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).

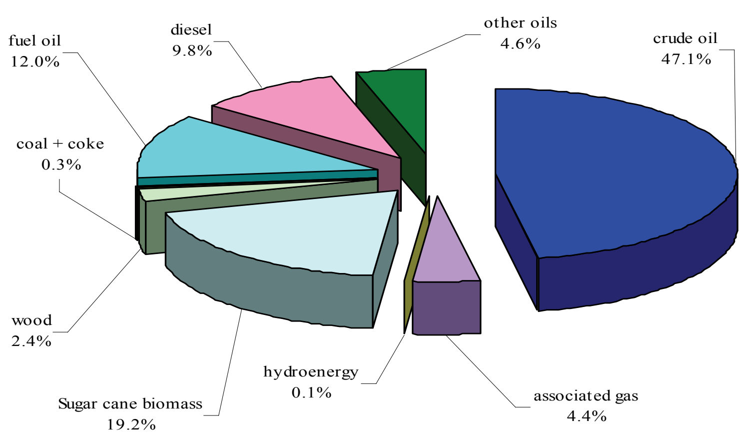

Figure 4.1. Total energy supply
Source: ONE, 2003

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).

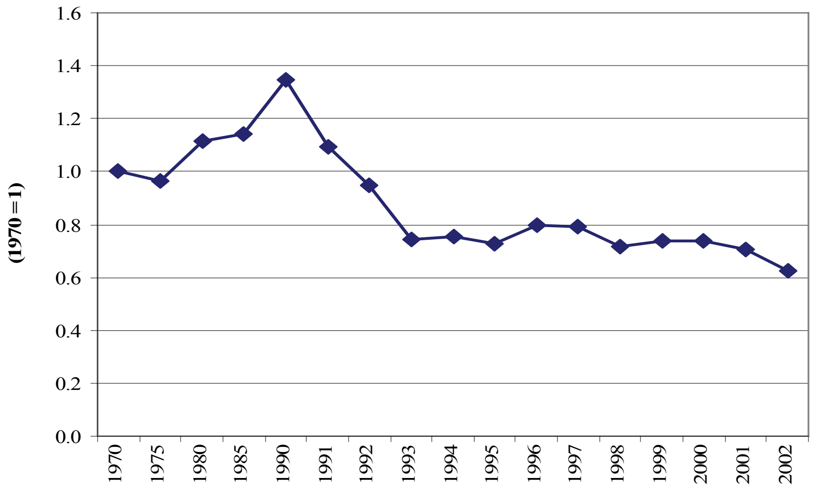

Figure 4.2. Index of total final energy use (1970=1)
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003
Note: The total final energy use in 1970 was 10.3 million toe

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.

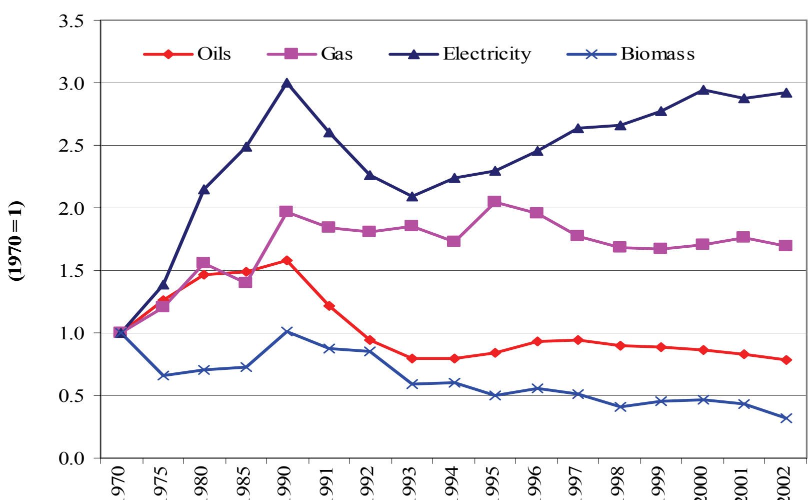

Figure 4.3. Index of final energy use by fuels and electricity (1970=1)
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003
Note: In 1970 the final use of oils (crude oil and oil products) was 4.8 million toe, gas 0.05 million toe, electricity 0.34 million toe and biomass 5.1 million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

