.56	2.44	2.41	2.44	2.45	2.46	2.43	-5
CO_2 emissions/GDP using PPP's	tCO_2/ 1,000$	1.82	1.83	1.8	1.84	1.88	1.8	1.83	0.5
CO_2 emissions/population	tCO_2/ person	13.34	12.27	10.58	10.34	10.24	9.92	9.63	-27.8

Source: OECD/IEA (2000)
1 % change
2 These data are only energy related CO_2, not for any other greenhouse gases.

TABLE 7.35 AMBIENT CONCENTRATION OF POLLUTANTS IN URBAN AREAS IN 1995

Country	City	City population, Thousands	Total suspended particulates, microgram per cubic meter	Sulfur dioxide, microgram per cubic meter	Nitrogen dioxide, microgram per cubic meter
India	Delhi	9,948	415	24	41
Mexico	Mexico City	16,562	279	74	130
Philippines	Manila	9,286	200	33	n.a
Russian Federation	Moscow	9,269	100	109	n.a
Russian Federation	Omsk	1,199	100	9	30
Thailand	Bangkok	6,547	223	11	23
Sweden	Stockholm	1,545	9	5	29
United Kingdom	London	7,640	n.a	25	77
United States	New York	16,332	n.a	26	79
United States	Los Angeles	12,410	n.a	9	74

Source: UNEP (2004)

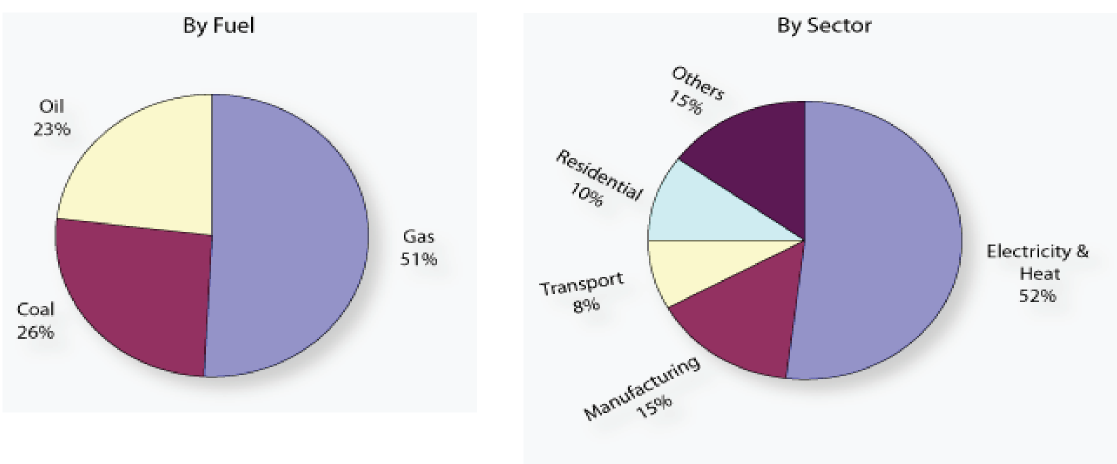

Figure 7.11 CO2 emissions by fuel and by sector in Russia in 1998

TABLE 7.36 STATUS OF DEVELOPMENT OF ENVIRONMENTAL PROTECTION TECHNOLOGIES IN RUSSIA.

Indicator	1993	1994	1995	1996	1997	1998	1999	2000
Sewage effluents, total, Bcm	27.2	24.6	24.5	22.4	23.0	22.0	20.6	20.3
FEC, Bcm	2.34	2.2	2.14	1.73	1.87	1.48	1.65	1.58
Air pollutant emissions, total, Mt	24.8	22	21.3	20.2	19.3	18.7	18.5	18.8
FEC, Mt	11.5	11.5	10.3	10.84	9.94	9.3	9.5	9.64
Sewage effluents abatement technologies total, Mm^3/day [1]	1.3	1.4	1.4	0.8	1	0.6	0.4	0.2
FEC, Mm^3/day	0.1	0.2	0.46	0.25	0.15	.08	0.04	0.14
Pollution abatement technologies total, Mm^3/h [1]	4.3	5.9	7.5	6.3	3.1	1.2	3.8	3.1
FEC, Mm^3/h	1.3	N/a	3.86	3.47	1.66	1.15	0.85	1.3
Investment in environmental protection, total, % [2]	N/a	109	102.7	76.4	95.6	100.4	95.3	139.1
FEC, %	94.2	119	178	144.7	78.8	96.8	123	154

Source: MIE (2003b)
1 Annual commissioning
2 Percentage of previous year

TABLE 7.37 FOREST RESOURCES, REFORESTATION AND DEFORESTATION IN RUSSIA

	Unit	European Russia and the Urals	Asian Russia	Total
Forested (stocked) area	Million hectare	167	603	770
Total growing stock	Billion cubic metres	22	59.9	81.9
Of which: Coniferous stands	Billion cubic metres	13.2	48.3	61.5
Growing stock of mature and overmature stands	Billion cubic metres	9.6	34.2	43.8
Of which: Coniferous stands	Billion cubic metres	380	600	980
Annual growth	Million cubic metres	380	600	980
Allowable cut	Million cubic metres	208	334	542

Source: IEA (2003b)

7.5.1.4. Institutional dimension

The institutional dimension can affect all three other dimensions—social, economic and environmental—through corrective response policy actions affecting the sustainability of the whole energy system.

The correct or incorrect institutional framework defines to a considerable extent the current state and prospects for any sector of the FEC, and the direction of national energy policy.

The unfavourable investment climate in the economy and in the FEC in particular was noted above. Weaknesses in investment legislation and the limited use of advanced investment mechanisms (e.g., production sharing, leasing, etc.) are the major factors restricting the use of foreign investment in domestic energy.

Ineffective regulation in energy prices and taxes, and the unsolved problem of energy subsidy removal are the main obstacles standing in the way of creating internal investment potential in the FEC.

Developing the right set of institutional measures is very important for successfully implementing market reforms in the power engineering and gas industries.

The weakness of the Law "On Energy Conservation" and the limited financial incentives guaranteed by the government for energy conservation activity have not contributed to decreasing the energy intensity of the domestic economy.

The Strategy assumes an essential improvement in the institutional framework of the national energy policy.

More detailed explanations of the influence of institutional measures on the results of the FEC functioning and energy policy implementation, as well as measures that are going to be implemented in the future are, as outlined in sections below.

7.5.1.5. Energy policy priorities and ISED

The priorities for Russian energy policy are addressed and described by the various dimensions of sustainability (Table 7.38).

The priority connected with securing stable, uninterrupted and affordable energy supplies is related to the social dimension of sustainability; increasing energy efficiency and ensuring energy security are linked with the economic dimension; and the two remaining priorities are within the environmental dimension. The results of the above analysis show that institutional activities and policy implementation are important necessary conditions for realizing selected priorities.

The indicators presented in the list of ISED are divided into the three groups:

- State Indicators;
- Direct Driving Forces;
- Indirect Driving Forces.

The main priorities of the energy policy presented through the indicators from the list of ISED are given in Table 7.39.

As noted earlier, energy security is one of the most important components of economic and national security for the country. Development of the economy and improving the well-being of the population depend very heavily on both indigenous energy production (with the FEC providing energy for the economy) and the share of net energy import (i.e., net energy exports for the Russian Federation) in the country's TPES.

Among the driving forces which have a direct influence on the State Indicators relevant to this priority, the following should be noted:

- Expenditures on the energy sector, or investment in ensuring needed volumes of energy production in order to meet internal energy requirements and economically justified export supply;

TABLE 7.38 RUSSIA'S ENERGY POLICY PRIORITIES AND DIMENSIONS OF SUSTAINABILITY

Energy policy priorities	Dimension of sustainability
Securing stable, uninterrupted and affordable energy supply for the economy and households	Social dimension: Energy disparities Energy affordability and accessibility
Increasing energy efficiency of the economy Ensuring national energy security	Economic dimension: Economic activity levels Energy production, supply and consumption Energy pricing, taxation and subsidies End-use energy intensities Energy supply efficiency Energy security
Decreasing the negative environmental impacts of the energy system Developing and improving the energy resource base	Environmental dimension: Global climate change Air pollution Water pollution Wastes Energy resource depletion Land use Accident risks Deforestation
	Institutional dimension: All of the above issues as well as priorities taken individually as well as collectively

Source: MIE (2003a), IAEA/IEA (2003)

TABLE 7.39 THE MAIN PRIORITIES OF RUSSIA'S ENERGY POLICY PRESENTED THROUGH THE LIST OF ISED.

Priorities	State indicators	Direct Driving Forces	Major Indirect Driving Forces
Ensuring national energy security	17. Indigenous energy production 18. Net energy import dependence	14. Energy use per unit of GDP 15. Expenditure on energy sector	2. GDP per capita 3.End-use energy prices with and without tax/subsidy 4.Shares of sectors in GDP value added 12. Energy supply efficiency
Securing stable, uninterrupted and affordable energy supply for the economy and households	16. Energy consumption per capita 17. Indigenous energy production 22. Fraction of households heavily dependent on non-commercial energy, without electricity	14. Energy use per unit of GDP 15. Expenditure on energy sector 21. Fraction of disposable income/ private consumption per capita spent on fuel and electricity by average population, group of 20% poorest population	2. GDP per capita 3. End-use energy prices with and without tax/subsidy 4.Shares of sectors in GDP value added 5.Distance traveled per capita 6.Freight transport activity 7.Floor area per capita 8.Manufacturing value added by selected energy intensive industries
Increasing the energy efficiency of the economy		14. Energy use per unit of GDP	2. GDP per capita 3. End-use energy prices with and without tax/subsidy 4. Shares of sectors in GDP value added 5. Distance traveled per capita 6. Freight transport activity 7. Floor area per capita 8. Manufacturing value added by selected energy intensive industries 9. Energy intensity: manufacturing, transportation, agriculture, services, residential sector 10. Final energy intensity of selected energy intensive products 12. Energy supply efficiency
Developing and improving the energy resource base	17. Indigenous energy production 37. Lifetime of proven recoverable fossil fuels reserves 39. Lifetime of proven uranium reserves	15. Expenditure on energy sector 35. Fraction of technically exploitable capability of hydropower currently not in use	
Decreasing the negative environmental impacts of the energy system	24. Ambient concentration of pollutants in urban areas 25. Land area where acidification exceeds critical load 30. Accumulated quantity of solid wastes to be managed 32. Accumulated quantity of radioactive wastes awaiting disposal 34. Fatalities due to accidents	23. Quantities of air pollutant emissions from energy related activities 27. Radionuclides in atmospheric radioactive discharges 26. Quantities of greenhouse gas emissions from energy related activities 28. Discharges into water basin associated with energy activity 29. Generation of solid wastes 31. Generation of radioactive wastes from nuclear power cycle chain 33. Area of land taken up by energy facilities and infrastructure	2. GDP per capita 3. End-use energy prices with and without tax/subsidy 4. Shares of sectors in GDP value added 5. Distance traveled per capita 6. Freight transport activity 7. Floor area per capita 8. Manufacturing value added by selected energy intensive industries 9. Energy intensity: manufacturing, transportation,

			agriculture, services, residential sector 10. Final energy intensity of selected energy intensive products 11. Energy mix 12. Energy supply efficiency 13. Status of deployment of pollution abatement technologies

Source: MIE (2003a), IAEA/IEA (2003)

TABLE 7.40 LIST OF ISED: COMPACT FORM.

N	Indicator	Current state (1992-2001)	Forecast (to 2020)
1	Population: total; urban	Decreased by 2.65%. Share of urban population within 73-75%.	Future declining. Moving rural population into urban areas in case of continuation of economic hardships.
2	GDP per capita	Decreased by 12.2%	231% of 2000 in moderate scenario. 334% in optimistic scenario.
3	End-use energy prices with and without tax\subsidy	End-use energy prices have been constantly growing. Energy subsidies exist.	End-use energy prices will continue growing to achieving cost-based level. Energy subsidies will be eliminated.
4	Shares of sectors in GDP value added	Share of services increased. Share of industry decreased.	Further optimization of GDP structure directed at developing services sector and low energy intensive industries.
5	Distance traveled per capita: total, by urban public transport mode	Practically repeats dynamics of GDP and GDP per capita.	It will grow along with GDP growth and improving living standards of the population
6	Freight transport activity: total, by mode	Practically repeats dynamics of GDP and GDP per capita.	It will grow along with GDP growth and improving disposable income of the population
7	Floor area per capita	Some increase within 15-20% used to take place. Today this indicator is equal to 20 sq. m/person	This indicator will grow up to the level of leading industrially developed countries.
8	Manufacturing value added by selected energy intensive industries	Manufacturing value added: Food and tobacco- 17% Textiles and clothing- 4% Machinery and transport equipment- 20% Chemicals- 9% Other manufacturing- 51% (1997)	The share of energy intensive industries in manufacturing value added will have a trend to decline.
9	Energy intensity: manufacturing, transportation, agriculture, commercial & public services, residential sector	One can speak about growing trends because of the energy intensity of GDP increase. It concerns mostly manufacturing industry.	This indicator is growing but will decline.
10	Final energy intensity of selected energy intensive products	In 1995-1999 energy intensity of steel production had declined by 20% because of increasing industrial output and closing inefficient enterprises. The similar situation takes place for the other energy intensive products in the latest years	It will have a trend to decline due to further growth of production and technical improvements in energy efficiency.
11	Energy mix: final energy, electricity generation, primary energy supply	Final energy mix: heat – 32%, gas – 28%. Electricity and primary energy mix: dominating role of natural gas (42% and 52%, respectively).	Electrification and motor fuels consumption growth. Declining share of natural gas in the fuel and energy balance. Primary energy consumption

		Final energy consumption decreased by 27%, electricity generation – by 11.8%, Primary energy supply – by 19.8%.	and electricity generation growth.
12	Energy supply efficiency: fossil fuel efficiency for electricity generation	Energy supply efficiency is much lower than in leading developed countries. High level of distribution losses.	Modernization and rehabilitation of equipment and infrastructure of energy supply systems are going to be implemented.
13	Status of deployment of pollution abatement technologies: extent of use, average performance	Current activity is not enough to deal with negative environmental consequences of energy development.	Enhancing activity in R&D, improving legislative base and additional investment will be undertaken.
14	Energy use per unit GDP	Increased by 6.3%. In the last 2-3 years some decline took place.	56% of 2000 in moderate scenario. 42% of 2000 in optimistic scenario.
15	Expenditure on energy sector: total investment, environmental control hydrocarbon exploration & development, R&D, net energy import expenses	Lack of investment practically in all sectors of Russia's FEC used to take place.	Planning investment in 2000-2020: gas industry – 170-200 bln USD; Oil industry – 230-240 bln USD; Electricity – 120-170 bln USD; including 25-35 bln USD in nuclear power plants; coal industry – 20 bln USD; heat supply systems – 70 bln USD; energy conservation - 50-70 bln USD.
16	Energy consumption per capita Primary energy, toe/person Electricity, kWh/person	1992 2001 primary energy 5,211 4,293 electricity 6,107.5 5,319	The dynamics of these indicators will correlate with the growth rates of primary energy and electricity demand.
17	Indigenous energy production Electricity generation	Decreased from 1,118.7 mln toe in 1992 to 996.2 mln toe in 2001 (-10.95%) Decreased from 1,008.4 bln kWh in 1992 to 889.3 bln kWh in 2001 (-11.8%).	Moderate scenario – 1,265 mln toe. Optimistic scenario – 1,420 mln toe. Moderate scenario – 1,215 bln kWh. Optimistic scenario –1,365 bln kWh.
18	Net energy import dependence	Relatively sharp decrease in energy demand used to contribute to increasing share of net energy export in TPES from 42.4% in 1992 to 59.1% in 2001.	The share of net energy export in TPES will account for 55-60%.
19	Income inadequate	40 times in 2000 according to the World Factbook 2002.	Serious efforts are going to be undertaken by government in order to decrease existing gap.
20	Ratio of daily disposable income/private consumption per capita of 20% poorest population to the prices of electricity and major household fuels	Official statistics are not available; however, it is clear that financial burden of payments for energy use is getting heavier.	In 2020 expenditures on energy use (per capita) will reach 233-235% of 2000.

21	Fraction of disposable income/private consumption spent on fuel and electricity by: average population; group of 20% poorest population	16% for average households.	Energy Strategy assumes increase of personal income by 3.4-3.7 times in comparison with expenditures on energy use by 2.3-2.4 times.
22	Fraction of households: heavily dependent on non-commercial; without electricity	About 1.5%; 100% electrification	Increasing use of local (mostly non-commercial) energy resources is very important for ensuring reliable and stable energy supply in remote areas.
23	Quantities of air pollutant emissions (SO_2, NO_x, particulates, CO, VOC).	Decrease because of declining energy demand.	Active measures of environmental protection are to be implemented.
24	Ambient concentration of pollutants in urban areas: SO_2, NO_x, suspended particulates, CO, ozone	Not worst in the world but far from being perfect	Environmental protection measures will be needed
25	Land area where acidification exceeds critical load	Official statistics are not available.	Official statistics are not available.
26	Quantities of greenhouse gas emissions	Decreased due to energy demand reduction.	75-80% of 1990 by 2010. Will not exceed the level of 1990 in 2020.
27	Radionuclides in atmospheric radioactive discharges	Official statistics are not available.	Official statistics are not available.
28	Discharges into water basins: waste/storm water, radionuclides, oil into coastal waters	The problem is very current	Urgent legislative and technical measures are needed.
29	Generation of solid waste	36 mln t in 1995, 19.6 mln t in 2000	It will grow along with energy consumption
30	Accumulated quantity of solid wastes to be managed	Official statistics are not available.	Official statistics are not available.
31	Generation of radioactive waste	Official statistics are not available.	Official statistics are not available.
32	Accumulated quantity of radio-active wastes awaiting disposal.	Official statistics are not available.	Official statistics are not available.
33	Land area taken up by energy facilities and infrastructure	Official statistics are not available.	Official statistics are not available.
34	Fatalities due to accidents with breakdown by fuel chains	Official statistics are not available.	Official statistics are not available.
35	Fraction of technically exploitable capability of hydropower currently not in use	90.7%	It will decline due to hydropower production growth.
36	Proven recoverable fossil fuel reserves	coal 157,000 Mt oil 6,700 Mt gas 48,000 bcm	Proven recoverable reserves growth: oil – by 7.5-10 bln t natural gas – by 11,200-18,800 bcm
37	Life time of proven recoverable fossil fuel reserves	coal 600 years oil 36 years gas 80 years Additions to explored domestic proven recoverable reserves of fossil fuels were below the production volumes.	The objective is to ensure a high level of energy resource self-sufficiency in the long term.
38	Proven uranium reserves	145,000 t	Compensation of annual production is to be

			ensured.
39	Life time of proven uranium reserves	56	Positive trend is to be achieved
40	Intensity of use of forest resources as fuelwood	5 million households use forest resources as fuelwood, at a rate of about 50 mln m^3 annually.	Woods are going to be an important source of decentralized energy supply for the future (for remote areas).
41	Rate of deforestation	Annual growth- 980 mln m^3 Allowable cut- 542 mln m^3 Unauthorized cut takes place.	It is necessary to strive for rehabilitation of forest resources, to their renewability.

Source: MIE (2003a), IAEA/IEA (2003)

- Net energy export revenues, which provide a bulk of the investment for the energy system, and one of the most important sources of budget receipts;
- Energy use per unit of GDP, the decline of which, for example, both influences the energy export potential growth and allows a decrease in the level of indigenous energy production without any threats to energy security.

Indirect driving forces (IDF) affecting energy security levels are also shown in Table 7.39. Explanations suggesting why these IDF have been selected are provided below.

A specific level of the economic development (i.e., GDP per capita) requires both the relevant availability and quality of energy services, and their provision in turn requires corresponding expenditures.

The level of end-use energy prices in the Russian Federation is one of the key factors influencing the dynamics of energy exports and the state of energy security within the country. In particular, several gasoline crises have taken place in large cities. They were caused by a deficit of motor fuels within the internal market, which was created by private companies that benefited from a favourable situation in foreign markets.

The influence of the GDP structure (i.e., the shares of various sectors in GDP value added) also plays a role in Direct Driving Forces. The higher the share of raw material and energy intensive branches of the industry, the more investment required for the energy system (in particular, in the energy production sector), and the more problems that could emerge in addressing the energy export potential. The result will be a higher total energy intensity of GDP.

The energy supply efficiency affects the energy use per unit of GDP, and the establishment of the energy export potential. It should be noted that both the Direct and Indirect Driving Forces on some priorities of energy policy will be duplicated; therefore, these comments will not be repeated in the text. For example, in addressing concerns about ensuring energy security, the other energy policy priorities can all be considered as structural components.

Among the State Indicators related to the next energy policy priority (i.e., securing stable uninterrupted and affordable energy supply for the economy and households) the following ones can be noted:

- Energy consumption per capita (which is a very important indicator reflecting the level of energy and economic development);
- Indigenous energy production;
- Fraction of households heavily dependent on non-commercial energy, without electricity (this indicator reflects the level of accessibility and affordability of commercial energy resources for consumers).

The indicator related to the direct driving force is the fraction of disposable income/private consumption per capita spent on fuel and electricity by the average population and a group of 20% poorest population. In other words, this indicator shows how heavy the financial burden associated with payments for energy resources is for different groups of the population. As mentioned above, the share of expenditures for fuel and electricity should be reasonable in order to stimulate energy conservation activity in the population, and to ensure economic affordability of energy carriers for all groups of the population.

It is worth noting that if the total payments from households for a set of services provided for the residential sector (e.g., energy carriers, telephone, waste management, maintenance, etc.) exceed 25% of disposable income, then the difference is to be reimbursed by a subsidy.

Major Indirect Driving Forces related to considering energy policy priorities include mostly the indicators reflecting economic activity levels in the country. These are, in particular, transportation activity, living standards of the population (e.g., floor area per capita), as well as manufacturing value added by selected energy intensive industries.

As for increasing energy efficiency, a set of the IDF includes indicators characterizing the level of economic development; end-use energy prices (as a factor influencing the energy conservation activity of consumers); the structure of the economy (e.g., industry and transport); the energy intensity of various industrial branches; and energy supply efficiency.

According to the Strategy, end-use energy price growth is a principal factor for successful implementation of the national energy conservation policy.

The energy policy priority "Developing and improving the energy resource base" is described by the following State Indicators:

- Lifetime of proven recoverable fossil fuel reserves; and
- Lifetime of proven uranium reserves.

These indicators show the level of self-sufficiency for relevant fuel reserves. They show the ratio between the available level of proven recoverable fossil fuel (or uranium) reserves and the annual level of their production. Higher ratios indicate higher levels of self-sufficiency.

Direct Driving Forces related to energy policy priorities reflect the quantitative levels (volume) of proven recoverable fossil fuel (and uranium) reserves as well as the potential for hydropower development (i.e., the fraction of technically exploitable capability of hydropower currently not in use).

"Expenditure on hydrocarbons exploration and development" and "Indigenous energy production" could be referred to as IDF for the priority "Developing and improving the energy resource base." The growth of the first indicator contributes to an increase in proven recoverable reserves, and growth of the second one to their depletion.

The last priority indicated in Table 7.39 concerns the environmental impact of energy development (i.e., decreasing the negative environmental impacts of the energy system).

The State Indicators related to this priority mostly reflect the quantitative results of the negative impact of energy development on the environment. It concerns, in particular, accumulated quantities of solid and radioactive wastes, areas of land taken up by energy facilities and infrastructure, etc.

Among the Driving Forces directly influencing on the State Indicators related to the environmental priority of Russia's energy policy are the following:

- Quantities of air pollutant (and greenhouse gas) emissions from energy related activities;
- Generation of solid (and radioactive) wastes;
- Discharges into water basin; and radionuclides in atmospheric radioactive discharges.

Among the IDF linked to decreasing the negative environmental impacts of the energy system are indicators related to economic activity, since economic development causes increased energy consumption (and therefore a negative environmental impact); end-use energy prices (with or without subsidies and environmental taxes); energy intensities and supply efficiency; and the status of deployment of pollution abatement technologies and expenditures on their development.

7.6. Assessment of Current Energy Policies in Priority Areas

7.6.1. The main results of the ISED implementation

Implemented analysis of the ISED package is useful from the standpoint of better understanding the interrelationships between separate indicators and sustainability dimensions. It allows an evaluation of the level of effectiveness of various political measures undertaken to improve sustainability of energy and economic development, as well as energy policy as a whole.

Table 7.40 provides a vision of the current state (for the period 1992-2001) and prospects (to 2020) of ISED by means of brief quantitative and qualitative analysis. Considering retrospective dynamics (1992-2001) of most indicators from the ISED listing, the following negative trends can be observed:

- Available data on GDP per capita demonstrate a declining trend;
- End-use energy prices demonstrate constant growth, but have not yet stimulated energy conservation and environmental protection activities; energy subsidies still exist;
- Energy intensities in separate sectors of the economy and in selected energy intensive products are still high;
- The decline in GDP, primary energy production and consumption (including consumption per capita) has been accompanied by an increase in energy use per unit of GDP; therefore, Russia's economy has become more energy intensive;
- A sharp lack of investment has occurred within the FEC (and concerns practically all energy industries);
- Payments for energy bills are becoming a greater financial burden for the poorest portion of the population;
- The main environmental indicators reflecting the negative influence of energy development on the environment (in particular air pollutant emissions) have demonstrated some positive (i.e., declining) trends, mostly connected with a reduction in energy production and consumption (rather than from environmental protection policies);
- Low energy supply efficiency exists (i.e., there are high distribution losses);
- Despite a large energy resource base, additions to explored domestic proven recoverable fossil fuel reserves were below production volumes.

Among the positive trends and factors within ISED, the following should be noted:

- Service sector growth in GDP value added, and a simultaneous decline of industry's share (in 1998 the aggregated structure of GDP value added was: services, 58%; industry, 35%; and agriculture, 7%);
- Increase of energy export potential (i.e., the share of net export in TPES);
- High share of CHP in electricity and heat generation.

All selected priorities and relevant indicators were classified according to dimensions of sustainability (Table 7.38), as well as State Indicators, Direct and Indirect Driving Forces (Table 7.39).

The effectiveness of energy policy needs serious improvement, in order to ensure sustainable energy development in the long-term. A listing of the improvements related to each particular energy policy priority is outlined below.

7.7. Strategies for Improvements in Priority Areas

Achievement of identified energy policy priorities requires the implementation of relevant strategies and response actions.

7.7.1. Ensuring national energy security

Two major problems are to be solved in implementing this priority of Russia's energy policy:

- Modernization and refurbishment of the technological base of the FEC, as well as compensation for the loss of productive capacities and correlation between domestic proven recoverable reserves of fossil fuels and production volumes. The lack of investment will not ensure large-scale construction of new capacities in the current decade. In this regard, priority will be given to the technological modernization of existing capacities, and prolongation of their life times;
- Structural change in energy consumption directed towards increasing the share of hydro and nuclear power, renewables and coal (based on clean coal combustion technologies); and

diversification of the geography of hydrocarbons production (from West Siberia to East Siberia, Far East, the northern regions of the European part, and the Caspian region).

7.7.2. Securing stable, uninterrupted and affordable energy supply for the economy and households

Implementation of this priority could include planning and active social policies designed to minimize the negative consequences of end-use-energy price growth for the socially unprotected (i.e., the poorest) groups of population. The following measures are to be realized:

- Compensating end-use energy price growth by increasing the personal income of the country's population;
- Creating effective systems of social protection for the poorest part of the population;
- Ensuring effective use of budgetary and financial means aimed at social protections, and strict control over their spending.

Even in cases where necessary financial means are available for fuel, energy purchases, and the modernization and refurbishing of existing capacities and infrastructure (e.g., in preparation for the winter heating season), it is extremely important to ensure that such means are strictly controlled and effectively employed. It is a frequent practice that the financial means allocated from the federal budget to prepare for the winter season in various regions of the country are spent by local administrations for other purposes. As a result, some districts in the country could not be heated in winter because of a shortage of fuel for boilers and power plants, and technical accidents occurred in heat and hot water supply systems. Accordingly, it is also very important to strengthen the personal responsibility and accountability of the leadership of the fuel and energy supply companies, and regional and local administrations, if they break or interrupt energy supplies to consumers, or fail to implement contractual agreements and obligations.

7.7.3. Increasing the energy efficiency of the economy

The main quantitative target of the energy policy related to this particular priority, energy use per unit of GDP, is likely to decline in 2020 by 42-56% of the levels found in 2000. The set of measures to be implemented within this policy includes:

- Increasing the share of services within the GDP value added, and low energy intensive industries within manufacturing value added. Moreover, the share of manufacturing industries in the total industrial structure will be increased from 50% in 2002 to 64-65% in 2020;
- Achieving the technical potential of energy conservation.

In order to enhance energy conservation activity in the country, economically justified end-use energy price growth is necessary. This price growth should be profitable for federal and regional budgets, and FEC's enterprises, but affordable for the consumers. Energy prices should become an important stimulating factor for energy conservation in the Russian Federation.

At the same time, it is necessary to implement a package of measures with organizational, administrative, economic and information characteristics, including:

- Strengthening existing norms and standards defining specific volumes of fuel and energy consumption in various sectors of the domestic economy. Introducing these norms and standards for buildings (first addressing heat efficiency standards) and a number of residential electric appliances (in particular for refrigerators, consuming about 50% of total electricity in the residential sector) has already given promising results;
- Ensuring energy use efficiency in industry (in particular through regular energy audits);
- Organizing information and educational programmes for various categories of consumers;
- Creating workable and effective financial incentives;

- Enhancing activity in R&D aimed at creating and introducing advanced, energy efficient and environmentally sound technologies;
- Introducing advanced financial schemes for energy efficiency project implementation.

7.7.4. Developing and improving the energy resource base

A lack of investment was noted as being among the main reasons for the deteriorating state the country's energy resource base. The Strategy estimates the potential investment needed for improving the sustainability of the energy resource base at 40-50 billion USD through 2020.

The main problems to be solved within this energy policy priority are the following:

- Exploring new oil and gas fields;
- Creating new, efficient and environmentally sound technologies for fossil fuel extraction, directed at increasing the productivity of fuel production while simultaneously decreasing fuel costs;
- Improving the legislative base, especially in the field of licensing;
- Creating a favourable investment climate in the fuel producing sector;
- Enhancing activity for including local and renewable energy sources in the fuel and energy balance.

7.7.5. Decreasing the negative environmental impacts of the energy system

In recent years, there has been some decline in the negative influences of the FEC on the environment associated with the decreasing energy demand in the country. Nevertheless, the environmental consequences of energy development are still a very serious threat to environmental security in the country.

In this regard, the following measures are envisaged:

- Scientific R&D into environmentally secure technologies for energy production, transportation, processing, and use;
- Transition from a situation of pollutant releases, disposal, and recovery to the elimination of such pollutants through the introduction of modern technologies, minimization of wastes, and reduction of energy facility land degradation;
- Development of unified, industry-wide norms and rules, normative and technical documents and standards, the regulation of environmental protection and rational nature management; and
- Certification and licensing management with regards to innovative domestic and foreign technologies, equipment and materials that meet current environmental requirements.

Continuous environmental monitoring is essential for the main energy-producing regions, as well as for the transition from regulating maximum permitted emissions to maximum permitted impacts on nature. It is important to encourage the transfer to no-and-small-waste processes that require the recovery of associated gas at oil fields and coal-bed methane, and use the ash/slag wastes of power plants (both new wastes and those already in ash dumps) for construction and for the fabrication of construction materials.

7.7.6. Interrelationships amongst energy policy priorities

There are interrelationships amongst energy policy priorities, the principal response actions for implementing energy policy, and the ISED indicators positively affected by these response actions (Table 7.41).

Response actions given in Table 7.41 represent a broad range of directions for the energy policy. They include improvements in investment, legislative, environmental and structural directions. In addition to the positive influences on the identified targeted indicators (whose improvements lead to implementing the relevant energy policy priority), these response actions will also have a positive influence on other indicators in the ISED list.

For example, one of the targeted indicators related to the priority "Securing stable, uninterrupted and affordable energy supply for the economy and households" is the third listed for ISED (i.e., "End-use energy prices with and without tax/subsidy"). Indeed, end-use energy prices play an important role in ensuring stable, uninterrupted and affordable energy supply. Introducing the right energy prices will allow the FEC enterprises to obtain investment needed for ensuring normal functioning and development, including the modernization and refurbishment of existing productive capacities and infrastructure, and the construction of additional capacities.

TABLE 7.41 ENERGY POLICY PRIORITIES, RESPONSE ACTIONS AND TARGETED AND POSITIVELY AFFECTED ISED

Priorities	Targeted Indicators	Response Actions	Positively Affected Indicators as numbered in ISED list
Ensuring national energy security	15. Expenditure on energy sector	Increase expenditure on hydrocarbon exploration and development	17, 18, 36, 37
		Increase R&D expenditure for energy technology	9, 10, 12-14, 16-18, 21-41
Securing stable, uninterrupted and affordable energy supply for economy and households	11. Energy mix	Diversify energy supply	15, 18
		Increase share of renewables in fuel mix	15, 18, 20-32, 34-41
		Increase share of nuclear in fuel mix	23-26, 28-30, 34, 36, 37
	3. End-use energy prices with and without tax/subsidy	Include externalities in full cost of energy	5-7, 9, 10, 13,-16, 18, 23-29
		Eliminate energy subsides except for the poor population	5-7, 9, 10, 14-18, 23-24, 36-39
		Provide energy subsidies to the poor population	20-22, 40, 41
Increasing energy efficiency of the economy	3. End-use energy prices with and without tax/subsidy	Introduce taxes on polluting fuels (other response actions are given above)	5-7, 9, 10, 14-16, 18, 23-30
	4,8. Shares of sectors and sub-sectors in GDP value added	Optimize economic levels through reducing shares of energy intensive sectors/manufacturing industries	9, 14-18, 23-24, 36-39
	9,10. Energy intensity of economic sectors and selected energy intensive products	Decrease energy intensities through end-use energy efficiency improvement	14-18, 21-34, 36-41
	12. Energy supply efficiency	Increase efficiency of energy supply, in particular in electricity generation	14-18, 23-29
		Increase fraction of electricity supplied by CHP plants	14-18, 23-26, 28-30, 33, 36, 37
Developing and improving	11. Energy mix	Diversify energy supply	15, 18

the energy resource base	15: Expenditure on energy sector	Increase expenditure on hydrocarbon exploration and development	17, 18, 36, 37
Decreasing the negative environmental impacts of energy system	13. Status of deployment of pollution abatement technologies	Improve performance of pollution abatement technologies	23-25
		Extend use of pollution abatement technologies	23-25
	15. Expenditure on energy sector	Increase expenditure on radioactive waste management	31-33
		Increase expenditure on waste management	29-33
		Increase expenditure on air pollution abatement	13, 23-25
	29. Generation of solid waste	Decrease amounts of waste through recycling and reuse	30, 33, 36, 37
	31. Generation of radioactive waste from nuclear power fuel chain	Decrease amounts of radioactive waste through its recycling, treatment and conditioning	32, 38,39
	33. Land area taken up by energy facilities and infrastructure	Extend protected area as a percent of total land area	40, 41
	40. Intensity of use of forest resources as fuelwood	Extend managed forest area	41

Source: IAEA/IEA (2003)

That is why response actions related to this indicator include the following:

- Including externalities within the full cost of energy. This will allow the FEC enterprises to be reimbursed for all appropriate expenditures and investments, and to obtain economically justified profits necessary for further development;
- Eliminating energy subsidies. Along with the previous action, such a step will contribute to improving the financial state of the FEC, and stimulate rational and efficient approaches to energy use (including the implementation of energy conservation measures).

However, about 30% of Russia's population can be considered poor. These people will not be able to pay full cost of energy. That is why some form of financial support or other relevant measures of social protection should be made available for the poorest part of the population.

These actions will contribute to the decline of energy intensity of the GDP and its main sectors and industries, as well as improvements in the environmental situation, due to a decrease in non-productive energy losses.

However, the minimization of the influence of end-use energy price growth on the financial state of the poorest part of the population (Indicators 20-22 in particular) depends not only on saving some form of energy subsidies. The problem is that end-use energy price growth leads to general price growth for practically all industrial products and services which are not subsidized. For example, as soon as motor fuel prices increase, the population will clearly feel the influence of inflation. It will concern all aspects of the economy—including production in the food industry, for example.

Another targeted indicator affecting several priorities is the energy mix. To ensure stable and at the same time affordable energy supply in Russia's regions (including those suffering from energy shortages), it is necessary to diversify the sources of energy supply as much possible, and decrease the energy net import dependence by using local and renewable energy sources (and also increasing the share of nuclear power in the fuel mix).

These measures will also contribute to improving the environmental situation, saving the most economically effective part of fossil fuel reserves, as well as decreasing the financial burden on the population and other categories of energy consumers.

Concluding the above analysis, one finds that using indicators from the ISED list for describing the key priorities of Russia's energy policy can and should be very helpful for monitoring the national energy policy, and preparing strategies, programmes and governmental decrees on actual problems of energy development.

7.8. Conclusions and recommendations

1. Achieving sustainable energy development in Russia, as in any other country, can only be accomplished through well-developed and strictly-applied energy policies. The key priorities of such policies can be realized by analyzing the status of a broad range of indicators, including those in the ISED list, and representing all dimensions of sustainability (i.e., social, economic, and environmental), as well as institutional considerations.

2. The current state of the FEC is closely linked with the general economic situation in the country.

3. The 1992-2001 period considered in the study was characterized by a deterioration of the energy resource base, as well as a decrease in energy production and consumption.

4. This situation in domestic energy largely arose due to factors external to the FEC, and in particular the inconsistent implementation of macroeconomic reforms during 1992-1997.

5. As a result of economic hardships, energy demand declined, and a lack of investment in practically all sectors and branches of the FEC occurred.

6. Among the most serious problems in the FEC (as well as the main energy consuming sectors) is the problem of low energy supply efficiency; foremost is the problem of high distribution losses, and simultaneously high energy intensity within primary and final consumption.

7. One of the main reasons for the high energy intensity of the economy is the traditionally high share of material and energy intensive branches within domestic industry.

8. The decline of energy demand as a result of economic problems resulted in a definite decrease of air pollutant emissions and GHG emissions.

9. End-use energy prices, and in particular prices associated with the natural monopolies of electricity and natural gas, have been constantly growing during recent years. However, these have not yet stimulated energy conservation activities.

10. The Energy Strategy assumes that serious improvements in national energy policies will take place. It forecasts essential economic growth, social progress, enhanced industrial activity, and an improved institutional framework, legislative base, economic state and environmental characteristics for the FEC.

11. Collecting reliable statistics is very important for implementing a correct analysis following the ISED approach. Among the problems of collecting information related to ISED, the following are notable:

- Availability of statistics;
- Accessibility to needed statistical data;
- Quality of available statistics.

For the most part, relevant information has been collected. However, some statistical data are not available (or the probability of obtaining the data is very low), and remaining parts may not be accessible. The procedure necessary to obtain them may be very long and complex. The quality of some parts of the obtained information may not allow analysts to construct relevant indicators in time series, nor analyse their dynamics or influence on the energy situation within the country.

12. This report recommends incorporating the ISED package into national databases. The organization able to collect the necessary information and present it in the desirable units of measure (and in a form suitable for comparison on an international basis) is the State Committee for Statistics (Goscomstat). It is necessary for the Russian Government to decide the level of involvement of Goscomstat in collecting and providing such information.

13. A number of key priority areas for the energy policy have been identified. Among them:

- Ensuring national energy security;
- Securing stable, uninterrupted and affordable energy supply for the economy and households;
- Increasing energy efficiency of the economy;
- Developing and improving the energy resource base;
- Decreasing the negative environmental impacts of the energy system.

These priorities cover the most difficult issues of the FEC and the national economy as a whole. They will be of crucial concern at least within the period considered within the Strategy (i.e., until 2020).

14. All identified priorities have a close correlation with relevant dimensions of sustainability:

Securing stable, uninterrupted and affordable energy supply for the economy and households	Social dimension
Increasing the energy efficiency of the economy and ensuring national energy security	Economic dimension
Developing and improving the energy resource base and decreasing the negative environmental impacts of the energy system	Environmental dimension

All of these priorities are closely linked with the institutional dimension as well.

15. The ISED indicators related to each priority area have been identified. These indicators have been classified according to dimensions of sustainability and divided into three groups: State Indicators, and Direct and Indirect Driving Forces.

16. The analysis of the key priority areas in the energy policy demonstrates a good applicability of the ISED package for evaluation of the current state of, and prospects for, the FEC and monitoring the energy policy of the country. The analysis indicates that the current state of the energy situation, as well as the effectiveness of energy policies in recent years, is far from being sustainable. For the most part, ISED have been used to demonstrate negative trends. Economic recovery in very recent years has contributed to enhancing activity within the FEC. Nevertheless, serious improvements are needed.

17. The FEC cannot be considered sustainable separately from the economy as a whole. In this connection, economic recovery and market- driven reforms are the principal (i.e., necessary) condition for achieving sustainable energy development.

18. Pricing policies (including taxes and subsidies) occupy a special place within the economic and energy strategy.

19. Eliminating energy subsidies and including externalities in the fuel cost will stimulate energy conservation activities of consumers. However, energy resources could become unaffordable for the poorest portion of the population. Therefore, an effective system of social protection must be created for this group of the population.

20. Energy prices can (and must) contribute to decreasing the negative environmental impacts of the energy system. The problem is to supply the internal market with affordable, energy efficient and environmentally sound technologies that energy consumers might purchase.

21. It is necessary to create workable and attractive financial incentives for energy conservation and environmental protection activities.

22. The legislative base in fuel exploration and extraction, energy conservation and environmental protection should be substantially improved.

23. If the targets identified by the country's Energy Strategy are achieved, the level of sustainability of the energy will be significantly increased.

24. In order to identify the real level of sustainability in energy development, inter-country comparative analyses utilizing ISED (quantitative and qualitative) should be conducted. The countries which participated in this research project would be a good starting point for comparison.

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ANNEX 7.1. RUSSIA'S FUEL AND ENERGY BALANCE IN 1992-2001 (MTOE)

	Years	Coal	Crude oil	Petroleum Products	Gas	Nuclear	Hydro	Geothermal, Solar, etc.	CRW	Electricity	Heat	Total
Production	1992	143.924	398.841		517.166	31.523	14.778	0.025	12.449			1,118.707
	1993	135.066	353.254		498.934	31.418	14.912	0.024	11.797			1,045.406
	1994	123.347	317.347		490.058	25.859	15.048	0.027	8.41			980.096
	1995	117.049	306.633		480.414	26.249	15.085	0.026	8.505			953.96
	1996	112.126	300.996		485.384	28.768	13.186	0.024	6.873			947.356
	1997	106.636	305.405		460.75	28.613	13.466	0.025	6.766			921.662
	1998	107.633	302.912		477.018	27.784	13.631	0.026	5.417			928.421
	1999	115.342	304.755		477.097	32.119	13.802	0.024	7.447			950.587
	2000	117.02	323.3		470.605	34.419	14.111	0.05	7.008			966.512
	2001	122.123	347.57		468.637	36.05	14.955	0.078	6.747			996.161
Net imports/ exports	1992	-1.396	-132.414	-41.375	-152.09					-1.397		-328.667
	1993	0.623	-117.842	-40.359	-132.78					-1.611		-291.972
	1994	1.362	-122.506	-42.91	-147.31					-1.763		-313.128
	1995	-3.284	-114.401	-43.522	-151.07					-1.686		-313.96
	1996	3.786	-120.311	-51.791	-155.86					-1.676		-333.419
	1997	-2.715	-123.499	-52.045	-158.59				-0.329	-1.693		-338.871
	1998	-2.599	-132.319	-47.286	-161.84					-1.549		-345.595
	1999	-8.468	-130.561	-47.804	-162.51					-1.218		-350.564
	2000	-7.714	-139.2	-53.647	-146.03					-1.209		-347.808
	2001	-9.254	-157.775	-56.217	-142.72					-1.364		-367.336
Stock changes	1992	-10.295	-4.033	----	-0.889				----			-15.217
	1993	-2.282	0.862	4.495	-10.276				0.037			-7.164
	1994	0.695	-2.171	0.969	-15.186				0.25			-15.443
	1995	2.902	-2.899	1.172	-12.801				0.0.31			-11.595
	1996	10.555	1.333	2.004	-11.299				0.06			2.653

	1997	2.77	-0.077	0.258	9.316				0.092			12.359
	1998	1.643	-0.257	1.09	-4.303				0.388			-1.439
	1999	2.209	0.921	-0.083	-0.112				0.072			3.009
	2000	1.508	-0.236	-0.22	-5.664				-0.111			-4.722
	2001	-6.284	-.913	0.305	-0.69				0.106			-7.476
Total primary energy supply	1992	132.233	262.395	-41.375	364.192	31.523	14.778	0.025	12.449	-1.397		774.823
	1993	133.407	236.275	-35.865	355.875	31.418	14.912	0.024	11.834	-1.611		746.27
	1994	125.405	192.67	-41.94	327.559	25.859	15.048	0.027	8.660	-1.763		651.524
	1995	116.668	189.332	-42.35	316.545	26.249	15.085	0.026	8.535	-1.686		628.404
	1996	118.895	182.017	-49.786	318.228	28.768	13.186	0.024	6.933	-1.676		616.589
	1997	106.691	181.827	-51.786	311.476	28.613	13.466	0.025	6.529	-1.693		595.15
	1998	100.676	170.335	-46.197	310.874	27.784	13.631	0.026	5.805	-1.549		581.386
	1999	109.082	175.116	-47.887	314.473	32.1119	13.802	0.024	7.519	-1.218		603.031
	2000	110.815	183.85	-53.867	318.916	34.419	14.111	0.05	6.897	-1.209		613.981
	2001	106.585	188.881	-55.913	325.222	36.05	14.955	0.078	6.853	-1.364		621.349
Statistical differences	1992	4.273	3.429	-2.370	1.233							6.565
	1993	3.197	-0.535	-5.027	12.177							9.752
	1994	-1.669	-1.346	-2.238	12.888							7.635
	1995	8.987	-2.634	-4.008	6.528							8.874
	1996	5.493	-1.545	1.191	1.425							6.564
	1997	0.668	-2.545	-0.657	3.864							-6.397
	1998	3.945	-0.898	0	0							3.047
	1999	2.452	0	-0.079	2.450							4.823
	2000	0.001	0	-	2.455							2.456
	2001	2.457	0	-1.823	2.503							3.137
Heat and electricity	1992	-86.222	-1.224	-58.012	-217.51	-31.523	-14.778	-0.025	-4.337	86.728	207.756	-119.147

production by CHP. Electric and heat plants	1993	-87.449	-1.501	-55.812	-213.466	-31.418	-14.912	-0.024	-3.468	83.191	226.062	-99.801
	1994	-84.356	-0.382	-46.132	-201.837	-25.859	-15.048	-0.027	-3.56	76.239	206.118	-95.843
	1995	-80.917	-0.392	-37.741	-189.986	-26.249	-15.085	-0.026	-4.042	73.876	192.301	-88.259
	1996	-84.965	-0.599	-35.843	-189.31	-28.768	-13.186	-0.024	-2.993	72.77	160.194	-122.725
	1997	-75.759	-1.0	-29.872	-186.01	-28.613	-13.466	-0.025	-3.0	71.654	152.837	-113.256
	1998	-72.588	-1.055	-32.966	-182.128	-27.784	-13.631	-0.026	-2.999	71.052	151.575	-110.547
	1999	-76.022	-1.0	-26.439	-185.56	-32.119	-13.802	-0.024	-3.725	72.7	151.228	-114.767
	2000	-79.903	-1.066	-22.273	-186.361	-34.419	-14.111	-0.5	-3.764	75.376	154.905	-111.625
	2001	-78.64	-1.046	-21.369	-189.691	-36.05	-14.955	-0.078	-3.956	76.482	153.502	-115.8
Distribution losses	1992	-8.74	-2.492	-0.311	-5.891					-7.232	N.a	-24.667
	1993	-7.879	-1.766	-0.029	-5.932					-7.543	-7.061	-30.21
	1994	-6.645	-1.587	-0.023	-6.543					-7.348	-6.553	-28.669
	1995	-6.152	-0.719	N.a	-6.385					-7.179	-5.731	-26.166
	1996	-5.661	-1.116	N.a	-6.681					-7.263	-5.098	-25.819
	1997	-4.211	-1.281	N.a	-5.375					-7.257	-4.891	-23.015
	1998	-3.964	-1.623	N.a	-5.817					-8.018	-4.772	-24.194
	1999	-4.516	-1.710	N.a	-5.862					-8.27	-4.137	-24.45
	2000	-1.072	-1.607	N.a	-5.532					-8.741	-7.745	-24.698
	2001	-0.174	-1.738	N.a	-5.017					-9.072	-6.415	-22.416
Total final consumption	1992	29.631	0.187	140.018	135.885				8.035	65.047	207.756	586.559
	1993	30.367	0.169	119.28	141.787				8.316	60.696	204.459	565.074
	1994	24.005	0.163	92.248	124.391				5.091	54.635	185.101	485.634
	1995	27.663	0.181	83.371	118.117				4.45	53.176	171.893	464.851
	1996	22.648	0.222	84.061	114.060				3.903	51.701	142.645	419.24
	1997	18.343	0.39	83.503	108.72				3.524	50.73	136.477	401.686
	1998	17.826	0.402	74.989	111.839				2.76	49.753	135.579	393.148
	1999	19.634	0.541	82.775	114.543				3.751	50.965	136.251	408.459

	2000	20.691	0.845	91.714	117.14				3.051	52.333	136.774	422.548
	2001	21.226	0.622	93.193	119.739				2.83	53.151	136.697	427.458
Total industry sector	1992	13.38	0.026	24.61	52.162				0.879	36.047	N.a	127.14
	1993	13.589	0.05	22.254	48.204				0.485	32.373	98.337	215.293
	1994	12.086	0.024	12.668	37.977				0.388	27.38	79.398	169.921
	1995	16.452	0.038	10.293	39.739				0.542	27.005	73.3	167.369
	1996	14.412	0.038	9.743	37.686				0.384	25.293	56.111	143.668
	1997	10.522	0.067	12.312	38.952				0.385	25.075	52.14	139.453
	1998	10.512	0.041	9.284	35.602				0.525	24.35	48.818	129.133
	1999	10.702	0.043	10.546	37.631				0.71	25.46	50.101	135.192
	2000	10.472	0.045	19.043	42.751				0.59	26.867	50.271	150.038
	2001	10.456	0.021	15.916	43.489				0.451	27.657	50.448	148.438
Iron and steel	1992	10.393		2.272	14.963				N.a	5.948	N.a	33.576
	1993	9.97		0.436	14.088				N.a	5.439	9.588	39.521
	1994	8.964		0.339	12.852				N.a	4.901	7.74	34.796
	1995	13.408		0.37	12.655				N.a	4.697	7.441	38.570
	1996	11.717		0.992	11.571				N.a	4.778	6.276	35.333
	1997	9.038		1.193	10.579				N.a	4.826	5.941	31.577
	1998	8.623		0.919	9.673				0.002	4.673	5.879	29.769
	1999	8.242		1.007	10.657				0.002	5.03	5.841	30.778
	2000	7.93		1.055	11.748				0.135	5.422	5.812	32.101
	2001	7.379		1.024	11.987				0.14	5.477	5.827	31.834
Chemical and Petrochemical	1992	0.338		10.461	31.232					6.02	N.a	48.051
	1993	0.32		10.701	29.224					5.115	22.087	67.446
	1994	0.316		5.12	20.508					4.025	17.837	47.806
	1995	0.338		2.642	17.302					3.715	17.473	41.471

	1996	0.312		2.403	14.976					3.522	13.354	34.566
	1997	0.157		2.59	17.407					3.589	12.857	36.6
	1998	0.186		2.852	15.981					3.417	11.699	34.136
	1999	0.222		2.842	16.698					3.554	12.43	35.746
	2000	0.047		11.689	19.379					3.65	13.393	48.158
	2001	0.237		9.592	19.606					3.729	13.332	46.496
Non-ferrous metals	1992	0.855	N.a	0.848	1.551				N.a	8.507	N.a	11.761
	1993	0.928	N.a	0.61	1.568				N.a	8.223	7.011	18.34
	1994	0.773	0.001	0.487	1.585				N.a	7.529	5.663	16.039
	1995	0.855	0.002	0.52	1.603				N.a	7.273	5.406	15.659
	1996	0.766	0.005	1.044	1.621				N.a	7.904	4.489	15.829
	1997	0.415	0.009	1.208	1.639				N.a	8.083	4.215	15.569
	1998	0.727	0.003	1.138	1.657				0.002	7.973	4.22	15.72
	1999	1.142	0.002	1.963	1.951				0.001	8.18	4.265	17.504
	2000	1.389	0.002	1.838	1.865				0.025	8.567	4.391	18.077
	2001	1.626	0.002	1.213	1.96				0.006	8.928	4.937	18.672
Machinery	1992	0.686	0.004	1.129	1.18					7.029	N.a	10.028
	1993	0.894	0.003	0.667	1.021					6.021	22.883	31.49
	1994	0.861	0.003	0.418	0.932					4.764	18.475	25.452
	1995	0.816	0.005	0.395	0.786					5.733	15.773	23.507
	1996	0.656	0.005	0.488	1.595					3.815	12.58	19.14
	1997	0.333	0.009	0.555	1.697					3.74	11.422	17.739
	1998	0.238	0.003	0.402	1.576				0.006	3.534	10.397	16.156
	1999	0.244	0.002	0.393	1.683				0.004	3.655	9.713	15.693
	2000	0.307	N.a	0.424	2.345				0.005	3.795	9.186	10.061
	2001	0.329	N.a	0.379	2.424				0.004	3.888	9.214	16.237

Total transport sector	1992		0.035	75.699	33.943					7.463		117.141
	1993		0.03	57.677	32.801					5.784		96.256
	1994		0.013	50.386	31.533					5.65		87.582
	1995		0.01	46.878	29.36					5.604		81.852
	1996		0.09	43.995	28.55					5.584		78.139
	1997		0.016	42.459	24.153					5.458		72.085
	1998		0.012	46.778	30.931					5.163		82.885
	1999		0.011	47.605	30.726					5.213		83.555
	2000		0.011	47.77	26.932					5.239		79.951
	2001		0.006	50.066	27.082					5.344		82.498
Air transport	1992			15.017								15.017
	1993			12.729								12.729
	1994			10.601								10.601
	1995			9.874								9.874
	1996			9.232								9.232
	1997			9.139								9.139
	1998			8.576								8.576
	1999			8.865								8.865
	2000			9.32								9.32
	2001			9.586								9.586
Road transport	1992			49.266	1.051							50.317
	1993			39.428	0.583							40.01
	1994			35.833	0.79							36.622
	1995			32.849	0.322							33.171
	1996			30.643	0.222							30.865
	1997			30.25	0.186							30.436

	1998			35.478	0.18							35.658
	1999			35.523	0.174							35.697
	2000			34.913	0.81							34.994
	2001			37.137	0.26							37.164
Rail transport	1992			4.572						N.a		4.572
	1993			3.871						3.353		7.225
	1994			2.35						2.758		5.108
	1995			2.208						2.701		4.909
	1996			2.233						2.625		4.859
	1997			1.862						2.619		4.481
	1998			1.573						2.342		3.914
	1999			1.727						2.602		4.329
	2000			2.136						2.856		4.993
	2001			1.807						2.975		4.782
Pipeline transport	1992		0.035		32.893					2.441		35.369
	1993		0.03		32.218					1.945		34.193
	1994		0.013		30.743					1.712		32.468
	1995		0.001		29.038					1.557		30.605
	1996		0.009		28..328					1.625		29.962
	1997		0.016		29.966					1.482		25.464
	1998		0.012	0.031	30.755					1.536		32.334
	1999		0.01	0.058	30.551					1.503		32.122
	2000		0.01	0.027	26.851					1.96		28.847
	2001		0.006	0.028	27.056					1.508		28.598
Internal navigation	1992			2.496								2.496
	1993			2.099								2.099
	1994			1.602								1.602

	1995			1.231								1.231
	1996			1.192								1.192
	1997			1.07								1.07
	1998			0.96								0.96
	1999			1.019								1.019
	2000			1.17								1.17
	2001			1.228								1.228
Agriculture	1992	0.435		11.587	0.488				0.73	6.009	N.a	19.248
	1993	0.417		9.384	0.576				0.468	5.951	7.866	24.662
	1994	0.374		9.551	0.634				0.032	5.284	8.819	24.692
	1995	0.344		10.431	0.636				0.461	4.561	7.938	24.371
	1996	0.329		7.002	0.639				0.359	4.189	6.049	18.566
	1997	0.313		6.906	0.643				0.131	3.62	5.328	17.122
	1998	0.296	0.013	5.85	0.599				0.04	3.299	4.905	15.002
	1999	0.292	0.015	5.881	0.645				0.19	2.95	4.546	14.519
	2000	0.252	0.001	5.904	0.506				0.148	2.598	4.325	13.734
	2001	0.256	0.011	5.917	0.422				0.145	2.187	4.021	12.977
Commercial and public services	1992	5.257		0.334	7.795				0.654	5.572	N.a	19.612
	1993	0.358		0.321	6.416				2.527	5.353	13.203	28.178
	1994	0.873		0.356	5.281				0.684	5.249	17.927	30.37
	1995	0.802		0.375	4.346				0.42	5.164	14.345	25.453
	1996	0.648		0.304	3.577				0.322	5.281	14.414	24.546
	1997	0.683		0.179	2.945				0.264	5.141	13.053	22.264
	1998	0.741		0.249	2.424				0.125	5.367	15.586	24.492
	1999	0.905		0.956	2.452				0.209	5.94	16.163	25.978
	2000	0.370		1.016	2.455				0.018	5.527	13.262	22.648
	2001	0.34		1.051	2.503				0.014	5.705	10.201	19.814

Residential sector	1992	9.49	0.089	8.555	40.612				5.67	9.957	N.a	74.372
	1993	9.106	0.088	8.271	52.935				4.257	10.42	85.053	170.13
	1994	8.271	0.126	6.031	48.234				3.881	10.84	78.956	156.243
	1995	7.623	0.133	5.305	42.234				2.993	10.842	76.311	146.441
	1996	7.175	0.175	4.511	42.833				2.788	11.353	66.071	134.907
	1997	6.784	0.307	5.33	41.28				2.53	11.435	65.957	133.623
	1998	6.277	0.336	3.468	41.559				2.071	11.573	66.269	131.553
	1999	7.735	0.472	5.226	42.333				2.643	12.048	65.440	135.898
	2000	8.512	0.722	4.438	43.111				2.091	12.102	68.916	139.892
	2001	9.013	0.506	4.672	45.416				2.012	12.258	72.028	145.905

Source: OECD/IEA (2003)

8. SLOVAKIA

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Profing spol. s r.o.

8.1. Introduction

Since 1999, the International Atomic Energy Agency (IAEA) has been engaged in a cooperative project with the UN Department of Economic and Social Affairs (UNDESA) and other international research organizations to formulate a set of comprehensive indicators for sustainable energy development (ISED) and to implement and test them in a number of countries (IAEA/IEA, 2003).

8.1.1. Slovakian Case study

Slovakia is one of seven countries that participated in a three-year coordinated research project (CRP) conducted by the IAEA, and set out to define, test and implement the ISED set. Slovakia's participation has at least one unique attribute –Slovakia is a new European Union (EU) member and experienced a process of economic transformation which accompanied the EU accession. Therefore an analysis of recent development using the selected indicators can provide relevant information about this economic transformation of the whole economy and EU accession process, as well as a basis for additional energy and environmental policy formulation.

This chapter summarizes the main findings of the review process carried out in Slovakia under the IAEA project entitled: *"Historical Evolution of Indicators of Sustainable Energy Development (ISED) and the Use of this Information for Designing Guidelines for Future Energy Strategies in Conformity with the Objectives of Sustainable Development"*. Detailed analyses have focused primarily on the following issues:

- Identification of national energy policy priority areas.
- Review of the energy statistical data capability of the country, identification of data relevant to the priority issues, and determination of additional indicators that could be collected and recorded in the future.
- Compilation of data (including time series) needed to develop relevant ISED specific information for priority issues.
- Priority area and relevant ISED trend analyses, and historical data.
- Recommendations related to the main issues, and relevant ISED to improve development of national energy and environmental policies.

8.1.2. Approach and Scope of the Study

The Slovakian case study was conducted during the 2002-2005 period. This final report reflects the situation and national energy priorities at the time of its preparation (i.e., the time when the EU accession process was ending). In the year 2004, Slovakia became a member of the EU, and in that same year a new proposal of Energy Policy (Ministry of Economy of Slovakia (MES), 2004) was prepared by the Ministry of Economy, just at the time this final report was being prepared. Therefore, previous progress reports had to be rewritten in order to reflect as far as possible new issues included in this final version. Nonetheless, the main objectives of the material did not differ substantially, and the main difference lay in the fact that the EU accession process was finalised.

Data collected for this study are the result of a close co-operation of the research team with the Slovak government representatives, namely from the Ministry of Economy, the Ministry of Environment, the Hydrometeorological Institute and also from the Statistical Office of Slovakia.

8.2. Overview of the Energy Sector

The total energy balance can be roughly split into the following energy chains, moving from primary energy sources through final energy use (Statistical Office of Slovakia (SOS), 2005):

- Primary energy sources, including indigenous fuels and energy imports;
- Conversion of primary fuels, including oil refinery and coke and coal derived gas production;
- Generation of energy carriers, including electricity and heat;
- Final energy uses in industrial, commercial, services, and residential sectors.

The energy balance for Slovakia is presented in ANNEX 1.

8.2.1. Primary energy sources

Lignite and hydropower represent the only domestic energy resources to any considerable extent. Slovakia is very dependent on imported energy, and the country has a very low degree of energy source diversification. Slovakia imports 90% of its basic energy requirements (if the basic nuclear fuel is included). Almost all the imported resources come from Russia while the rest is satisfied with imports from the Czech Republic, Poland and Ukraine. Domestic sources cover only 10% of PES – 3% from hydro, 6% from lignite and 1% from natural gas and oil. Data in Table 8.1 shows the primary energy supply for Slovakia for 2000.

TABLE 8.1 BALANCE OF TOTAL PRIMARY ENERGY SUPPLY (TPES), 2000 (TJ)

	Solid [1]	Liquid	Gaseous	Fuel total	Heat [2]	Electricity [3]	Total
Domestic	45,600	2,436	5,620	53,656	211,523	18,101	283,280
Import	145,321	231,362	242,613	619,296	0	3,424	622,720
Export	1,709	119,599	23	121,331	0	13,129	134,460
Stockpile change	-6,890	3,659	-18,215	-21,446	-	-	-21,446
Other sources	-675	2,851	15,479	17,655	0	0	17,655
TPES in total	181,647	120,709	245,474	547,830	211,523	8,396	767,749

1 Biomass is included in solid fuels

2 Nuclear primary heat released in primary circuit of nuclear power plant

3 Domestic sources represent electricity generated in hydropower and nuclear plants

8.2.2. Conversion of primary fuels

There are two crude oil refineries operating in Slovakia, one large and one very small. The Slovnaft, a.s., refinery in Bratislava is the only major one in Slovakia. It processes imported crude oil and produces motor fuels, fuel oils, lubricants and petrochemical products (plastics). The second one, a small refinery unit, is Petrochema's Dubová plant, which processes domestic low-sulphur crude oil of higher quality to produce medical oils and similar, high quality products. Motor and heating fuels are by-products. Technology for deep crude oil processing was installed in Slovnaft, a.s. in past years to increase the share of light products (gasoline, diesel) and decrease the share of heavy fuel oils.

The other process for fuel conversion is applied in a steel mill in the US Steel, a.s. facility at Košice. Coking coal is converted into coke and coking gases. Other gases are generated in the blast furnace

and converter, and all of these gases are used for heating in technology applications as well as in industrial combined heat and power (CHP).

8.2.3. Heat and electricity production

8.2.3.1. Public Power plants

The former Slovak electricity system consisted of four public utilities, which were the dominant producers and suppliers, and also a small number of independent power producers (in the industrial sector or some small hydropower producers). This public system included the electricity generation and transmission company Slovenské elektrárne, a.s. (SE) and three regional distribution companies that mainly supplied electricity (and heat) to the end-user.

The three regional distribution companies were privatised in 2001 into:

- Západoslovenská energetika, a.s. (west) – owned 49% by Deutsche E.ON Energie;
- Stredoslovenská energetika, a.s. (central) – owned 49% by Electricité de France;
- Východoslovenská energetika, a.s.(east) – owned 49% by Deutsche RWE Plus.

The Západoslovenská energetika, a.s and Stredoslovenská energetika, a.s. have their own CHP facilities, generating 2% of the total electricity.

SE owned and operated 86% of the installed capacity of power plants in Slovakia and produced 76% of the domestic supplies. The company was split in 2002 into a generation part and an electricity transmission part as follows:

- Slovenské elektrárne, a.s. – which owns 90% of the property from the previous SE, (nuclear, thermal and large scale hydro power plants), and is now privatized and owned by the company ENEL of Italy).
- Slovenská elektrizačná prenosová sústava, a.s. (Slovak electricity transmission system, a.s.) – which owns the transmission network (220 and 400 kV), transformer stations and the central dispatch centre in Žilina.
- Tepláreň Košice, a.s. – CHP to supply electricity and heat.

The SE owns and operates the following power plants:

1. The nuclear power plants (NPP) JEV1 and JEV2 located in Jaslovské Bohunice 70 km northwest of Bratislava. Each plant has two units with an installed capacity of 2 x 440 MWe (VVER type), for a total of 1,760 MWe. The old units in JEV1 were planned to be retired in 2006 and 2008, respectively, according to the Resolution of Slovakian Government No. 801/1999. The other nuclear power plant, JEV2, is located in Mochovce. Two units each of 440 MWe (VVER type) were put into operation in 2000, and two other units of the same capacity are currently about 60% completed. The future of these two units is not clear now, and will strongly depend upon both the transformation and privatisation processes, as well as on the developments following EU accession.

2. The thermal power plant ENO. This power plant uses domestic coal and is located in Zemianske Kostoľany (in the upper Nitra valley), close to the underground lignite mines. Currently the following units are installed:

- 2 x 110 MWe units with dry bottom boilers equipped with flue gas desulphurization (FGD)/wet scrubber technology;
- 2x 110 MWe units with dry bottom boilers without FGD, that do not comply with adopted environmental legislation (SO_2 stack concentration limit); their retirement by 2006 was under consideration;

- ENO A units, 28 + 32 MWe with dry bottom boiler without FGD, and 24.4 MWe with fluidized bed combustion boiler. The power plant supplies electricity as well as heat for the industrial and residential sectors.

3. The thermal power plant EVO1. This power plant has an installed capacity of 6 x 110 MWe, burning hard coal in wet bottom boilers. Two boilers were retrofitted with FGD, two others were repowered with fluidized bed combustion boilers, and the other two without FGD will be retired.

4. The thermal power plant EVO 2. This power plant has installed capacity of 6 x 110 MWe units with combustion of natural gas (NG) and/or heavy fuel oils. It covers the peak demand together with pumped storage hydropower plants (HPP).

5. The hydropower plant Gabčíkovo. On the Danube river, this has a total capacity of 746.5 MWe.

6. The hydropower plant Trenčin. Based on a dam cascade on the Váh river, it has a total capacity of 1,649 MW including pumped storage.

7. The hydropower plant Dobšiná. It has total capacity of 141 MWe including pumped storage.

8.2.3.2. Public CHP

Three regional distribution companies are responsible for about 2 % of the total electricity production, but their main role is to distribute and supply electricity and heat on a regional level. They own and operate the transmission lines of less than 220 kV and the local distribution networks. The CHP and heat plants (HP) in the cities of Bratislava and Trnava are fuelled by NG; CHP and HP in middle Slovakia (Žilina, Zvolen, Martin) are fuelled by a fuel mix of brown coal (lignite) and NG. The new established plant in Košice is fuelled by a fuel mix of hard coal and NG.

8.2.3.3. Local Heating Plants

District heat supply is assured from the boiler houses located in city districts close to the heat consumers. District heat is supplied for consumers in the residential, industrial, commercial and service sectors. In some cities, an integrated hot water supply system was built, and heat could be supplied from local heating plants (HP) and public and industrial CHP. In recent years, some consumers in the commercial and industrial sectors have shut down these connections and built their own heat sources. The aim of national policy is to sustain the share of district heat supplied by existing distribution networks.

The local HP typically use coal, biomass, oil and gas as fuel. Due to adopted environmental legislation for air quality protection, the share of NG has significantly increased since 1990.

8.2.4. Final energy uses

Table 8.2 outlines figures on final energy consumption by individual sectors in the year 2000.

TABLE 8.2 FINAL ENERGY CONSUMPTION BY SECTORS IN 2000 [TJ]

	Solid[1]	Liquid	Gaseous	Heat	Electricity
Forestry	61	704	114	101	138
Agriculture	346	5,825	2,034	2,120	2,585
Industry	47,411	8,597	87,338	36,356	100,046
Construction	82	2,800	1,398	479	873
Transport	801	8,792	396	3,474	4,553
Residential	2,066	15,330	60,814	19,508	35,759
Other	8,509	24,149	20,371	18,967	30,256
Final energy cons. in total	59,276	66,197	172,465	81,005	174,210

1 Biomass is included in solid fuels

8.3. Review of energy statistical data capability

Officially established institutions in Slovakia collect and provide data within a strictly defined legal framework. There are a wide range of activities, starting with data collection and recording; this is followed by reporting for official domestic and international statistics. These tasks can also be extended for other pre-defined purposes (e.g., estimating charges for air pollution, wastes, etc.). With regards to input data for ISED, the most important institutions were the Statistical Office of Slovakia and the Hydrometeorological Institute.

8.3.1. Statistical Office of Slovakia

The Statistical Office of the Slovakia performs statistical analyses to determine the demographic, economic and social developments in the country. The inputs are determined by the actual legislation framework, while outputs are issued periodically and presented primarily at four levels:

- basic indicators for long-term development;
- detailed indicators for short-term periods (i.e., from 1 to 5 years);
- brief indicators in regional classification mode;
- comparison of national and international data.

The Statistical Yearbook (SOS, 1995-2003) and Energy Statistics (SOS, 2005), published by this institute were the principal sources of ISED data for this study. Both of these were harmonised with EU and other international methodologies. The Statistical Office cooperates with EUROSTAT and other EU and international bodies, and also periodically issues other time series of specific selections of available data – for example, selected indicators of economic development, data on individual industries, etc. (SOS, 2002a), (SOS, 1997-2001).

The Statistical Office of Slovakia is the authority officially organizing and performing annual statistical analyses, and issuing related findings. The reporting duty to fill out statistical forms is issued by Act No. 322/1992 Coll. 27 on National Statistics, as amended. According to this Act, statistical determinations are also performed by relevant ministries and other central offices of the state administration. These determinations are advised by the Statistical Office as well, and regularly become integrated into the programme of state statistical findings.

8.3.2. Slovak Hydrometeorological Institute

The Slovak Hydrometeorological Institute ensures collection, recording and reporting of environmental data. Among others, it operates the database of individual sources of air pollution used for yearly balanced inventories of basic pollutants and greenhouse gas emissions. These data are covered by the National Emission Inventory System (NEIS) that covers not only emission data but also data addressing fuel consumption, thermal capacities of energy sources, etc. (MENV, 2000-2003). One new activity that is connected with environmental concerns is the National Allocation Plan for selected GHG emission sources, participating in the EU carbon dioxide emission trading scheme.

8.3.3. Other data sources

Other sources of data for ISED included the Ministry of Transport and Telecommunication, electric and gas utilities, the Energy Agency, and consultant offices in energy, environment and civil engineering fields. All of these data were also utilized in a previous national study of energy efficiency (World Bank/MES, 2002).

8.4. Implementation of ISED framework

The process of transition of the type of economy in Slovakia (similar to that in other Economies in Transition), does not allow the collection of a long time series of historical data, nor to use such time series as basis for energy development analyses under ISED. The situation in Slovakia is also complicated by the fact that it only became an independent country in 1993. This fact, together with ongoing changes of methodology in collecting and reporting statistical data, have had a negative impact on the availability of data over the entire period being considered. Energy Statistics (SOS, 2005) providing specific national energy data was first issued in 1997. Annually issued Statistical Yearbooks are continuously adjusted and updated for previous years due to the harmonisation of methodologies with the EU approaches. Another important concern arises from the fact that data are not expressed in the form or detail required for ISED calculation purposes.

A time series of selected ISED data have been developed for the period 1993–2000, with some additional data for 2002. This period begins in the year when Slovakia became an independent state. However, even for this relatively short period, data for the indicators have not always been available in consistent series. Statistical measures have been changed during the whole economic activity period. For example, the issuing of Energy Statistics in detail only started in 1997, and regularly issued Statistical Yearbooks have not covered all areas of interest in time series and/or in the type of data necessary for ISED. In order to obtain a full time series, some missing data have been extrapolated.

8.4.1. ISED implemented in the Slovakian case study

According to the IAEA methodology, the ISED considers four dimensions: social, environmental, economic and institutional.

Data were structured according to the framework proposed by the IAEA, and the total ISED time series for the 1993-2002 period are summarized in ANNEX B. Table 8.3 provides a summary of ISED that were fully or partly elaborated using available data for Slovakia.

TABLE 8.3 LIST OF ISED INDICATORS WITH ECONOMIC AND ENVIRONMENTAL DIMENSIONS

Indirect driving force	
ISED #1	Population
ISED #2	GDP per capita
ISED #3	End-use energy prices with and without tax/subsidy
ISED #4	Shares of sectors in GDP value added
ISED #5	Distance travelled per capita by passengers
ISED #6	Freight transport activity
ISED #7	Floor area per capita
ISED #8	Manufacturing value added by selected energy intensive industries
Indirect driving force within energy sector	
ISED #9	Energy intensities
ISED #10	Final energy intensity of production
ISED #11	Energy mix
ISED #12	Energy supply efficiency
ISED #13	Status of deployment of pollution abatement technologies
Direct driving force within energy sector	
ISED #14	Energy use per unit of GDP
State ISED	

ISED #16	Energy consumption per capita
ISED #17	Indigenous energy production
ISED #18	Energy net imports dependency
Direct driving force	
ISED #23	Quantities of air pollutant emissions
ISED #26	Quantities of greenhouse gas emissions from energy related activities
ISED #27	Radionuclides in atmospheric radioactive discharges
ISED #28	Discharges into water basin associated with energy activity
State ISED	
ISED #24	Ambient concentration of pollutants in urban areas
ISED #31	Generation of radioactive waste from fuel cycle chains of nuclear power generation
ISED #34	Fatalities due to accidents

8.4.2. Social dimension

Two main indicators of the social dimension are: energy disparities, and energy affordability and accessibility. These parameters are not critical in Slovakia's case, since there is a high degree of accessibility, and even small villages are fully connected to the electricity grid. The share of availability for the supply of natural gas increased in 2004 to more than 80% of all inhabitants. The social situation resulting from the relationship between energy prices and incomes does not appear to be critical, even though during the ongoing process of economic reforms subsidies for heat and electricity have already been fully removed and higher tariffs have been implemented (including in the residential sector, for gas and electricity prices).

As a specific critical social issue within Slovakia, the impact of the on-going economic transformation process, together with the impact of new environmental requirements on employment rates in the mining sector, have to be considered.

8.4.3. Environmental dimension

To evaluate the environmental dimension of sustainability according to the IAEA methodology, the following issues were addressed:

- Global climate change
- Air pollution
- Water pollution
- Wastes
- Energy resource depletion
- Land use
- Accident risks
- Deforestation

In view of impacts on the energy sector, global climate issues as well as air pollution by basic pollutant within regional, national and EU-region impacts must be considered.

8.4.3.1. Global climate change

The energy system is responsible for the bulk of GHG emissions in Slovakia, in that the energy related CO_2 emissions represent more than 80% of the total GHG balance. Slovakia ratified both the UNFCCC and the Kyoto Protocol (MENV, 1999), (Transport Research Institute, 2000). According to actual data of annual GHG emissions and their projections, Slovakia has a chance to participate within the GHG emission trading framework of the Kyoto Protocol's flexibility mechanisms and the EU emissions trading scheme (ETS). Both the Joint Implementation (JI) and the ETS can bring additional financial resources needed for a broader updating of existing equipment, and/or implementation of brand new energy conversion technologies.

8.4.3.2. Air pollution

The total amount of basic pollutant emissions from energy and industrial sources decreased during the period of economic transformation. It was primarily due to the impact of restructuring in industry, accompanied by a decrease in energy demand. It was also due to adopted environmental legislation, which directly motivates sources to implement abatement technologies. On-going adjustments of the Air Protection Act as well as harmonization of the existing environmental legislation framework with the EU will bring further decreases in levels of pollution. Specific applications of air quality legislation in Slovakia include emission quotas and trading for SO_2 emissions (already adopted), as well as a scheme for a CO_2 cap and trading system that is under development now. Slovakia should be able to benefit from the practical emissions trading experiences gained directly at the stakeholder level in potential international trading schemes, too.

8.4.4. Economic dimension

To qualify and quantify the economic dimension of sustainability, the following themes were considered:

- Economic activity levels
- Energy production, supply and consumption
- Energy pricing, taxation and subsidies
- End-use energy intensities
- Energy supply efficiency
- Energy security

8.4.5. Main problems implementing ISED in Slovakia

In order to utilize ISED for sustainable energy development a long time series of indicators is preferred. In such a case, consistent statistical input data should be available. The methodology of data collection and handling should not be dramatically changed during the period under consideration. Unfortunately, this is not the case for countries with Economies in Transition. Slovakia was established in 1993, and the methodology of data collection and processing has been changing due to both the period of transformation and the EU accession process. Therefore, the complete time series need for the implementation of the ISED was not available, and "jumps" can be observed in some of the available time series. These were caused mainly by the following issues:

- The process of privatization brought about changes in the classification of economic entities in economic sectors and industrial branches. It also caused some inconsistent changes in value added (VA) structures.
- The methodology for energy statistics changed in the year 2002, and reported energy data for the years 2001 and 2002 are based on the new methodology.

8.5. Identification of major energy priority areas and its relation to applied ISED

The 2000 issue of Energy Policy of Slovakia (MES, 2000) was used as the basis for the selection of major energy priorities. This document defined priorities at a relatively general level reflecting the main political targets of economic transformation and the EU accession process. The main objectives defined in the 2000 Energy Policy were:

- preparation of integration into the European Union internal market;
- security of energy supply;
- sustainable development.

The latest proposal of Energy Policy (IEA, 2005), (MES, 2004), which was issued in December 2004, strictly defined the following priorities of future energy policy:

Priority 1: Reliable, environmentally acceptable and economically effective energy supply

Priority 2: Involvement in international electricity and gas markets

Priority 3: Lower dependency on fossil fuel imports

Comparing the priorities selected on the basis of the previous Energy Policy issue and the most recent Energy Policy proposal, the same set of ISED with economic and environmental dimensions can be applied. The main differences between the last Energy Policy and its new proposal lies in the fact that, in year 2004, Slovakia became a member of the EU and all accession processes are now finalised. Nevertheless, the time series for ISED can illustrate the impact of economic transformation and the EU accession process on the energy sector, as well as make clear whether Slovakia is prepared to achieve the priorities defined by the new Energy Policy proposal.

Considering the objectives of the previous Energy Policy as well as the defined priorities of the new Energy Policy proposal, the following issues were analysed, using the ISED time series:

ISED related to the EU accession process

- Macroeconomic indicators
- Final energy prices
- Share of sectors for GDP value added
- Value added shares of industrial branches

ISED related to security of energy supply.

This issue is consistent with priority No. 3 of the new Energy Policy proposal - *lower dependency on fossil fuel imports*

ISED related to sustainable development

This issue is consistent with priority No. 1 of the new Energy Policy proposal - *Reliable, environmentally acceptable and economically effective energy supply*

8.5.1. EU accession process

The accession into the European Union, one of the objectives from the previous Energy Policy (MES, 2000), included several measures. It required a restructuring of the energy sector, new principles of regulation in the energy sector, price adjustments, and liberalisation and opening of the market. The main objective for integrating into the European internal market was to transform the energy sector to become a fully competitive sector of the economy, able and prepared to access the European market. From these EU priorities, only the price priority is related to the economic dimension of ISED. The

other priorities are related instead to the institutional dimension, and are not directly covered by ISED. Nevertheless, the impact of restructuring and privatisation of energy companies can be indirectly analysed by macroeconomic indicators used within ISED, such as GDP and its sectoral structure. Given the accession process for entering the EU, the comparison of ISED with other EU countries and/or the EU average is important for analyzing the transition process. Considering the list of ISED, the following were selected as most relevant to analyse the EU accession process:

Macroeconomic data, including population and GDP/capita (ISED # 1 and 2).

End-use energy prices, including automotive fuel, electricity, district heat, natural gas and light fuel oils. (ISED # 3).

Sectoral contribution to GDP (ISED # 4) and VA of manufacturing sectors (ISED # 8).

8.5.1.1. Macroeconomic data

The principal macroeconomic indicators are population and GDP growth rates, which are the driving force of the whole national economy and derived impacts (See Table 8.4).

TABLE 8.4 MACROECONOMIC DATA

ISED #	Indicator	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1.	Population											
1.1.	Total:	Million	5.336	5.356	5.368	5.379	5.388	5.393	5.399	5.403	5.379	5.379
2.	GDP											
2.1.	GDP c.p 95 USD/cap	$/cap	2,593	3,112	3,612	3,991	4,448	4,873	5,258	5,814	6,314	6,712
2.2.	GDP per capita (PPP):	$/cap	8,319	9,910	9,281	10,095	10,703	11,720	13,584	14,197	15,261	15,926

Figure 8.1 illustrates trends of GDP PPP/cap both for Slovakia and EU average (EUROSTAT, 2005) and the Slovakia/EU ratio of this ISED. Analyses of these trends help to assess Slovakia economic growth situation in relation to the EU countries average. While in the beginning of the period under consideration the Slovak GDP_{PPP}/cap curve lies below the $EU_{average}$ one, this trend was changed in 1998. That indicates that economic growth in Slovakia was higher than the EU_{av} after that year.

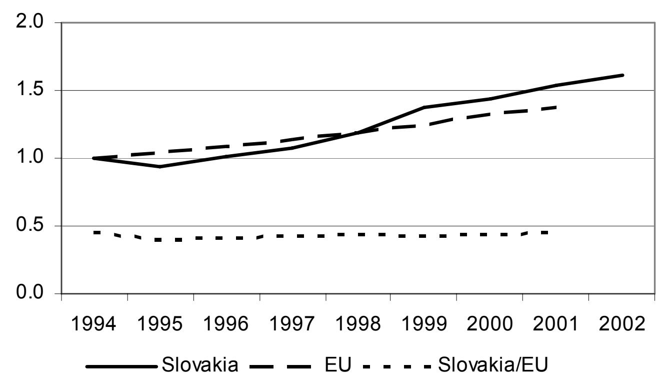


Figure 8.1 Indices of GDP_{PPP}/cap trends for Slovakia and EU $_{average}$ (1994 = 1.0)

8.5.1.2. End-use energy prices with and without tax/subsidy

For analyses of national priorities in connection with the EU accession process, the most important data and development trends concern the following end-use energy carriers:

- Automotive fuels
- Electricity

- District heat
- Natural gas
- Light fuel oil

Automotive fuels

TABLE 8.5 PRICES AND TAXES/SUBSIDIES OF AUTOMOTIVE FUELS (OECD/IEA, 2003)

ISED # 3.1.	Automotive fuel	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
3.1.1.	Leaded gasoline 91											
3.1.1.1	With tax/subsidy	$/1,000 liter	664	671	653	711	742	713	856	1,114	1,057	1,110
3.1.1.2	Without tax/subsidy	$/1,000 liter	257	258	242	289	330	315	379	510	463	424
3.1.2.	Unleaded gasoline 95											
3.1.2.1	With tax/subsidy	$/1,000 liter	647	665	655	702	745	734	910	1,126	1,067	1,012
3.1.2.2	Without tax/subsidy	$/1,000 liter	280	286	272	315	354	332	397	519	471	425
3.1.3.	Automotive gasoline											
3.1.3.1	With tax/subsidy	$/1,000 liter	452	455	474	535	702	706	738	867	838	769
3.1.3.2	Without tax/subsidy	$/1,000 liter	197	200	206	252	317	292	342	462	424	392

Figure 8.2 compares prices of automotive fuels in Slovakia with those for Germany (GR) and Netherlands (NL), both EU members. The comparison (using exchange rates for SKK/EUR) indicates that for gasoline, the typical EU prices are higher than those of Slovakia throughout the whole period, despite quite expensive domestic price increases (i.e., 60% over the period 1993-2003). In the case of diesel fuel, there is a smaller difference.

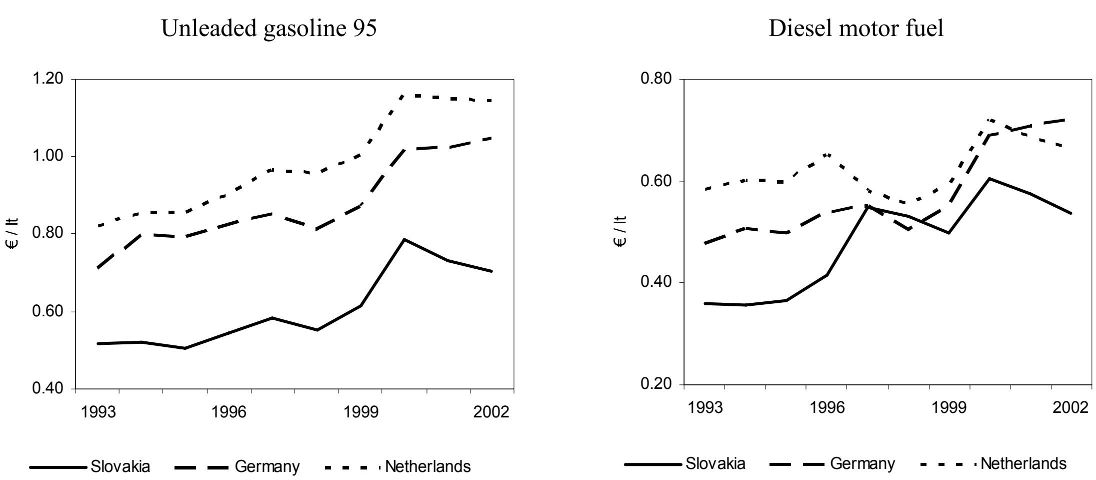


Figure 8.2. Comparison of automotive fuel prices

Slovakia successfully met a goal in 1993 by adopting a new tax system, which covered the same range of goods as the EU one. A comparison of the excise taxes for petroleum products for the EU and Slovakia in 2001 shows a high degree of similarity, even if the structure of the tax, as well as the manner of tax accounting and treatment, are still very different.

Prices of end-use energy carriers

TABLE 8.6 PRICES OF ELECTRICITY, DISTRICT HEAT AND NG FOR THE INDUSTRY AND HOUSEHOLD SECTORS

ISED #		Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
3.2	**Industry**											
3.2.1.	**Electricity**											
3.2.1.1	with tax/subsidy	$/MWh	48.9	48.6	48.6	50.8	55.1	57.7	57.5	65.7	70.1	72.2
3.2.1.2	without tax/subsidy	$/MWh	48.9	48.6	48.6	50.8	55.1	57.5	57.1	65.0	69.4	71.9
3.2.2	**Heat**											
3.2.2.1	with tax/subsidy	$/GJ	6.22	7.26	7.80	8.07	8.54	8.98	9.69	9.75		
3.2.3.	**Natural gas:**											
3.2.3.1	with tax/subsidy	$/GJ $_{GCV}$	2.8	2.9	3.1	3.1	3.2	3.5	3.6	3.8	4.2	4.9
3.2.3.2	without tax/subsidy	$/GJ $_{GCV}$	2.8	2.9	3.1	3.1	3.2	3.5	3.6	3.8	4.2	4.9
3.2.4.	**Light fuel oil**											
3.2.4.1	with tax/subsidy	$/1,000lt	176	145	133	147	155	150	167	240	324	350
3.2.4.2	without tax/subsidy	$/1,000lt	176	145	133	147	155	150	167	240	324	350
3.3.	**Households**											
3.3.1.	**Electricity:**											
3.3.1.1	with tax/subsidy	$/MWh	31	31	31	32	33	33	48	78	102	102
3.3.1.2	without tax/subsidy	$/MWh	30	30	30	31	31	31	44	70	92	92
3.3.2.	**Heat:**											
3.3.2.1	with tax/subsidy	$/GJ	4.04	4.37	4.71	4.71	4.88	5.55	8.24	11.77		
3.3.3.	**Natural gas:**											
3.3.3.1	with tax/subsidy	$/GJ $_{GCV}$	1.87	1.87	1.95	1.98	2.04	2.08	2.60	4.04	4.50	4.60
3.3.3.2	without tax/subsidy	$/GJ $_{GCV}$	1.77	1.76	1.84	1.87	1.92	1.96	2.40	3.67	4.09	4.18
3.2.4.	**Light fuel oil**											
3.2.4.1	with tax/subsidy	$/1,000lt	176	145	133	147	155	150	167	240	324	350
3.2.4.2	without tax/subsidy	$/1,000lt	10	9	300	301	308	317	327	344	352	45

Data sources: electricity and NG (OECD/IEA, 2003) district heat (World Bank/MES, 2002)

Data on electricity and NG end-use prices (Table 8.6) were derived from IEA Statistics [12]. Comparison of data on electricity and NG prices among individual countries is possible due to the identical methodology for reporting. A different situation exists for price data about district heating, which were not available from international statistical reviews and therefore not available for inter-country comparisons.

To assess national pricing policies within countries, prices for electricity and NG in selected EU countries (Germany and Netherlands were employed as the reference cases) were obtained in the industry and household sectors.

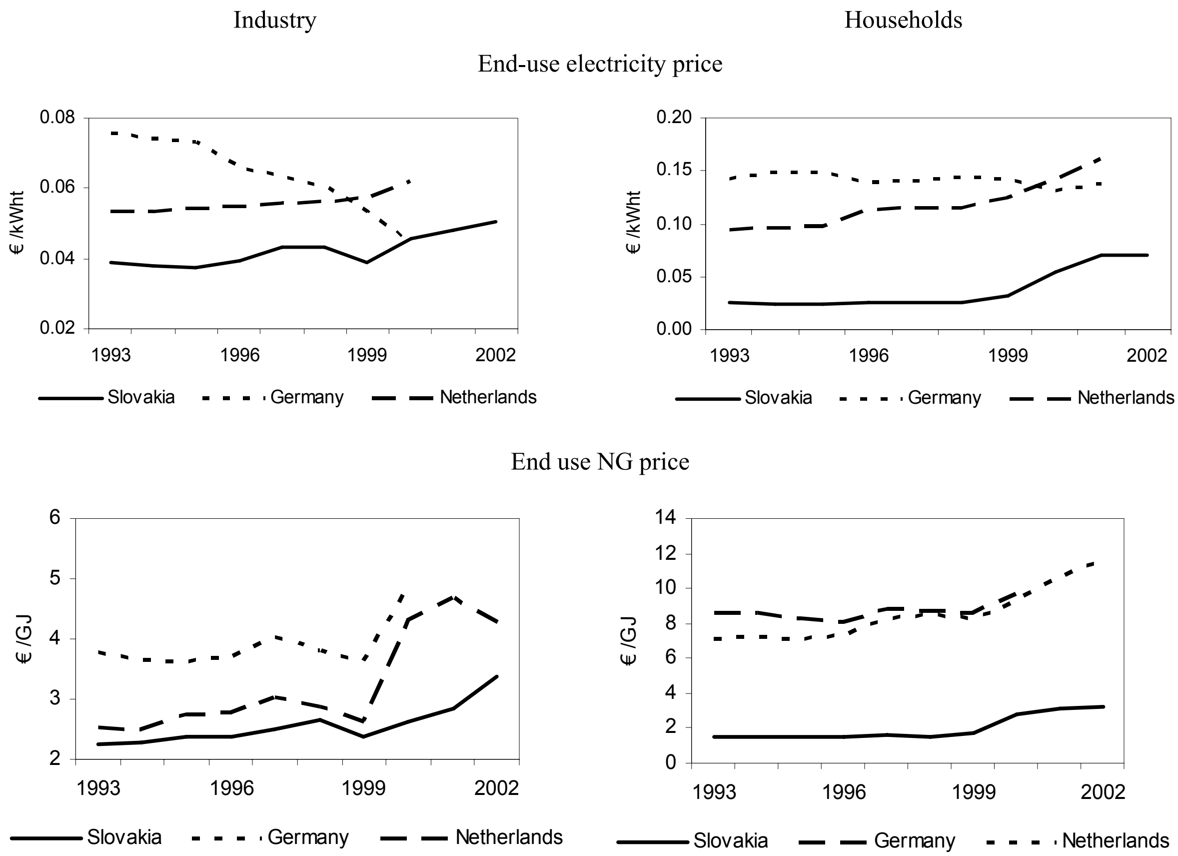


Figure 8.3. Comparison of end-use energy prices

The differences in end-use energy prices between Slovakia and EU representative countries are higher for the household sector than those for industry (Figure 8.3). Even though it is possible to identify continuously increasing end-use prices in Slovakia since 1999, during the whole period under consideration they remained lower than those for the EU representative countries, except for the price of electricity in Germany in the year 2000.

When tariff policies reflect production and distribution costs, then the end-use prices for households are higher than those for industry. This is usually the case for countries with a developed market economy. In former socialist countries, cross-sector subsidies were applied and the end-use energy prices for households were lower, balanced by higher energy prices in industry. Removing all types of subsidies is declared to be one of the main goals in existing national energy policy (MES, 2000). The time schedule for this process was defined in this policy in agreement with the harmonisation process with EU legislation. In Figure 8.4 the ratio of industry/households end-use prices for electricity and NG are compared.

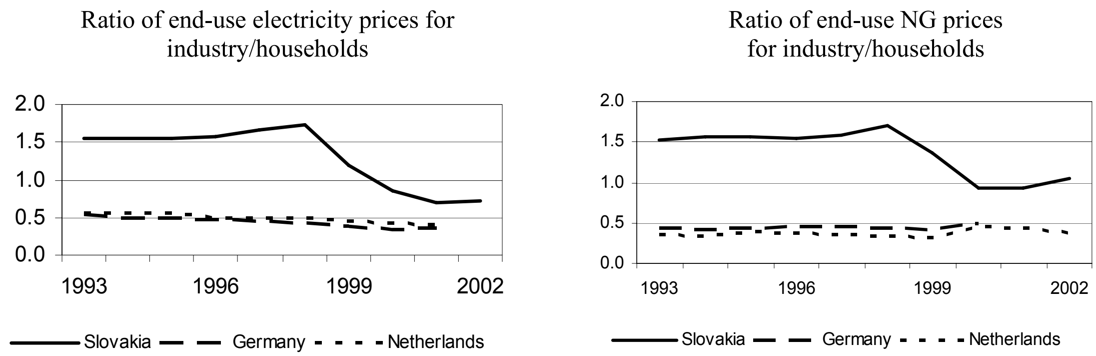


Figure 8.4 Ratio of end-use energy prices for the industry and households

As can be seen from the trends in Figure 8.4, the ratio of industry/household prices has been decreasing since 1999 as a result of national energy pricing policy. In spite of this, the price level of selected EU countries is still lower. Although the comparison among countries was not made for prices of district heating, a similar trend as that for electricity and NG could be assumed.

8.5.1.3. Sectoral contribution to GDP

This indicator quantifies the share of important economic sectors in total economic production. Figure 8.5 shows the value added and the ratio of individual sectors' contribution to the total GDP, expressed in current prices recalculated by the constant exchange rate of SKK/USD_{1995}. The part of the bar identified as industry represents the aggregation of industrial and construction sectors. There was a lack of consistent time series for individual industrial branches. The solid line indicates the share of manufacturing industries in industry and construction as a whole.

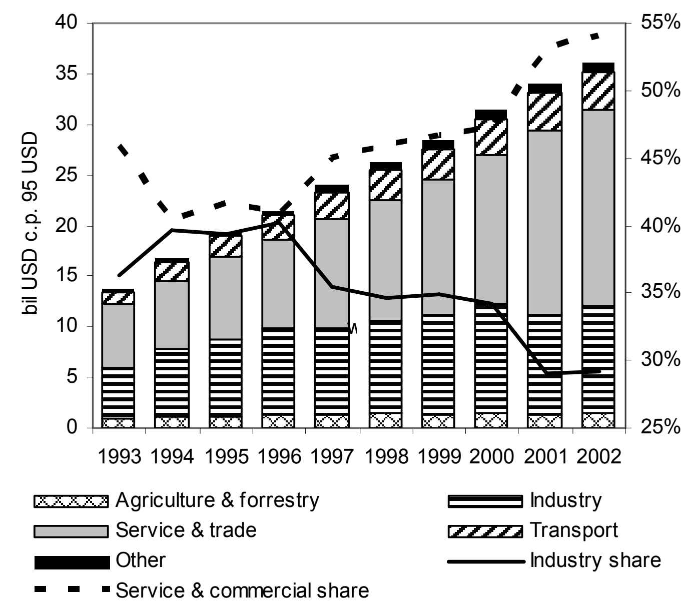


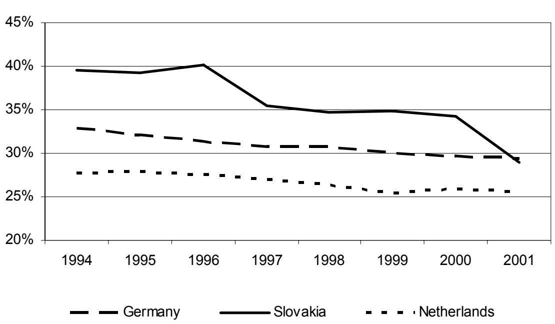
Figure 8.5 GDP by sectors (SOS, 2002a), (SOS, 1995-2003)

TABLE 8.7 SHARES OF ECONOMIC SECTORS IN TOTAL GDP (SOS, 2002A), (SOS, 1995-2003)

No	Indicator	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
4.1.	Industry and construction	%	36.4	39.6	39.3	40.2	35.4	34.6	34.9	34.2	29.0	29.2
4.2.	Agriculture & forestry:	%	6.3	6.9	6.1	5.7	5.7	5.4	4.7	4.7	4.1	4.2
4.3.	Commercial & public services:	%	46.0	40.4	41.6	40.8	44.9	46.0	46.6	47.2	53.2	54.0
4.4.	Transportation:	%	8.6	11.0	10.8	11.1	11.0	11.1	10.9	11.0	11.2	10.2
4.5	Other	%	2.7	2.1	2.2	2.2	2.9	2.9	2.9	2.9	2.5	2.5

Table 8.7 shows a decrease in the contribution of industry and construction versus an increase in the share of services (commercial & public services, hotels, restaurants, post and telecommunications, real estate, etc.) on total GDP. The impact of the restructuring process on industrial activity should be quantified by using an index of relative increase, as well as its share of the national GDP. These indicators are compared in Figure 8.6, similar to the case of end-use energy prices, with the same parameters for two typical EU countries – Germany and Netherlands (SOS, 2002a), (SOS, 1995-2003).

Comparison of industrial value added share



Index of growth for industrial value added share

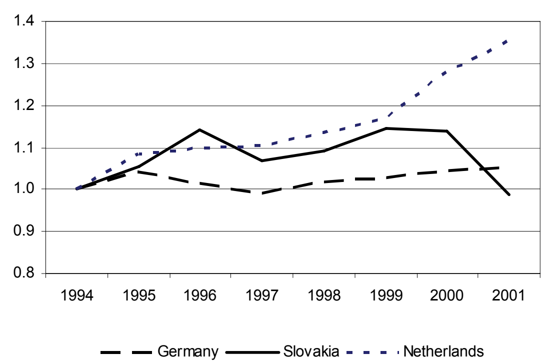


Figure 8.6 Share of industry in GDP, index of growth – comparison of data for Slovakia and EU representatives

At the beginning of the period, the contribution of industry to total GDP in Slovakia was higher than that in EU representative countries (GR, NL). This tendency was typical for a country formerly utilizing a central planning system, which stressed industrial activity development to a much larger extent than the commercial sector and services. After 1999, this parameter became much closer to the one for Germany. On the other hand, values for an index of growth for industry share in GDP were closer to those in the compared countries. A comparison of this parameter for the Netherlands and Slovakia shows similar values until 1999; after this year the NL curve shows higher growth. During the whole period, this index for Slovakia was higher than that of Germany. A more detailed assessment shows that the decrease in the industrial share in GDP for Slovakia is not the result of a decline in industrial activity, but rather the result of structural changes in GDP creation. This is an indication of progress in economic restructuring, and of positive changes enhancing less energy intensive sectors in the national economy (i.e., one of the country's policy priorities). The structural changes in the period were characterised by the decrease of industrial GDP, but also by changes in the VA of manufacturing branches. Based on the availability of data, required ISED information was developed for the following industry groups (see Table 8.8 and Figure 8.7):

- Iron and steel
- Non-ferrous metals
- Chemicals

- Petroleum refining
- Non-metallic minerals
- Paper and pulp

TABLE 8.8 VALUE ADDED SHARES OF INDUSTRIAL BRANCHES IN INDUSTRIAL SECTOR [%]

8.	VA shares of branches for ISED	1995	1996	1997	1998	1999	2000	2001	2002
8.	Iron and steel	12.2	12.4	12.2	10.7	9.5	13.8	15.9	13.7
8.2.	Machinery	15.7	15.6	17.6	18.7	20.1	22.5	24.6	26.0
8.3.	Chemicals	10.8	10.9	10.3	9.3	7.9	8.9	8.9	8.4
8.4.	Petroleum refining and coke production	4.1	3.8	5.1	3.9	3.2	6.4	4.6	4.1
8.5.	Non-metallic minerals	4.4	4.6	4.6	5.0	4.8	5.7	5.9	5.9
8.5.1.	Paper and pulp	4.6	3.5	3.5	4.0	3.8	4.5	5.8	5.4

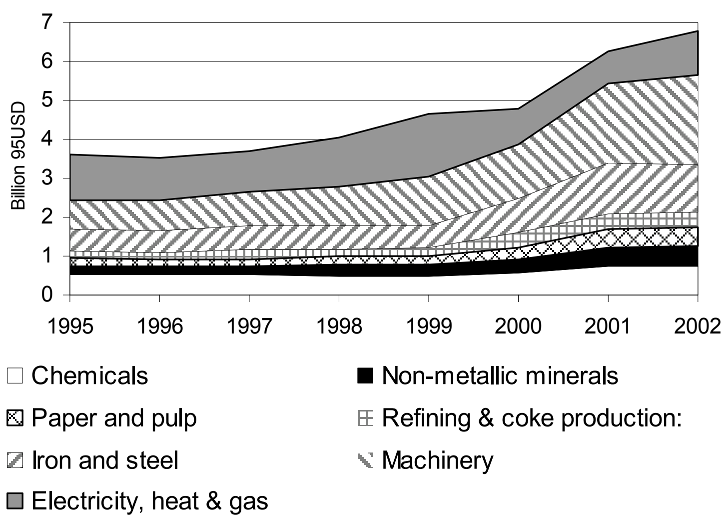


Figure 8.7 Value added for industrial branches

For energy intensive industries, machinery shows the largest increase in its VA share. Considering the new foreign investment in this branch (e.g., Peugeot, Kia, etc.), the share of the machinery industry should increase even further.

8.5.1.4. Conclusion of ISED related to EU accession process

- Even through the GDP/cap growth rate in the considered period was higher than the EU average, GDP per capita is still considerably lower than the average value for the EU.
- The growth rate of motor fuel consumption has a similar trend as that of selected countries in the EU (Germany, Netherlands), but the absolute level was still lower at the end of period. The analysis did not include development during and after 2005, when the situation in motor fuel prices was drastically changed.
- The cross-sectoral subsidies in Slovakia were gradually removed in the case of end-use energy prices (i.e., NG, electricity and district heat) during the transition period. Despite this development, the absolute price level was lower and the ratios of industrial/residential end-use prices of NG and electricity were still higher than in Netherlands and Germany.

- The economic transformation is characterized by the decrease of industrial sector share of the GDP VA, and the increase of the service and commercial sector share. This trend is typical for an economic transformation from the central planning system to an open market economy. In 2000, the industrial GDP share was at the same level as that in Germany, but still higher than in the Netherlands. The manufacturing VA structure is characterized by an increase of the machinery VA share. Due to the increase of foreign investment in this sector, the present period will reinforce this trend.

8.5.2. ISED related to security of energy supply

This issue is consistent with priority No.3, from the new proposal of energy policy - *Lowering dependency on fossil fuel imports*. The ISED listed below can be used to analyze the following strategies for this priority:

Strategy 1: To use the nuclear energy industry as a diversified, cost-effective and environmentally acceptable option for power generation

ISED 11.1 - Final energy mix

ISED 11.2 - Electricity generation mix by fuel types

ISED 11.3 - Total primary energy supply mix

Strategy 2: To increase the use of domestic primary energy sources

ISED 17- Indigenous energy production

ISED 18- Energy net imports dependency

Strategy 3: To increase the utilization of renewable energy sources

Included in principle 1 by ISED

ISED 11.3.7. - Non-combustible renewable:

ISED 11.3.8. - Renewable and wastes:

Strategy 4: To Support the utilization of sources with combined heat and power generation

ISED 12.6. Electricity supplies from CHP plants as percentage of total electricity generation

8.5.2.1. ISED related to strategy 1 - Final and Primary energy mix

Table 8.9 and Figure 8.8 present the final energy mix.

TABLE 8.9 FINAL ENERGY MIX

11.1	Final energy mix		1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
11.1.1.	Coal	%	18.6	17.9	15.7	16.1	15.5	13.8	12.8	12.5	9.5	11.2
11.1.2.	Petroleum products	%	12.0	16.5	15.1	11.2	12.2	12.3	14.3	14.0	22.8	26.7
11.1.3.	Gas	%	29.3	30.3	31.6	34.4	31.6	37.3	36.6	36.5	38.1	33.2
11.1.4.	Electricity	%	13.4	14.4	15.3	16.3	16.9	15.5	16.7	17.2	17.8	17.6
11.1.5.	Heat	%	26.8	20.9	22.2	22.1	23.8	21.0	19.6	19.7	9.3	9.2
11.1.7.	Renewable & wastes	%	0.03	0.04	0.03	0.04	0.04	0.05	0.02	0.01	2.41	2.04

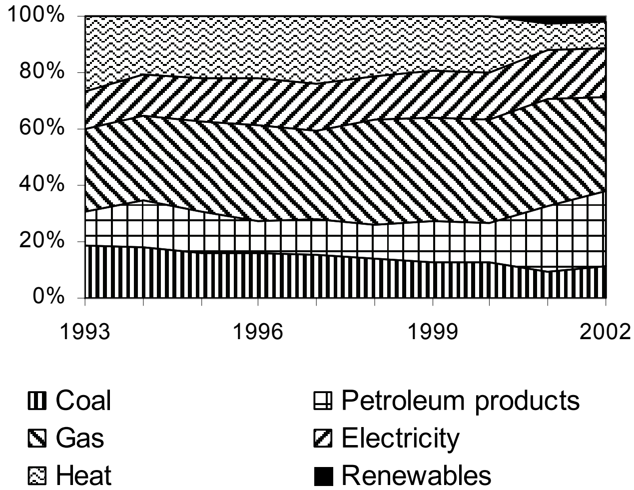


Figure 8.8 Final energy mix

Figure 8.9 shows the trends of energy mix.

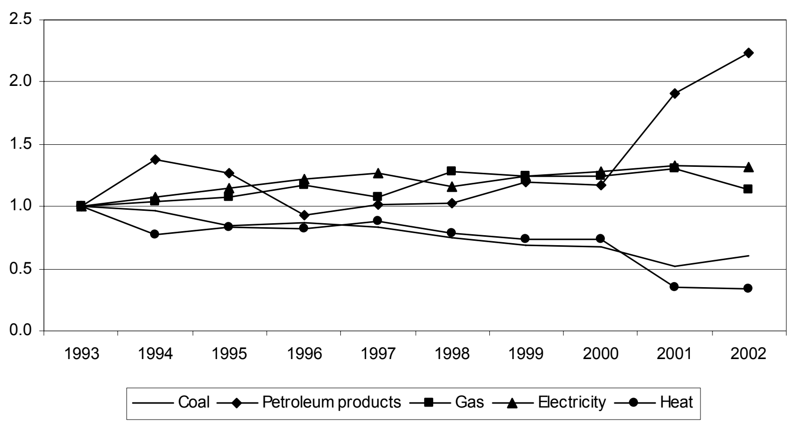


Figure 8.9 Trends of energy mix (1993 = 100%)

While electricity and gas show an increased share of the final energy mix, centralized district heating and coal consumption indicate a decreased share. This is closely related to the total economic and industrial restructuring. An increase of commercial and service activity growth, and the increasing share of machinery cause the increase for electricity. New investment in these branches of the industry will strengthen this trend. The decrease of coal and the increase of the NG share is a result of new environmental legislation, as well as the very aggressive policies of the gas utility which in the past year has expanded its national distribution network even in small villages. The district heating share decrease has many reasons, one of them being that some consumers have unplugged from the public hot water distribution network and applied their own heating sources, using gas as fuel.

Considering the later and future trends of electricity demand increases, the ISED No. 11.2 *Electricity generation mix by fuel types* will have an important impact on the security of energy supply. According to the definition, the electricity generation mix reflects the share of electricity produced by different types of electric power plants. Due to the fact that some Slovak power plants simultaneously use more than one fuel type, data for thermal power plants were roughly estimated. The figures for the electricity generation mix in Table 8.10 and Figure 8.10 show an increase in the nuclear power share (included in the energy balance as nuclear primary heat).

TABLE 8.10 ELECTRICITY GENERATION MIX

11.2.	Electricity generation mix	Unit	1997	1998	1999	2000	2001	2002
11.2.1.	Coal	%	26.48	25.53	22.66	18.34	20.17	20.27
11.2.2.	Oil products	%	4.97	6.16	3.21	2.42	0.73	1.153
11.2.3.	Gas based	%	6.87	6.32	8.53	7.77	8.14	9.825
11.2.4.	Nuclear power	%	51.33	51.55	55.66	62.46	64.54	62.39
11.2.5.	Hydro power	%	6.67	6.69	6.39	6.07	5.99	5.7
11.2.7.	Renewables & wastes	%	3.69	3.74	3.53	2.95	0.43	0.661

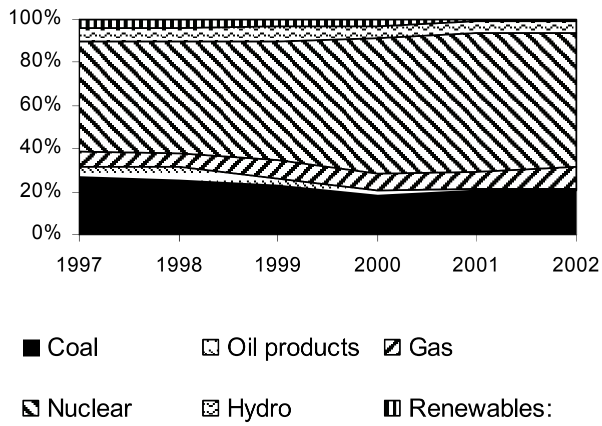


Figure 8.10 Electricity generation mix

The increasing share of nuclear was caused by the installation of two units (2 x 440 MWe) at the nuclear power plant Mochovce.

Table 8.11 shows total primary energy supply mix (ISED 11.3).

TABLE 8.11 TOTAL PRIMARY ENERGY SUPPLY MIX

11.3.	Total primary energy supply mix	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
11.3.1.	Coal	%	33.9	30.7	29.4	28.7	27.8	25.9	25.0	23.3	22.8	22.4
11.3.2.	Oil	%	16.4	18.1	19.0	18.4	18.2	19.3	17.3	15.7	15.4	17.8
11.3.3.	Gas	%	27.4	26.7	28.6	29.7	30.8	31.7	32.0	32.0	32.2	31.0
11.3.4.	Nuclear power	%	18.7	21.2	19.6	19.0	18.7	19.8	22.8	27.6	28.4	26.5
11.3.5.	Hydro power	%	1.7	2.1	2.3	2.1	2.1	2.2	2.3	2.4	2.3	2.5
11.3.6.	Electricity net import	%	0.9	0.2	0.6	1.6	1.9	0.6	0.3	-1.3	-1.6	-1.9
11.3.8.	Renewables & wastes	%	0.9	1.0	0.4	0.4	0.5	0.4	0.4	0.3	0.5	1.6

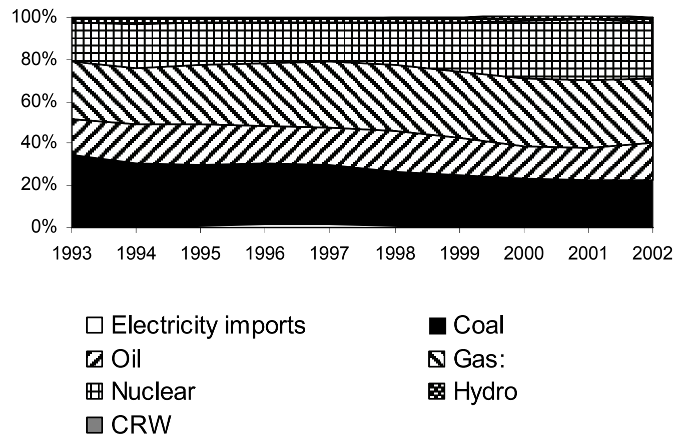


Figure. 8.11 Total primary energy supply mix

Table 8.11 and Figure 8.11 illustrate the increase of nuclear and NG share in the primary fuel mix. This is related to the change of final energy mix and the impact of environmental requirements. Nevertheless, this time series did not include the next stage of development, which is likely to be influenced by the retirement of old nuclear units and increasing NG prices on the world market.

8.5.2.2. ISED related to strategy No. 2 - To increase the use of domestic primary energy sources

Slovakia is dependent on energy imports, but the role of dependency nevertheless decreased from 72% in 1993 to 64% in 2001. The new nuclear power plant installation has had significant and positive impacts on this process.

The only domestic fuel to play some role in the total energy balance of Slovakia is brown coal/lignite from underground mining. This coal is directly used for electricity generation in thermal power plants located close to the mine site. The quality of the coal is low, with high sulphur content per thermal units. Adopted environmental legislation, as well as accepted international commitments (MENV, 1999), decrease the competitiveness of this coal in relation to imported ones from the Czech Republic and Poland. The Resolution of the Slovak Government No. 559/2000 stipulates the preferred purchasing of electricity generated from locally extracted PES (lignite), and this will play an important role for extraction and use of domestic coal until 2010.

Table 8.12 provides figures on the total amount of indigenous fuel as well as the share of individual energy types in the total indigenous primary energy supply.

TABLE 8.12 INDIGENOUS ENERGY PRODUCTION

No	Item	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
17.1.	Total indigenous primary energy production	Mtoe	5.10	5.69	5.46	5.48	5.24	5.38	5.87	6.76	6.93	6.9
17.1.1.	Coal	%	19.0	18.9	18.8	20.8	20.3	19.8	17.4	15.1	14.3	13.8
17.1.2.	Oil	%	1.3	1.2	1.4	1.3	1.2	1.1	1.1	0.9	3.0	0.8
17.1.3.	Gas	%	4.1	4.1	5.2	4.7	4.3	3.8	2.8	2.0	2.2	2.2
17.1.4.	Nuclear indigenous	%	66.4	66.3	65.6	64.7	65.3	66.6	70.5	74.8	69.2	72.4
17.1.5.	Hydro power	%	5.9	6.6	7.7	7.1	7.3	7.4	7.1	6.4	6.0	6.4
17.1.7.	Renewables & wastes	%	3.4	3.0	1.4	1.4	1.6	1.3	1.1	0.9	5.3	4.5
17.2.9.	Total electricity	TWh	25.3	25.6	27.7	28.8	28.9	26.8	28.3	28.0	28.4	31.0

Table 8.13 shows the ratio of net import (imports minus exports) to the primary energy consumption for each particular year as a total as well as by fuel types, such as oil and petroleum products, gas, coal and electricity. Although nuclear energy (balanced as nuclear primary heat) is considered an indigenous primary energy source, all of the nuclear fuel elements are imported and Slovakia does not have any enrichment arrangements.

TABLE 8.13 NET ENERGY IMPORTS DEPENDENCY [%]

No	Item	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
18.1.	Total primary energy	%	71.7	68.0	70.2	70.6	71.3	70.2	67.7	63.1	63.4	63.3
18.3.	Oil	%	97.8	97.9	97.9	97.9	98.1	98.3	97.9	98.0	92.9	98.4
18.4.	Gas	%	95.8	95.1	94.6	95.3	96.0	96.5	97.2	97.7	97.6	97.4
18.5.	Coal	%	84.2	80.3	80.9	78.7	79.1	77.3	77.5	76.2	77.7	77.6
18.6.	Electricity	%	5.6	1.7	5.0	12.2	14.0	4.8	2.0	-9.6	-13.0	-13.4

The indigenous and imported energy shares show a stable trend (Tables 8.12 and 8.13). Only in the case of nuclear energy share in the years 1998 - 2000 is there an impressive increase, due to the operation of new nuclear units. It brings about a decrease of electricity imports as well as the import of other energy sources used to generate electricity. However, the planned retirement of the old nuclear plants will lead to an import dependency increase. The future of nuclear energy is connected with the privatisation process of the power utility. There are now potentially available two additional units (i.e., 2 x 440 MWe), and their finalisation and operation are a subject of discussions. Their operation should help maintain the present share of energy imports. The requirements for the completion of these units are included in the new proposal for energy policy.

8.5.2.3. Conclusion of ISED related to the security of energy supply

- Domestic low grade brown/lignite coal and hydropower represent important indigenous primary energy sources.
- The potential for additional hydropower increases is limited, as well as for domestic brown coal resources.
- The resources of domestic coal are dedicated for installed thermal power plants, and its use must overcome environmental limitations, both from the point of view of basic pollutants (i.e., SO_2, NO_x, CO and SP) and GHG (i.e., CO_2) emissions.
- Nuclear energy is a dominant domestic source, although the nuclear fuel is imported. The increase of nuclear capacity brought about an increase in the indigenous energy share and less dependency on the short-term energy market situation.
- The planned shut down of the old nuclear plant will bring an additional increase of energy import dependency, if the new nuclear units are not finalised.
- The completion of the two additional nuclear units (2 x 440 MWe) is required in the new proposal of energy policy, and represents one of the measures to increase energy supply security.

8.5.3. Sustainable development

This issue of sustainable development in Slovakia is consistent with priority No.1 of the new proposal of energy policy - *Reliable, environmentally acceptable and economically effective energy supply*, defined by the following strategies of this priority:

Strategy 1: To adopt adequate measures for elimination of impacts from shut-down of some of the currently operating plants, so as to avoid a dependence on electricity imports in long-term perspective.

Strategy 2: To modernize energy plants and technology processes with the simultaneous decrease of energy intensity and the reduction of negative environmental impacts.

Strategy 3: To replace the 220 kV system by 400 kV systems gradually in compliance with planned changes in the infrastructure of the national economy and industry for coordinated advancement of all Slovak regions.

Strategy 4: To ensure technical safety of energy plants, quality and proper maintenance levels of systems and networks.

Strategy 5: To ensure continual nuclear safety and operational ability of nuclear power plants.

Strategy 6: To optimize operating and investment costs to cover the main operations and achievement of adequate profit necessary for further development of the power and gas systems.

Strategy 7: To increase economic and energy efficiency.

Strategy 8: To support research and development, and development of applied research in the energy industry.

Strategy 9: To introduce new technologies, innovations and best available techniques in the energy industry.

Strategy 10: To ensure operating management of the SR power system with the objective of reaching well-balanced electricity consumption and generation in real time.

Strategy 11: To decrease the dependence on sources from risky regions; to realize the measures derived towards increasing the reliability of energy supply from foreign sources.

Strategy 12: To monitor the security of electricity and gas supply.

Considering the above strategies, ISED indicators related to energy efficiency are fully consistent with Strategy 7. Nevertheless, common objectives of this priority can be classified and analysed fully or partly with the following ISED:

Energy intensity and efficiency of energy supply

ISED # 9. Energy intensities

ISED # 12. Energy supply efficiency

ISED # 14. Energy use per unit of GDP

ISED # 16. Energy consumption per capita

Environmental impact of energy system

ISED # 13. Status of deployment of pollution abatement technologies

ISED # 23. Quantities of air pollutant emissions

ISED # 24. Ambient concentration of pollutants in urban areas

ISED # 26. Quantities of greenhouse gas emission from energy related activities

8.5.3.1. Energy intensity and efficiency of energy supply

Final energy intensity

The data on ISED # 9 in Table 8.14 represent an *Indirect Driving Force Within the Energy Sector.* The energy intensity of individual economic sectors relates energy demand to production activity, and is given by the share of sectoral contribution to GDP creation and final energy consumption. The development of final energy intensity by sectors during the studied period is illustrated in Figure 8.12 and Table 8.14.

TABLE 8.14. END-USE ENERGY INTENSITIES BY SECTORS

9.	Energy intensities	Units	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
9.1.	Final energy intensity	toe/ 1,000$	0.755	0.661	0.631	0.603	0.54	0.519	0.515	0.485	0.470	0.447
9.1.1.	Industry & construction	toe/ 1,000$	1.084	0.908	0.896	0.802	0.766	0.663	0.682	0.747	0.614	0.597
9.1.2.	Agriculture	toe/ 1,000$	0.582	0.325	0.34	0.325	0.321	0.28	0.285	0.258	0.185	0.159
9.1.3.	Commercial & services	toe/ 1,000$	0.352	0.334	0.25	0.277	0.235	0.285	0.258	0.182	0.147	0.138
9.1.4.	Transportation	toe/ 1,000$	0.253	0.234	0.24	0.139	0.141	0.139	0.131	0.136	0.521	0.707

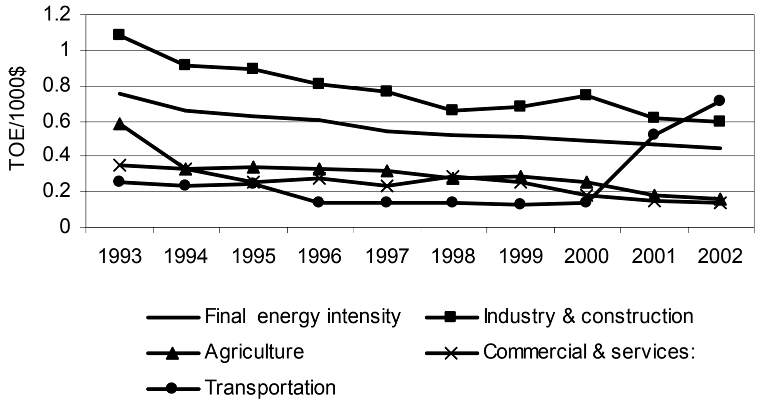


Figure 8.12 End-use energy intensities by sectors

Final energy intensity was continuously decreasing in all sectors until 2000. In some sectors this parameter started to increase again in 2001. The changes which occurred were mainly related to the economic restructuring process that had impacts on both the final energy consumption and energy intensity. Figure 8.13 compares the trends of energy intensity (EI), final energy use (FEU) and VA growth in two important sectors - industry and services and commercial.

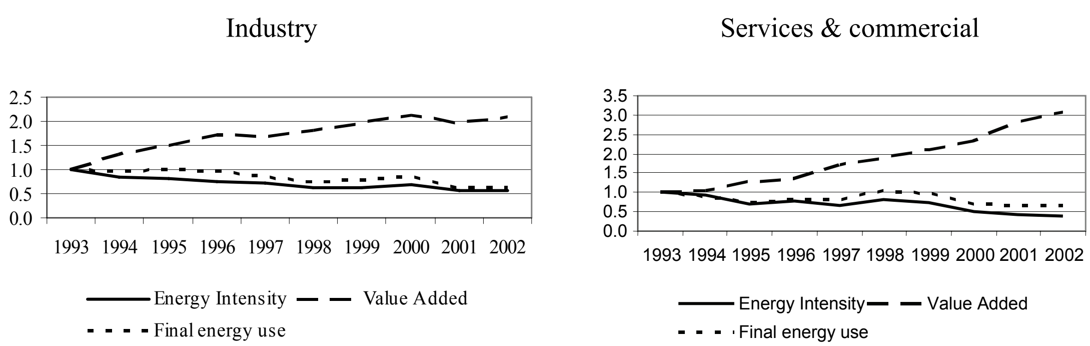


Fig. 8.13 Trends of final energy intensity - EI, final energy uses FEU and VA growth

The transportation sector is one of the sectors with increasing fuel consumption. Available statistical data in a form which enables calculations of ISED for Slovakia have only been issued since 1997. Table 8.15 gives the input data and ISED calculated per actual activity in passengers and freight transport.

TABLE 8.15 END-USE ENERGY INTENSITY OF TRANSPORT

	Unit	1997	1998	1999	2000
Passenger travel	Bpkm	37	37	36	34
Energy consumption	MTOE	0.707	0.761	0.754	0.751
Passenger travel energy intensity	kgoe/1,000 pkm	19.31	20.72	21.00	21.79
Freight transport	Btkm	29.243	30.972	30.039	41.198
Energy consumption	MTOE	0.533	0.602	0.535	0.503
Freight transport energy intensity	kgoe/1,000 tkm	18.23	19.43	17.81	17.09

The main impact on final energy intensity in the residential sector is from the use of space heating and electricity (see Table 8.16). Related ISED were calculated from Energy Statistics, excluding data for motor fuel consumption for transportation. The item *Total energy* represents the sum of fuel, heat and electricity consumption per capita, while conventional energy represents the consumption of fossil fuels.

TABLE 8.16 ISED FOR ENERGY INTENSITY IN THE RESIDENTIAL SECTOR

9.1.5.	Indicator	Unit	1993*	1994*	1995*	1996*	1997	1998	1999	2000	2001	2002
9.1.5.1	Total energy	kgoe/cap	417	360	401	455	448	465	470	436	484	550
9.1.5.2	Conventional energy	kgoe/cap	417	360	401	455	448	465	470	436	484	550
9.1.5.3	Space heating	kgoe/m^2	16.0	16.0	16.0	16.0	16.0	16.0	16.5	15.7	N/A	N/A

*Data extrapolated from these in period 1997-2000

A World Bank study on energy efficiency (World Bank/MES, 2002) was used as input data for the estimation of specific heat consumption per area. Data for period 1993-1996 were extrapolated from those in period 1997-2000.

Data on electricity intensity were calculated based on input data from Energy Statistics (SOS, 2005).

Time series of these data by sectors are outlined in Table 8.17.

TABLE 8.17 ISED OF ELECTRICITY INTENSITY BY SECTORS

		Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
9.2.	Electricity intensity	kWh/$	1.17	1.11	1.12	1.14	1.06	0.94	1.00	0.97	0.97	0.91
9.2.1.	Industry and construction	kWh/$	1.29	1.40	1.20	1.27	1.32	1.22	1.20	1.29	1.38	1.24
9.2.2.	Agriculture	kWh/$	1.46	0.75	0.76	0.73	0.92	0.70	0.64	0.57	0.53	0.50
9.2.3.	Commercial & services	kWh/$	0.66	0.44	0.66	0.68	0.53	0.40	0.56	0.48	0.62	0.56
9.2.4.	Residential	kWh/cap	775	838	931	1,013	1,022	1,042	1,051	1,003	971	912
9.2.5.	Transportation	kWh/$	0.75	0.73	0.66	0.43	0.42	0.41	0.36	0.38	0.01	0.28

Energy supply efficiency

As in ISED group #9, the ISED group #12 represent indirect driving forces. Data are summarized in Table 8.18.

TABLE 8.18 PARAMETERS OF ENERGY SUPPLY EFFICIENCY

12.	Energy supply efficiency	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
12.1.	Ratio of total final energy to total primary energy supply	%	72.2	68.2	66.9	66.6	63.7	64.5	64.5	61.5	59.9	58.7
12.2.	Average fuel effectiveness of thermal power plants	%					30.8	30.2	30.4	31.0	31.2	0.0
12.3.	Electricity transmission and distribution losses	%					7.2	7.6	6.5	6.5	4.7	3.6
12.4.	Gas transportation and distribution losses	%					0.0	0.0	0.0	0.0	0.4	0.0
12.5.	Oil refining efficiency	%					85.4	86.6	86.4	87.9	N/A	N/A
12.6.	Electricity supplies from CHP plants as percentage of total electricity generation *1	%					18%	18%	17%	17%	16%	14%

*1 This ISED is relevant to the Priority No 3.

Decreases in the total final/primary energy supply ratio is caused by the increasing share of nuclear energy. The efficiency of nuclear PWR power plants is lower than that of thermal power plants due to the physical characteristics of the PWR reactor, which do not allow the generation of superheated steam.

Energy use per unit of GDP and per capita

The most important driving forces for country development are the activities of the national economy and the related energy intensity. This ISED #14 represents a direct driving force, while ISED #16 represents a state indicator (see Tables 8.19 and 8.20). Both of them are the result of the interaction between previous ISED groups - the final energy intensity and the energy supply efficiency. Historical figures for Slovakia (similarly as in other Economies in Transition countries) show a decrease in energy intensity, primarily due to the industrial restructuring and economic transformation.

For primary conventional energy, fossil fuel consumption is considered, while total energy represents the sum of fuels, primary (nuclear and geothermal) heat, and electricity (import /export balance and hydropower).

TABLE 8.19 ENERGY USE PER UNIT OF GDP

No	Item	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
14.1.	Total primary energy	toe/ 1,000$	1.05	0.97	0.94	0.91	0.85	0.81	0.80	0.79	0.78	0.76
14.2.	Primary conventional energy	toe/ 1,000$	1.04	0.96	0.94	0.90	0.84	0.80	0.80	0.79	0.77	0.75
14.3.	Electricity use	kWh/$	1.47	1.40	1.43	1.40	1.34	1.19	1.24	1.20	1.18	1.25

Considering the national priorities, the ISED #14.1 *Energy use per unit of GDP* characterizes the bulk of national energy policy, covering the efficiency of energy transformation process as well as the efficiency of final energy use. The EU accession processes as well as economic transformation should move this indicator closer to the one of the EU average. To obtain the necessary time series for EU average, data from the *Energy intensity of the economy* issued by the EUROSTAT was employed (EUROSTAT, 2005). This indicator is calculated as a ratio of the gross inland consumption of energy and the gross domestic product. The gross inland consumption of energy is here estimated as the sum of the gross inland consumption of five energy types: coal, electricity, oil, natural gas and renewable energy sources. This is different than the primary energy sources definition used for the national

balance in Slovakia, where this parameter represented the sum of primary sources, including fuel consumption, primary nuclear heat, electricity export/imports and renewable energy sources. To preserve consistency in this comparison, the EUROSTAT approach for processing of domestic data was employed. All energy intensity data are expressed in units of kgoe per GDPppp in 1,000 EUR (1995).

TABLE 8.20 ENERGY CONSUMPTION PER CAPITA

16.	Energy consumption/cap	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
16.1.	Total primary energy	toe/cap	3.38	3.32	3.41	3.46	3.39	3.35	3.37	3.39	3.52	3.51
16.2.	Automotive fuel	toe/cap	N/A	0.24	0.24	0.23	0.26	0.28	0.27	0.26	0.26	0.31
16.3.	Renewables & wastes	toe/cap	0.03	0.03	0.01	0.01	0.02	0.01	0.01	0.01	0.07	0.06
16.4.	Electricity	MWh/cap	4.74	4.78	5.16	5.35	5.36	4.96	5.24	5.18	5.27	5.76

8.5.3.2. Environmental impact of energy system

Current stage of air pollution abatement technology deployment

Data for FGD were calculated as the ratio of power plant capacity with the applied abatement technology to the total installed capacity. The figures in Table 8.21 were obtained for the public thermal power plants only, as there are not any installed abatement technologies (except for suspended particulates precipitators) in other units and industrial CHP. Emission abatement policy in sectors other than the electricity sector is preferably focused on fuel switching towards less carbon intensive fuels (Slovenske Elektrarne, 1996-2000).

TABLE 8.21 EXTENT OF APPLICATION FOR BASIC POLLUTANTS ABATEMENT (%)

13.1.	Extent of use of pollution abatement	Unit	1997	1998	1999	2000	2001
13.1.1.	SO_2	%	13	13	13	25	25
13.1.2.	NOx	%	1	1	19	31	31
13.1.3.	Particulates	%	100	100	100	100	100
13.2.	Average performance of removal						
13.2.1.	SO_2	%	79	79	79	79	79
13.2.2.	NOx	%	35	35	35	35	35
13.2.3.	Particulates	%	98	98	98	98	98

Emissions of basic air pollutants

Figures in Table 8.22 correspond to production of energy related emissions of basic pollutants from fossil fuel combustion and transformation processes.

TABLE 8.22 ENERGY RELATED EMISSIONS OF BASIC AIR POLLUTANTS (MENV, 2003)

No	Item	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
23.1.						Energy related activities:						
23.1.1.	SO_2	kt	228	151	148	125	114	108	105	72	89	68
23.1.2.	NOx:	kt	77	61	69	44	42	44	44	41	39	32
23.1.3.	Particulates:	kt	98	55	53	42	38	36	35	33	32	27
23.1.4.	CO:	kt	202	66	65	75	61	63	62	65	61	43
23.1.5.	VOC:	kt	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
23.2.						From electricity production:						
23.2.1.	SO_2:	kt	84	58	64	83	79	74	74	43	52	41
23.2.2.	NOx:	kt	37	30	36	26	25	26	25	23	18	12
23.2.3.	Particulates:	kt	14	9	11	10	12	11	10	9	8	7
23.2.4.	CO:	kt	2	2	2	2	2	2	2	2	2	2
23.2.5.	VOC:	kt	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
23.3.						From transportation:						
23.3.1.	SO_2:	kt	1.8	1.8	2.4	2.3	2.4	2.7	1.1	0.9	0.9	0.9
23.3.2.	NOx:	kt	51.9	52.5	52.9	43.4	44.5	46.3	42.9	38.3	40.6	44.7
23.3.3.	Particulates:	kt	3.1	3.1	3.2	2.5	2.7	2.9	2.7	8.0	9.0	10.3
23.3.4.	CO:	kt	151	185	181	154	144	145	133	38.3	40.6	44.7
23.3.5.	VOC:	kt	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

Slovakia has accepted international treaties and commitments for reduction of NO_x and SO_2 emissions. According to the *Protocol on acidification, eutrofication and ground layer ozone* (MENV, 1999), the total emissions of SO_2 for Slovakia in 2010 cannot exceed a level of 110 kt , and for NOx of 130 kt. Actual data in Table 8.22 also indicate offsets in NOx and SO_2 emissions related to these targets, but additional measures to ensure the meeting of this goal have nonetheless been adopted.

Energy related greenhouse gas emissions

Another important parameter that was the subject of this study is GHG emissions (see Table 8.23).

TABLE 8.23 ENERGY RELATED GHG EMISSIONS (TRANSPORT RESEARCH INSTITUTE, 2000)

No	Item	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
26.1.	Total GHG	Mt CO_2 eq.	44.5	41.4	42.8	43.4	43.6	41.9	40.6	38.7	40.2	40.7
26.1.1.	CO_2	Mt CO_2 eq.	42.9	39.8	41.1	41.6	41.8	40.1	38.9	37.0	38.5	38.9
26.1.2.	CH_4	Mt CO_2 eq.	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.4	1.4	1.5
26.1.3.	N_2O	Mt CO_2 eq.	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.3	0.3
26.2.	GHG/capita	Mt CO_2 eq./cap	8.3	7.7	8.0	8.1	8.1	7.8	7.5	7.2	7.5	7.6
26.3.	GHG/GDP	Mt CO_2 eq./1,000 $	2.6	2.3	2.2	2.1	2.0	1.9	1.8	1.6	1.7	1.6
26.4.	Energy related	Mt CO_2 eq.	39.4	36.0	37.0	37.5	37.5	35.4	34.3	32.9	33.7	34.9
26.5.	Transportation	Mt CO_2 eq.	4.0	4.2	4.5	4.6	4.7	5.1	5.0	4.5	4.9	5.8

The ISED #26.4 in Table 8.23 quantifies GHG emissions from electricity generation. Data on GHG emissions by sectors in IPCC tables were given in aggregated form only (electricity, heat production and transport activity), and therefore these data were put into Table 8.23. The total balance of GHG emissions is determined by contributions of:

Energy related GHG emissions – emissions from fossil fuel combustion and transformation (includes thermal power plants, CHP, HP and technological combustion), except for the input from mobile sources in transport and agriculture.

The EU as a whole (i.e., under the bubble concept) agreed in the Kyoto Protocol to an 8% reduction of its greenhouse gas emissions, compared to the base year 1990, during the first commitment period 2008-2012. The reductions for each of the EU-15 countries have been agreed upon under the so-called EU Burden Sharing agreement, which allows some countries to increase emissions, provided these are offset by reductions in other Member States. Some of EU associated countries have chosen other reduction targets and other base years, as was allowed in the Kyoto Protocol. Slovakia has agreed to reduce GHG emissions at the same level as the EU, and used the same base year 1990.

For almost the entire period, Slovakia accounts for potential GHG emission offsets. This offset is the result of a total decline of national economic performance after 1990, followed later by its increase in connection with simultaneous structural changes in primary energy use. The use of nuclear energy for electricity generation also played an important role.

Solid and liquid waste production

Data on the production of solid and liquid wastes necessary for ISED were only available from the public electric utilities (Slovenske Elektrarne, 1996-2000). Therefore, the figures in Table 8.24 do not include data from regional public CHP and HP, or industrial sources.

TABLE 8.24 SOLID, LIQUID AND RADIOACTIVE WASTES FROM ENERGY ACTIVITY

No	Item	Unit	1997	1998	1999	2000
28.1.	Wastewater discharges: (Storm water discharges associated with energy related activity)	m^3	312,180	275,949	289,207	267,950
28.2.	Radionuclides in liquid radioactive discharges	GBq	35,560	N/A	N/A	23,887
28.2.1.	Info\244.doc	GBq	0	N/A	N/A	0
28.2.2.	Info\245.doc	GBq	35,560	N/A	N/A	23,887
31.1.2.	Low and intermediate level radioactive waste, long-lived (LILW-LL)	m^3	172.0	314.5	169.8	217.0

Ambient concentration of air pollutants in urban areas

Ambient concentrations of SO_2, NO_x, CO, suspended solid particulates and ozone are measured and recorded in several monitoring stations in Slovakia (SOS, 1995-2003) (see Table 8.25). Annual data for pollution (i.e., ambient concentrations and emission inventories) are issued by the SHMÚ for selected regions and towns. To quantify air pollution, data from the city of Banska Bystrica, located in the middle of Slovakia, were chosen for this analysis.

TABLE 8.25 AMBIENT CONCENTRATION OF AIR POLLUTANTS IN THE CITY OF BANSKA BYSTRICA

24.	Pollutant	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001
24.1.	SO_2	$\mu g/m^3$	33.2	31.4	27	31.6	26.1	24	18.8	14.4	10.9
24.2.	NO_x	$\mu g/m^3$	89.31	112.7	74.5	81.5	94.6	72.5	55.4	61.3	58.6
24.3.	TSP*	$\mu g/m^3$	78.29	85	75.7	82.9	60.6	45.4	36.5	40.1	35.0
24.4.	CO	$\mu g/m^3$	1,240	911.5	1,354	1,400.8	704	335.8	288.1	266.7	226.7
24.5.	Ozone	$\mu g/m^3$	35	34	38	28	35	42	42	41	N/A

*****_TSP Total suspended particulates_

8.5.3.3. Conclusions of ISED related to sustainable development

The total final energy intensity declined during the period under consideration. Nevertheless, in the case of the industrial sector, there was some increase of energy intensity connected with the revival of the steel making industry due to foreign investment (i.e., by the company US STEEL). Metallurgy is a very energy-intensive manufacturing branch, but the additional investment in machinery with lower energy intensity will lead to a decrease of energy intensity in the industrial sector too. The main decrease of bulk final energy intensity is due to the increase of commercial and service sector share of the GDP.

The passenger travel energy intensity (kgoe/1,000 pkm) increased, while freight transport energy intensity (kgoe/1,000 tkm) also increased in the period from 1997-2000. The analysis did not include an important development since 2004, which was an increase of motor fuel prices.

Total energy intensity (kgoe/cap) in the residential sector indicated a decrease in the beginning of the period of analysis, followed by an increase in recent years. The planned investment in building insulation should lead to an improvement in this situation.

The electricity intensity (kWh/$) on the national level decreased, even though in some sectors this value increased (i.e., industry). This trend is related to the process of industrial restructuring and economic transformation, represented by the changing GDP structure.

Energy supply efficiency expressed by ISED #12.1: *Ratio of total final energy to total primary energy supply* declined, due to the installation of new nuclear units.

The gross energy intensity for Slovakia fluctuated around the same level, and was higher than the $EU_{average}$ value during the entire period under consideration.

Basic pollutants (SO_2, NOx, CO and SP) and GHG emissions declined during the period under consideration. This was due to the decrease of energy intensity, the installation of new nuclear unit, as well as the increasing share of NG in the fuel mix. The basic pollutant emissions decrease had a beneficial effect on ambient pollutant concentrations.

8.6. Applied ISED as a Tool for Assessment of Current Energy and Environmental Policy in Priority Areas

The IAEA methodology looks at targeted indicators, and the opportunity for responses that could positively influence selected ISED. Observed trends of historical data are important in such an analysis, and consistent data for a long time period are preferred. Even though the time schedule in this analysis only covers the period 1993 - 2002, it is possible to observe some interdependencies of individual ISED from these historical data. These relationships are significant from the economical transformation and EU accession points of view.

Based upon research experiences gained from analyses of available data, it is estimated that a decisive role for achieving energy system sustainability in Slovakia will depend upon the following factors:

- The role of nuclear energy in the electricity generation mix. Two new nuclear units have been brought into operation during the analysed period.
- Adopted environmental policy aimed at emission reductions of basic air pollutants (SO_2, NO_x, SP and CO). Emission charges and emission stack concentration limits represent the active tools.
- Pricing policies, targeted at removing energy price distortions and accomplishing price liberalisation.

In the next section, the impacts of the above specified factors are illustrated, with the help of designed ISED and their relationships.

8.6.1. Bulk indicators of economic development and impacts on energy system and environment

The following indicators enable the quantification of economic development and its impact on the energy system and the environment:

- GDP as indicator of national economic development;
- Total primary energy supply (TPES) and final energy uses (FEU) as indicator of development in the whole energy system;
- Energy related CO_2 and SO_2 emissions as the most sensitive indicators of environmental impacts of the energy system.

These indicators can be shown together (Figure 8.14) to analyze the overall trend. Data for the GDP in Figure 8.14 are reported using fixed prices for the year 1995 and fixed exchange rate for the same year (GDP fp.95USD).

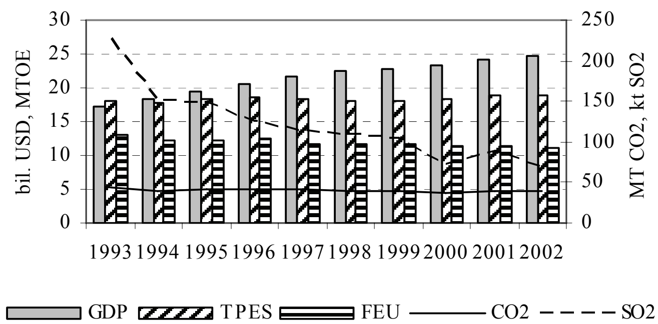


Figure 8.14 GDP, TPES, FEU and emissions of CO_2 and SO_2

While the GDP increases, TPES and FEU trajectories are quite stable. CO_2 emissions show a slight tendency to decrease, while the decline of SO_2 emissions is more impressive.

Based upon research experience gained during the ISED analyses, it appears that the evaluation of the energy system and its environmental impacts in Slovakia, from a sustainable development point of view will depend upon:

- The economy's development and the process of its restructuring;
- The primary energy mix, together with the role of nuclear energy for electricity generation;
- Adopted environmental policies aimed at emission reductions of basic air pollutants (SO_2, NO_x, SP and CO). Emission charges and emission stack concentration limits represent active abatement policy tools.
- Liberalisation of energy prices, and pricing policies aimed at removing energy price distortions.

8.6.2. Structural Changes and Final Energy Demand

The main characteristics of the process of economic restructuring in Slovakia have already been presented. A decreasing share of industry versus increasing shares of the commercial and services sector in GDP creation were identified. This should ultimately result in a decrease of the final energy use intensity.

There is interdependency between the industrial share of the GDP and the total final and primary energy intensity.

In addition to a decrease in the total national energy intensity, the energy intensity of the industrial sector has also changed during the observed period (Figure 8.15).

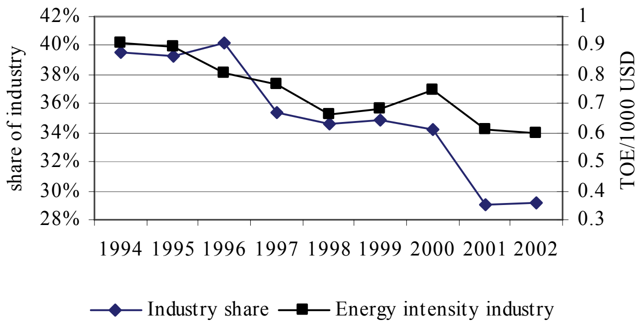


Figure 8.15 Industrial energy intensity and share of GDP

The continuous decrease in the industrial energy intensity began to change in 1998, when there was a slight increasing tendency. This primarily reflected the situation in the metallurgy sector (i.e., the process of privatisation and economical revival after restructuring). This is illustrated in Figure 8.16 too, which compares trends of industrial share of GDP, industrial final energy uses (FEU) and industrial energy intensity (EI).

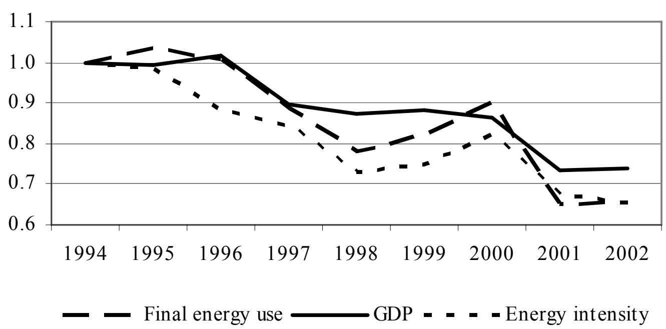


Figure 8.16 Trends of industrial GDP, FEU and EI (1994 = 100%)

It appears that the electricity share of final energy use could serve as the ISED indicator to illustrate the intensity of economic restructuring. This parameter will be influenced by the share of final/primary energy, too. It is a very sensitive indicator, especially in the industrial sector, where it can quantify the stage of transferring from heavy, highly energy intensive industrial entities towards new, less energy intensive ones. Figure 8.17 provides trends of industrial electricity intensity (Elect), compared with the trends for industrial final energy use (FEU) and industrial share of GDP(GDP). The Figure also gives the shares of individual sectors in final electricity consumption during the period. As one might note, the sectoral share for electricity consumption seems to be stable, and the tendency for electricity intensity follows quite closely the final energy intensity curve.

Electricity, final energy use and GDP trends for industry Share of industrial sectors in final electricity consumption

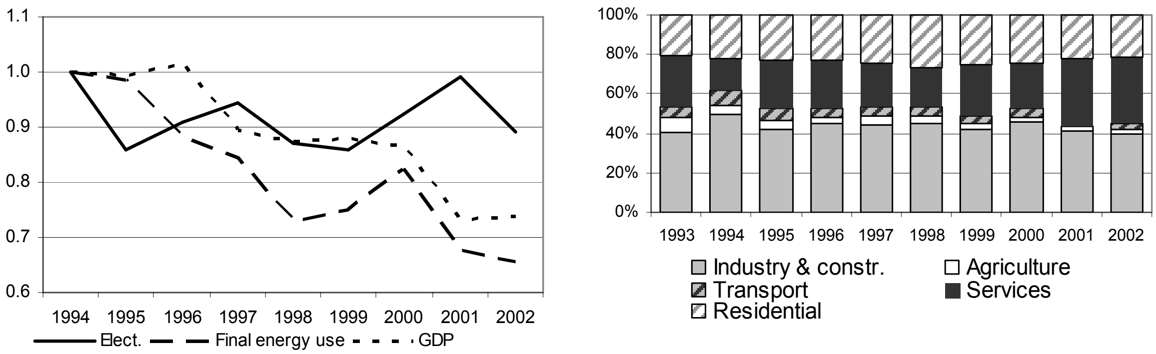


Figure 8.17 Trends of industrial electricity demand (1994 =100%) and shares of individual sectors in final electricity consumption

8.6.3. Energy Mix and Its Impact on Energy and Emission Intensity

Energy intensity is influenced by the structure of the fuel and energy mix as well. The fuel mix has a direct impact on the environment, and is therefore affected to some degree by adopted environmental policy. Changes in the share of fossil fuels with different carbon intensity, as well as the share of nuclear sources in electricity production, play an important role and therefore represent very sensitive issues.

The data in Table 8.18 show a continuous decrease in the ratio of FEU/TPES in Slovakia. The main reason for the observed tendency is an increase in the share of nuclear primary energy in the TPES.

The energy conversion efficiency in a PWR nuclear plant is limited by the physical characteristics of this technology. Therefore the ISED *Ratio of total final energy to total primary energy supply* does not illustrate the actual situation of the energy efficiency process, but only the structure of the primary energy supply. Although the increase in primary nuclear heat brings about a decrease in the final/primary energy ratio, it still has positive impact on air pollution.

Considering that the primary energy level is stable, the decrease in CO_2 emissions is therefore a result of changes in the primary energy mix. The penetration of non-fossil energy and NG, as well as declines in coal consumption, play an important role. These trends can also be seen in Figure 8.18, which shows growth indices of energy carriers' consumption and energy related CO_2 and SO_2 emissions. While for CO_2 emissions fuels used play an important role in the primary energy mix, in the case of SO_2 the use of abatement technology has a significant impact as well. Both of these impacts resulted in greater reductions of SO_2 emissions after the years 1995 and 1999.

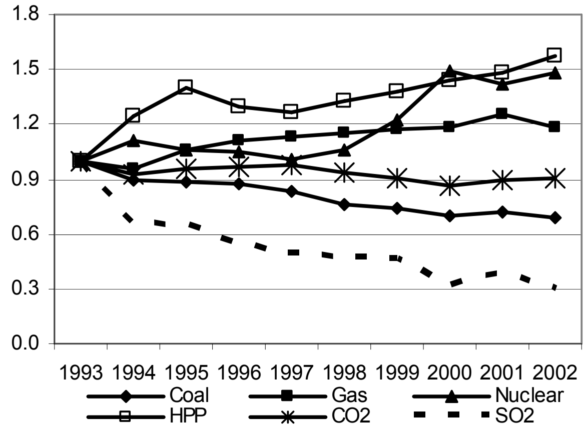


Figure 8.18 Comparison of primary energy and CO_2 & SO_2 emission trends (1993 = 100%)

8.6.4. Decrease in final energy use by applying energy conservation measures

Energy conservation measures are demonstrated options that could be directly stimulated by adopting economic measures and/or technical benefits.

Figure 8.19 illustrates the impact of pricing policy, where the district heating price is related to the district heating demand in the residential and industrial sectors.

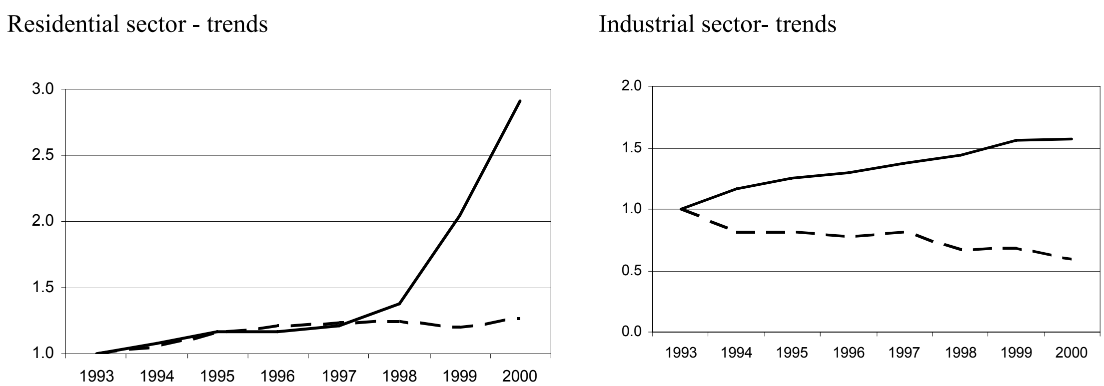


Figure 8.19 Trends of district heat demand and prices by sectors (1993 =100%)

The correlation between the price of heat and heat demand doesn't seem to exist in the residential sector as it does for industry. This is not the only reason for the industrial decline, however, as on-going structural changes also played an important role. Increases in gasoline prices in the transportation sector do not correlate with a decrease in motor fuel consumption (see Figure 8.20). The reason for this trend may be that passenger transport is driven more by the business activities of new private companies than by the use of a car for private purposes. Simultaneously, a reduction of public transport outputs could play an important role as well.

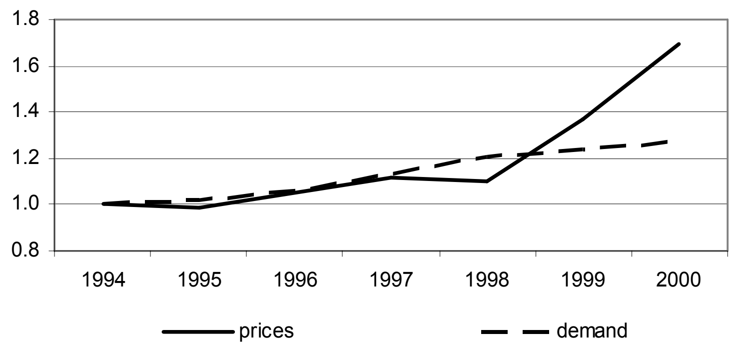


Figure 8.20 Trends of gasoline prices and demand (1994 =100%)

8.6.5. Environmental Impacts of Energy System

A number of issues related to primary energy supply have already been discussed (see Section 8.6.1). Response actions that will have a direct impact on the primary energy mix have been initiated by the adopted environmental legislation framework. Implementation of stack emission concentration limits and energy charges for basic pollutants in Slovakia stimulate fuel switching to less carbon intensive fuels (e.g., the use of NG instead of the sulphur-containing fuels such as coal or HFO, the use of lower sulphur content coal, such as at the CHP at US Steel, etc.). Figure 8.21 illustrates the trends in non-fossil primary energy and NG shares, along with the rends in emissions of air pollutants. The increasing share of less carbon intensive energy carriers brought about a decline in emissions.

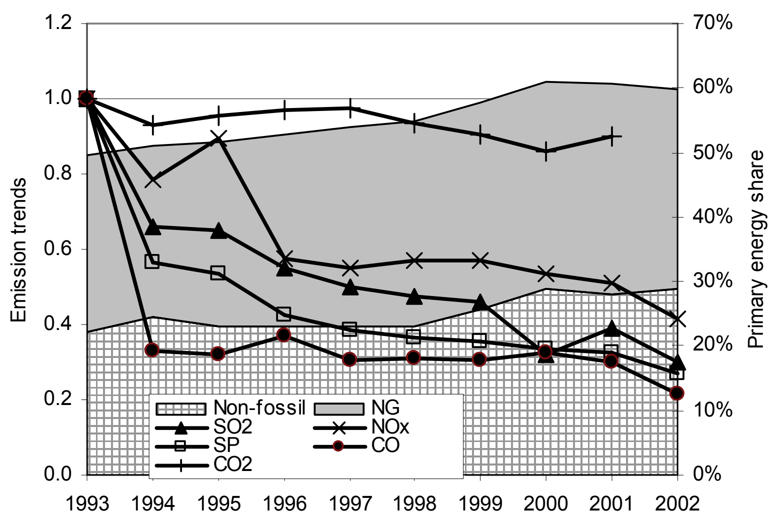


Figure 8.21 Correlations of primary energy mix and emission trends

The role of nuclear energy is usually the subject of heated discussions. There has been a demonstrated positive impact of increased share of nuclear and other non-fossil primary energy sources on pollutant emissions. A negative impact from the use of nuclear is the generation of radioactive wastes. The data in Table 8.26 show the radioactive waste releases and the share of nuclear in primary energy, for the period 1997-2000. The data show that the increases in radioactive emissions are lower than the increase in the primary nuclear energy share. This represents a positive trend.

TABLE 8.26 NUCLEAR ENERGY SHARE AND RADIOACTIVE EMISSIONS, 1997 AND 2000

ISED #	Item	ISED unit	1997	2000	2000 values/ 1997 values
11.3.4.	Nuclear power share in electricity	%	18.7	27.6	1.47
27.1.	noble gases:	GBq	26,300	29,232	1.11
27.4.	iodine-131:	GBq	0.87	0.97	1.11
28.2.	Radionuclide in liquid radioactive discharges	GBq	35,560	23,887	0.67
31.1.2.	Low and intermediate level radioactive waste, long-lived (LILW-LL):	m^3	172.0	217.0	1.26

8.7. Strategies for Improvements in Priority Areas

The future strategy of Slovakia's national energy system development will be heavily influenced by the country's EU membership effort. This will result in:

- a liberalization of its energy market;
- participation in the EU CO_2 emissions trading scheme;
- full harmonization of energy and environmental legislation system with EU practices;

Using the IAEA analytical tool ENPEP/BALANCE, three scenarios (i.e., low, medium and high) have been designed and analysed. This enabled an analysis of the impact of new strategies for energy sector development on potential trajectories by selected ISED. Details on key assumptions used to develop these scenarios are provided in Annex 8.D and are summarised as follows:

Scenario 1 - Low GDP growth rate as a driving force, combined with a high nuclear option and impacts of energy and environmental policy on final energy demand and fuel mix (including the use of renewable energy sources).

Scenario 2 - Medium GDP growth rate as a driving force, combined with a low nuclear option and impacts of energy and environmental policy on final energy demand and fuel mix (including use of renewable energy sources).

Scenario 3 - High GDP growth rate as a driving force, combined with a low nuclear option and development without impacts of energy and environmental policy on the final energy demand and fuel mix.

The high nuclear option holds that the retired 2 x 440MWe nuclear units in NPP Bohunice will be replaced by the finalized units in NPP Mochovce with the same capacity. The low nuclear option holds that the retired 2 x 440MWe nuclear units in NPP Bohunice will be replaced by newly installed NG-fired combined cycle units. The impact of environmental policy represents an increase of the NG share of the fuel mix for electricity and heat generation. Without this impact, the fuel mix for electricity and heat generation would not be influenced by environmental legislation.

Based on available input and calculated output data, the trajectories of the following ISED have been estimated:

- Macroeconomic data (i.e., population growth rate and GDP/cap development);
- Share of individual economic sectors in GDP to illustrate stages of economic transformation;
- Primary energy consumption and primary energy mix;
- Evaluation of environmental impacts through trends of basic air pollutants.

8.7.1. Population growth rate and GDP/cap

Table 8.27 and Figure 8.22 provide projections for the population growth rate. In all demographic scenarios published by the Slovak Statistical Office (SOS, 2002b), a decrease in total population is considered. This predicted trend closely follows observed trends in other developed countries, but in Slovakia some changes in the social structure due to the process of economic transformation will also play an important role. The natural increase or decrease in the population and the final number of inhabitants will also influence other ISED (i.e., where this figure is used as a denominator).

TABLE 8.27 PREDICTION OF POPULATION DEVELOPMENT

Population	Unit	2000	2005	2010	2015	2020	2025
Low scenario	mill.	5.403	5.373	5.342	5.291	5.211	5.096
Medium scenario	mill.	5.403	5.377	5.360	5.329	5.278	5.199
High scenario	mill.	5.403	5.379	5.386	5.388	5.374	5.335

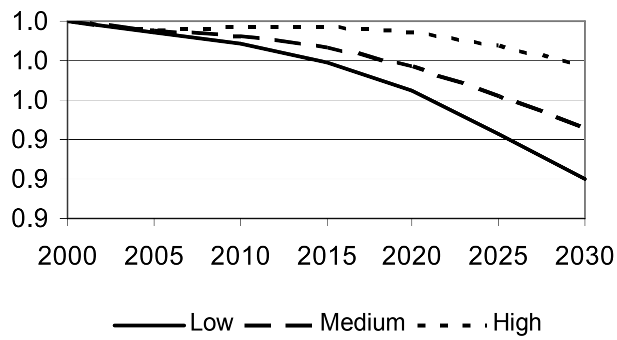


Figure 8.22 Future trends of population growth rate (2000 = 100%)

Table 8.28 shows projections of GDP and GDP/cap growth.

TABLE 8.28 GDP AND GDP/CAP GROWTH

Scenario		Unit	2000	2005	2010	2015	2020	2025
Low	GDP	bil.USD	31.28	34.85	39.43	44.61	50.47	57.11
	GDP/cap	$/ cap	5,790	6,486	7,381	8,432	9,686	11,206
Medium	GDP	bil.USD	31.28	35.95	42.29	49.74	58.51	68.82
	GDP/cap	$/ cap	5,790	6,686	7,890	9,334	11,085	13,237
High	GDP	bil.USD	31.28	36.76	46.91	59.87	76.41	97.52
	GDP/cap	$/ cap	5,790	6,833	8,710	11,112	14,219	18,280

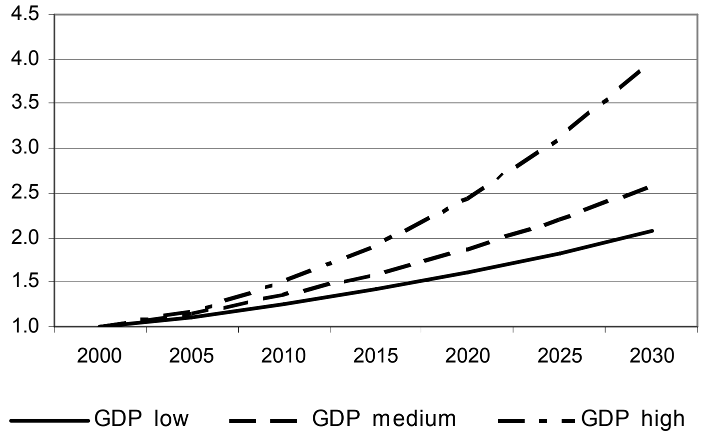


Figure 8.23 Comparison of GDP and GDP/cap trends

As is seen in Figure 8.23, the slope of the GDP/cap curve is higher than that of the GDP one, due to the decreasing number of inhabitants in all scenarios.

8.7.2. Share of economic sectors in GDP and transformation process

The shares of industry and services and commercial sectors in GDP creation serve as an indication of structural changes. Data for the individual sector's share are presented in Annex 8.D. Figure 8.24 indicates the share of these sectors for individual scenarios.

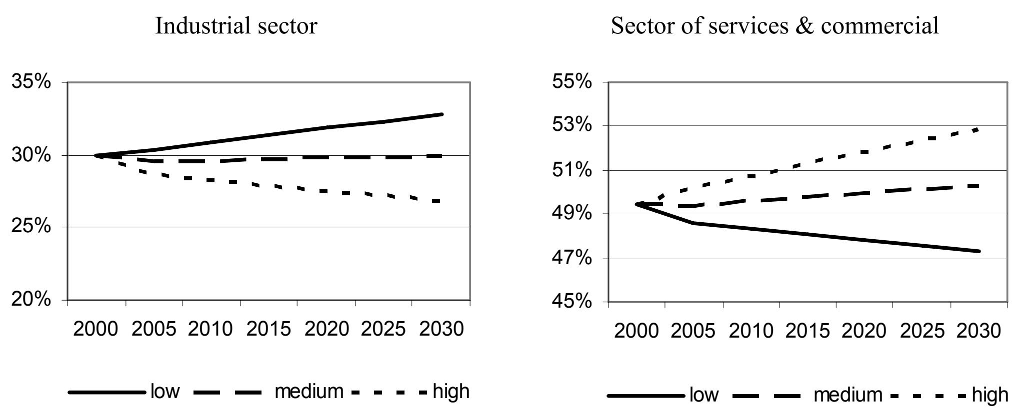


Figure 8.24 Development of GDP share for industrial and service and commercial sectors for individual scenarios of GDP growth rate.

As is seen in Figure 8.24, the scenario with the high GDP growth rate will bring a decrease in the share of the industrial sector, and an increase in the share of the services and commercial sector in GDP. A contrary tendency is observed in the low GDP scenario, and thus the higher GDP growth rate is connected primarily with an increase of activity in the services and commercial sector. This fact will also positively affect the level of energy intensity. Projections show that the VA share of individual industrial branches will not be changed substantially during the period followed (as is seen in Table 8.29).

TABLE 8.29 VA SHARE OF INDUSTRIAL ENERGY INTENSIVE BRANCHES

Year	2005			2010			2015		
Scenario	low	medium	high	low	medium	high	low	medium	high
Iron and steel	13.4%	13.4%	13.4%	12.9%	12.9%	12.9%	12.3%	12.3%	12.3%
Machinery	23.7%	23.6%	23.6%	24.3%	24.2%	24.2%	24.9%	24.9%	24.8%
Chemicals	7.9%	7.9%	7.9%	8.0%	8.0%	8.0%	8.2%	8.2%	8.2%
Petroleum refining and coke production	5.7%	5.7%	5.7%	5.8%	5.8%	5.8%	6.0%	6.0%	6.0%
Non-metallic minerals	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%
Paper and pulp	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%

8.7.3. Structure of Primary Energy Sources

Based on the scenario assumptions, estimates of primary energy consumption and primary energy mix were calculated, together with relevant ISED. Figure 8.25 gives the structure of TPES for each scenario. All scenarios consider the retirement of old units of existing power plants. In the low scenario, the building of new units is considered. The higher share of nuclear in the case of the “low” scenario brings about a decrease in the share of fossil fuels. A preferred case is the one in which natural gas is used as fuel in newly installed combined cycle units. These units are considered to replace retired capacity of old nuclear power plants in the years after 2008, together with addressing the increase in electricity demand.

Figure 8.25 Predicted structures of primary energy sources for 2010 and 2020

8.8. Findings and recommendations

8.8.1. ISED Relation to National Priorities

The applicable ISED, designed according to IAEA methodology, are directly and/or indirectly related to the following priority groups of national policy:

8.8.1.1. EU accession process

Comparing energy price relationships in Slovakia and selected EU countries (i.e., Germany and Netherlands), it can be seen that price levels for end-use energy carriers in Slovakia is still lower than those for EU representatives. On the other hand, energy price distortions have been continuously removed, in the cases of natural gas, district heat and electricity. The price relationship in households and the industrial sector was changed towards a real economic model by removing cross-sector subsidies. The newest fiscal measure is levelization of taxes (both income tax and VAT) at the level of 19%, and involvement of only one group of VAT. These were applied in January 2004, and were not discussed in this study, but they will have a significant impact on future economic development in Slovakia.

The process of economic restructuring is connected with the structural changes of GDP creation by sectors. In the period studied, total GDP was increasing continuously, and the share of industry slightly declined while the share of the commercial and services sector increased. These changes are directly reflected in the final energy intensity figures. The trends for the industrial share of GDP indicated decline, and in the year 2000 reached approximately the level of Germany, but it remained higher than for the other reference EU country (i.e., the Netherlands). The process of privatization in the last year, accompanied with higher foreign investments, resulted in some revival in the machinery and metallurgy branches. These changes resulted in some increase in industrial energy intensity. Future development of metallurgy in Slovakia will strongly depend on the actual EU policy related to quotas for steel exports (as this could determine additional revival in this energy intensive industrial sector) and/or environmental requirements.

8.8.1.2. Security of energy supply

Slovakia is a country highly dependent on energy imports. The only meaningful domestic indigenous energy sources are brown coal and hydropower. Both are limited in their potential, and domestic coal/lignite is, in addition, characterized by low quality. For a system with these characteristics, it is obvious that only a combination of intensive energy conservation policies, active participation in the European and world energy markets, and a higher diversification of energy sources could ensure the security of energy supply. The required legislative framework has already been implemented and is still being enhanced in Slovakia.

8.8.1.3. Sustainable development

Security of energy supply and environmental issues represent the additional parameters that need to be attained in terms of sustainability. The adopted environmental legislation framework for air protection in Slovakia first focused on the reduction of basic pollutants, which also had a positive side effect on the emissions of greenhouse gases (namely CO_2). To meet emission standards, fuel switching towards less carbon intensive fuels has been the measure most frequently used. This has a direct impact on the primary energy mix (i.e., increasing the share of natural gas). The levels of both basic air pollutants and GHG emissions have been positively influenced by the economy restructuring, through its positive effect of decreasing energy intensity. A new comprehensive legislation framework for waste treatment adopted in Slovakia is in all areas fully compatible with EU directives, and serves as another supporting tool for sustainable development. It appears that further steps in harmonization with EU environmental directives will result in additional energy savings and decreased emission intensity on both a GDP and per capita basis. The combination of higher incomes in recent years with the adopted tax reform (i.e., one tax level of 19%) seems to provide a promising situation, with the latter tool offering a positive impact by decreasing the unemployment rate.

8.8.2. Interdependency of Applied ISED

The IAEA methodology looks at targeted indicators, and the opportunity for responses that could positively influence selected ISED. Even though the period covered in this analysis was relatively short, there has been an attempt to clarify the interdependency of the ISED and to illustrate the impact of the economic transformation process and environmental measures on the energy system.

Concerning the pricing policy, the only strong direct relationship between price and demand was found in the distict heat supply for industry. Nevertheless, considering that both a price increase and industrial restructuring should be accompanied by a decrease in energy intensity and both occurred over the same period, the actual heat demand decrease would have been influenced simultaneously by both factors. There were other complex relationships in energy pricing and demand as well. For example, even though the price of gasoline increased significantly, this had no direct impact on gasoline consumption. The gasoline consumption probably increased due to the increased number of cars in the vehicle fleet, and also because of the increase in private enterprise activities.

The process of economic restructuring has had a positive impact on both the energy and emission intensity. On the other hand, the process of privatisation and the increase in foreign investment led to the revival in metallurgy branches and have had a direct impact on negative changes in energy intensity and GHG emissions production. However, the production level of GHG emissions will be directly limited by the EU quota rules and, therefore, should not result in any dramatic increase.

8.8.3. Recommendations for Additional Analyses

Based on experience gained with the collection of data, data quality analyses, design of ISED and analyses of ISED trends, findings during the development of this study could be summarized as follows:

The proposed set of ISED is relevant for Slovakia, except for the ISED related to the energy access for the poorest group of inhabitants; until now, the electricity and gas network is available to 90% of the population.

The indicator addressing the *Percentage in urban areas* is not very relevant for the final energy use analyses in Slovakia. A better approach would be to implement an ISED relevant to the dwelling structure and the type of heat supply (e.g., share of population living in family and apartment housing; share of heat supply from centralized district heat versus individual space heating system; split of thermal energy consumption to space heating versus hot water supply; etc.). Based on available data, time series for new proposed ISED indicators were calculated, and the results are given in Table 8.30.

TABLE 8.30 INDICATOR FOR HEAT SUPPLY IN THE RESIDENTIAL SECTOR

Parameter	Unit	1993	1994	1995	1996	1997	1998	1999	2000
Share of family houses	%	50.2	50.3	50.3	50.3	50.3	50.3	50.5	50.7
Share of apartment houses	%	49.8	49.7	49.7	49.7	49.7	49.7	49.5	49.3
Share of centralized heat supply	%	92.4	92.4	92.3	92.2	92.2	92.1	92.0	91.9
Share of individual heat supply	%	7.6	7.6	7.7	7.8	7.8	7.9	8.0	8.1

The ISED related to activities in the transportation sector do not fully reflect the on-going transformation process in this sector. This process is namely characterised by changes in vehicle fleet numbers and structures, especially in the individual transport mode (see Table 8.31). Since 1990 the number of vehicles per capita has increased in Slovakia by 34% on average, with Bratislava and Košice getting the largest share of this increase (64% and 46%, respectively). Slovakia is among EU countries with medium-developed motorism. To compensate for this huge increase in energy consumption and negative impacts on air pollution (i.e., sustainability aspects), legislation and regulatory rules regarding improvements in car quality have been adopted as well.

TABLE 8.31 DEVELOPMENT OF VEHICLE FLEET STRUCTURE FOR PERSONAL CARS (TRANSPORT RESEARCH INSTITUTE, 2000)

Vehicles	Unit	1994	1995	1996	1997	1998	1999	2000
<1,400ccm	%	75.1	73.5	68.5	56.8	53.3	50.3	48.5
<1,400ccm & catalyst	%	3.6	5.0	8.9	12.3	13.6	14.4	15.2
1,400-2,000ccm	%	9.7	9.8	9.6	13.9	14.9	15.2	15.5
1,400-2,000ccm & catalyst	%	1.1	1.2	2.3	3.0	5.0	6.3	7.3
>2,000 ccm	%	2.8	2.9	3.2	3.9	3.7	3.5	3.4
>2,000 ccm & catalyst	%	0.3	0.5	1.1	0.9	1.0	1.0	1.0
diesel cars	%	2.0	2.3	2.3	6.7	6.8	6.9	7.0
LPG cars	%	0.0	0.0	0.0	0.0	0.0	1.3	1.5
2 stroke cars	%	5.3	4.7	4.1	2.5	1.7	1.0	0.5

Availability of input data was a determining factor for some of the ISED. The adopted legislation framework (i.e., especially the "*rules of three companies,*" in which energy and other statistical data for individual sector or industrial branches can only be openly published if this aggregation has more than three companies) does not allow the development of ISED for some of the most important production and energy consuming companies.

Although energy data are available for a relatively wide range of industrial branches, the definition of activity as a mass or volume of product presents a problem.

8.8.4. Dissemination of Project Results

Among the main goals of this project, the dissemination of lessons learned and results throughout the nationwide network of experts and official representatives involved directly in the decision making process for energy sector development plays an important role.

The Interim Report developed during the first year of the project was distributed to official representatives in all institutions related to the subject in order to provide comprehensive information on priority areas and policies and to show the results from this study.

Results from the first project phase were also summarised in an article published in the domestic expert and public journal ENERGETIKA, issued by the Slovak Energy Agency.

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ANNEX 8.A Total Fuel Balance

TABLE A.1 TOTAL BALANCE OF SOLID FUELS – YEAR 2000 [TJ]

	Coking coal	Hard coal	Brown coal	Briquettes	Coke	Other solid fuel	Total
Domestic	0	0	42 629	-	-	2 971	45 600
Import	75 751	56 245	9 164	92	4 069	0	145 321
Export	0	0	80	0	1 629	0	1 709
Stock exchange	-174	-6 263	-526	2	417	-346	-6 890
Other sources	0	1 093	-1 768	0	0	0	-675
Primary sources	75 577	51 075	49 419	94	2 857	2 625	181 647
Production	0	0	0	0	47 969	1 198	49 167
Consumption	64 645	44 900	40 676	0	17 520	3 797	171 538
Mining	0	0	24	0	0	0	24
Transformation	64 645	0	0	0	17 449	1 198	83 292
Heat generation	0	14 056	16 776	0	71	2 475	33 378
Electricity generation	0	30 821	23 876	0	0	124	54 821
Distribution, losses	0	23	0	0	0	0	23
Final energy uses	10 932	6 175	8 743	94	33 306	26	59 276
Forestry	3	1	28	0	14	15	61
Agriculture	7	17	261	1	60	0	346
Industry	10 893	5 863	0	2	30 653	0	47 411
Construction	2	5	66	0	8	1	82
Transport	0	30	478	3	290	0	801
Residential	27	25	1 926	22	56	10	2 066
Other	0	234	5 984	66	2 225	0	8 509

Other solid fuel – includes biomass and waste

TABLE A. 2 TOTAL BALANCE OF LIQUID FUELS – YEAR 2000 [TJ]

	Crude oil	Gasoline	Diesel oil	LFO	HFO	Kerosene	OLF	Total
Domestic	2 436	-	-	-	-	-	-	2 436
Import	221 184	4 220	4 095	2	1 461	0	400	231 362
Export	609	37 620	60 421	779	17 494	407	2 269	119 599
Stock exchange	2 856	435	46	-37	374	-15	0	3 659
Other sources	0	-605	915	0	2 867	-326	0	2 851
Primary sources	225 867	-33 570	-55 365	-814	-12 792	-748	-1 869	120 709
Production	0	59 635	90 279	1 523	20 563	2 035	24 399	198 434
Consumption	225 867	18	12	95	4 429	0	22 525	252 946
Mining	0	0	0	0	0	0	0	0
Transformation	225 825	0	0	0	122	0	369	226 316
Heat generation	0	0	5	95	3 052	0	16 197	19 349
Electricity generation	0	0	0	0	1 247	0	5 959	7 206
Distribution, losses	42	18	7	0	8	0	0	75
Final energy uses	0	26 047	34 902	614	3 342	1 287	5	66 197
Forestry	0	68	578	3	0	55	0	704
Agriculture	0	252	5 459	112	2	0	0	5 825

Industry	0	1 321	3 877	142	3 220	37	0	8 597
Construction	0	420	2 205	170	0	0	5	2 800
Transport	0	1 186	6 998	4	120	484	0	8 792
Residential	0	12 805	2 525	0	0	0	0	15 330
Other	0	9 995	13 260	183	0	711	0	24 149

LFO – Light fuel oil
HFO – Heavy fuel oil
OLF – Other liquid fuels includes liquid residues from refinery and residual oil from refinery and chemical industry and black liquor

TABLE A.3 TOTAL BALANCE OF GASEOUS FUELS – YEAR 2000 [TJ]

	NG	CoG	BFG	LPG	OGF	Total
Domestic	5 620	-	-	0	-	5 620
Import	241 349	0	0	1 264	0	242 613
Export	0	0	0	23	0	23
Stock exchange	-18 158	0	0	-57	0	-18 215
Other sources	15 479	0	0	0	0	15 479
Primary sources	244 290	0	0	1 184	0	245 474
Production	-	12 164	17 123	173	13 473	42 933
Consumption	87 793	5 772	9 861	0	12 516	115 942
Mining	141	0	0	0	0	141
Transformation	9 075	1 691	4 711	0	8 628	24 105
Heat generation	55 705	2 449	3 047	0	3 708	64 909
Electricity generation	20 104	1 542	1 339	0	180	23 165
Distribution, losses	2 768	90	764	0	0	3 622
Final energy uses	156 497	6 392	7 262	1 357	957	172 465
Forestry	114	0	0	0	0	114
Agriculture	1 911	0	0	117	6	2 034
Industry	72 581	6 392	7 262	158	945	87 338
Construction	1 117	0	0	281	0	1 398
Transport	384	0	0	6	6	396
Residential	60 360	0	0	454	0	60 814
Other	20 030	0	0	341	0	20 371

NG – natural gas
CoG – coking gas from coking battery
BFG – blast furnace gas
OGF – other gaseous fuels include converter gases in metallurgy and refinery gases

ANNEX 8.B Data of ISED

TABLE B 1. ISED #1- POPULATION, #2- GDP #3 - END USE PRICES

ISED #	Indicator	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1.	**Population**		5.336	5.356	5.368	5.379	5.388	5.393	5.399	5.403	5.379	5.379
1.1.	Total:	Million										
2.	**GDP per capita**											
2.1.	GDP per capita (using ER)	$/ cap	2,593	3,112	3,612	3,991	4,448	4,873	5,258	5,814	6,314	6,712
2.2.	GDP per capita (using PPP):	$/ cap	8,319	9,910	9,281	10,095	10,703	11,720	13,584	14,197	15,261	15,926
3.	**End-use energy prices with and without tax/subsidy**											
3.1.	***Automotive fuel***											
3.1.1.	Premium gasoline/unleaded gasoline (91 RON)											
3.1.1.1	with tax/subsidy	$/1,000 lt	664	671	653	711	742	713	856	1,114	1,057	1,010
3.1.1.2	without tax/subsidy	$/1,000 lt	257	258	242	289	330	315	379	510	463	424
3.1.2.	Premium unleaded gasoline (95 RON)											
3.1.2.1	with tax/subsidy	$/1,000 lt	647	665	655	702	745	734	910	1,126	1,067	1,012
3.1.2.2	without tax/subsidy	$/1,000 lt	280	286	272	315	354	332	397	519	471	425
3.1.3.	*Automotive gasoline (diesel) for commercial use*											
3.1.3.1	with tax/subsidy	$/1,000 lt	452	455	474	535	702	706	738	867	838	769
3.1.3.2	without tax/subsidy	$/1,000 lt	197	200	206	252	317	292	342	462	424	392
3.2.	**Industry**											
3.2.1.	***Electricity:***											
3.2.1.1	with tax/subsidy	$/MWh	49	49	49	51	55	58	57	66	70	72
3.2.1.2	without tax/subsidy	$/MWh	49	49	49	51	55	58	57	65	69	72
3.2.2.	***Heat:***											
3.2.2.1	with tax/subsidy	$/GJ	6.2	7.3	7.8	8.1	8.5	9.0	9.7	9.8	N/A	N/A
3.2.2.2	without tax/subsidy	$/GJ	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3.2.3.	***Natural gas:***											
3.2.3.1	with tax/subsidy	$/GJ (GCV)	2.84	2.94	3.07	3.08	3.21	3.54	3.56	3.78	4.16	4.85
3.2.3.2	without tax/subsidy	$/GJ (GCV)	2.84	2.93	3.07	3.08	3.21	3.54	3.56	3.78	4.16	4.85
3.2.4.	***Light fuel oil***											
3.2.4.1	with tax/subsidy	$/thousand lt	175.7	145.5	133.1	147.5	155.2	150.3	167.1	240.4	324.2	350
3.2.4.2	without tax/subsidy	$/thousand lt	175.7	145.5	133.1	147.5	155.2	150.3	167.1	240.4	324.2	350
3.2.5.	***Steam coal:***											
3.2.5.1	with tax/subsidy	$/tone	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3.2.5.2	without tax/subsidy	$/tone	34.1	40.7	43.3	47.6	49.6	53.9	58.1	59.9	N/A	N/A
3.3.	**Households**											
3.3.1.	***Electricity:***											
3.3.1.1	with tax/subsidy	$/MWh	31.4	31.4	31.4	32.5	33.2	33.2	48.4	78.0	102.2	101.6

3.3.1.2	without tax/subsidy	$/MWh	29.8	29.7	29.7	30.6	31.3	31.3	44.5	70.1	92.0	91.8
3.3.2.	***Heat:***											
3.3.2.1	with tax/subsidy	$/GJ	4.0	4.4	4.7	4.7	4.9	5.5	8.2	11.8	N/A	N/A
3.3.2.2	without tax/subsidy	$/GJ	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3.3.3.	***Natural gas:***											
3.3.3.1	with tax/subsidy	$/GJ (GCV)	1.87	1.87	1.95	1.98	2.04	2.08	2.60	4.04	4.50	4.60
3.3.3.2	without tax/subsidy	$/GJ (GCV)	1.77	1.76	1.84	1.87	1.92	1.96	2.40	3.67	4.09	4.18
3.3.4.	***Light fuel oil***											
3.3.4.1	with tax/subsidy	$/1,000 lt	176	145	133	147	155	150	167	240	324	350
3.3.4.2	without tax/subsidy	$/1,000 lt	10	9	300	301	308	317	327	344	352	45
3.3.5.	***Brown coal***											
3.3.5.1	with tax/subsidy	$/t	30.8	39.8	44.5	47.2	51.2	56.2	64.1	67.8	N/A	N/A

TABLE B.2. ISED #4 - SECTORAL GDP SHARES, #5 & #6- TRANSPORTATION, #7 FLOOR AREA, #9-EI

ISED #	Indicator	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
4.	**Shares of sectors in GDP value added in:**											
4.1.	Industry and construction	%	36.36	39.58	39.31	40.16	35.41	34.63	34.86	34.19	29	29.18
4.2.	Agriculture:	%	6.307	6.921	6.121	5.685	5.745	5.399	4.702	4.699	4.103	4.158
4.3.	Commercial & public services:	%	45.97	40.36	41.63	40.84	44.93	45.97	46.65	47.17	53.19	53.96
4.4.	Transportation:	%	8.644	11	10.75	11.08	11.04	11.1	10.9	11	11.21	10.18
4.5	Other	%	2.717	2.134	2.185	2.235	2.863	2.909	2.893	2.938	2.491	2.527
5.	**Distance traveled per capita by passengers**											
5.1.	Total:	pkm/cap	N/A	N/A	N/A	N/A	6,801	6,814	6,647	6,376	N/A	N/A
5.2.	By urban public transport:	pkm/cap	N/A	N/A	N/A	N/A	654	742.1	859	692.9	N/A	N/A
5.3.	Share of electrically driven vehicles in urban public transport:	%	N/A	N/A	N/A	N/A	0.4	0.395	0.387	0.414	N/A	N/A
6.	**Freight transport activity**											
6.1.	Total per capita:	Btkm/cap	N/A	N/A	N/A	N/A	5,427	5,743	5,564	7,625	N/A	N/A
6.2.	Percentage by truck:	%	N/A	N/A	N/A	N/A	52.49	57.84	61.64	69.37	N/A	N/A
6.3.	Percentage by train:	%	N/A	N/A	N/A	N/A	42.31	37.95	32.82	27.27	N/A	N/A
6.4.	Percentage by inland water:	%	N/A	N/A	N/A	N/A	5.194	4.213	5.536	3.357	N/A	N/A
7.	**Floor area per capita**	m^2/cap	25.73	25.74	25.78	25.84	25.91	26.02	26.17	26.37	N/A	N/A
8.	**Manufacturing value added by selected energy intensive industries**											
8.1.	Iron and steel:	%	N/A	N/A	12.17	12.41	12.18	10.71	9.547	13.83	15.94	13.7
8.2.	Machinery	%	N/A	N/A	15.69	15.63	17.63	18.65	20.09	22.52	24.61	25.99
8.3.	Chemicals:	%	N/A	N/A	10.84	10.94	10.32	9.256	7.919	8.86	8.914	8.412
8.4.	Petroleum refining and coke production:	%	N/A	N/A	4.118	3.844	5.07	3.942	3.159	6.422	4.631	4.114
8.5.	Non-metallic minerals:	%	N/A	N/A	4.393	4.552	4.639	4.998	4.834	5.651	5.893	5.859
8.5.1.	Paper and pulp:	%	N/A	N/A	4.607	3.486	3.519	3.966	3.849	4.54	5.83	5.419
9.	**Energy intensities**											
9.1.	***Final energy intensity:***	toe 1,000$	0.755	0.661	0.631	0.603	0.54	0.519	0.515	0.485	0.47	0.447
9.1.1.	Industry and construction	toe 1,000$	1.084	0.908	0.896	0.802	0.766	0.663	0.682	0.747	0.614	0.597
9.1.2.	Agriculture:	toe 1,000$	0.582	0.325	0.34	0.325	0.321	0.28	0.285	0.258	0.185	0.159
9.1.3.	Commercial and public services:	toe 1,000$	0.352	0.334	0.25	0.277	0.235	0.285	0.258	0.182	0.147	0.138
9.1.4.	Transportation:	toe 1,000$	0.253	0.234	0.24	0.139	0.141	0.139	0.131	0.136	0.521	0.707
9.1.4.1	Passengers travel:	kgoe 1,000 pkm		N/A	N/A	N/A	19.31	20.72	21	21.79	N/A	N/A

9.1.4.2	Freight activity:	kgoe 1,000 tkm		N/A	N/A	N/A	18.23	19.43	17.81	17.09	N/A	N/A
9.1.5.	***Residential sector***											
9.1.5.1	Total energy:	kgoe/cap	452	405.9	464.8	510.4	514.8	532.4	545	503.8	571.6	549.7
9.1.5.2	Total conventional energy:	kgoe/cap	452	405.9	464.8	510.4	514.8	532.4	545	503.8	571.6	549.7
9.1.5.3	Space heating:	kgoe/m^2 floor area	15.99	15.99	15.99	15.98	15.98	15.98	16.49	15.72	N/A	N/A
9.2.	Electricity intensity	kWh/$	1.173	1.109	1.121	1.141	1.061	0.937	0.999	0.969	0.97	0.915
9.2.1.	Industry and construction	kWh/$	1.293	1.397	1.2	1.271	1.318	1.215	1.2	1.288	1.384	1.245
9.2.2.	Agriculture:	kWh/$	1.464	0.755	0.761	0.73	0.918	0.697	0.644	0.565	0.535	0.498
9.2.3.	Commercial and public services:	kWh/$	0.664	0.444	0.657	0.677	0.531	0.398	0.561	0.481	0.618	0.564
9.2.4.	Residential sector:	kWh/ cap	775.3	838.1	931.1	1,013	1,022	1,042	1,051	1,003	970.8	912.2
9.2.5.	Transportation:	kWh/$	0.754	0.728	0.662	0.432	0.425	0.406	0.364	0.378	0.011	0.285

TABLE B.3. ISED #11 -ENERGY MIX, #12-EFFICIENCY, #13- ABATEMENT TECHNOLOGY

ISED #	Indicator	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
11.	**Energy mix:**	-	-	-	-	-	-	-	-	-	-	-
11.1.	***Final energy mix***											
11.1.1.	Coal:	%	18.6	17.9	15.7	16.1	15.5	13.8	12.8	12.5	9.5	11.2
11.1.2.	Petroleum products:	%	12.0	16.5	15.1	11.2	12.2	12.3	14.3	14.0	22.8	26.7
11.1.3.	Gas:	%	29.3	30.3	31.6	34.4	31.6	37.3	36.6	36.5	38.1	33.2
11.1.4.	Electricity:	%	13.4	14.4	15.3	16.3	16.9	15.5	16.7	17.2	17.8	17.6
11.1.5.	Heat:	%	26.8	20.9	22.2	22.1	23.8	21.0	19.6	19.7	9.3	9.2
11.1.7.	Renewable & wastes	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	2.0
11.2.	**Electricity generation mix by fuel types**											
11.2.1.	Coal:	%	N/A	N/A	N/A	N/A	26.5	25.5	22.7	18.3	20.2	20.3
11.2.2.	Oil products:	%	N/A	N/A	N/A	N/A	5.0	6.2	3.2	2.4	0.7	1.2
11.2.3.	Gas based:	%	N/A	N/A	N/A	N/A	6.9	6.3	8.5	7.8	8.1	9.8
11.2.4.	Nuclear power:	%	N/A	N/A	N/A	N/A	51.3	51.5	55.7	62.5	64.5	62.4
11.2.5.	Hydro power:	%	N/A	N/A	N/A	N/A	6.7	6.7	6.4	6.1	6.0	5.7
11.2.7.	Renewable & wastes:	%	N/A	N/A	N/A	N/A	3.7	3.7	3.5	2.9	0.4	0.7
11.3.	**Total primary energy supply mix**											
11.3.1.	Coal:	%	33.9	30.7	29.4	28.7	27.8	25.9	25.0	23.3	23.4	22.4
11.3.2.	Oil:	%	16.4	18.1	19.0	18.4	18.2	19.3	17.3	15.7	15.8	17.8
11.3.3.	Gas:	%	27.4	26.7	28.6	29.7	30.8	31.7	32.0	32.0	32.9	31.0
11.3.4.	Nuclear power:	%	18.7	21.2	19.6	19.0	18.7	19.8	22.8	27.6	25.3	26.5
11.3.5.	Hydro power:	%	1.7	2.1	2.3	2.1	2.1	2.2	2.3	2.4	2.3	2.5
11.3.6.	Electricity net import	%	0.9	0.2	0.6	1.6	1.9	0.6	0.3	-1.3	-1.7	-1.9
11.3.8.	Renewable & wastes:	%	0.9	1.0	0.4	0.4	0.5	0.4	0.4	0.3	1.9	1.6
12.	**Energy supply efficiency**											
12.1.	Ratio of total final energy to total primary energy supply:	%	72.2	68.2	66.9	66.6	63.7	64.5	64.5	61.5	59.9	58.7
12.2.	Average fuel effectiveness of thermal power plants	%	N/A	N/A	N/A	N/A	30.8	30.2	30.4	31.0	31.2	N/A
12.3.	Electricity transmission and distribution losses	%	N/A	N/A	N/A	N/A	7.2	7.6	6.5	6.5	4.7	3.6
12.5.	Oil refining efficiency:	%	N/A	N/A	N/A	N/A	85.4	86.6	86.4	87.9	N/A	N/A
12.6.	Electricity supplies from CHP plants as percentage of total electricity generation	%	N/A	N/A	N/A	N/A	0.2	0.2	0.2	0.2	0.16	0.142
13.	**Status of deployment of pollution abatement technologies**											
13.1.	***Extent of use for abatement of:***											

13.1.1.	SO_2:	%	N/A	N/A	N/A	13.3	13.3	13.3	13.3	25.3	25.3	25.3
13.1.2.	NOx:	%	N/A	N/A	N/A	1.3	1.3	1.3	19.3	31.3	31.3	31.3
13.1.3.	Particulates:	%	N/A	N/A	N/A	100	100	100	100	100	100	100
13.2.	Average performance for removal of:											
13.2.1.	SO_2:	%	N/A	N/A	N/A		79	79	79	79	79	79
13.2.2.	NOx:	%	N/A	N/A	N/A		35	35	35	35	35	35
13.2.3.	Particulates:	%	N/A	N/A	N/A		98	98	98	98	98	98

TABLE B.4. ISED #14 = TPES/GDP, #16- TPES/CAP, #17 - INDIGENOUS ENERGY, #18- IMPORT

ISED #	Indicator	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
14.	**Energy use per unit of GDP**											
14.1.	Total primary energy:	toe/ 1,000$	1.045	0.97	0.944	0.905	0.848	0.805	0.798	0.789	0.784	0.761
14.2.	Primary conventional energy:	toe/ 1,000$	1.035	0.96	0.94	0.902	0.844	0.802	0.795	0.787	0.769	0.748
14.3.	Electricity use:	kWh/$	1.467	1.399	1.428	1.4	1.341	1.193	1.243	1.205	1.177	1.247
16.	**Energy consumption per capita**											
16.1.	Total primary energy:	toe/ cap	3.379	3.316	3.41	3.463	3.389	3.349	3.366	3.394	3.515	3.512
16.2.	Automotive fuel:	toe/ cap	0	0.236	0.245	0.231	0.259	0.276	0.269	0.265	0.255	0.312
16.3.	Renewable & wastes	toe/ cap	0.032	0.032	0.014	0.014	0.015	0.013	0.012	0.012	0.068	0.058
16.4.	Electricity:	MWh/cap	4.741	4.785	5.158	5.354	5.36	4.961	5.242	5.18	5.274	5.759
17.	**Indigenous energy production**											
17.1.	***Indigenous primary energy***	Mtoe	5.1	5.69	5.463	5.481	5.236	5.377	5.871	6.758	6.925	6.924
17.1.1.	Coal:	%	18.99	18.91	18.8	20.78	20.28	19.79	17.4	15.07	14.28	13.75
17.1.2.	Oil:	%	1.297	1.175	1.354	1.294	1.225	1.113	1.111	0.861	3.05	0.79
17.1.3.	Gas:	%	4.079	4.062	5.164	4.714	4.312	3.766	2.818	1.986	2.197	2.198
17.1.4.	Nuclear power:	%	66.38	66.27	65.58	64.72	65.35	66.6	70.51	74.76	69.18	72.35
17.1.5.	Hydro power:	%	5.889	6.58	7.682	7.112	7.253	7.393	7.062	6.398	6.034	6.421
17.1.7.	Renewable & wastes	%	3.365	3.006	1.42	1.372	1.587	1.341	1.094	0.928	5.262	4.484
17.2.9.	Total electricity:	TWh	25.3	25.63	27.69	28.8	28.88	26.76	28.3	27.99	28.37	30.98
18.	**Energy net imports dependency**											
18.1.	Total primary energy:	%	71.71	67.96	70.15	70.58	71.33	70.23	67.69	63.15	63.38	63.35
18.2.	Total conventional energy	%	100	100	100	100	100	100	100	100	100	100
18.3.	Oil:	%	97.77	97.92	97.87	97.93	98.07	98.29	97.93	97.98	92.93	98.37
18.4.	Gas:	%	95.8	95.12	94.61	95.33	95.98	96.46	97.15	97.71	97.56	97.41
18.5.	Coal:	%	84.19	80.26	80.95	78.7	79.13	77.25	77.54	76.19	77.7	77.55
18.6.	Electricity:	%	5.601	1.669	4.992	12.23	14.04	4.822	1.971	-9.63	-13	-13.4

TABLE B.5. ISED #23 - #31 ENVIRONMENTAL IMPACT

ISED #	Indicator	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
23.	**Quantities of air pollutant emissions**											
23.1.	***From all energy related activities:***											
23.1.1.	SO_2:	kt	228	151	148	125	114	108	105	72	89	68
23.1.2.	NOx:	kt	77	61	69	44	42	44	44	41	39	32
23.1.3.	Particulates:	kt	98	55	53	42	38	36	35	33	32	27
23.1.4.	CO:	kt	202	66	65	75	61	63	62	65	61	43
23.2.	***From electricity production:***											
23.2.1.	SO_2:	kt	84	58	64	83	79	74	74	43	52	41
23.2.2.	NOx:	kt	37	30	36	26	25	26	25	23	18	12

23.2.3.	Particulates:	kt	14	9	11	10	12	11	10	9	8	7
23.2.4.	CO:	kt	2	2	2	2	2	2	2	2	2	2
23.3.	***From transportation:***											
23.3.1.	SO_2:	kt	2	2	2	2	2	3	1	1	1	1
23.3.2.	NOx:	kt	52	53	53	43	45	46	43	38	41	45
23.3.3.	Particulates:	kt	3	3	3	3	3	3	3	8	9	10
23.3.4.	CO:	kt	52	53	53	43	45	46	43	38	41	45
24.	**Ambient concentration of pollutants in urban areas**											
24.1.	SO_2:	mg/ m^3	33.2	31.4	27	31.6	26.1	24	18.8	14.4	10.9	N/A
24.2.	NOx:	mg/ m^3	89.31	112.7	74.5	81.5	94.6	72.5	55.4	61.3	58.6	N/A
24.3.	Total suspended particulates:	mg/ m^3	78.29	85	75.7	82.9	60.6	45.4	36.5	40.1	35	N/A
24.4.	CO:	mg/ m^3	1,240	911.5	1,354	1,401	704	335.8	288.1	266.7	226.7	N/A
24.5.	Ozone	mg/ m^3	35	34	38	28	35	42	42	41	N/A	N/A
26.	**Quantities of greenhouse gas emission from energy related activities**											
26.1.	Total GHG	Mt CO_2 eq.	44.5	41.4	42.8	43.4	43.6	41.9	40.6	38.7	40.2	40.7
26.1.1.	CO_2:	Mt CO_2 eq.	42.9	39.8	41.1	41.6	41.8	40.1	38.9	37.0	38.5	38.9
26.1.2.	CH_4:	Mt CO_2 eq.	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.4	1.4	1.5
26.1.3.	N_2O:	Mt CO_2 eq.	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.3	0.3
26.2.	Total GHG per capita	t CO_2 eq./cap	8.3	7.7	8.0	8.1	8.1	7.8	7.5	7.2	7.5	7.6
26.3.	Total GHG per GDP	tCO_2 eq./1,000 $	2.6	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.7	1.6
26.4.	GHG from combustion and fuel transformation	Mt CO_2 eq.	39.4	36.0	37.0	37.5	37.5	35.4	34.3	32.9	33.7	34.9
26.5.	GHG from transportation	Mt CO_2 eq.	4.0	4.2	4.5	4.6	4.7	5.1	5.0	4.5	4.9	5.8
27.	**Radionuclide in atmospheric radioactive discharges**											
27.1.	noble gases:	GBq	N/A	N/A	N/A	N/A	26,300	N/A	N/A	29,232	N/A	N/A
27.4.	iodine-131:	GBq	N/A	N/A	N/A	N/A	0.87	N/A	N/A	0.967	N/A	N/A
28.	**Discharges into water basin associated with energy activity**											
28.1.	Wastewater discharges:	m^3	N/A	N/A	N/A	N/A	3E+05	3E+05	3E+05	3E+05	N/A	N/A
28.2.	Radionuclide in liquid radioactive discharges	GBq	N/A	N/A	N/A	N/A	35,560	N/A	N/A	23,887	N/A	N/A
28.2.1.	info\244.doc	GBq	N/A	N/A	N/A	N/A	0.236	N/A	N/A	0.266	N/A	N/A
28.2.2.	info\245.doc	GBq	N/A	N/A	N/A	N/A	35,560	N/A	N/A	23,887	N/A	N/A
31.	**Generation of radioactive waste from fuel cycle chains of nuclear power generation**											
31.1.2.	Low and intermediate level radioactive waste, long-lived (LILW-LL):	m^3	N/A	N/A	N/A	N/A	172	314.5	169.8	217	N/A	N/A
31.1.3.	Low and intermediate level radioactive waste, short-lived (LILW-SL)	m^3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
34.	**Fatalities due to accidents:**											
34.6.1.	Hydro:	%	N/A	N/A	N/A	N/A	20.3	N/A	20	N/A	N/A	N/A
34.6.2.	Thermal power plants:	%	N/A	N/A	N/A	N/A	28.7	N/A	24	N/A	N/A	N/A
34.6.3.	Nuclear power plants:	%	N/A	N/A	N/A	N/A	51	N/A	56	N/A	N/A	N/A

ANNEX 8.C Key Assumptions applied for scenarios

TABLE C.1 FORECAST OF ANNUAL GROWTH RATE (AGR) OF ELECTRICITY DEMAND

AGR [%]	2000 / 2005	2005 / 2010	2010 / 2015	2015 / 2020	2020 / 2025	2025 / 2030
Low	1.72	0.79	0.86	0.90	0.74	0.59
Middle	1.87	1.16	1.08	0.92	0.77	0.60
High	1.75	2.49	2.40	2.24	2.15	2.04

TABLE C.2 HEAT AND HOT WATER DEMAND IN FAMILY HOUSES [%]

	2000	2005	2010	2015
Heat demand low				
Existing	0.00	-2.00	-2.00	-2.00
New build	5.98	9.71	5.58	3.99
Heat demand high				
Existing	0.00	-2.00	-2.00	-2.00
New build	5.98	11.72	6.02	4.32
Hot tap water demand low				
Existing	0.00	-2.00	-2.00	-2.00
New build	6.03	9.85	5.59	4.00
Hot tap water demand high				
Existing	0.00	-2.00	-2.00	-2.00
New build	6.03	11.89	6.01	4.33

TABLE C.3 HEAT AND TAP HOT WATER DEMAND IN APARTMENT HOUSES [%]

	2000	2005	2010	2015
Heat demand low				
Existing	0.00	-2.00	-2.00	-2.00
New build	2.24	5.91	4.55	3.44
Heat demand low with heat insulation				
Existing	-2.09	-6.80	-2.00	-2.00
New build	0.11	0.72	4.55	3.44
Heat demand high				
Existing	0.00	-2.00	-2.00	-2.00
New build	4.12	5.70	4.93	3.80
Heat demand high with heat insulation				
Existing	-2.09	-6.80	-2.00	-2.00
New build	1.94	0.52	4.93	3.80
Hot tap water demand low				
Existing	0.00	-2.00	-2.00	-2.00
New build	2.32	6.38	4.67	3.47
Hot tap water demand high				
Existing	0.00	-2.00	-2.00	-2.00
New build	4.26	6.09	5.13	3.83

TABLE C.4 ANNUAL IMPROVEMENT OF ENERGY INTENSITY IN THE INDUSTRY [%]

Energy intensity AGR	2005/2000	2020/2005	2015/2010	2020/2015	2025/2020	2030/2025
Low scenario						
Heat and technology fuels	-3.1	-3.1	-3.5	-2.9	-3.3	-3.1
Electricity	-2.0	-2.0	-2.2	-2.1	-2.1	-2.2
Middle scenario						
Heat and technology fuels	-3.1	-3.5	-2.9	-3.3	-3.1	-4.0
Electricity	-1.9	-2.3	-2.4	-2.6	-2.6	-2.7
High scenario						
Heat and technology fuels	-3.1	-3.5	-2.9	-3.3	-3.1	-4.0
Electricity	-1.9	-2.3	-2.4	-2.6	-2.6	-2.7

TABLE C.5 ANNUAL GROWTH RATE OF FINAL ENERGY DEMAND FOR CHEMICALS IN [%]

Energy intensity AGR	2005/2000	2020/2005	2015/2010	2020/2015	2025/2020	2030/2025
Low scenario						
Heat	0.233	-0.309	0.329	-0.072	0.127	-0.852
Technology fuels	1.350	1.086	1.146	1.189	0.984	0.843
Electricity	-3.080	-3.540	-2.910	-3.310	-3.060	-4.020
Middle scenario						
Heat	0.347	0.147	0.816	0.414	0.450	-0.571
Technology fuels	1.537	1.435	1.356	1.203	0.906	0.765
Electricity	-3.080	-3.540	-2.910	-3.310	-3.060	-4.020
High scenario						
Heat	0.191	1.455	2.134	1.727	1.956	0.937
Technology fuels	1.452	2.759	2.681	2.527	2.419	2.294
Electricity	-3.080	-3.540	-2.910	-3.310	-3.060	-4.020

TABLE C.6 ANNUAL GROWTH RATE OF FINAL ENERGY DEMAND FOR STEEL PRODUCTION IN [%]

Energy intensity AGR	**2005/2000**	**2020/2005**	**2015/2010**	**2020/2015**	**2025/2020**	**2030/2025**
Low scenario						
Heat	0.018	-1.592	-0.923	-1.401	-1.182	-2.199
Technology fuels	1.133	-0.215	-0.117	-0.157	-0.336	-0.528
Electricity	-3.080	-3.540	-2.910	-3.310	-3.060	-4.020
Middle scenario						
Heat	0.116	-1.107	-0.475	-1.001	-0.244	-1.644
Technology fuels	1.304	0.164	0.058	-0.223	0.209	-0.322
Electricity	-3.080	-3.540	-2.910	-3.310	-3.060	-4.020
High scenario						
Heat	-0.045	0.193	0.793	0.193	0.567	-0.544

Technology fuels	1.213	1.481	1.332	0.981	1.023	0.793
Electricity	-3.080	-3.540	-2.910	-3.310	-3.060	-4.020

TABLE C.7 ANNUAL GROWTH RATE OF FINAL ENERGY DEMAND FOR MACHINERY AND OTHER METALLURGY IN [%]

Energy intensity AGR	**2005/2000**	**2020/2005**	**2015/2010**	**2020/2015**	**2025/2020**	**2030/2025**
Low scenario						
Heat	0.018	-1.592	-0.923	-1.401	-1.182	-2.199
Technology fuels	1.133	-0.215	-0.117	-0.157	-0.336	-0.528
Electricity	-3.080	-3.540	-2.910	-3.310	-3.060	-4.020
Middle scenario						
Heat	0.116	-1.107	-0.475	-1.001	-0.244	-1.644
Technology fuels	1.304	0.164	0.058	-0.223	0.209	-0.322
Electricity	-3.080	-3.540	-2.910	-3.310	-3.060	-4.020
High scenario						
Heat	-0.045	0.193	0.793	0.193	0.567	-0.544
Technology fuels	1.213	1.481	1.332	0.981	1.023	0.793
Electricity	-3.080	-3.540	-2.910	-3.310	-3.060	-4.020

TABLE C.8 ANNUAL GROWTH RATE OF FINAL ENERGY DEMAND FOR OTHER INDUSTRY IN [%]

Energy intensity AGR	**2005/2000**	**2020/2005**	**2015/2010**	**2020/2015**	**2025/2020**	**2030/2025**
Low scenario						
Heat	0.182	-0.876	-0.230	-0.642	-0.385	-1.365
Technology fuels	1.298	0.512	0.581	0.612	0.468	0.320
Electricity	-3.080	-3.540	-2.910	-3.310	-3.060	-4.020
Middle scenario						
Heat	0.265	-0.366	0.282	-0.136	0.215	-0.761
Technology fuels	1.455	0.915	0.819	0.649	0.670	0.573
Electricity	-3.080	-3.540	-2.910	-3.310	-3.060	-4.020
High scenario						
Heat	0.093	0.962	1.612	1.201	1.447	0.458
Technology fuels	1.353	2.260	2.156	1.996	1.907	1.809
Electricity	-3.080	-3.540	-2.910	-3.310	-3.060	-4.020

ANNEX 8.D: Abbreviation and symbols

Abbreviation	Description
BC	Brown Coal
cap	Capita
CHP	Combined Heat and Power generation
EI	Energy Intensity
EU	European Union
FEU	Final Energy Uses
FGD	Flue Gas Desulphurization
GDP	Gross Domestic Product
GHG	Greenhouse Gases
HFO	Heavy Fuel Oil
HP	Heating Plant
HPP	Hydropower plant
IAEA	International Atomic Energy Agency
ISED	Indicator of Sustainable Energy Development
NG	Natural Gases
NPE	Nuclear Primary Energy
NPP	Nuclear Power Plant
PPP	Purchasing Power Parity
PWR	Pressure Water Reactor
SE	Slovak Electric Utilities
SP	Solid Particles
SR	Slovakia
TFC	Total Final Consumption
TPES	Total Primary Energy Supply
VA	Value Added
WB	World Bank

9. THAILAND

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9.1. Introduction

In 1995, the United Nations Work Programme on Indicators of Sustainable Development (WPISD) developed a core set of indicators covering the various dimensions of sustainable development: environmental, social, economic and institutional. Several major studies on energy- and environment-related indicators complemented these efforts, including those of the Organisation for Economic Co-operation and Development (OECD), EUROSTAT, European Commission (EC), European Environment Agency (EEA), International Energy Agency (IEA), and the Division of Sustainable Development/United Nations Department of Economic and Social Affairs (UNDESA). The common objective of all these activities is to measure and monitor important changes and significant progress towards the achievement of sustainable development. None of them, however, focused on indicators for sustainable energy development (ISED). Thus, the International Atomic Energy Agency (IAEA) in cooperation with other international organizations developed a comprehensive set of indicators specifically addressing the energy sector with the following general objectives: (1) to supplement the general indicators of sustainable development (ISD) developed under the WPISD; and (2) to allow the use of ISED for making necessary modifications to the relevant databases and analytical tools and structuring assistance to member states in the formulation of their energy strategies in conformity with the objectives of sustainable development.[1]

The present study aims to apply the “Indicators for Sustainable Energy Development” (ISED) framework initiated by IAEA to Thailand. It assesses the sustainable energy development performance of Thailand focusing on energy conservation and efficiency policy. The main reasons for focusing on energy efficiency issues are the following:

- Thailand has been a good example in terms of energy conservation efficiency policy implementation.
- The policy was introduced in the early 1990s so programs are already in full-scale implementation, and the ISED concept can be applied to assess the effectiveness of the policy.
- Energy data are well established at the aggregate and sectoral level.
- It is expected that the analytical framework developed in this study can be applied to other countries.

[1] IAEA, jointly with other international organizations, published in 2005 the methodology and guidelines for these indicators.

9.2. Overview of Thailand Energy Sector

9.2.1. Introduction

Thailand is located in Southeast Asia and has a land area of approximately 513,115 sq. km. The country is divided into six regions, with the northern and northeastern regions being the largest. Real GDP in 2000 was Baht 2,985 billion (constant 1988 prices). The population was about 62.4 million in 2000. Per capita GDP in 2000 reached Baht 78,783 (US$1,964). Energy consumption per capita in 2000 was 0.78 toe per person while electricity consumption per capita was 1,386.97 kWh per person (Table 9.1).

9.2.2. Overall energy balance

The overall structure of Thailand's energy supply and demand is summarized in the energy balance shown in Table 9.2. As shown, Thailand produces a lot of coal and petroleum but also imports significant quantities of these fossil fuels to meet domestic energy demand. Thus, for example, imported oil accounted for 60% of the total primary energy supply of petroleum in 2000.

TABLE 9.1: THAILAND BASIC ECONOMIC AND ENERGY INDICATORS

	1980	1985	1990	1995	2000
GDP (million Baht 1988 prices)	913,733	1,191,255	1,945,372	2,946,252	2,984,961
Population (millions)	46.72	51.68	55.84	59.40	62.39
GDP per capita (Baht)	19,558	23,051	34,838	49,599	47,841
Energy use per capita (toe/person)	0.32	0.36	0.55	0.77	0.78
Electricity use per capita (kWh/person)	279.18	384.26	682.28	1,173.70	1,386.97

Source: ADB, 2001; DEDP, Electric Power in Thailand 2000.

TABLE 9.2: THAILAND ENERGY BALANCE 2000, KTOE

Commodities Transaction	Coal	Petroleum	Petroleum products	Electricity	Renewable energy	Grand Total
Domestic Production	5,148	22,797		1,335	14,392	43,672
Imports	2,631	35,665	1,167	253	14	39,730
Exports		-509	-4,874	-17	-1	-5,401
Stock change/statistical difference	13	687	-613			87
TOTAL PRIMARY ENERGY SUPPLY	**7,792**	**58,640**	**-4,320**	**1,571**	**14,405**	**78,088**
Oil refining		-37,817	31,896			-5,921
NG processing plant		226	1,665			1,891
Power plant	-4,165	-14,015	-2,322	6,843	-385	-14,044
Hydro				-820		-820
Steam	-3,659	-2,270	-2,283	3,239		-4,973
Gas turbine		-392		98		-294
Combined cycle		-9,653	-15	3,462		-6,206
Diesel			-4	1		-3
Cogeneration	-506	-1,700	-20	865	-385	-1,746
Others				-2		-2
Other conversion			132		-4,888	-4,756
TOTAL TRANSFORMATION	**-4,165**	**-51,606**	**31,371**	**6,843**	**-5,273**	**-22,830**
Own uses		-3,883		-275		-4,158
Losses		-146		-647		-793
TOTAL FINAL ENERGY CONSUMPTION	**3,627**	**3,005**	**27,050**	**7,492**	**9,132**	**50,306**

Final non-energy uses		1,629	338			1,967
Final energy consumption	3,627	1,376	26,712	7,492	9,132	48,339
Agriculture			2,148	13		2,161
Mining			11	74		85
Manufacturing	3,627	1,374	4,136	3,346	4,258	16,741
Construction			149			149
Residential and commercial			1,621	4,056	4,874	10,551
Transportation - total		2	18,647	3		18,652
Road		2	14,873			14,875
Rail			95	3		98
Air			2,856			2,856
Waterway			823			823

Source: DEDP, Thailand Energy Situation, 2000.
Note: Others include geothermal, solar cell, and wind turbine.

Oil and coal accounted for 85% of total primary energy supply in 2000. The balance is accounted for by renewable hydroelectricity and biomass fuels.

On the demand side, petroleum products accounted for more than half of total final energy demand. The dominance of petroleum products is explained by the dominance of the transportation sector, representing 38% of total final energy demand in 2000. But final energy demand in the manufacturing and residential and commercial sectors followed very closely at 35% and 22%, respectively, of total final energy demand.

9.2.3. Indigenous energy production

Thailand is endowed with rich and diverse fossil and conventional energy resources (see

Table 9.3). Yet, traditional biomass resources dominated indigenous energy production and until 1998 accounted for the bulk of indigenous energy production. Since then, natural gas production, which was increasing at 25% per year between 1981 and 2000, has assumed this dominance and accounted for 40% of indigenous energy production in 2000 (See Figure 9.1 and Figure 9.2). Oil production was also growing by 25% per year during the same period, but accounted for 12% of indigenous energy production in 2000. The production of coal (or lignite) was also increasing by more than 18% per year until 1997, but began to decline through 2000, also contributing 12% like oil. Thailand also has huge hydropower potential. However, strong opposition against new large hydropower plants has slowed hydropower production to an average of less than 4% and its contribution to indigenous energy production reduced to 3% from a peak of 6%.

TABLE 9.3: THAILAND ENERGY RESERVES (AS OF DECEMBER 2000)

Energy resource	Proven reserves	Probable reserves	Possible reserves	Total
Lignite (million tons, Mt)				
Mae Moh province	1,227			1,227
Kra Bi province	112			112
Li province	1			1
Others	817			817
Hydro potential (MW)				
Indigenous				15,606
International*				11,328
Natural gas (billion cubic feet, BCF)				
Offshore	12,101	9,321	10,722	32,144
Onshore	604	278	679	1,561
Condensate (million barrels, Mbbl)				

Offshore	266	228	230	724
Oil shale (Mt)				
Tak province				18,600
Crude oil (Mbbl)				
Offshore	159	175	203	537
Onshore	90	38	31	159

*Potential power purchased from hydroelectricity produced in the Mekong and Salween Rivers.
Source: DEDP, Thailand Energy Situation 2000.

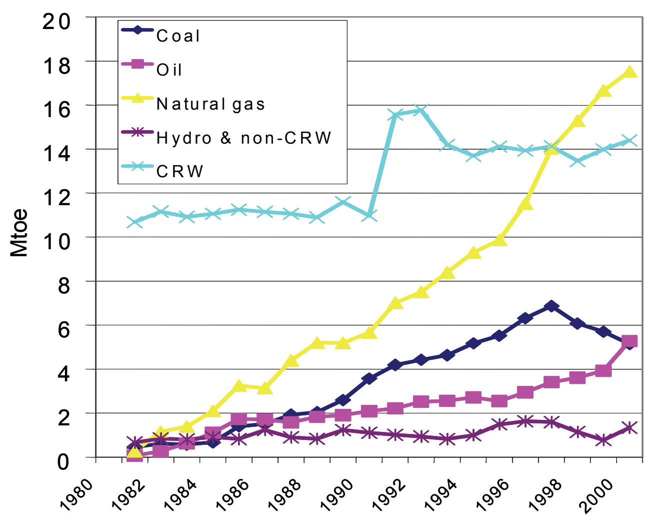

Figure 9.1: Indigenous Energy Production

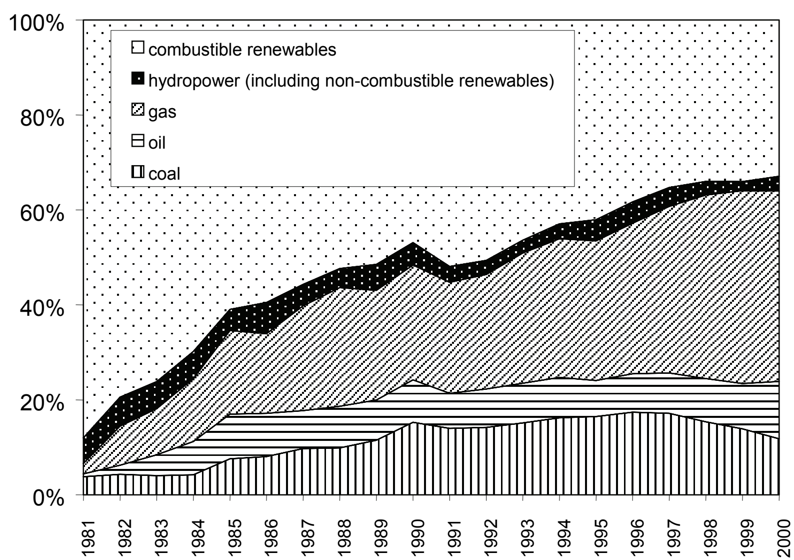

Figure 9.2: Indigenous Energy Mix

9.2.4. Energy import dependency and primary energy supply mix

Even with increasing domestic energy production, energy imports continue to be very significant. As shown in Figure 9.3, energy imports accounted for half of domestic energy supply in the late 1990s through 2000. Most of this, 85%, is oil. More than 70% of Thailand's oil imports come from the Middle East, mainly the United Arab Emirates (UAE), Oman, and Saudi Arabia (

Table 9.4). Its ASEAN neighbours, mainly Brunei and Malaysia, also supply oil to Thailand. In 2000, ASEAN contributed 22%, which was as large as that of UAE, to Thailand's oil imports.

Overall, oil (and condensate) accounted for half of the total primary energy supply mix in 2000, up from 35% in 1981(Figure 9.4). Meanwhile, the contribution of domestically produced natural gas continued to increase, from only 1% in 1981 to 25% in 2000.

Thailand also imports coal, which in 2000 accounted for one-third of coal's contribution in the primary energy supply mix.

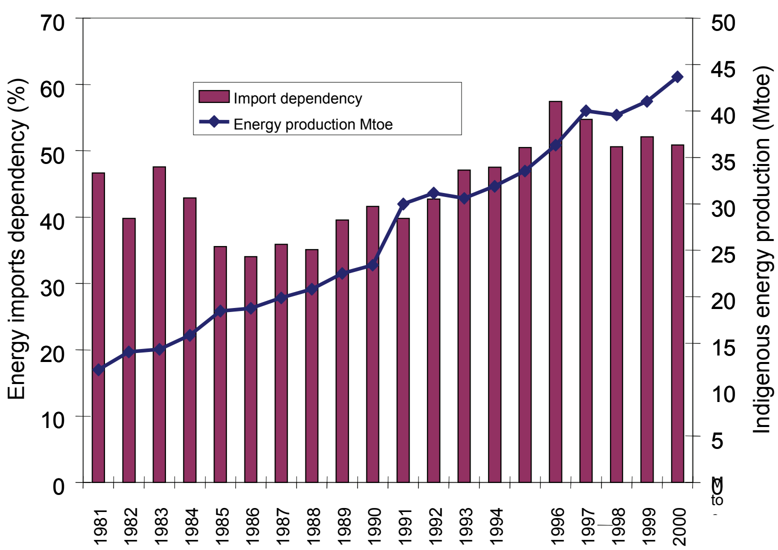

Figure 9.1: Energy Import Dependency vs. Total Energy Production

TABLE 9.4: CRUDE OIL IMPORTS, 2000 (MILLION LITERS)

Origin	Total
ASEAN	8,620
Asia-Pacific	1,235
Middle East	28,784
Africa	310
Europe	293
Total	39,242

Source: DEDP, Oil and Thailand 2000.

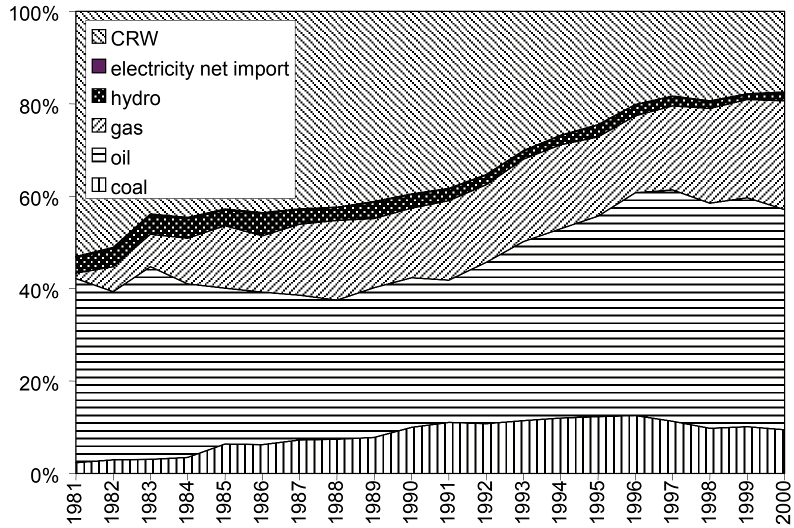

Figure 9.2: Primary Energy Supply Mix

9.2.5. Power generation mix

Natural gas, coal, and oil are the main fuels for power generation. Power generation from natural gas was increasing by 21% per year between 1981 and 2000 (Figure 9.5), when its share also increased from just 10% to 63% (Figure 9.6). The share of natural gas in total power generation actually decreased in the early 1990s when domestic production, although increasing, could not meet very high growth in electricity demand. Power generation from coal, which has been providing base load generation, was also increasing by 13%, but its share in the total generation mix remained at around 20% between 1985 and 2000. Oil remains an important fuel for power generation even with the close competition between natural gas and coal. Figure 9.6 also shows that oil began to be substituted by domestically produced natural gas from the early to late 1980s, but increased its contribution again in the early 1990s to meet high growth in electricity demand. With natural gas production recovering in the late 1990s, oil's contribution to total power generation dropped to less than 12% in 2000. In fact, actual energy generation from oil decreased from 1996, most likely due to the retirement of oil thermal plants during this period. Hydropower generation grew by 3.7% during this period but its share decreased from a high of 23% in 1982 to just 7% in 2000.

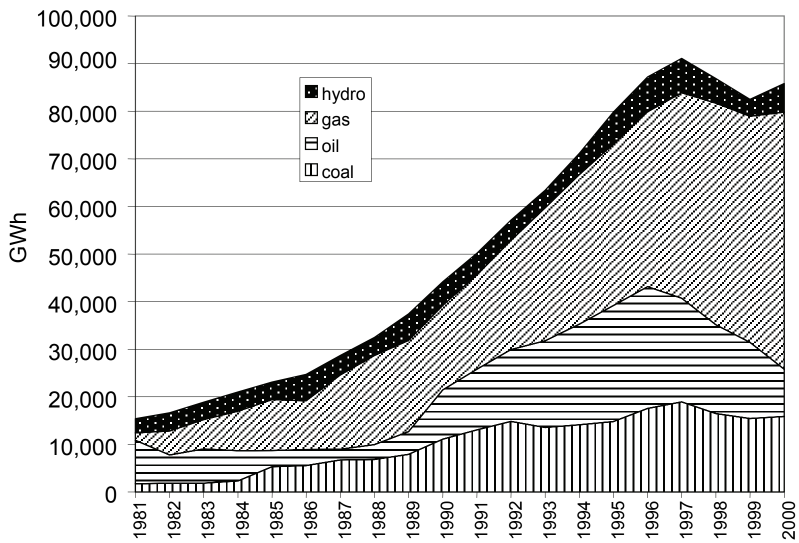

Figure 9.3: Growth in Power Generation

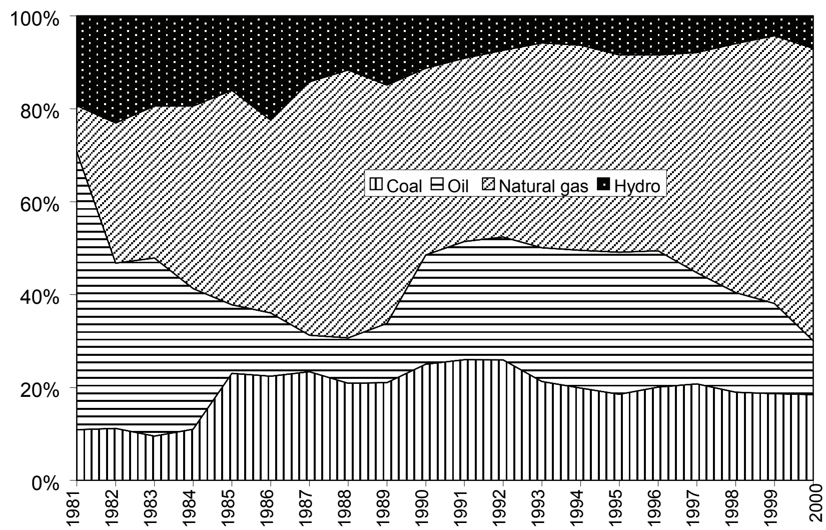

Figure 9.4: Power Generation Mix

9.2.6. Final energy demand

Petroleum dominates the final energy demand mix and dictates the growth of total final energy demand. It accounted for more than half of total final energy demand in 2000 and was increasing at 6.6% per year between 1981 and 2000 (Figure 9.7 and Figure 9.8). The reason for petroleum's dominance is the large and fast increasing energy demand from transport and manufacturing sectors, as well as the large and growing demand from the residential and commercial sectors (Figure 9.9). The transport and manufacturing sectors each grew by more than 7% during this period and each accounted for more than 30% of total final energy demand in 2000. Meanwhile, the residential and commercial sectors grew by slightly more than 3% but accounted for 22% of total final energy demand in 2000.

Electricity and coal also exhibited significant growth of 10% and 20%, respectively, during the period. The only difference is that the demand for coal tapered off during the financial crisis. Coal is used in industries, and the decrease in energy demand from industries during the crisis reduced as well the demand for coal. The demand for electricity, used in all sectors but to a relatively greater extent in the residential and commercial sector, was just slowed down by the crisis. Natural gas demand also recorded strong growth of 25% during this nearly 20-year period, when its use in the manufacturing sector expanded.

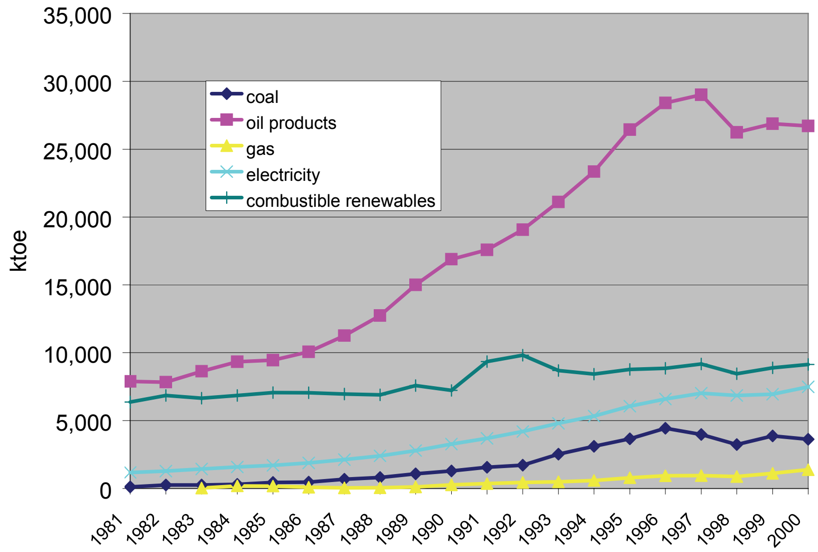

Figure 9.5: Final Energy Demand by Fuel

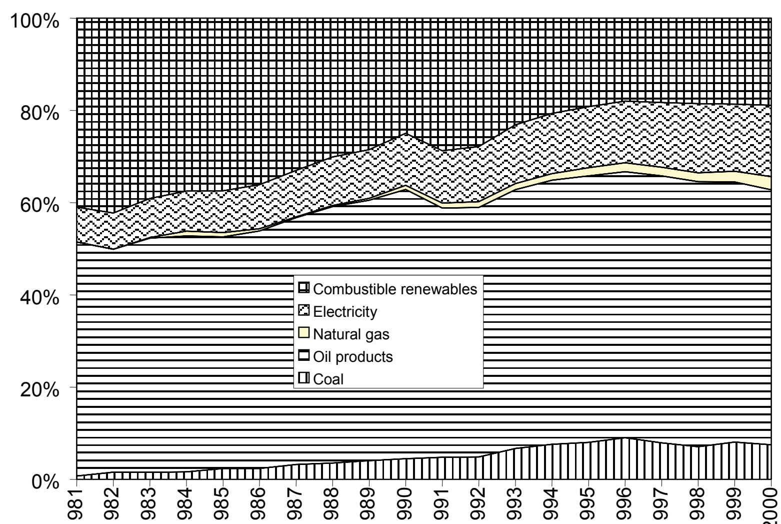

Figure 9.6: Final Energy Mix by Fuel

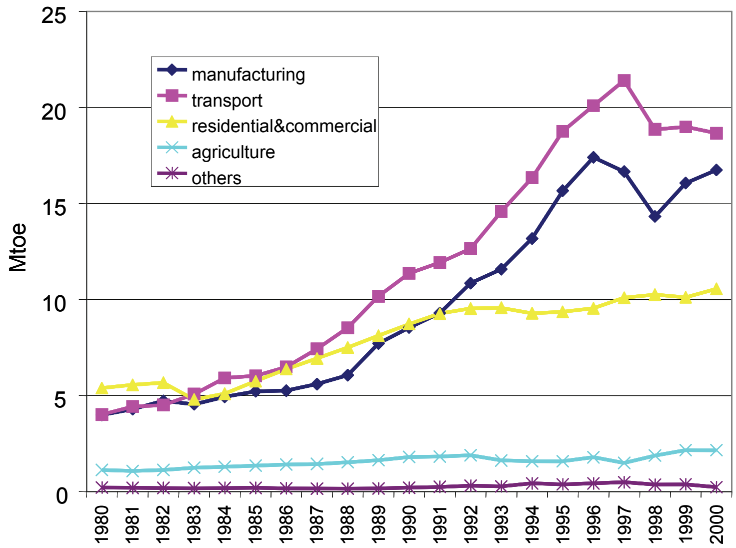

Figure 9.7: Final Energy Demand by Sector

9.3. Review of Energy Statistical Data Capability

9.3.1. Assessment of the available data in Thailand

9.3.1.1. Demographic and Socio-Economic Data

Various statistics on Thailand's demography and socio-economy are available at the National Statistical Office (NSO). The NSO is the main statistical information centre of the country, with provincial offices acting as information centres in the provinces. Data available at NSO are not only those produced by the office but also those data produced by other government agencies.

The NSO conducts various surveys and censuses in order to collect statistics. These surveys and censuses include (NSO website, 2002):

Population and Housing Census. Thailand's first national census was conducted in 1909 and afterwards censuses were carried out in 1919, 1929, and 1947. The Ministry of the Interior undertook the first five censuses. Since 1960, the National Statistical Office has been in charge of undertaking censuses every 10 years under the authorization of the 1952 Statistical Act (amended in 1965). In 1970 the first housing census was conducted simultaneously with the population census. The 1990 Population and Housing Census are the ninth population census and the third housing census, respectively, of Thailand. The main objective of the census is to quantify population demographic and socioeconomic characteristics as well as housing characteristics for the National Economic and Social Development Plan (NESDP).

Household Socio-Economic Survey. The first Household Socio-Economic Survey was conducted by the NSO in 1957, known as "The Household Expenditure Survey". This name was changed to Household Socio-Economic Survey in 1968 - 1969 and the survey has been conducted every five years. Due to the rapid economic expansion and the importance of the survey in order to set anti-poverty policy, the Ministerial Cabinet approved on September 8, 1987 that NSO carry out the survey every two years. The 2000 survey is the fifteenth survey of this kind.

Household Energy Consumption Survey. The NSO carried out the first two surveys of Household Energy Consumption in 1984 and 1985, following a request by the Office of the National Economic and Social Development Board (NESDB), at the same time as the Labour Force Survey. Since 1986, this survey has complemented the Household Socio-Economic Survey. The objective of the survey is to collect information on the quantity and household expenditures on fuel such as petroleum products

(e.g., L.P.G. for cooking), electricity, charcoal and wood, etc. Since 1996, the data collection has focused only on expenditures for fuel, excluding information about quantities. The 2000 survey is the ninth survey of this kind.

The other surveys conducted by NSO are:

- Labour Force Survey to estimate the number and characteristics of the labour force in the country;
- Housing Survey to estimate areas of dwelling units;
- Survey of Population Change to measure changes in the population and other population characteristics; and the
- Construction Survey, started in 1999, to look into the size of various establishments in the country.

Time series statistics on demographic and socio-economic data for Thailand are also being published by international organizations such as the Asian Development Bank (ADB), the United Nations Organization (UN), and the World Bank (WB) on a regular basis.

9.3.1.2. Industrial Statistics

The NSO also conducts the following surveys to generate data and information on industries:

Industrial Census. The industrial census is conducted in order to collect basic industrial information (e.g., the number and characteristics of manufacturing establishments), for economic development planning, and for setting industrial policies at the macro and micro level. The second industrial census was conducted in 1997, and NSO plans to conduct the census every 10 years.

Manufacturing Industry Survey. The main objective of this survey is to collect basic industrial information, such as: number of establishments, number of persons engaged, number of employees, compensation, value of raw materials, parts and components purchased, sales value of goods produced and purchased for resale, and inventory and value of fixed assets.

Yet, the NSO census and survey do not include statistics on the production output of various industries of the country. The Office of Industrial Economics of Thailand produces a semi-annual report on industrial statistics (e.g., production, sales and sale values, etc.) but covers only a few industries. The publication of these statistics started only in the mid-1990s.

9.3.1.3. Energy and Environmental Statistics

The Department of Energy Development and Promotion[2] (DEDP) publishes three volumes of energy and environment statistics annually: *Power in Thailand*, *Oil and Thailand*, and *Thailand Energy Situation*. These statistical reports contain rich information on energy balances, energy production, energy consumption, energy imports and exports, energy prices, reserves, sectoral information, environmental statistics, and others.

These reports, however, do not give detailed information beyond the sectoral level. For example, energy use of cement, glass, and other non-metallic products industries are lumped together; energy consumption of road transport is not classified into passenger or freight but disaggregated by fuel and mode of transport such as road, rail, water and air.

Other sources of energy data in Thailand are the Energy Policy and Planning Office (EPPO) also now under the new Ministry of Energy, which regularly updates and prepares the national load forecast; the Electricity Generating Authority of Thailand (EGAT), which regularly publishes the national Power Development Plan (PDP); and the Provincial Electricity Authority (PEA). EGAT's and PEA's annual reports are also rich sources of power statistics.

[2] DEDP is now under the new Ministry of Energy and since October 2002 has changed its name to Department of Alternative Energy Development and Efficiency (DEDE).

9.3.1.4. Transport Statistics

The Ministry of Transport and Communications (MOTC) provides annual data on transport statistics for all transport modes. Road statistics are essentially based on surveys carried out by the Department of Land Transport, focusing primarily on freight statistics. Vehicle stock data are also produced by MOTC, based upon the registration of motor vehicles covered under the Land Act of 1979. There are no data available on passenger-kilometres for road and urban transport.

For rail transport, the State Railway of Thailand (SRT) is the only rail operator and therefore the only source of information. Freight statistics are based on SRT's detailed records, while rail passenger statistics are based on records from ticket sales. For electrically driven mass rail transit such as the BTS (Bangkok Transit System), statistics are still not available at this writing as its operation began only in 2000.

Domestic water transport covers inland waterway transport running on rivers and canals, as well as coastal shipping[3]. In this sector, only freight transport statistics are being provided, as there are no available data on passenger transport. The main source of data for inland waterway transport is the Royal Irrigation Department, while statistics on coastal shipping come from the Department of Customs in coastal ports.

The main source for domestic air transport statistics is the Department of Aviation. Statistics covered include passenger and freight movements, origin-destination data, as well as statistics on the fleet of aircraft registered.

Surveys to gather information for statistics on distance travelled by passengers for road and water transport are not carried out in Thailand. Also, there are no pipeline transport statistics available in the country.

9.3.2. International Sources of Data on Thailand

In addition to local sources, socio-economic, industrial, energy, and environmental data on Thailand are also available from internationally published statistics. The Asian Development Bank (ADB) publishes annually the *Key Indicators of Developing Asian and Pacific Countries*, which is a time-series collection of macroeconomic statistics, including production statistics on energy intensive industries, for ADB developing member economies. The International Energy Agency (IEA) also publishes annually the *Energy Balances and Statistics* for OECD and non-OECD countries, as well as quarterly *Energy Prices and Taxes*. The United Nations also publishes air and rail transport statistics (except for road and water passenger transport).

9.3.3. Data development in relation to energy efficiency policy

The following data have been collected to derive the indicators related to energy efficiency:

- Energy prices (pre-tax prices and taxes) of unleaded gasoline octane 95 (ULG 95) and premium gasoline for transport, automotive diesel for commercial uses, heavy fuel oil and steam coal for industrial uses, LPG and kerosene for residential uses, and electricity prices for commercial, residential and industrial uses;
- Gross domestic product (GDP), and value added of economic sectors (manufacturing, transport, services/commercial, agriculture, and others);
- Value added of energy intensive industries such as basic metals, chemicals, non-metallic, pulp and paper and others;
- Freight transport activity by mode of transport;
- Total commercial area in square kilometres;

[3] Inland waterway transport is extended from the mouth of the Chao Praya River to along the coast of Eastern Sea Board.

- Total population, urban population/household population, urban and rural;
- Employment;
- Sectoral and sub-sectoral energy consumption, energy mix;
- Production of energy intensive industries (iron and steel, cement, pulp and paper only);
- Daily disposable income of poorest 20% household;
- Average disposable income of the population;
- Private consumption per capita spent on fuel and lighting of 20% poorest household;
- Average private consumption of population spent on fuel and lighting;
- Structure of households by mode of cooking fuel;
- Number of households with and without electricity;
- Quantities of green house gas and air pollutant emissions (such as CO_2, CO, NOX, CH_4, SO_2, SPM)
- Ambient concentration of pollutants in urban areas: CO, TSP (road side and ambient air quality).

9.3.4. Potential data parameters to be collected in the future

Many surveys are undertaken in the country periodically. However, they focus more on demography, expenditures, socio-economic classes, infrastructure, economic standing, and other more general information not related to energy.

End-use energy data are vital for understanding the real situation of the main economic sectors. In Thailand's case, little has been done in the past to collect energy end-use data. In fact, energy statistics published by various energy institutions tend to be aggregated in nature. Thus, there is a need to improve the energy data system by collecting more disaggregated or specific end-use energy data through frequent surveys to support future studies and for the development of the indicators for sustainable development.

9.4. Thailand's Energy Efficiency Policy and Programs

The main legislative provision in the field of energy efficiency and conservation in Thailand is the Energy Conservation Promotion Act B.E. 2535 (1992). This is where the government's energy efficiency policy is made explicit. The Act also serves as the foundation for all of the plans and programmes the government undertakes in order to promote energy conservation and efficiency in the country. The Thai government has undertaken two notable programmes since 1992 towards this end: i) energy conservation programs; and ii) demand side management programs.

9.4.1. The Energy Conservation Promotion Act 2535

The Energy Conservation Promotion Act, 2535 (1992) was enacted to mandate the production and use of energy efficiently and economically; and in parallel to this, to encourage the production and use of high-energy efficiency machineries and equipment. The Act targets three groups: (i) Designated Factories, (ii) Designated Buildings, and (iii) Producers or distributors of energy equipment and machinery. In order to facilitate energy conservation activities, the Act has made the following provisions:

<u>Energy conservation in plants</u>: Factories having a transformer of more than 1,000 kVA or an annual energy use exceeding 35 million Btu are required to conduct energy audits. The establishments have to appoint a full-time certified energy manager, keep records of energy use and submit those to the government, and submit an energy rationalization plan for review and approval. Non-compliance will

be met with penalties, e.g. by increasing tariffs. Factory owners are given three years to meet requirements.

Energy conservation in large buildings: Owners of designated buildings are required to appoint energy managers, conduct audits and keep records of energy use, and submit an energy plan for review and approval. A three-year time frame is given to owners to meet their efficiency requirements. A model energy code for new commercial and institutional buildings has been prepared.

Standards for appliance equipment and materials: The government has issued regulations concerning the minimum efficiency of equipment appliances, building materials and control systems.

Energy conservation promotion fund: The Act has made a provision of low-interest loans and grants for energy efficiency and renewable energy projects, as well as for research and development, demonstration, promotion and education.

9.4.2. The Energy Conservation Program (ENCON)

The Act gave birth to the Energy Conservation (ENCON) Program that is being implemented with the objective of promoting energy efficiency, energy conservation, sustainable use of natural resources, and protection of the environment. The lead agency for implementing this program is the Department of Energy Development and Promotion (DEDP) under the Ministry of Science, Technology and Environment (MOSTE).[4] The main tasks of the ENCON program include:

- Providing financial assistance and incentives for energy conservation, energy efficiency and renewable energy projects;
- Supporting demonstrations of energy conservation and renewable energy technologies;
- Supporting the promotion and dissemination of proven energy conservation and renewable energy technologies;
- Increasing research and development and training in energy conservation technology;
- Organizing public relations campaigns to promote energy conservation.

Under the ENCON program, the National Energy Policy Office (NEPO)[5] also supports voluntary activities for promoting wider application of renewable energy and its technologies. Such activities are supported with financial assistance and other incentives. The voluntary programs are mainly focused on the following:

- **Renewable Energy and Rural Industries Programs:** Biogas for power generation from livestock wastes in small and medium firms; biogas digesters among individual farmers; and landfill gas pilot projects.
- **Research and Development Programs:** This program aims at developing new or improving existing technologies, with support to small scale demonstration projects as well as information dissemination.
- **Industrial Liaison Program:** The purpose of this program is to enhance the capacity of the industrial sector to produce energy efficient and renewable energy equipment in Thailand.

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[4] DEDP is now the Department of Alternative Energy Development and Efficiency (DEDE) and has been moved to the new Ministry of Energy. The new Ministry of Energy started on 1 October 2002 along with the new Ministry of Science and Technology and Ministry of Environment and Natural Resources.

[5] Similarly, NEPO has been re-named EPPO or the Energy Planning and Policy Office, also under the new Ministry of Energy.

9.4.3. The Energy Conservation Promotion Fund (ENCON Fund)

One of the key policy aspects to promote energy conservation activities in Thailand is the establishment of the energy conservation fund (ENCON Fund) for providing financial support to various energy conservation activities. The fund called "the Conservation Fund" was created in 1992 in accordance with the Energy Conservation Promotion Act 2535 (1992) to promote energy conservation activities in factories and commercial/service buildings. The fund is sourced from the imposed levies on petroleum products. It is mainly used to provide either soft loans or grants for energy efficiency and renewable energy projects. This fund is also used for supporting research, development, demonstration, promotion and educational activities in the field of energy conservation and new and renewable energy. Additionally, funds also come from the government, the private sector, foreign governments and international organizations including the World Bank and the Asian Development Bank. Funds may be granted to individuals, businesses, non-government organizations and government agencies.

9.4.4. The Demand Side Management (DSM) Program

In parallel with the ENCON Program, the government through its three electric power utilities has also launched the demand-side management program (DSM). The first phase ran between 1993 and 1998, and the second phase covers the period 2002-2006.

9.4.4.1. DSM Program Phase 1

The government and the Electricity Generating Authority of Thailand (EGAT) implemented a Five-year DSM Master Plan beginning in 1993 to deal with a huge investment demand for electricity supply capacity expansion resulting from the rapid economic growth. The program had four main objectives:

- to educate, encourage (through incentives), and inform consumers about energy conservation;
- to stimulate manufacturers and importers to produce or import energy-saving and efficient appliances and equipment;
- to support and pursue energy efficiency and load management technologies; and
- to build sufficient institutional capability in the electricity sector and the energy-related private sector to deliver cost-effective energy services throughout the economy.

The program was started with a total budget of US$189 million, of which the Global Environmental Facilities (GEF) provided US$15.5 million, the Overseas Economic Cooperation Fund (OECF) of Japan granted US$25 million in concessional loans, and the remainder was sourced internally by the Electricity Generating Authority of Thailand (EGAT).

The Master Plan originally targeted a reduction of 238 MW peak demand, some 1,427 GWh of electricity generation, and 1.16 million tons of CO_2 emissions. The program achieved more than it had targeted. By 30 September 1998[6], the program resulted in reductions of 468 MW of peak demand, 2,194 GWh of electricity generation, and 1.64 million tons of CO_2 emissions. By September 2001, the overall program resulted in 651 MW peak demand cut and 3,665 GWh energy reductions.[7] This is why the DSM program in Thailand has been internationally regarded as extremely successful, and a model DSM program for developing countries.

The DSM Program Phase I consisted of six major sub-programs. These are the Residential Program, Commercial/Governmental Building Program, Industrial Sector Program, Load Management Program, Energy Conservation Attitude Promotion Program, and Program Monitoring and Evaluation. The first three programs focused on energy-efficient appliances, particularly lighting equipment, high-efficiency refrigerators and air-conditioners, and high-efficiency motors.

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[6] Due to implementation delays, the project had been extended and closed on June 30, 2000.

[7] Information on similar CO_2 reductions is not available.

Lighting

- Energy Efficient Fluorescent Lamp Program persuaded five local manufacturers to switch production from 40 W and 20 W fluorescent tubes (Fat Tube) to 36 W and 18 W (Thin Tube) instead;
- Lighting Retrofit Program in the Royal Project Foundation was a pilot program to persuade agriculturists to save energy utilized in their businesses;
- "Million Hearts Million Lights" Program encouraged consumers to use compact fluorescent lamps (CFL) instead of incandescent lamp bulbs;
- Street Lights Program was a pilot program to stimulate replacement of fluorescent tubes with high-pressure sodium vapour lamps;
- Energy Efficient Ballast Program created a market for energy efficient ballasts by stimulating manufacturers to produce them. The campaign was first focused on producing energy efficient ballast named 'Safety Ballast No. 5';
- Low-Income Fluorescent Program promoted the use of fluorescent tubes instead of incandescent lamp bulbs among low-income households.

Refrigeration and air conditioning

- Energy Efficient Refrigerator Program persuaded the five manufacturers of refrigerators in the Thai market to have refrigerators tested for efficiency rating labelling;
- Energy Efficient Air-Conditioner Program persuaded local manufacturers and importers to have split-type air-conditioners tested for efficiency rating labelling and encouraged consumers to purchase high efficiency air-conditioners; all 55 air conditioner manufacturers joined the testing and labelling program and it is evident that consumers have been attracted by energy-efficient air-conditioners;
- Thermal Energy Storage promoted the utilization of thermal storage systems instead of central air-conditioning systems during peak demand periods;
- Appliance Testing Laboratory Program aimed at widening the testing of energy efficiency of refrigerators and air-conditioners in The Thai Industrial Standard Institute (TISI).

Energy efficient electric motors

- High Efficiency Motor Program encouraged motor manufacturers and importers to produce and import high efficiency motors and convince industrial entrepreneurs to utilize high efficiency motors. Since early 1996, EGAT has offered industrial customers a savings incentive of US$440 per peak kilowatt (kW) when they purchase energy-efficient motors.

Other programs

- Heat Pipe Program monitored implementation and cost studies of dehumidification heat pipes;
- Green Building Program stimulated both existing and new commercial buildings, offices, hotels, hospitals or department stores to utilize electricity in compliance with the Ministerial Regulations issued to complement Energy Conservation and Promotion Act 1992. To overcome the cost barrier to the installation of more energy-efficient equipment, EGAT provided building owners with an interest-free loan which was repaid over three to five years. By early 1996, owners of more than 180 large commercial buildings were participating;
- Energy Service Company (ESCO) provides current and modern technologies to enhance full-scale energy utilization in industry. The program is anticipated to prove to commercial and industrial entrepreneurs that ESCOs can improve the energy utilization in more efficient and cost-effective ways, and also bring confidence among new entrepreneurs on the importance of energy conservation activities;

- Attitude Creation Program created awareness of energy conservation and energy efficient utilization;
- Industrial Cost Reduction Program provided assistance and suggested energy efficient applications to industrial factories. Pre-capital investment was funded by the Energy Conservation Fund, and then repayment was made afterwards if appliance retrofitting was necessary;
- Low Efficiency Buy-Back Program transformed the operations and early retirement of low efficiency appliances utilized within the system, and also pressured manufacturers to produce only high efficiency appliances.

9.4.4.2. DSM Program Phase II (2002-2006)

The government has formulated another five-year (2002-2006) DSM Master Plan for the second phase of the DSM operation. DSM Phase II consists of 13 DSM programs targeting three major sectors of the economy, namely, residential, commercial, and industrial. Moreover, EGAT plans to build about 330 green learning rooms to create awareness of energy conservation in the curriculum.

Strategies for Phase II will include additional efforts, such as the promotion of energy efficiency and load management technologies in small and medium enterprise (SME) and the enhancement of standardization of energy use in corporations and the social sector. It will also build on successful approaches implemented during Phase I, such as market transformation, energy efficiency labelling, customer-oriented program design, public-private sector partnership (ESCOs), and attitude creation.

The total savings targeted for the Phase 2 DSM program is 632 MW peak demand and 2,508 GWh of energy. This will translate into a reduction of more than 1.85 million tons of CO_2 from accumulated energy savings at the end of 2006. According to EGAT, the program will cost Baht 2,155 million (i.e., Baht 1,700 million for the 13 DSM programs, and Baht 455 million for the attitude creation programs).

9.5. Implementation of ISED Framework

The conceptual framework of the present study follows ISED's model framework called Driving Force-State-Response (DSR), specifically fine-tuned for the energy sector. The DSR framework illustrates the interrelationship of the three principal pillars of development (i.e., economic, social, and environmental), as well as the institutional dimension so critical in the development of the energy system. The "Driving Force" indicators encompass human activities, processes and patterns that impact sustainable development, positively or negatively (UN, 1996). The "State" indicators refer to the state of sustainable energy development, while "Response" indicators highlight corrective policy actions affecting sustainability of the whole energy system. The environmental state of the energy system is the consequence of the driving forces coming from the economic and social dimensions of the energy system. The driving forces from the economic dimension also influence the social state of the energy system. The institutional dimension affects all three dimensions by means of laying out various policy options that affect the sustainability of the energy system.

Figure 9.8 illustrates the interrelationship of the four dimensions.

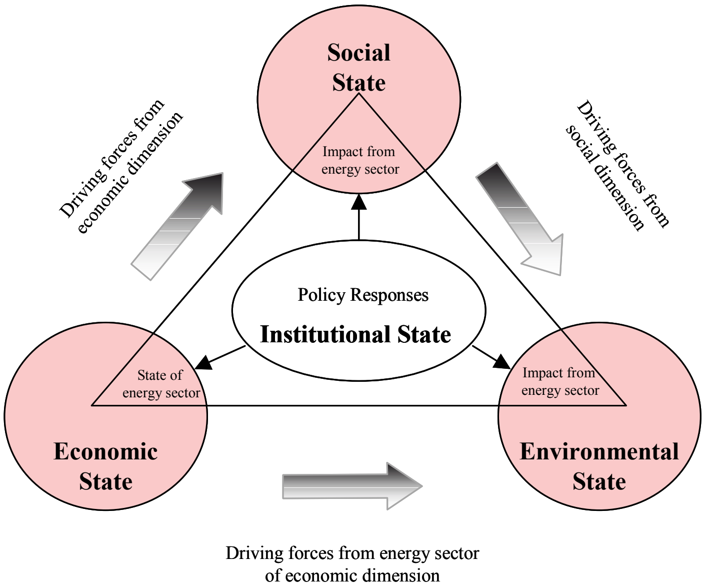

Figure 9.8: Interrelationship Among Sustainability Dimensions of the Energy Sector
Source: IAEA (2000)

9.5.1. Energy intensity as indicators in the economic dimension

The present study applies energy efficiency and conservation as "State" indicators of the economic dimension. Energy efficiency and conservation are measured through improvements in energy intensity, a measure of how much energy is used to perform a particular activity (e.g., production of output). It can be expressed both in monetary terms, in which energy consumption is denominated with monetary value of production, and in physical terms, when energy use is linked to physical output of production. The latter is usually called "specific consumption," to distinguish it from energy intensity that is usually expressed in monetary units.

At the highest levels of aggregation, two types of indicators are constructed: the national or aggregate energy intensity and sectoral energy intensities defined respectively as the total and sectoral energy consumption divided by gross domestic product or sectoral gross value added, and thus expressed in monetary terms as toe/Baht (see Figure 9.9). Due to the large level of aggregation, these broad indicators often include various structural and other effects. Thus, improvements in aggregate and sectoral energy intensities do not necessarily imply an increase in energy efficiency but could be a result of such factors as declining importance of energy intensive sectors (structural change) and non-energy related improvements. In turn, higher energy intensities also do not necessarily mean less efficient use of energy, as the structure of the economy might be moving towards more energy-intensive industries. There is a need, therefore, to decompose the energy intensity. Decomposition isolates the effect of changes in the economy's structure from the impact of real energy intensity. Real or pure energy intensity could be an explanatory indicator of energy efficiency, although efficiency improvements is not the main factor for reductions in energy intensity as the latter also could be attributed to changes in the fuel mix, changes in technology and operational changes. Several methods are used to decompose energy intensities. In this study, the *Divisia* method is used to decompose various effects on the aggregate energy intensity such as activity, structural and pure intensity effects.

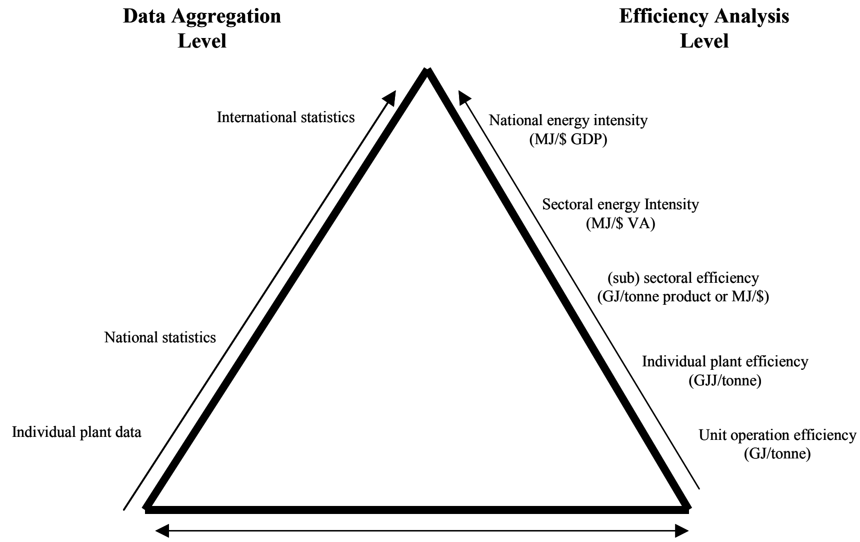

Figure 9.9: The Energy Efficiency Indicator Pyramid
Source: Phylipsen et al, 1998

At the lower level of aggregation, the number of indicators that can be constructed is increasing; thus, the influence of structural effects as well as other factors also declines. Few of the indicators at the lower level of aggregation include sub-sectoral efficiency measured from the ratio of energy consumption to a measure of human activity in physical terms (for example, toe/ton of product, for industry, kilogram of oil equivalent (kgoe)/billions of ton-kilometres for transport, etc.) and individual plant efficiency, or end-use efficiencies. These indicators are referred to as physical energy intensity, which are commonly called specific energy consumption (SEC) or unit energy consumption (Phylipsen et al, 1998). These physical energy efficiency indicators can reflect the effect of energy savings measures, for example, through the decrease of the SEC, leading to a greater understanding of the state of energy efficiency. In order to develop these physical energy efficiency indicators, substantial data are required. However, the accumulation of such data becomes increasingly more complex and costly as well.

Various driving forces influence changes in energy intensity. Mostly, these driving force indicators are economic and social in nature and affect the behaviour and preferences of energy consumers. For example, energy prices and taxes (as a government policy tool or an institutional response) affect the behaviour of energy consumers leading to either increases or decreases in energy intensity. The modal structure of transport can also influence energy intensity: the rapid growth of cars, which consumers prefer most, contributes to a more energy intensive transport system. Mass transport such as buses or trains are relatively more efficient compared to cars. The structure of the economy also influences energy intensity: a drive towards high value added and less energy intensive sectors reduces energy intensity. The government through its policy responses, therefore, has a major role in influencing these major driving forces that directly affect the behaviour of energy consumers as well as the structure of the economy leading to variations in energy intensity.

Moreover, there are other indicators affecting energy intensity, such as floor area per capita, freight and passenger activities, structure of manufacturing energy intensive industries, and others that are subsequently discussed in this study.

9.5.2. Indicators in the Social Dimension

Interrelationships between the state of energy efficiency and the state of social dimensions are also strong. For example, the heavy dependence on traditional energy in households and the share of households without electricity (state indicators under the social dimension) affect energy intensity: higher dependence over time on traditional energy would mean less improvement in energy intensity, as traditional fuels are less efficient than modern energies. Traditional fuels, for the case of Thailand,

are fuelwood, charcoal, and paddy husk, while modern energies include LPG, electricity, and kerosene. With respect to lighting, households without access to electricity tend to use less efficient candles and kerosene lamps in lieu of more efficient electric lamps. These state indicators are, in fact, poverty-related—income dictates the type of energy households will use. Income therefore is the main driver that can influence households' preference of fuel as well as the type of technology. Moreover, income also affects the affordability of various energy fuels (i.e., LPG, kerosene, and KWh of electricity) used by the poorest households, as well as the degree of use of these fuels. These can be measured by the share of income spent on fuel and electricity to total private consumption expenditures in the poorest households.

9.5.3. Indicators in the environmental dimension

The state indicator under the environmental dimension seen as particularly relevant is the ambient concentration of pollutants,[8] since this is a major consequence of fuel use among various sectors (driving forces) of the economy:

- Transport vehicles emit pollutants. The amount of pollution released is chiefly related to the type of energy consumed, as well as the technology used. Yet there are other contributing factors as well, including the volume or stock of vehicles, the age of the fleet (also related to technology), and other technically-related factors such as the engine, tail types, etc.
- Industrial activities contribute to pollution. The burning of fuels either for thermal (to produce heat) or mechanical uses (to drive engines and motors) contribute to emissions. The type of technology, which also depends on the type of fuel used, is similarly of concern with regards to industrial pollution.
- Residential and commercial sectors contribute to increased pollution due to various activities (cooking, lighting, etc.), using certain types of energy as input and specific technologies in order to obtain various services.

Annex 9.1 summarizes the selected set of indicators in the ISED package, as well as a number of additional indicators employed, and other indicators relevant to energy efficiency. There are in fact numerous relevant indicators for explaining the state of energy efficiency; however, due to limited disaggregated data available, this study did not address them.

9.6. The Economic Dimension

9.6.1. Manufacturing sector energy intensity

The manufacturing sector accounted for about 35% of the total final energy consumption of the country in 2000. It also generated more than 36% of the country's total gross domestic product during the same period (Table 9.5).

[8] Rate of deforestation is also applicable as a state indicator but not covered by this study as there are no data available.

TABLE 9.5: STRUCTURE OF ENERGY CONSUMPTION AND GDP BY SECTOR

	Energy Consumption, 2000 (Ktoe)	Share (2000)	1980 GDP[1] in Million Baht	1980 GDP Share	2000 GDP[1] in Million Baht	2000 GDP Share
Manufacturing	16,741	34.6%	211,031	23.1%	1,085,104	36.4%
Transport	18,652	38.6%	65,669	7.2%	292,431	9.8%
Residential	7,433	15.4%				
Commercial	3,118	6.5%	403,714	44.2%	1,169,735	39.2%
Agriculture	2,161	4.5%	184,576	20.2%	298,060	9.9%
Others	234	0.5%	48,743	5.3%	139,631	4.7%
TOTAL	48,339	100%	913,733	100%	2,984,961	100%

1 At constant 1988 prices

Over the years, non-metallic manufacturing is by far the most energy intensive industry in Thailand (Figure 9.12). Although its energy intensity slightly declined from the 1980s through the early 1990s, it has remained since then at its highest level. In fact, its energy intensity rebounded in the following years, peaking in 1999. The basic metals industry became the second most energy intensive manufacturing sub-sector, beginning in 1989. Its energy intensity increased sharply until early 1992, dropped until 1995, and has climbed steadily since 1996. Fabricated metal manufacturing posted a smooth growth of energy intensity during the period 1986-1991, and beginning in 1993. Food manufacturing, on the other hand, registered a slight decrease in energy intensity between 1981 and 2000. Other manufacturing industries have maintained their average energy intensity since the 1980s.[9]

A different picture appears for final electricity intensity. The basic metallic industry and fabricated metal are the most electricity intensive manufacturing industries (Figure 9.13). These two industries present similarly increasing patterns from 1993 onwards. Non-metallic manufacturing remained stable over the years, except for a slight decline in 1992. Electricity intensity in wood manufacturing started to climb sharply beginning in 1998 from its past 10 year stable level. Paper and chemical manufacturing industries posted a slight decline in electricity intensity while other industries maintained almost constant electricity intensities over the last two decades.

Looking at the physical energy intensity of selected manufacturing sub-sectors, based on the limited available data, the glass industry, under the non-metallic manufacturing sub-sector, is the most energy intensive industry. Other industries such as cement, pulp and paper, iron and steel, chemicals and others have much lower intensities that have been stable over the years.

9.6.2. Transport Sector Energy Intensity

Transport is the most energy intensive economic sector in the country, and energy intensity, which is usually defined with respect to total GDP (APERC, 2002), had been on a rapid upward trend, growing at 2.75% per year, until the financial crisis in 1997-2000 (see Table 9.5 and Table 9.6).

For passenger transport, only data for rail transport are available. As shown in Table 9.6, the energy intensity of rail transport has not shown any general improvement over the years. Between 1981 and 1997, the average growth rate of energy intensity was inching up by about 0.5% per year. The energy intensity of rail passenger transport is estimated by dividing the total energy consumption of rail transport over the total rail passenger-kilometres.

For freight transport, freight energy intensity expressed as million toe per ton-kilometre cannot be determined as there are no available data to show energy consumption of freight transports.

[9] There are no available data in Thailand showing individual gross value added (GVA) of energy intensive industries. Thus, energy and electricity intensities in monetary terms were derived using GVA of aggregate sector. For example, non-metallic products include cement and glass industries.

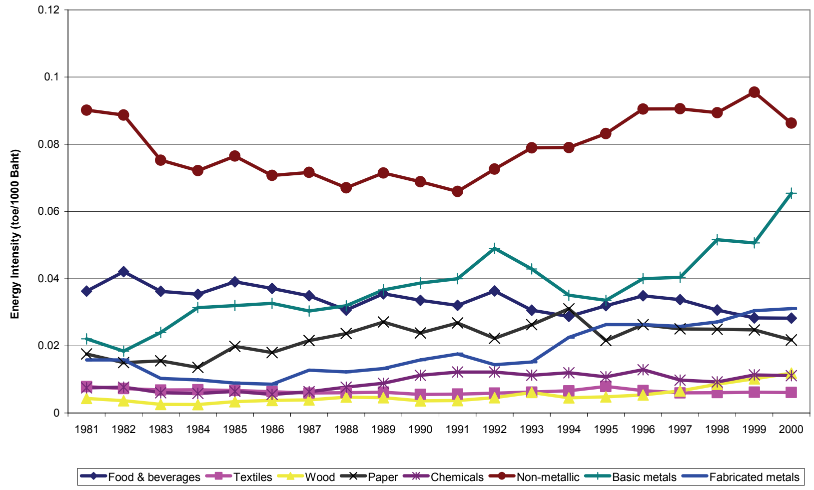

Figure 9.10: Energy Intensity of Manufacturing (toe/1,000 Baht at constant 1988 prices)

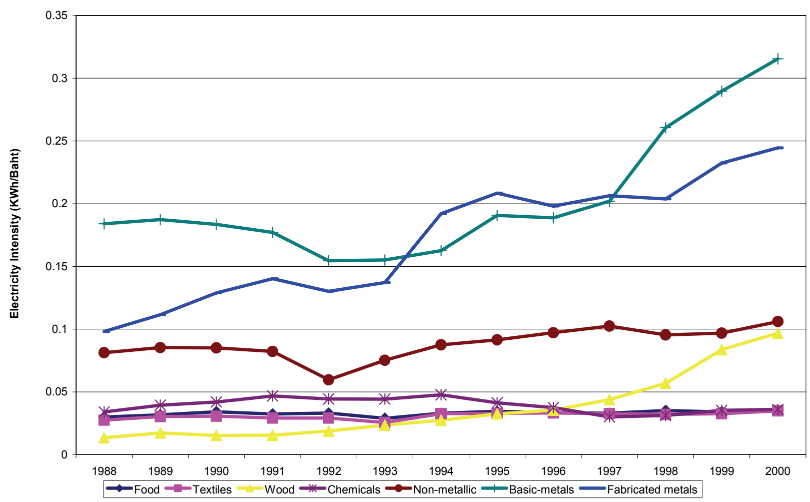

Figure 9.11: Electricity Intensity of Manufacturing (kWh/Bht at constant 1988 prices)

TABLE 9.6: ENERGY INTENSITY IN THE TRANSPORT SECTOR

Indicators	1982	1985	1988	1991	1994	1997	2000
Final energy intensity of transport (toe/1,000 Baht)	0.004	0.005	0.005	0.006	0.006	0.007	0.006
Rail Passenger travel energy intensity (mtoe/ pkm)	8.99	9.63	7.96	9.05	7.96	9.66	
Freight activity energy intensity (mtoe/ ton-km)	No data available						

9.6.2.1. Unit Consumption of Vehicles

The unit consumption of vehicles expressed as litres of fuel consumption required per 100-kilometer travel is a reliable measure of energy efficiency, in a technological sense. Although vehicles have a standard test value, the fuel efficiency can be influenced by the following parameters: for passenger cars, it depends on the speed, traffic and road condition, as well as drivers' behaviour; for freight vehicles, it depends on the type of service (load, average speed), the engine technology, and the external conditions (Guibet, 1999).

Notably, for cars, there was a trend for improved fuel efficiency using smaller size and less powerful cars after the oil crises. However, when energy prices moderated, consumer preferences shifted again towards bigger and more powerful vehicles, partially offsetting the previous improvements in fuel economy (IEA, 1997).

Cars

In Thailand, car sales are shifting towards larger and more fuel consuming vehicles such as luxury cars and sport utility vehicles (Bangkok Post, 1996). Despite severe traffic congestion problems, the relatively low prices of fuels and automobiles induce Thai customers to shift from small cars (i.e., below 1,600 cc), to medium ones (i.e., 1,600 cc and above) (TDRI, 1993). Hence, though it seems that vehicle efficiency has improved for certain cars in the past years, this structural change in the composition of the private car fleet has made it doubtful whether the overall fuel economy of the whole fleet has decreased significantly.

The correct assessment of the average fuel efficiency of the total car fleet is extremely difficult since a reliable figure can only be obtained by surveys. However, there are no surveys available for recent years in Thailand. The most recent survey of fuel consumption for cars was carried out by NEPO in 1991 for the preceding year. The outcome was a fuel consumption of 10 litres/100 kilometer gasoline for new cars and 11.5 litres/100 km for the whole fleet, taking into consideration its age structure (NEPO, 1992). A study by ONEB (1993) assumes that the fuel consumption under standard traffic conditions is 11 litres/100 km and 13 litres and 14 litres /100 km in the congested Bangkok Metropolitan Area (BMA) in 1991 and 1996. IIEC (1992) quotes data from the National Energy Administration, which revealed an even wider range for the fuel consumption level. For gasoline vehicles the fuel efficiency ranged from 7.1 to 14.3 litres/100 km, depending on the congestion level, while the consumption of diesel cars lies between 10.7 and 12.1 litres/100 km.

Buses

The fuel economy of urban buses is shown in the Table 9.7, based on the 1997 Survey of Bangkok Mass Transit Authority (BMTA)[10]. It is striking that air-conditioned buses consume almost 50% more fuel per 100 km than ordinary buses (without air-conditioning units). Even though there is no clear trend recognizable for the development of the individual unit consumption of ordinary and air-conditioned buses, the overall trend of the average unit consumption for the whole fleet is increasing, mainly due to a shift towards more fuel consuming air-conditioned buses (Table 9.7).

TABLE 9.7: EVOLUTION OF UNIT CONSUMPTION OF BUSES IN THAILAND

	1992	1993	1994	1995	1996
Ordinary bus [liter/ 100 km]	39.74	40.14	40.33	40.17	39.68
Air-cond. bus [liter/ 100 km]	62.91	59.43	57.49	60.54	62.57
Natural Gas Bus [m^3/ 100 km]	-	-	-	86.50	85.13
Weighted Average [liter/ 100 km]	42.43	43.66	43.93	44.71	45.51

Source: BMTA, 1997.

On the other hand, there are no recent data available concerning fuel consumption of buses outside the Bangkok Metropolitan Area. Based on NEPO statistics, average fuel consumption in 1992 for the non-Bangkok bus fleet was 37.5 l/100 km, indicating a larger proportion of ordinary buses than air-conditioned buses. For freight and other passenger vehicles, there are no available data on fuel efficiency in the country.

[10] The BMTA is directly operating BMTA-owned buses and, at the same time, responsible for supervising bus services from the private sector.

9.6.3. Service sector energy intensity

Changes in the overall service sector energy intensity over the past decade show three clear trends (Figure 9.14). It increased by more than 14% per year in 1989-1991, and then dropped steadily by more than 15% annually from 1991 to 1995. In 1998, however, energy intensity had jumped by more than 122% from its 1997 level, and then moderately increased in the following years.

A similar trend can be observed for the energy intensity by floor space, even though data are only up to 1995. This energy intensity measures the amount of energy consumed for every square meter of commercial floor area. It increased by 3.5% between 1989 and 1991, then decreased annually by 12% through 1995.

The declining service sector energy intensity from 1991 may be due to the comprehensive building codes and the introduction of building energy management services such as building improvement and energy audit programmes beginning in 1992. The large increase in service sector energy intensity from 1997 is most likely due to the financial crisis, when output or value added, from all economic sectors (except probably agriculture) was drastically reduced, but energy consumption did not follow at the same rate.

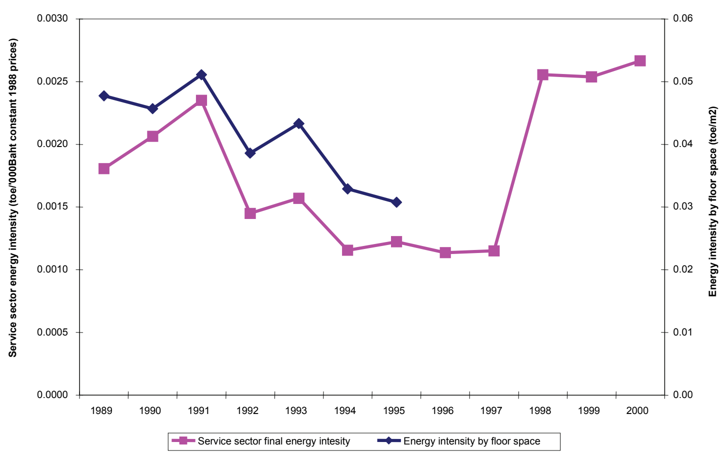

Figure 9.12: Service Sector Energy Intensity

The trend of electricity intensity in the service sector is rather different. Beginning in 1983 and continuing through 1998, total final electricity intensity (kWh/Baht at constant 1988 prices) and employee electricity intensity (kWh/employee) exhibited a robust growth in the exact same pattern, but at different rates—about 7% and 12%, respectively (Figure 9.15). The rapid increase indicated speedy development of office and commercial buildings, including the robust penetration of electrical office equipment (such as computers, faxes, photocopying machines, etc.) contributing to the growth in average unit consumption per employee. Electricity consumption in the commercial sector, however, slowed down starting in 1998, following the economic downturn which started in mid-1997.

9.6.4. Residential sector energy intensity

The evolution of residential sector electricity intensity expressed in terms of electricity consumption per household (kWh/hh) grew steadily in the past (Table 9.8). Two main factors explain this trend: an increase in the number of electrical appliances per household, and an increase in the utilization of existing appliances. The impact of the Asian financial crisis is evident with the decline of electricity consumption in 1999.

A different pattern can be observed for traditional fuel energy intensity (expressed in total traditional energy consumption per household). Over the years, consumption of traditional energy (including charcoal, paddy husk, and fuelwood) in the residential sector was declining at the rate of more than

9% per annum from 1990 to 1998. One of the reasons for the decline of traditional energy intensity is the shift to alternative fuels and technologies, for example from kerosene lighting to electric lamps, or from charcoal cooking stoves to LPG stoves. The shift to more modern fuels and technologies may be due to the increase in household income.

Modern energy intensity, on the other hand, remained stable over the years. Modern energies include kerosene and LPG (electricity was separated for a better grasp of the picture).

In sum, residential sector energy intensity has declined due to the shift to more efficient household equipment or technologies.

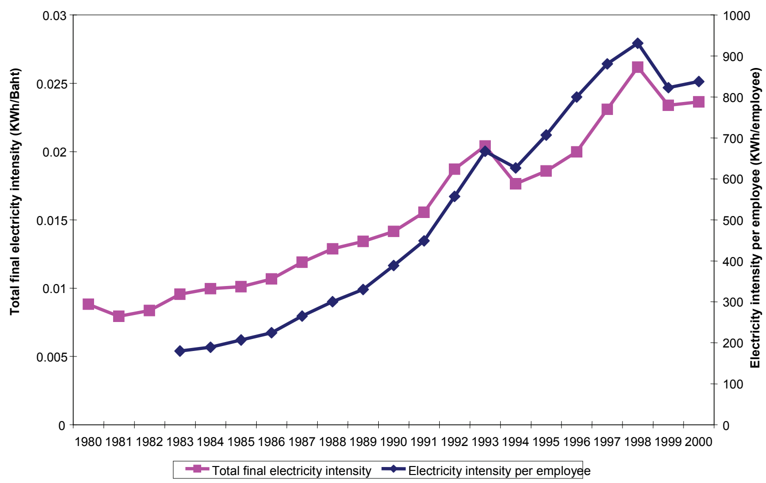

Figure 9.13: Electricity Intensity of Service Sector

TABLE 9.8: ENERGY INTENSITY IN THE RESIDENTIAL SECTOR

Indicators	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Residential sector energy intensity (Kgoe/hh)	675.5	690.5	668.9	639.2	593.5	569.1	533.2	526.5	557.4	461.5	446.2	450.0
Traditional energy intensity (Kgoe/hh)	48.5	49.3	45.9	43.4	40.0	37.2	33.1	31.5	30.8	22.9	23.2	22.9
Modern fuel per capita (Kgoe/hh)	13.1	13.0	13.7	13.6	11.7	11.8	11.7	12.2	15.3	13.1	11.8	12.0
Residential electricity intensity (KWh/hh)	702.6	800.2	856.0	805.9	894.8	921.2	994.9	1,046.0	1,140.1	1,187.5	1,122.7	1,179.1

Source of basic data: NSO and DEDP, various editions and issues
* hh means household
Note: Modern fuel excludes electricity.

9.6.5. Agriculture sector energy intensity

The evolution of the agriculture sector energy intensity showed an increasing trend until 1997 and a declining trend until 2000. Between 1989 and 1997, energy intensity grew annually by 12% on average, although sharp declines occurred in 1993 and 1995. Between 1997 and 2000 agriculture energy intensity fell by 19.1% per annum (Figure 9.16)

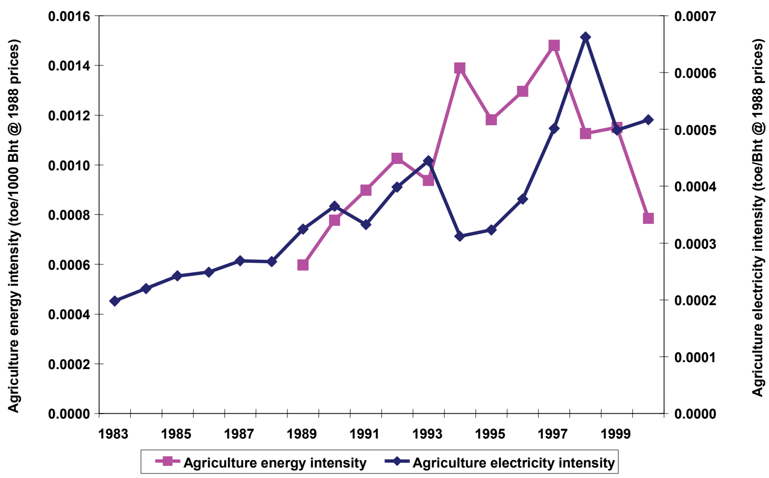

Figure 9.14: Agriculture Energy Intensity

Agriculture electricity intensity (expressed as total electricity consumption over the agriculture gross value added at constant 1988 prices) showed an overall sharply increasing trend between 1983 and 2000, except for two abrupt drops in 1994 and 1999 that were driven by the decrease in electricity consumption. In the decade to 1993, electricity intensity increased annually by more than 8%, despite a slight decrease in 1990-1991. Following a huge 30% drop in 1994, electricity intensity increased by around 21% per annum through 1998. By 1999, it dropped again by around 25%, before starting to rebound in 2000.

9.6.6. Aggregate energy intensity

Figure 9.17 shows the national aggregate as well as sectoral energy intensities for Thailand. Total final energy intensity is expressed as the ratio of total final energy consumption over total GDP while sectoral energy intensities are expressed as energy consumption of each economic sector over their corresponding gross value added (GVA).

Overall, aggregate and sectoral energy intensities remained fairly flat during the 12-year observation period through 2000. Only the transport sector energy intensity exhibited a significant decline, but only when approaching 2000.

The pattern of electricity intensity is rather different.[11] The electricity intensity of the commercial sector was increasing very fast at the rate of 5% per annum between 1980 and 2000, while those of the manufacturing and agriculture sectors remained rather constant. The trend of the aggregate (total final) electricity intensity follows that of the commercial sector (see Figure 9.16).

[11] Transport sector, particularly rail transit, only started to use electricity beginning in 2000.

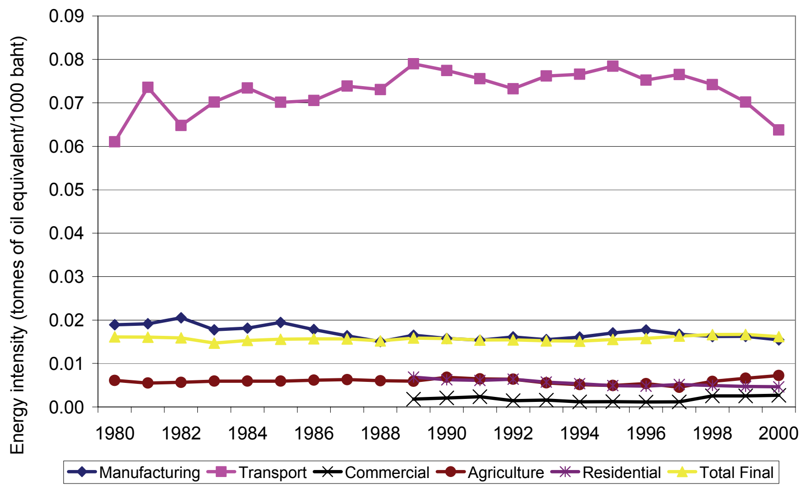

Figure 9.15: Total Final and Sectoral Energy Intensity (toe/1,000Baht constant 1988 prices)
Note: Residential energy intensity was calculated based on the total energy consumption of residential sector over total GDP at constant 1988 prices.

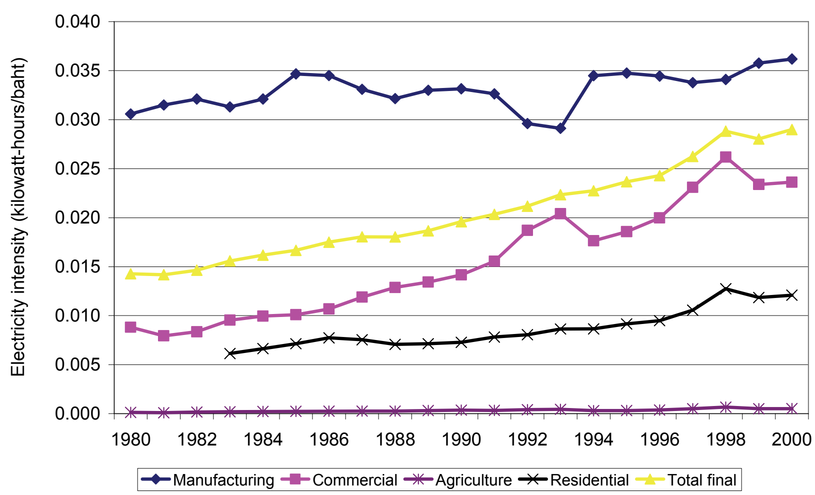

Figure 9.16: Total Final and Sectoral Electricity Intensity (kWh/Baht at constant 1988 prices)
Note: Residential electricity intensity was calculated using total GDP in constant prices.

9.6.7. Decomposition analysis of changes in aggregate energy intensities

Decomposition analysis is applied to the total or aggregate energy intensity to demonstrate the impact of structural changes on energy intensity and to separate the activity effect from structural and pure intensity effects. Activity effect refers to overall growth of the economy as measured by GDP; structural effect refers to changes in the structure of the economy, or the contributions of the main economic sectors; and pure energy intensity is the energy consumption to produce a certain value of output, or here expressed as toe per 1,000 Baht.

The structural effect measures variation in energy intensity brought about by changes in the structure of the economy. Some sectors require large amounts of energy to produce output. For example in the manufacturing sector, glass, cement, and iron and steel industries consume more energy than other industries to produce one unit of output. Other sectors, such as agriculture, are less energy intensive. A positive structural effect implies a structural shift to more energy intensive economic sectors like some manufacturing industries. It also means that the share of energy intensive sectors to GDP has increased

compared to some base year. A negative structural effect indicates that the energy intensive sectors have decreased their share of GDP compared with that in the base year.

The pure energy intensity effect measures the improvement in energy efficiency, changes in technology, fuel mix changes, and other factors that are not related to activity or structure. A positive effect signifies a higher energy use per unit of GDP implying worsening energy efficiency, while a negative pure intensity effect indicates an improvement in energy use per unit of GDP.

Figure 9.19 shows the decomposition of changes in Thailand's aggregate energy consumption into activity, pure intensity and structural effects, and illustrates the advantages of disaggregating such components to isolate the main factors affecting the aggregate energy intensity.[12] The changes in energy use from year to year are depicted in the chart by the bars. The overall effect of these factors is captured by the changes in the aggregate energy intensity with respect to 1990 (1990=1.0) as shown by the intensity index represented by the curve.

The activity and structural effects held positive values all throughout the period, indicating the strong industrialization process of Thailand during this period and the shift of the economy towards more energy intensive sectors. In fact, during this period, the share of the manufacturing industry in GDP climbed sharply from 29% in 1990 to 36% in 2000. A closer examination of the structural changes in the manufacturing sector shows that the share of energy-intensive sectors increased from 20% to 27% in the same period. This is a typical pattern of energy use and efficiency for developing countries in the industrialization stage.

Pure intensity effect, on the other hand, maintained consistently negative values, indicating efficiency improvements with respect to the 1990 levels (the chosen base year) resulting from the very effective energy efficiency policies implemented by Thailand during the period. In fact, this effect explains, in part, the net 4% decline in aggregate energy intensity between 1990 and 1994. However, over the whole 1990-2000 period, the activity and structural effects dominated, leading to a net increase in aggregate energy intensity during this longer period.

9.6.8. Analysis of driving force indicators for energy efficiency under economic dimension

9.6.8.1. Population Growth, Urbanization and Employment

Thailand's total population was growing steadily at the rate of 1.4% per year in the last two decades and reached 62.4 million in 2000. Available data indicate that about 22% live in urban areas.

Metropolitan Bangkok, the national capital, is the most populous and most dense province of Thailand. It is estimated that Bangkok residents number more than 11 million (18% of total), equivalent to more than 7,000 persons per sq. km. In contrast, the largest and the second most populous province, Nakhon Ratchasima, has a population of less than three million (4.5% of total), or 130 persons per sq. km. Nonthaburi, the second most crowded province located 20 km north of Bangkok (also in the Central Region), is estimated to have a population density of 1,500 persons per sq. km.

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[12] The decomposition analysis is based on a Divisia Index approach. For more information on this approach, see APERC 2001; IAEA, et al., 2005, Annex 3; and Ang, B.W., 2004.

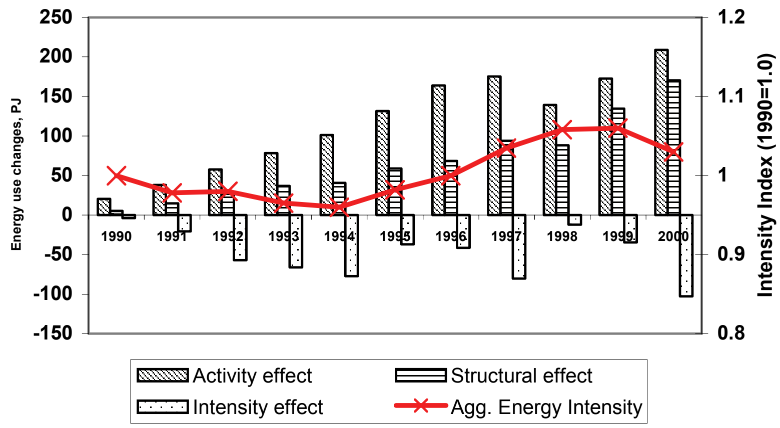

Figure 9.17: Decomposition of Aggregate Energy Intensity

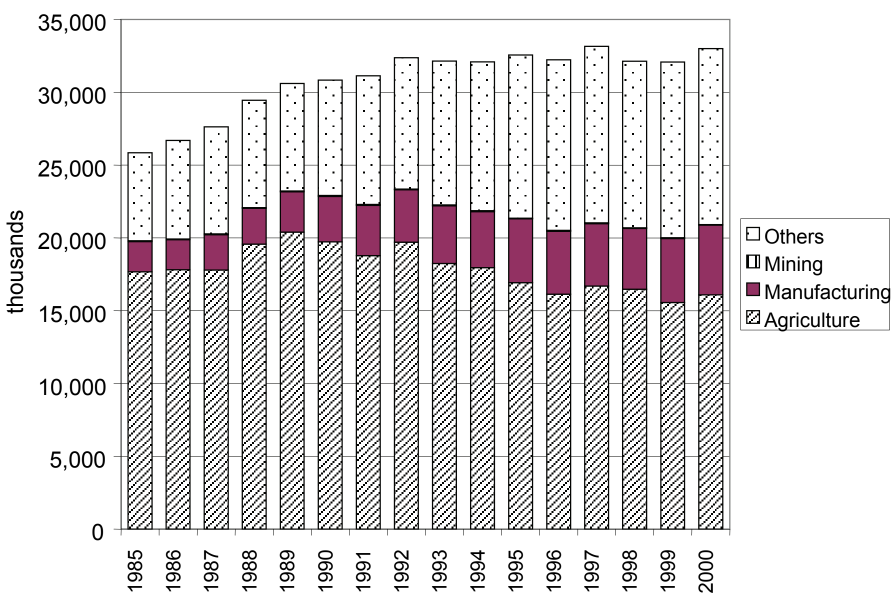

Figure 9.18: Structure of Employment

The economic boom in the late 1980s caused a rapid migration of the population from the provinces to Bangkok and nearby urban areas where industrial expansion was taking place. As a consequence, as shown in Figure 9.20, employment in the agriculture sector dropped to 49% (16.1 million) of those employed in 2000 from 68% (17.7 million) in 1985. On the other hand, those employed in the manufacturing sector increased by 2.7 million to 4.7 million in 2000, from 8% to 14.5% of those employed. The unemployment rate has been going down. Even though it deteriorated from a low of 1% to 3.4% in 1998 because of the financial crisis, it then improved to 1.8% in 2002 (see Figure 9.19).

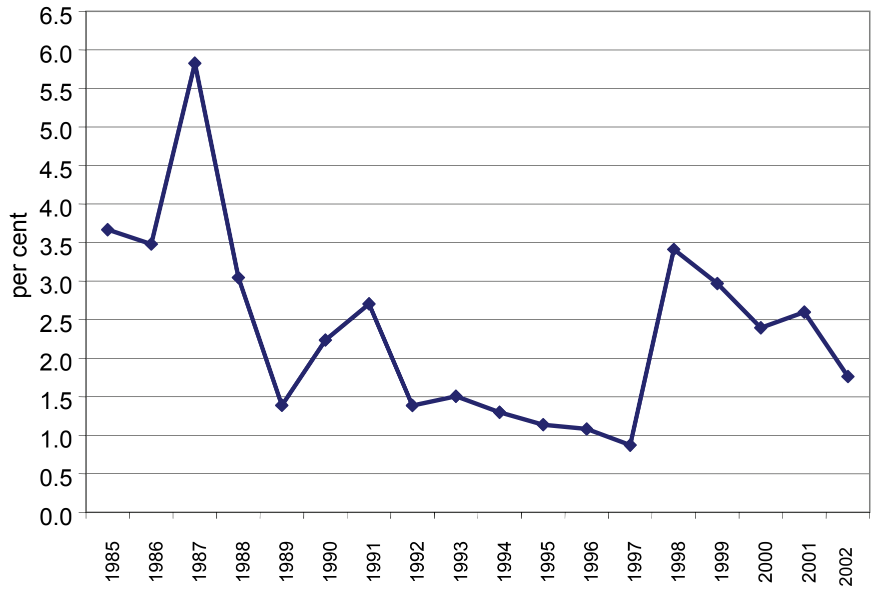

Figure 9.19: Unemployment Rate
Source of basic data: ADB, 2003.

9.6.8.2. Macroeconomic Structure and Performance

Thailand's economy experienced gradual but notable changes over the past two decades. The service sector has remained the largest contributor to the Thai economy, but its share decreased slightly from 45% in 1981 to 39% in 2000 (Figure 9.20). Manufacturing was catching up, with its share increasing from 23% in 1981 to 36% in 2000, more than any other sector. The manufacturing sector (primarily export-oriented industry) was at the forefront of Thailand's economic growth between 1985 and 1995, growth that was unprecedented in this part of the world and elsewhere. The 13.1% annual growth rate of the manufacturing sector during that period was responsible for the 9.5% annual GDP growth in the same period (Figure 9.23). The share of transport and communications also inched up from more than 7% in 1980 to almost 10% in 2000.

The growth in the manufacturing sector's contribution to GDP came at the expense of agriculture, whose share was halved from 20% to 10% between 1981 and 2000. Yet, the agriculture sector continues to provide inputs to food, beverages, and tobacco manufacturing that accounted for 16-19% of total manufacturing output during the pre-crisis years.

Having recovered from the financial crisis, Thailand expected its economy to grow by more than 8% in 2004[13], which is close to the average pre-crisis growth levels.

[13] 2004 GDP growth rate is 6.1%.

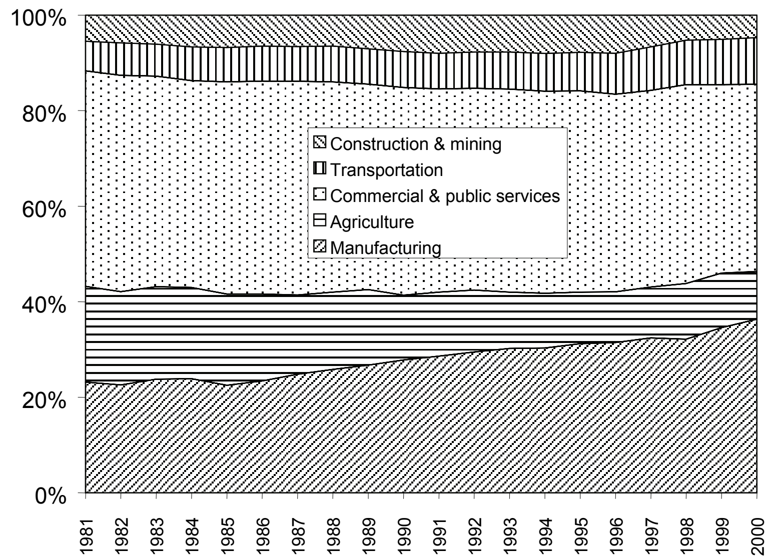

Figure 9.20: Sectoral Contribution to GDP

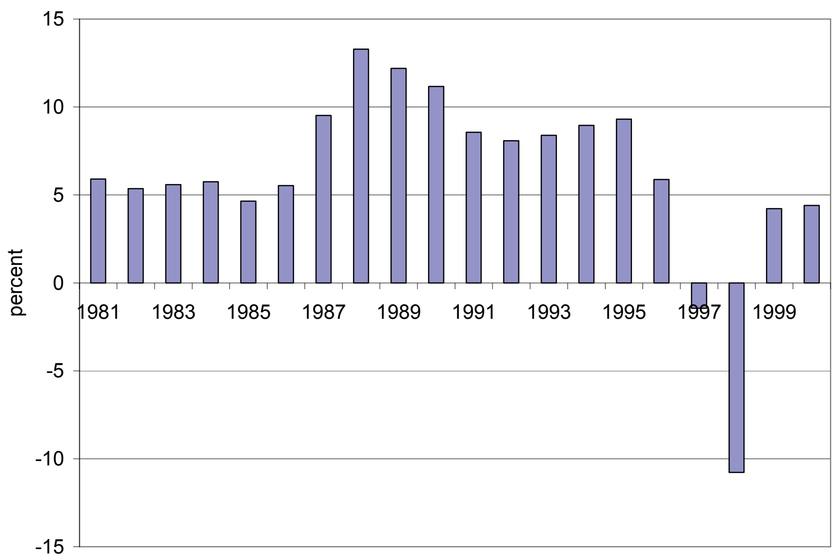

Figure 9.21: GDP Growth

9.6.8.3. Structure of Manufacturing Value Added of Energy Intensive Industries

Among the economic sectors, manufacturing plays an important role in the economy as it directly contributes to industrialization and creates linkages for the development of the other sectors (i.e., services and agriculture). To fully understand the patterns of energy consumption between energy and non-energy intensive manufacturing industries, it is also essential to identify the structure of the manufacturing industry.

In the manufacturing sector, the chemical industry remains the single biggest contributor to manufacturing value added. In fact, the industry's contribution to total manufacturing valued added increased from 15% in 1980 to 18% in 2000. The next biggest contributors after the chemical industry were non-metallic minerals, pulp and paper, and basic metals (iron and steel). Yet, more than 70% of the total value added of manufacturing came from other non-energy intensive industries (Figure 9.24).

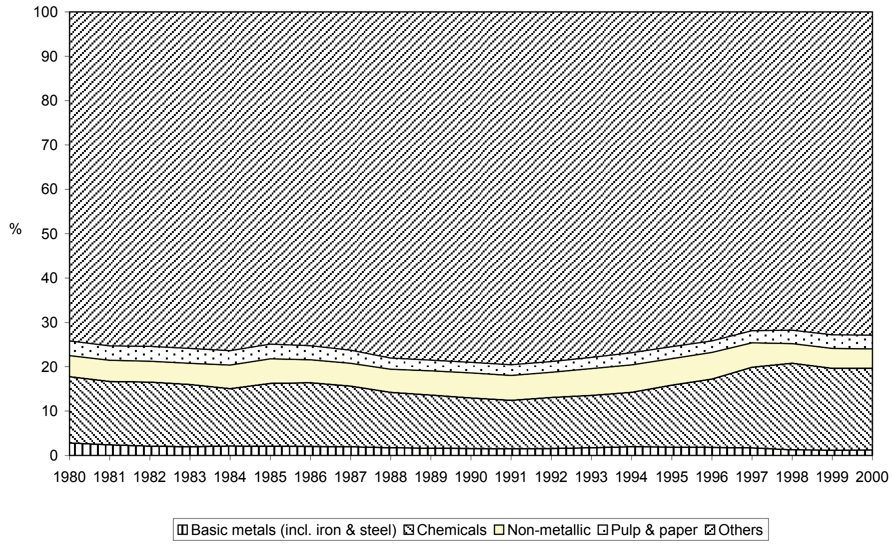

Figure 9.22: Structure of Manufacturing Value Added of Energy Intensive Industries

9.6.8.4. Energy Prices and Taxes[14]

Energy prices and taxes are essential policy tools to promote energy efficiency and conservation. For developed countries, energy prices can be used as a disincentive to increased energy consumption, while for the developing countries, there are concerns about energy affordability as well as incentives for energy conservation and efficiency improvement (IAEA/UN, 2002).

In Thailand, taxes were used as measures to promote energy efficiency and conservation. For example, a premium rate of about 0.04 Baht[15]/litre (adjusted from 0.01 beginning October 1998) is imposed on gasoline, diesel, kerosene and fuel oil. The revenues derived from the additional levies on petroleum products go to the Energy Conservation Promotion Fund (ENCON Fund) to support energy conservation projects in Thailand. Another example is the 5% tax reduction allowed on imported machines, materials, and equipment that can lead to the conservation of energy and protection of the environment.

Petroleum retail prices in Thailand generally increased annually between 1991[16] and 1999, from a low increasing annual rate of 0.26% for LPG cooking gas to a high of 6.47 % for heavy fuel oil (for industrial uses). (See Figure 9.25 to Figure 9.28) During the same period, taxes were highest for kerosene at 34% and lowest for heavy fuel oil at 16% of the total retail price. But, looking back during the late 1980s, the highest tax was levied on premium gasoline (95) reaching 52% in 1988 and from 42% to 50% in 1996 (Figure 9.25). The tax on premium gasoline was intended to discourage its use primarily due to concerns about the environment. Because of the government's drive to decrease pollution in the country, consumption of premium gasoline was actually discontinued after 1996. Unleaded gasoline (95), with competitive prices, was introduced in 1991 (Figure 9.26).

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[14] Petroleum prices used in this study are standard Bangkok retail prices. Retail price is the sum of the ex-refinery price (import price), excise and municipal taxes, the marketing margin, the Oil Fund contribution, the Energy Conservation Fund contribution, and value added tax (VAT). For this study, taxes include only ex-refinery excise taxes and municipal taxes, and for imported oil products, import duty is included. For electricity, electricity price is the average price charged to MEA and PEA customers. Prices exclude VAT. There are no available data for the complete structure of retail electricity prices (i.e., for the proportions of generation, transmission, and distribution costs).

[15] 1 Baht = 100 Satang; 1 US$ = ~43.5 Baht

[16] Beginning 19 August 1991, the oil market in Thailand was deregulated. The tax structure and several other regulations were revised with the aim of increasing competition in the domestic oil market.

The tax on kerosene was also very high in 1988, about 44% of the total retail price. It then began to decrease annually by more than 5%, dropping to as low as 22% by 2000 (Figure 9.25). The high tax levy for kerosene may be due also to the government's drive to discourage use of kerosene (especially in the residential sector), as its energy efficiency is very low. Kerosene is used for lighting and cooking in the residential sector, particularly in rural areas, and also for other uses in other sectors.

The annual average growth of the LPG retail price for cooking in the residential sector was only 0.3 % per annum between 1991 and 2000 (Figure 9.26). During the same period, pre-tax prices for the cooking gas also increased slightly by 1% per year, lowest among other petroleum prices such as heavy fuel oil (6.54%), ULG 95 (6.02%), kerosene (3.39%), and automotive diesel (2.94%). This was because LPG prices received a subsidy from the government at the rate of 1.40 Baht per kilogram. The government has deregulated the LPG market with the belief that energy use will be most effective and best adaptable to the changes in fuel prices without the price distortions caused by government subsidy. However, a certain level of subsidy is still maintained by the government at the present time for LPG prices[17], as it has a strong correlation with food prices that can affect the poor and become a political issue—and possibly fuel political uncertainty (Sajjakulnukit, 2001). Moreover, the low prices of LPG can encourage low-income households to shift to the more energy efficient cooking technologies.

Retail prices of heavy fuel oil for industrial uses also rose robustly at 6% per year between 1987 and 1999. The fast growth was induced mainly by the high taxes imposed for fuel oil. On the other hand, steam coal price for industrial uses is decreasing by more than 6% per year for the period 1980 to 1992 (recent data are not available).

Like the heavy fuel oil for industrial use, the retail prices of automotive diesel for commercial uses exhibited substantive growth of around 6% per annum (Figure 9.27). This growth, however, was brought about by increases in the pre-tax prices and not by taxes.

Meanwhile, average retail electricity prices in the country moved slowly up and down beginning in the early 1980s and continuing through the mid 1990s. The commercial sector maintained its highest prices from 1980 through 1993, but residential prices had a dramatic growth between 1994 and 2000, surpassing prices within the industrial and commercial sectors (Figure 9.28).

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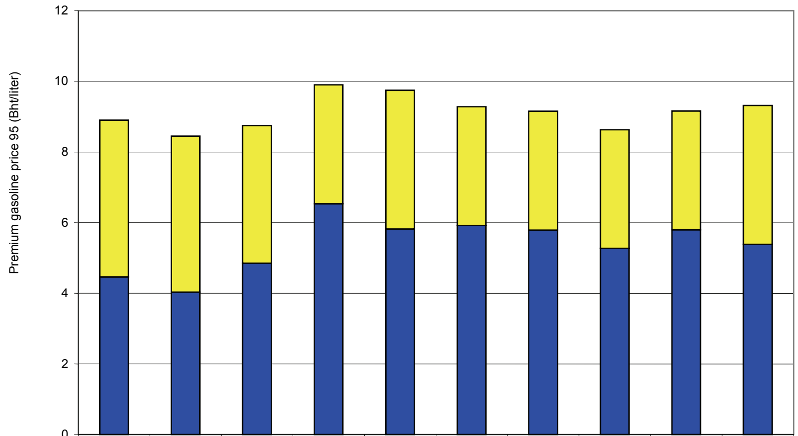
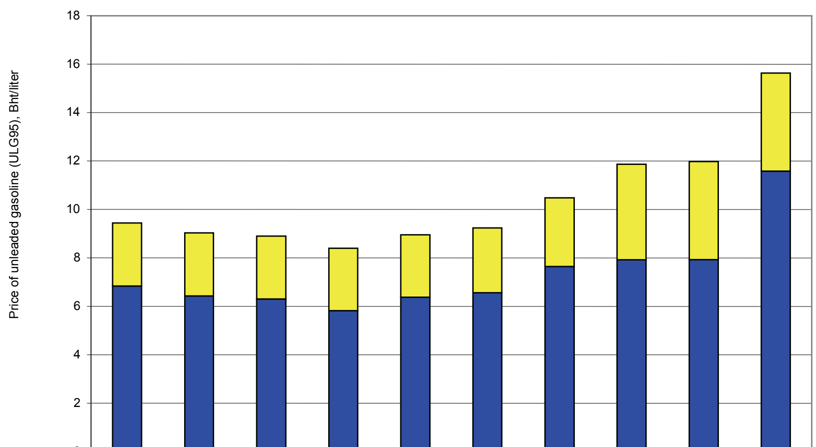
[17]The Thai government owed some two billion baht to the country's six oil refineries for selling LPG to the public at about 40% of its actual cost. The government controlled LPG prices at an artificially low level of about $125 per tonne, although the actual reference price on the world market had soared to $300 per tonne, resulting in oil refineries having to sell LPG to traders at $175 a tonne below cost. The heavy outflow from the Oil Fund amounted to nearly 1 billion baht a month. The Oil Fund, whose prime application is to subsidise local LPG prices, is sourced from levies imposed as part of the official pricing structure of oil products, especially petrol (Bangkok post 2000 Year-End Economic Review).



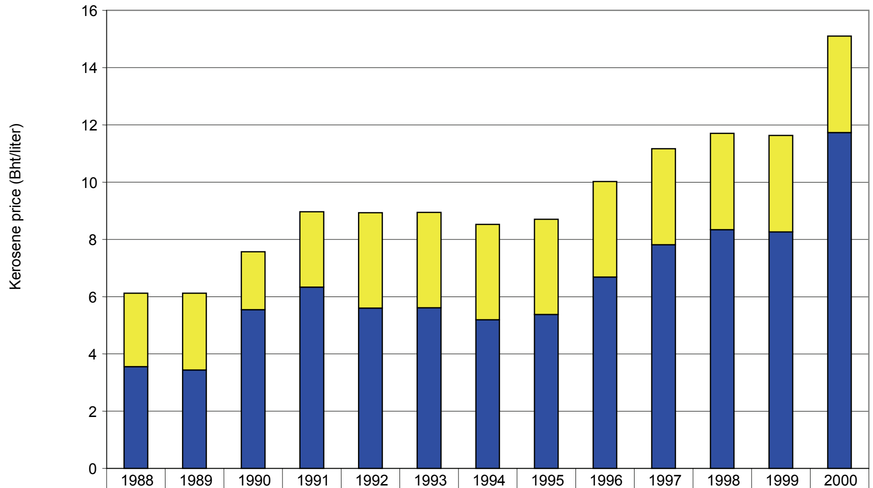
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Tax	4.44	4.42	3.9	3.37	3.93	3.36	3.36	3.36	3.36	3.94
Pre tax	4.46	4.03	4.85	6.53	5.82	5.92	5.79	5.27	5.8	5.38

Figure 9.23: Retail Price and Tax for Premium Gasoline 95 (Transport Sector)



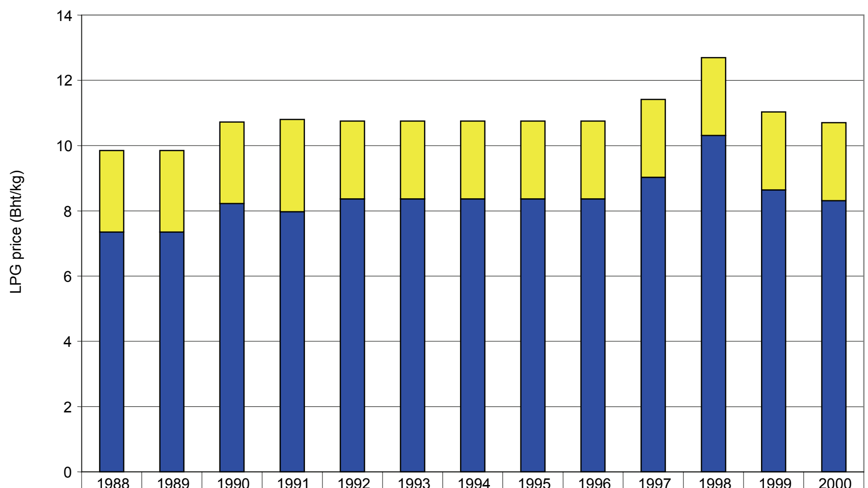
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Tax	2.6	2.6	2.6	2.58	2.58	2.68	2.84	3.94	4.0535	4.0535
Pre tax	6.84	6.43	6.3	5.82	6.37	6.56	7.64	7.92	7.9265	11.5765

Figure 9.24: Retail Price and Tax for Unleaded Gasoline 95 (Transport Sector)



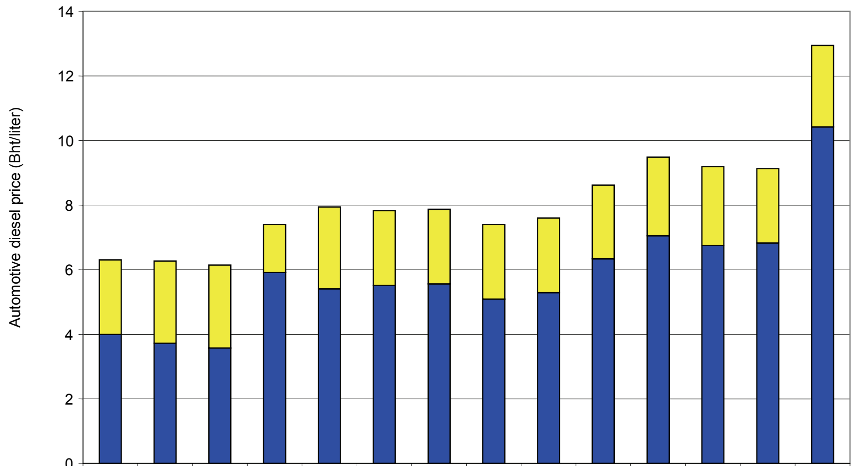
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Tax	2.56788	2.6815	2.025	2.63019	3.3325	3.3325	3.3325	3.3245	3.3325	3.35525	3.3655	3.3655	3.3655
Pre tax	3.55213	3.4385	5.545	6.32981	5.5975	5.6075	5.1875	5.3755	6.6875	7.81475	8.3345	8.2645	11.7345

Figure 9.25: Retail Price and Tax for Kerosene (Residential Sector)



	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Tax	2.5005	2.5005	2.5005	2.8275	2.3875	2.3875	2.3875	2.3874	2.3875	2.38745	2.392	2.38975	2.3875
Pre tax	7.3495	7.3495	8.2245	7.9725	8.3625	8.3625	8.3625	8.3626	8.3625	9.02255	10.308	8.64025	8.3125

Figure 9.26: Retail Price and Tax for LPG (Residential Sector)



	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Tax	2.3	2.54	2.57	1.49	2.53	2.31	2.31	2.31	2.31	2.28	2.44	2.44	2.3045	2.53
Pre tax	4	3.73	3.58	5.91	5.41	5.52	5.56	5.09	5.29	6.34	7.05	6.75	6.8255	10.42

Figure 9.27: Retail Price and Tax for Automotive Diesel (Commercial Sector)

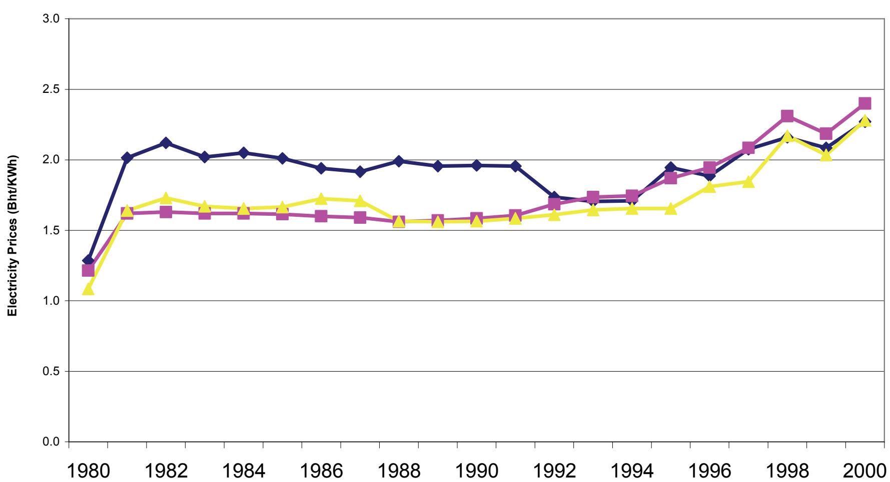


Figure 9.28: Sectoral Average Electricity Prices (Baht/kWh)

9.6.8.5. Car and Motorcycle Ownership

The actual size and composition of private vehicle stock such as cars and motorcycles has a big influence on the transport energy consumption level. Private cars, for example, are the most energy intensive mode of transport. An uncontrolled growth of cars causes traffic congestion and over-consumption of energy, as there are more vehicles required to move people than if large buses were used. Thus, policies that favour public or mass over motorized private transport vehicles can significantly reduce energy intensity levels.

The stock of cars increased tremendously as a result of increasing purchasing power that, in turn, was due to the rapid economic growth experienced by Thailand in the late 1980s to mid-1990s.[18] Indeed, the car ownership ratio more than quadrupled, from 126 persons per car in 1983 to 30 persons per car in 2000. This yielded a total vehicle car stock of around 2.3 million cars in 2000 (Table 9.9).

TABLE 9.9: CAR AND MOTORCYCLE OWNERSHIP (PERSONS PER STOCK)

	1983	1985	1990	1995	2000
Car ownership per capita (persons/car)	125.86	95.78	71.83	42.92	29.56
Motorcycle ownership per capita (persons/motorcycle)	28.81	28.29	11.69	6.38	4.52

Source: Vehicle stock - Ministry of Transport and Communications Annual Statistics Report 1990-2000; Population: ADB Key Indicators 2000

On the other hand, the stock of motorcycles in 2000 was almost seven times larger than the stock of cars, totalling 15.2 million in 2000 and translating to an ownership ratio of 4.5 persons per motorcycle. Further, the growth of motorcycles in Thailand also outperformed car growth rate between 1983 and 2000. The former grew by an average of more than 13% per annum, while the latter increased by 10% annually. Motorcycles are indeed very popular in Thailand; they are very affordable and can prevail over the usually heavy traffic. They are also used as taxis, and thus provide a source of livelihood for many low-income households in Bangkok.

The slowdown in the increase in vehicle stock in 1997-2000 may be due to the excise tax increase of 5 percent on *all* types of road vehicles in 1997 (*The Nation*, 1997), as well as to the financial crisis.

9.6.8.6. Modal Structure of Road Vehicle Stock

Transport energy consumption is linked to the corresponding dominant transport type. Hence, it is important to distinguish between vehicle types or mode of transport and whether these are used for passenger or goods transport, as the respective dynamics are very different. For passenger transport, it is also essential to categorize them by mode as the structure of the transport has a decisive influence on the level of energy consumption. For example, road and rail public transport are less energy intensive than cars.

The structure of vehicle stocks in Thailand showed that over the years, passenger vehicles continue to dominate Thailand's road transport system. Around 97% of the country's total vehicle stocks are passenger vehicles and only 3% are freight vehicles (Table 9.10). Among the country's passenger vehicle stocks, motorcycle vehicles have held an overwhelming proportion, averaging more than 70% of the total stocks. This gives an amount of 15.3 million motorcycles in year 2001 from just 1.7 million eighteen years ago, equivalent to an annual escalation rate of more than 13%. Vans and pick-ups followed well behind, accounting for 15.3% in 2001, up from 14% in 1983.[19] Meanwhile, the average share of sedan cars was around 12% and that of the bus fleet 3% of total road passenger transports (Figure 9.29).

In addition, it can be observed that there are changes in the structure of passenger transports. Stocks of motorcycles, vans and pick-ups increased at the expense of cars, buses and other passenger transports. The share of motorcycles increased from 62% in 1983 to around 70% in 2001, while vans and pick-ups grew slightly by 1.44 percentage points from a share of 13.8% during the same period.

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[18] One should add to these reasons the Thai's penchant for cars, as well as the easy financing terms to own a car.

[19] Note, however, that in Thailand, pick-ups are used for two purposes: for freight and passenger pick-ups. Passenger pick-ups, mainly called "Songthaew", are pick-ups modified in such a way that they allow for passenger transport instead of freight transport. These pick-up vehicles run on fixed routes where other means of public transport (i.e., buses) are insufficient or not available. However, they can also be hired directly like a shared taxi. This would obviously bring about a quite different usage pattern for the pick-up fleet. However, the national vehicle registration data do not differentiate between pick-ups for freight transport and pick-ups for passenger transport.

TABLE 9.10: SHARE OF PASSENGER AND FREIGHT VEHICLES (%)

	1983	1985	1990	1995	2000
Passenger cars	93.11	93.13	95.35	96.28	96.76
Freight vehicles	6.89	6.87	4.65	3.72	3.24

Source: Ministry of Transport and Communications Annual Statistics Report 1990-2000

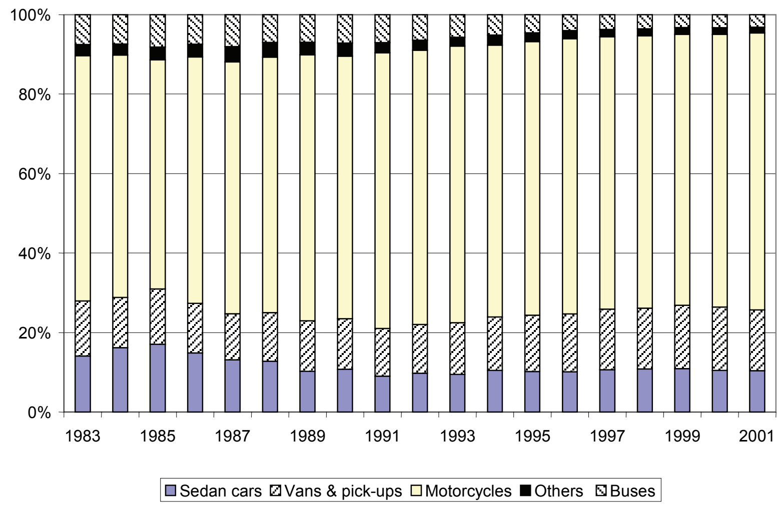

Figure 9.29: Modal Structure of Road Passenger Vehicles

Several mass rail transit system projects in Thailand are under construction or under implementation.[20] These projects are envisioned to form the basic core of a modern rapid transit network for the Bangkok Metropolitan Area. For example, the underground (subway) mass transit rail system has been formulated as four planned projects, eventually totalling 81 km: (1) the MRT Blue Line Hua Lamphong - Bang Sue, 20 km; (2) Blue Line North Extension: Red Line Bang Sue- Tha Phra , 13 km; (3) Blue Line South Extension: Brown Line Hua Lamphong - Bang Kae, 14 km; and (4) Orange Line Phase I Project, 35 km. The underground mass transit system is projected to service 400,000 commuters a day. The Blue Line had been initially planned to operate by December 2002 but was delayed due to technical and financial issues. It finally opened to the public on 3 July 2004. The Orange Line is now planned for the Bangkapi – Bang Bamru route totaling 24 km. Another line will extend from Bang Yai to Rat Burana, totalling 40 km. Thus, the currently operating Hua Lamphong – Bang Sue line will be extended by another 91 km, and this is planned over a period of six years.[21]

It is, therefore, expected that in the near future, once all the mass transit projects are completed, significant passenger diversions would take place. Some passengers will divert to rail transit, which will form the base load of the future mass transit systems. Riders are envisaged to pay a slightly higher fare for a premium service. However, it is not expected that the mass transit systems will completely eliminate the traffic congestion, as the majority of private car owners will probably continue to use their cars. [22] However, the diversion rate from private cars is expected to gradually rise as extensions of the mass transit system are brought on-line. Nevertheless, even with the full network of the mass transit systems in place, private car ownership will not significantly decline, as people would continue

[20] In fact, seventeen major infrastructure projects, worth 313 billion baht, mostly highway and railway projects, have been suspended over the past two to three years because of national budget constraints (Bangkok Post, 2002).

[21] Source: Mass Rapid Transit Authority of Thailand as quoted in "Surveys start for subway extension," Bangkok Post, 2004.

[22] It has been estimated that the first opened line of the subway systems would not significantly improve traffic congestion in Bangkok.

to use cars occasionally for weekend or special trips. Moreover, people will continue to put a high social value on cars. Who would want to abandon the comfort, convenience, and status symbol of owning a car!

9.6.8.7. Freight Transport Activity

Freight activity is linked with the country's overall industrial production activity, and is thus associated with industrial gross value added. Increases in freight activity will also increase the level of transport energy consumption.

Thailand's freight transport activity rose 8% per year between 1992 and 1997 (Figure 9.30). The freight transported consisted mostly of agricultural products (46%) and non-metallic minerals (24%), with the remainder including chemicals, wood and other products. The principal vehicle used to transport these products is the truck, accounting for almost 89.4% of the country's total freight ton-km in 1997. Other products are transported through inland water (6.5%) and by train (more than 4%). Domestic airfreight contributed a very minimal portion (0.04%) of total freight ton-km (Figure 9.33).

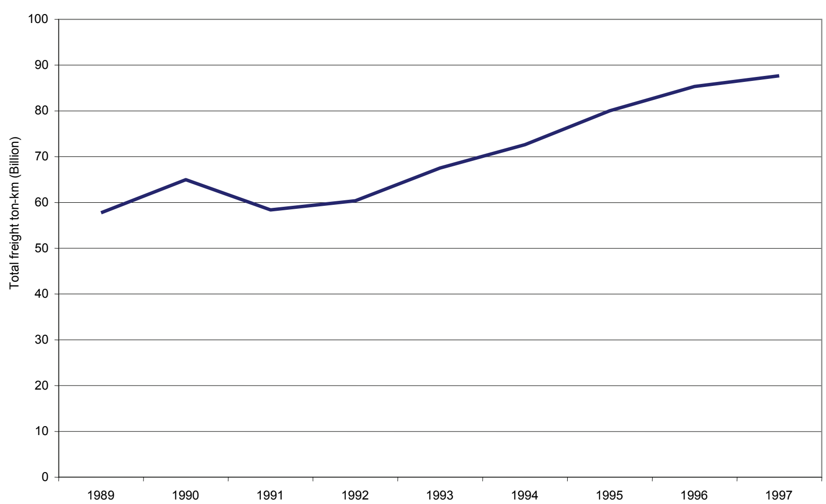

Figure 9.30: Freight Transport Activity

9.6.8.8. Floor Area per Capita

Service sector floor area per employee measures how many square meters each person utilizes. In this study, the floor area used refers to commercial building areas while the population refers to employee population. The only available data are 1985-1995. There are no available data for the residential sector.

The ratio of floor area to employee population in the service sector increased remarkably during the said period, from only 0.35 in 1985 to 1.5 in 1995 or by 15% growth rate per year (Figure 9.32).

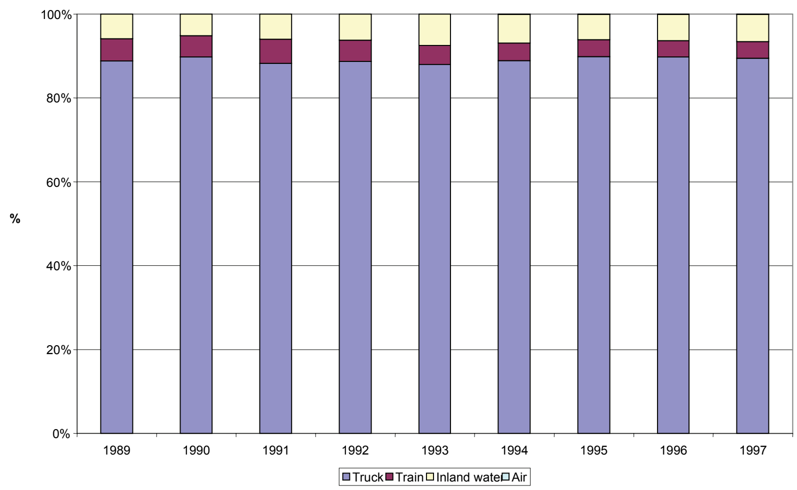

Figure 9.31: Modal Structure for Freight Transport Vehicles

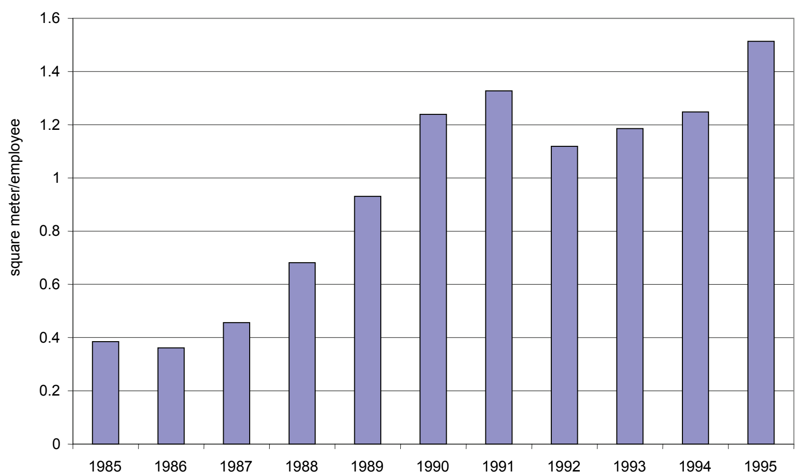

Figure 9.32: Floor Area per Capita

9.7. The Social Dimension

9.7.1. The state of social dimension

The state indicators under the social dimension contribute to the evolution of residential energy intensity. Consider the following facts for Thailand:

- Biomass is an essential energy commodity in the residential sector. Biomass use (mainly traditional fuels such as fuelwood and charcoal) accounts for a large portion of total residential energy consumption, amounting to 65.6% or around 5 Mtoe in 2000; and
- Around three million households in Thailand, based on DEDE (Department of Alternative Energy Development and Efficiency) statistics, had not been electrified as of 2000. These households continued to rely on traditional fuels for their energy needs, in particular heating for cooking that accounts for around 60% of end-use energy consumption in households.

There are two ways to improve energy efficiency in the households: (1) *fuel substitution*, which means, for example, moving away from less efficient biomass fuels to more efficient electric and LPG

stoves for cooking (efficiency for fuelwood stoves ranges from 5% to 15% and for charcoal stoves from 20% to 27%) or switching from kerosene lighting to electric lamps; and (2) *improvement of equipment,* such as choosing more efficient cooking stoves or switching to more efficient lighting. For Thailand, there has been a shift toward the use of more efficient fuels in lieu of traditional fuels, as described in the following section. Further, the government has financially supported the improvement of cooking stoves. In fact, the efficiency of fuelwood stoves has improved to about 20% and charcoal stoves to about 34% as a result of these efforts (Sajjakulnukit, 2001).

9.7.2. Dependence on traditional energy

The information on the structure of household energy consumption is based upon socio-economic surveys published every two years by the National Statistical Office of Thailand. The survey focuses primarily on cooking methods used by various households in Thailand. This is because cooking is the dominant household energy activity.

TABLE 9.11 shows the country's household structure in terms of various types of cooking carriers. The figure shows that the relative importance of traditional cooking fuels among households has decreased substantially. In 1981, the percentage of households using traditional fuels for cooking was very high, at around 90% of total household population. By 2000, the share significantly dropped by more than half to 38.2%. Conversely, the share of households using modern fuels for cooking jumped from just around 10% in 1981 to 62% in 2000. Among households, the share of LPG stove users increased significantly over the years, from 6.6% in 1981 to around 58% in 2000. Where LPG is readily available or widespread and household income is also sufficient, the situation has encouraged the shift of households from wood or charcoal to LPG stoves. Aside from this, the government continues to subsidize LPG prices. A preference for more convenience has also contributed to the fuel switching.

Yet, the overall structure of energy consumption in the residential sector conveys a rather different message. Fuelwood and charcoal continue to dominate (Table 9.11). In 2000, these biomass fuels accounted for about 65% of the total energy consumption of the residential sector. The main reason behind this seemingly contradictory information is that in many rural areas of the country, biomass energy use in small household businesses and home-based livestock production (for example cooking animal feeds) is reported under total household energy use rather than under industrial or agriculture sectors.

TABLE 9.11: HOUSEHOLD STRUCTURE FOR COOKING (%)

% of Households	1981	1986	1988	1990	1992	1994	1996	1998	2000
Modern fuel	9.60	18.00	22.70	30.00	38.00	47.70	58.70	58.40	61.80
Kerosene	0.30	0.10	0.10	0.20	0.20	0.30	0.30	0.20	0.20
Gas	6.60	15.00	19.90	26.60	33.50	43.40	54.70	54.90	58.10
Electricity	2.70	2.90	2.70	3.20	4.30	4.00	3.70	3.30	3.50
Traditional fuels	90.40	82.00	77.30	70.00	62.00	52.30	41.30	41.60	38.20
Charcoal	41.90	43.70	38.10	34.30	29.80	25.70	19.10	19.50	15.30
Wood	43.90	34.00	34.00	31.20	27.80	21.50	17.10	16.80	17.90
Others	2.20	1.00	0.80	0.50	0.40	0.30	0.20	0.20	0.10

Source: NSO Household Socio-economic Survey (various editions)

9.7.3. Electricity Access

The majority of the households in Thailand is already electrified or has access to electricity. In 2000, of the total 16.25 million households in the country, about 13.19 million were electrified (Figure 9.33). In fact, the proportion of electrified households in the country has risen to 82% in 2000 from 68% in 1989. All of the villages in the country already have access to electricity supply, demonstrating the successful electrification program of the Thai government.

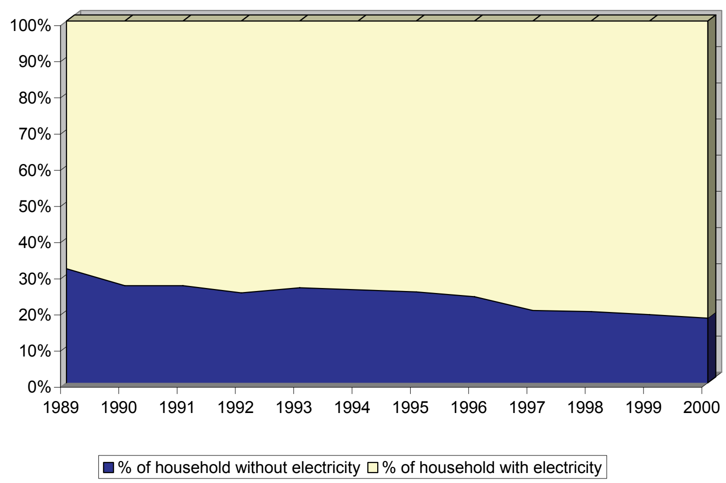

Figure 9.33: Share of Households With and Without Electricity in the Country
Source: DEDP, various issues

Focusing on the rural electrification program[23] in the country, between 1980 and 2000, some 430,000 households were being electrified every year, increasing the number of residential electricity connections from 1.85 million in 1980 to 10.44 million in 2000 (Figure 9.34). Households consuming less than 150 kWh dominate in the rural areas, but their share decreased from 89% in 1988 to 76% in 2000 (Figure 9.35).

[23] Rural areas or provincial areas mentioned here are those areas outside the Greater Bangkok Metropolitan Area.

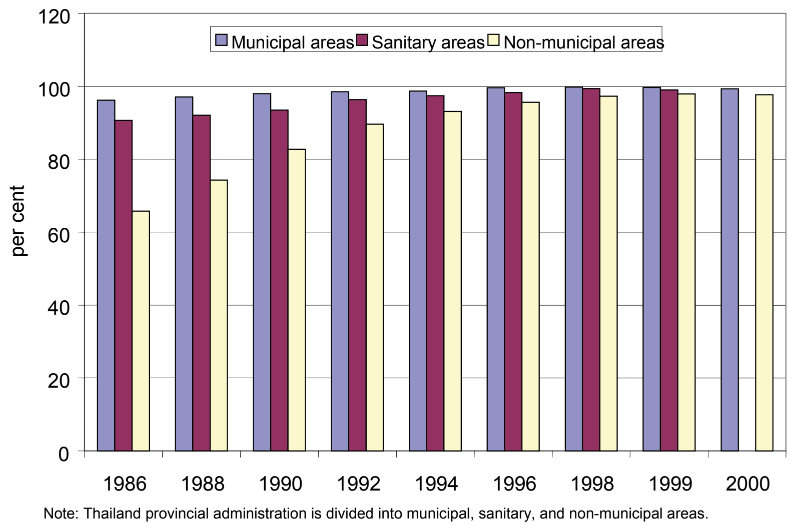

Figure 9.34: Electricity Access in Rural Areas
Note: In late 1990s, non-municipal areas and sanitary areas were combined together.
Source of basic data: NSO

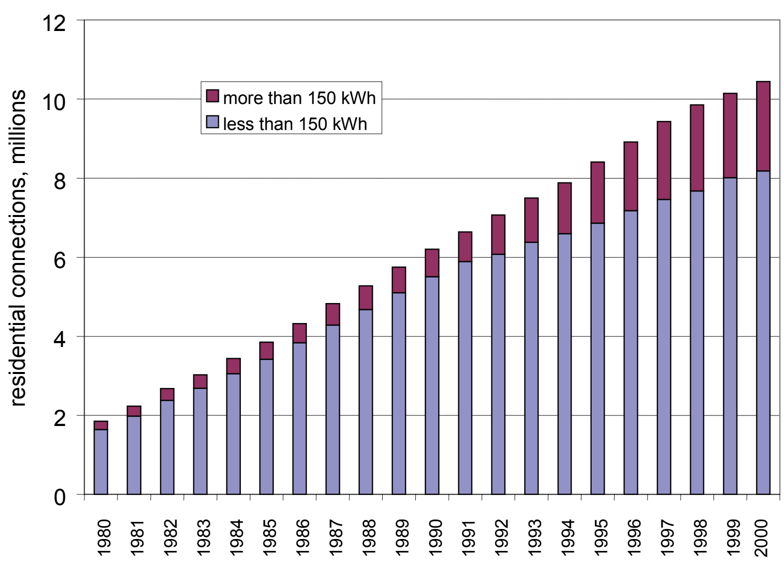

Figure 9.35: Growth in Residential Connections
Source of basic data: PEA

9.7.4. The driving forces under socio economic dimension

9.7.4.1. Daily Fuel Consumption per Capita of 20% Poorest Household Population

Daily consumption of electricity of the poorest 20% population (per household and per capita) in Thailand has been increasing over the years. Electricity consumption of households based on their daily disposable income and average prices of electricity increased by more than 6% per year from around 23 kWh/day/hh in 1986 to more than 43 kWh/day/hh in 1996 (Table 9.12). Similarly, daily electricity used per capita grew at the same rate of more than 6%, from 6.9 kWh/day/capita to almost 13 kWh/day/capita during the same period. However, beginning in mid-1997 to 2000, daily use of electricity per household and per capita began to decrease largely due to the financial crisis.

TABLE 9.12: DAILY CONSUMPTION OF FUELS OF THE POOREST 20% POPULATION PER HOUSEHOLD AND PER CAPITA

	1986	1988	1990	1992	1994	1996	1998	2000
Electricity KWh per hh	23.31	26.62	31.76	35.95	41.28	43.22	35.83	35.58
KWh per capita	6.89	7.55	8.30	11.16	12.13	12.81	12.46	11.21
LPG								
Gj/day/hh	0.20	0.21	0.24	0.28	0.34	0.39	0.33	0.40
Gj/day/capita	0.06	0.06	0.06	0.09	0.10	0.12	0.11	0.13
Kerosene								
Liters/day/hh		6.79	6.65	6.78	8.45	8.39	7.07	5.66
Liters/day/capita		1.92	1.74	2.11	2.49	2.49	2.46	1.78

Source: NSO Household Socio-economic Survey (various editions)

Daily use of LPG for heating and cooking for the poorest 20% population grew faster than electricity. From 1986 to 1996, consumption of LPG per household and per capita increased annually at the rate of around 7% (Table 9.12).

While the use of electricity and LPG by the 20% poorest population in the country has been growing in recent years, the trend for kerosene consumption has fluctuated. For example, between 1988 and 1990, daily consumption of kerosene of the poorest 20% household declined from 6.79 liters/day/hh to 6.65 liters/day/hh. Daily consumption of kerosene then began rising, but after 1994, it began to fall and continued falling through the year 2000 (Table 9.12). The decreased consumption of kerosene may have been brought about by the shift to other fuels (or technologies) by households belonging to the 20% poorest population in the country.

9.7.4.2. Fraction of Disposable Income/Private Consumption Spent on Fuel and Electricity

The share of disposable income paid for fuel and electricity by (a) the average population per capita, and (b) the poorest 20% population per capita were found to be in very close range over the years. Based upon available statistics, the ratio has been between 3.63% and 4.36% for average population, while for the group of poorest 20% population the share has been between 5.05% and 5.76% (Figure 9.38.

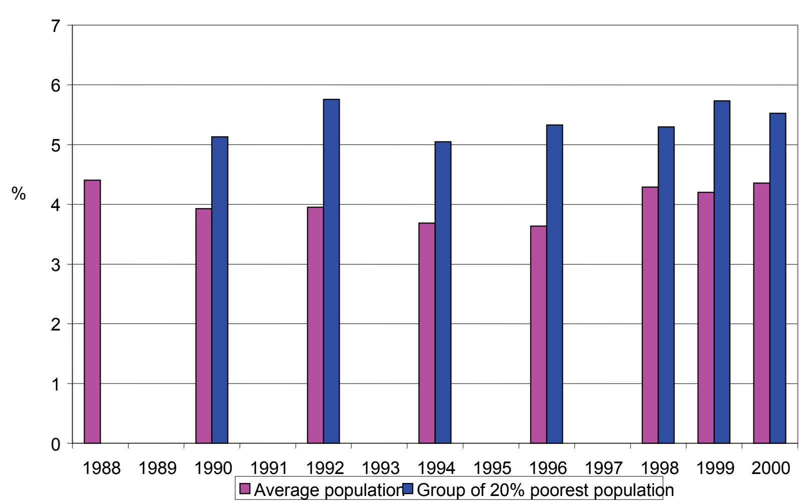

Figure 9.36: Fraction of Disposable Income Spent on Fuel and Electricity to Total Private Consumption

9.8. The Environmental Dimension

9.8.1. The state indicator: ambient concentration of pollutants in urban areas

Figure 9.39 shows that the concentration of carbon monoxide (CO), largely from vehicles, in the urban areas of Thailand has been kept around 1 part per million (ppm). On the other hand, the quantity of total suspended particulates matter (TSP), has changed rather erratically, but the overall trend has been going down. For example, measured in terms of roadside air quality, the TSP in Thailand's urban areas started from a high of 3.2 mg/m^3 in 1992 and went down to a low of 0.5 mg/m^3 in 2000. Meanwhile, the TSP measured in terms of ambient air quality also came down from 0.49 mg/m^3 to 0.34 mg/m^3 during the same period.

9.8.2. The driving forces

9.8.2.1. Quantities of Green House Gas Emissions

Carbon dioxide (CO_2) is the main contributor to the country's greenhouse gas (GHG) emissions. In 2000, its share of total GHG emissions stood at 96.1%, amounting to 81.6 million tons, even though its quantity has declined annually by almost 1% between 1990 and 2000. Among other pollutants, methane (CH_4) has grown substantially, registering an annual growth of more than 10% per annum. Its share is almost negligible, however, at about 0.1% of total emissions. The quantity of other pollutants such as carbon monoxide (CO), sulfur dioxide (SO_2), and nitrogen oxide (NOx) went down due to more stringent measures by the government (Table 9.13). Some of the measures include: requirements for installation of catalytic converters; fuel reformulation by limiting the content of some chemicals (e.g., benzene, aromatics and sulphur) by a certain percentage; emission standards for new vehicles using a national or international reference standard; an inspection and maintenance program and roadside inspection; traffic management and the reduction of vehicle kilometre travelled; and other measures such as use of cleaner alternative fuels, including LPG and natural gas.

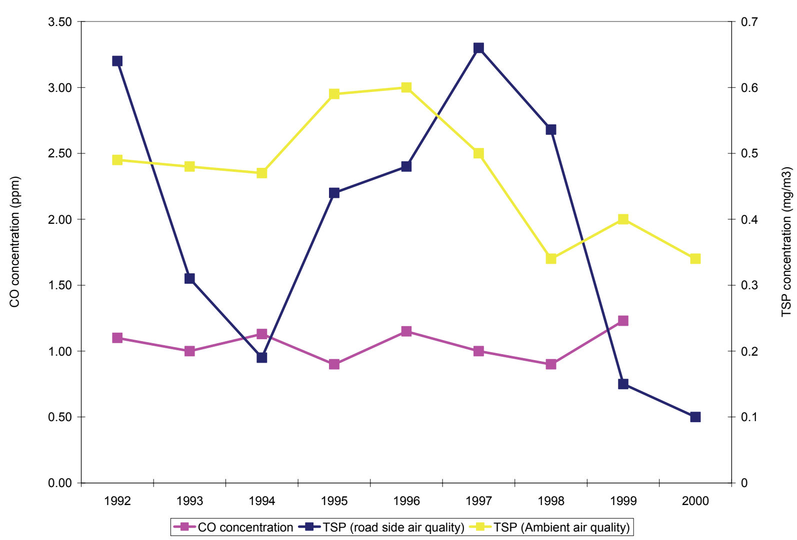

Figure 9.37: Ambient Concentration of Pollutants in Urban Areas

TABLE 9.13: ANNUAL GROWTH RATE OF POLLUTANTS BETWEEN 1990 AND 2000

Pollutants	Annual Growth Rate (%)
Carbon dioxide (CO_2)	-0.75
Carbon monoxide (CO)	-5.52
Nitrogen oxides (NOx)	-1.34
Methane (CH_4)	10.16
Sulfur dioxide (SO_2)	-3.70
Total Suspended Particulates matter (TSP)	4.62

The transport sector is responsible for more than half (57%) of total CO_2 emissions, or about 46 million tons in 2000 (Figure 9.38). Road transport is obviously the primary contributor, as it is the largest energy consumer among all modes of transport. Further, manufacturing contributed more than one third of total CO_2 emissions, while the remaining 5.3% came from the residential and commercial sectors.

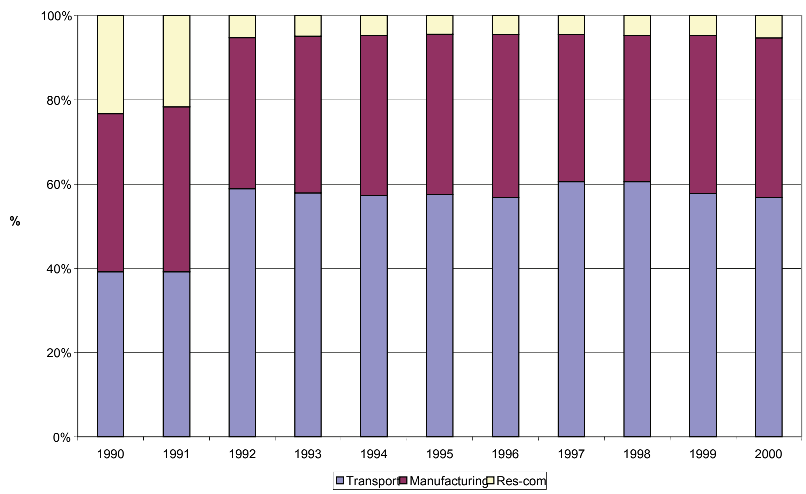

Figure 9.38: Sectoral Share to Total CO_2 Emissions

9.8.2.2. Carbon Dioxide Intensity

CO_2 emissions are directly linked with energy consumption in the various sectors of the economy. Any increase in energy consumption to produce an output will lead to higher emissions if fossil fuels are used. This is especially true for energy intensive industries that require more energy when production is expanded. Energy efficiency improvements are thus an important tool for mitigating greenhouse gas emissions.

Carbon dioxide intensity is the ratio of the sector's CO_2 emissions to its gross value-added or GDP. Figure 9.39 compares the evolution of carbon dioxide intensity in the transport, manufacturing, and combined residential and commercial sectors. It shows clearly the impact of the financial crisis on CO_2 intensity of the transport and manufacturing sectors. CO_2 intensity of the residential and commercial sectors continued to rise, even during the crisis period, despite a decline in the residential sector, because of the strong demand from the commercial sector. Notwithstanding, trends in CO_2 emissions remain strongly correlated with GDP or GVA, as with energy consumption.

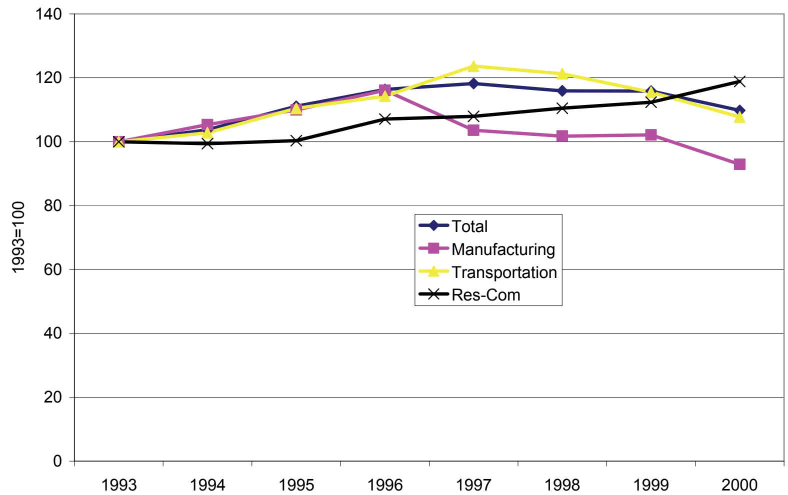

Figure 9.39: Trends in Sectoral CO_2 Intensity

9.9. Policy Response: Strategic Plan for Energy Efficiency

Thailand has targeted a reduction in the country's energy elasticity from the current 1.4:1 to 1:1 by 2007 and consequently a reduction in national energy expenditures by 3.1 trillion baht (77.5 million USD) in 2007-2017.[24] In order to achieve this target, energy efficiency measures have been established for the transport and industrial sectors which combined contributed 73% of final energy demand in 2000.

In Thailand, almost 80% of energy consumption in the transport sector is accounted for by land transportation, of which 78.6% is road transport and the remaining by rail (see Table 9.14). With the growing number of cars each year, passengers using mass transportation in Bangkok and its vicinities decreased from 1,224 million in 1997 to 938 million in 2001. The number of passengers using inter-province buses also dropped from 12.6 million in 1997 to 10.8 million in 2001. Similarly, train passenger numbers dropped from 64.9 million to 56.7 million in the same period. Thus, measures to promote energy efficiency in the transport sector focus on the development of the mass transportation system, including:

- Switching the mode of transport, for both passengers and freight, from cars and light trucks (pick-ups) to the rail system. In Bangkok and its vicinities, the rail system and other forms of mass transport will be developed. In the provinces, investment will be made in dual-rail tracks.
- Developing efficient networks of multimodal transport. Towards this end, the networks of the transportation system (both land and waterway) and the nationwide depot system will be improved, including oil transport via the oil pipeline networks.
- Promoting the use of energy efficient vehicles.
- Using the town and country planning system in determining goods transport routes.
- Introducing tax or fiscal measures to induce energy conservation in the transportation sector.

[24] EPPO, 2003.

TABLE 9.14: ENERGY DEMAND IN THE TRANSPORT SECTOR

Transport mode	Energy demand (ktoe)	Share(%)
Land	14,743	79.1
Road	14,638	78.6
Rail	105	0.5
Water	851	4.6
Domestic	57	0.3
Overseas	794	4.3
Air	3,038	16.3
Domestic	307	1.6
Overseas	2,731	14.7

Source: EPPO, 2003.

Sources of capital for such measures include investments from the private sector, the public sector and various energy funds (e.g., the Oil Fund, the Energy Conservation Promotion Fund, etc.).

The Ministry of Transport, the Ministry of Finance, the Ministry of Energy and the Office of the National Economic and Social Development Board (NESDB) will jointly study and accelerate joint ventures in the integration of the rail system, coastal navigation and the logistics networks, together with efficient town and country planning. The same agencies will also jointly review the transportation infrastructure, with to the intention of increasing energy efficiency within the sector.

The following measures will be implemented for the industrial sector:

- The Ministry of Industry, the Ministry of Finance, the Ministry of Energy, the National Competitiveness Committee (NCC) and the NESDB will jointly determine measures and accelerate industrial structure reform to enhance the competitive edge of the country. They will also review the investment promotion policy, attaching greater importance to energy aspects and economic value.
- The Ministry of Finance will devise tax measures to promote energy conservation in factories and goods transportation. Consideration will be given to exemptions of juridical body income tax for the profits gained from auditable energy savings. Interested industries can submit a petition for tax exemptions and apply for energy conservation plan development on a voluntary basis.
- The Ministry of Industry and the Ministry of Energy are to jointly speed up the implementation of the following:
    - enforcement of the Minimum Energy Performance Standards (MEPS) for electrical appliances and energy-efficiency labeling for cars;
    - establishment of the Energy Conservation Certification for factories; and
    - promotion of energy production systems with efficient combined use of energy, such as co-generation systems in the industrial estates and district heating/cooling systems.

9.10. Summary and Conclusions

The Indicators for Sustainable Energy Development (ISED) have proven to be a useful framework for analyzing the performance of the energy sector in Thailand, in particular with respect to energy efficiency and conservation. It does so in all three dimensions of sustainable development. The framework identifies the main driving variables, the interrelationships among economic and social state indicators and their consequences on the state of the environment, and finally the institutional response that serves as the main denominator affecting all three dimensions. Nonetheless, a few

additional indicators were also derived in this study to analyze the state of energy efficiency within the country.

This section summarizes the progress of Thailand towards sustainable development in the economic, social, and environmental dimensions, as well the contributions and performance of the energy sector using ISED and a few derived indicators. The summary uses a radar diagram to track the movement of indicators between 1990, the chosen base year just before the implementation of the national Energy Conservation Program, and 2000, when most recent data are available. For this purpose, all indicators have been indexed with respect to their 1990 values.

Economic Dimension. The main indicator used in the study to measure economic sustainability was energy intensity.

Figure 9.42 indicates that energy consumption -- particularly in the transport, agriculture, and commercial sectors -- continues to increase faster than the respective sectoral gross value-added. An examination of these trends shows that the results were nevertheless affected by the financial crisis, which had caused total energy consumption to drop between 1997 and 1999, before recovering in 2000. The financial crisis, however, barely affected energy use in the commercial sector, which actually increased in 1998–2000. Energy consumption in the residential sector did not recover by 2000 — thus energy intensity for the sector has declined.

Figure 9.43 shows the other indicators that were used to measure sustainability in the economic dimension. The higher values in 2000 compared to their values in 1990 indicate economic growth and industrialisation. The higher income and electricity consumption per capita and the significant improvement in car ownership point to an increase in the economic status of the Thai people and to higher purchasing power. The higher electricity consumption implies greater affordability and accessibility. Similarly, the higher contribution of manufacturing value-added to GDP points to industrialisation. However, the higher energy consumption because of increased income and higher share of energy-intensive manufacturing industries because of industrialization imply increasing emissions that must be mitigated in order for growth and industrialization to be sustainable.

Social Dimension. The selected indicators shown in Figure 9.44 point to significant progress towards social sustainability. The figure shows that the proportions of households relying on traditional fuels and those without access to electricity have declined. These two parallel indicators also indicate increased access to modern energy services and complement the higher electricity consumption per capita noted above. Figure 9.44 also includes indicators to show the change in the social status of the poorest 20% of the population in Thailand. Similarly, the selected indicators point to improvement in the latter's access to modern energy services.

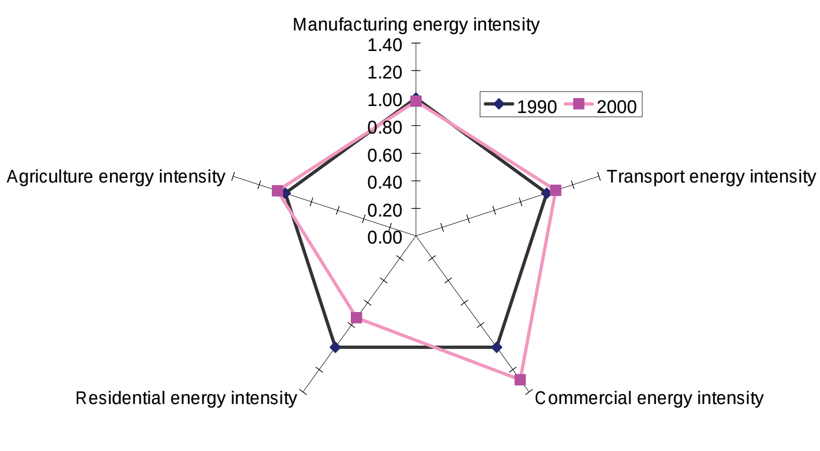

Figure 9.40: Progress Towards Energy Efficiency (Indexed to 1990 base year)

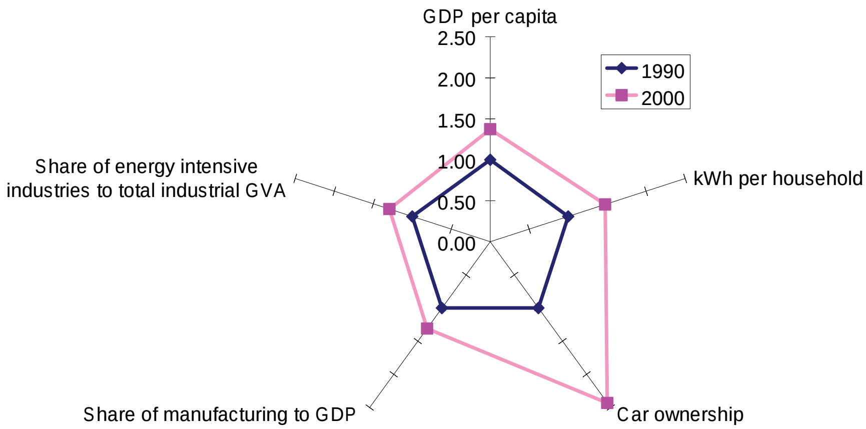

Figure 9.41: Progress Towards Economic Sustainability (Indexed to 1990 base year)

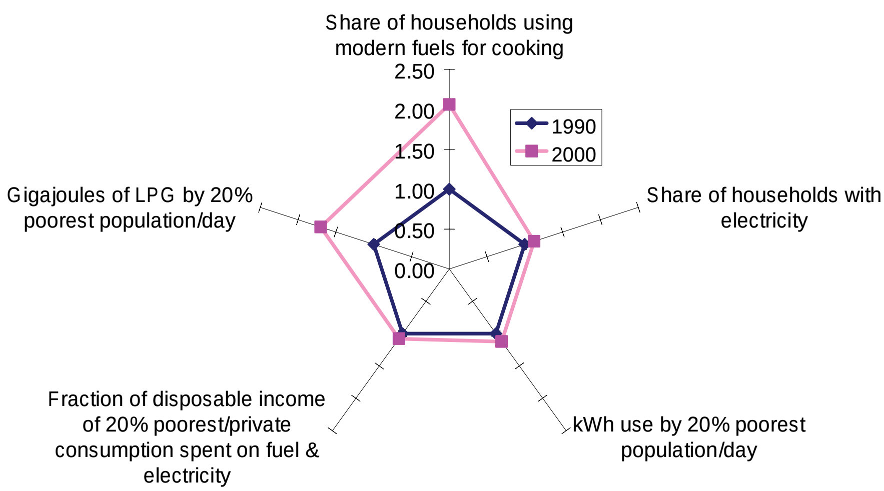

Figure 9.42: Progress Towards Social Sustainability (Indexed to 1990 base year)

Environmental Dimension. Figure 9.43 indicates increasing CO2 emissions even during the period of the financial crisis, particularly for the transport and residential–commercial sectors. Moreover, this is also true for the manufacturing sector even if its CO2 intensity dropped from 1993 to 2000. The reason for this is that the growth in CO2 emissions of manufacturing (4.4% per year) was lower than the growth in its gross value-added during this period (5.5%).

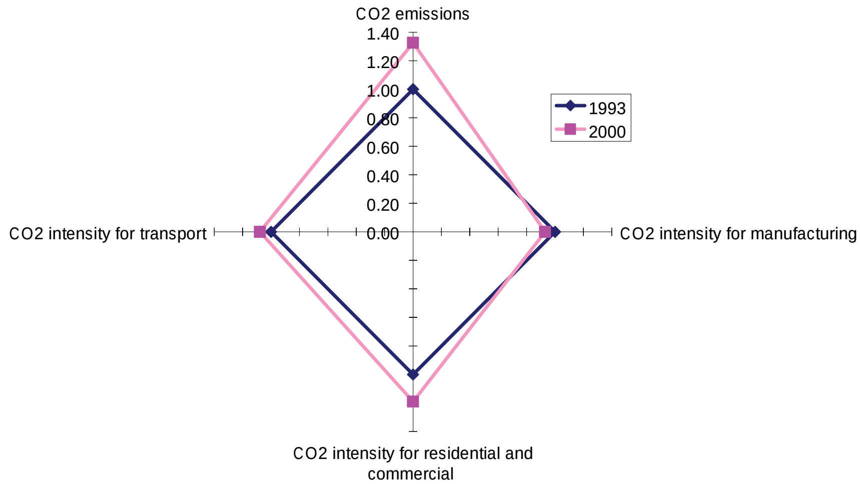

Figure 9.43: Progress Towards Environmental Sustainability (indexed to 1990 base year)
Note: Base year for residential and commercial CO_2 intensity is 1992.

Overall Assessment. Figure 9.44 attempts to integrate the analyses presented above. Aggregate energy intensity remained fairly stable, as the increasing energy intensities in the transport and commercial sectors were compensated by decreasing energy intensity in the residential sector and stable energy intensity in the manufacturing sector. The reductions in energy use during the financial crisis did cause reductions in environmental emissions, in particular CO2 emissions, but emissions quickly rebounded in 2000 along with growth in energy consumption. This demonstrates that environmental impacts are closely linked to energy consumption, as well as to economic activity.

Yet, despite the distortions caused by the financial crisis in the environmental and energy efficiency performance of Thailand, significant achievements can be noted in the economic and social dimensions. The financial crisis notwithstanding, the last two decades saw significant improvements in per capita and household incomes and access to and affordability of modern energy services, especially for the poorest segments of the population.

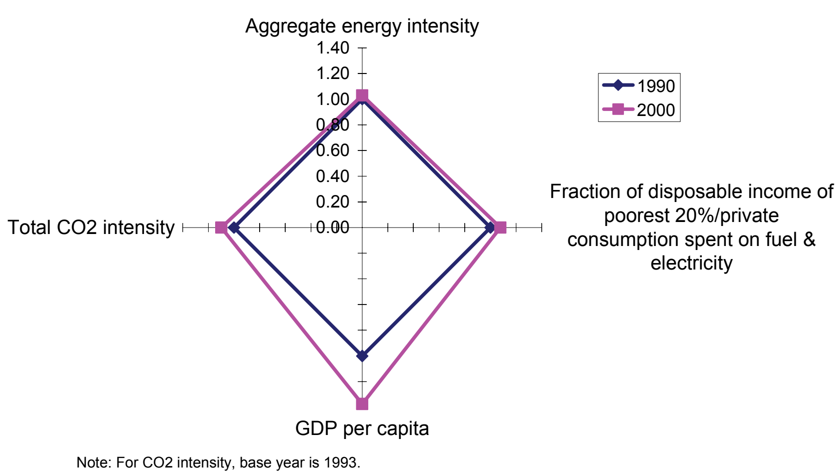

Figure 9.44: Progress Towards Sustainable Energy Development

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Annex 9.1: Summary of Indicators Used to Analyze State of Energy Efficiency

Structure of GDP value added (manufacturing, transportation, service, agriculture)
Structure of manufacturing value added of energy-intensive industry (but not disaggregated fully)
Modal structure of road vehicle stock (by passenger and freight transport)
Car ownership
Motorcycle ownership
Floor area per capita
Energy price and taxes by sector (industry, transport, residential and commercial)
Energy mix by sector (manufacturing, transport, service, residential, agriculture)
Aggregate energy intensity (total final energy consumption per GDP)
Decomposition of aggregate energy intensity

Sectoral energy intensity (manufacturing, transport, service, residential) in monetary terms
Manufacturing sub-sectoral final energy and electricity intensity (in monetary and physical terms)
Rail passenger energy intensity
Freight energy intensity
Unit consumption of vehicles
Service sector energy/electricity intensity (by floor space and per employee)
Residential energy intensity (by type of fuel and per household)
Agriculture energy intensity
Energy mix in the residential sector
Ratio of households using traditional and commercial fuels
Ratio of daily disposable income of poorest 20% household to price of: -electricity -main fuel used for heating and cooking -kerosene used for lighting
Fraction of disposable income/private consumption per capita spent on fuel and electricity -Average population -Group of 20% poorest population
Fraction of households: -heavily dependent on non-commercial energy -without electricity
Quantities of air pollutant emissions
Industrial carbon dioxide intensity by industrial VA
Transportation carbon dioxide intensity by total GDP
Services carbon dioxide intensity by services GDP
Residential carbon dioxide intensity per capita
Ambient concentration of pollutants in urban areas
Relevant Indicators But Not Available
Distance traveled per capita by passenger (total, urban public)
Fully disaggregated manufacturing value added by selected energy intensive industry
Energy intensity for passenger travel (kgoe/pkm)
Space heating (kgoe/m2 of floor area)
Passenger travel (kWh/pkm) –applicable for Thailand beginning 2000
Final energy intensity of production for energy intensive industries (the study covered very few)

Note: Indicators in **bold** are additional indicators or ones derived during the study, but which do not form part of the original set of ISED.

Annex 9.2: Sources of Statistical Data and Acronyms

STATISTICS	SOURCE
Ambient concentration of pollutants in urban areas	MOSTE, Pollution Control Department, ADB, Suksod, J.
Average disposable income spent on fuel and electricity	NSO
Daily disposable income of poorest 20% household	NSO
Disposable income of 20% poorest household spent on fuel and electricity	NSO
Electrified households	DEDP
Employment population	NSO
Energy consumption (total, sectoral, by type of fuel)	DEDP, IEA statistics
Energy prices	DEDP
Floor area for commercial sector	ERI
Freight transport activity (ton-kilometer by mode of transport)	MTC, UN Statistics

Gross domestic product in constant 1988 prices	
Indirect within energy sector	NSO
Non-electrified households	DEDP
Number of households using modern fuel (by type of cooking mode)	NSO
Number of households using traditional fuel (by type of cooking mode)	NSO
Population	ADB indicators, NSO
Production for selected manufacturing industry	OIE
Quantities of green house gas emissions (by type)	DEDP
Rail passenger -kilometer	UN Statistics
Stock of vehicles	MTC
Total disposable income	NSO
Total number of households	NSO
Unit consumption of buses	BMTA
Unit consumption of cars	NEPO, ONEB, IIEC
Urban and rural population	NSO, DOLA
Value added of economic sectors (in constant 1988 prices)	ADB indicators, Bank of Thailand, NESDB
Volume of production by manufacturing subsector	UN Statistics, ADB indicators, APERC

Acronyms

MTC	Ministry of Transportation and Communication
ADB	Asian Development Bank
NSO	National Statistical Office
IIEC	Institute of Energy Conservation
ONEB	Office of the National Environment Board
UN	United Nations
NESDB	National Economic and Social Development Board
APERC	Asia Pacific Energy Research Centre
BMTA	Bangkok Mass Transit Authority
ERI	Energy Research Institute
IEA	International Energy Agency
MOSTE	Ministry of Science, Technology and Environment
OIE	Office of Industrial Economics
DOLA	Department of Local Administration
DEDP	Department of Energy Development and Promotion

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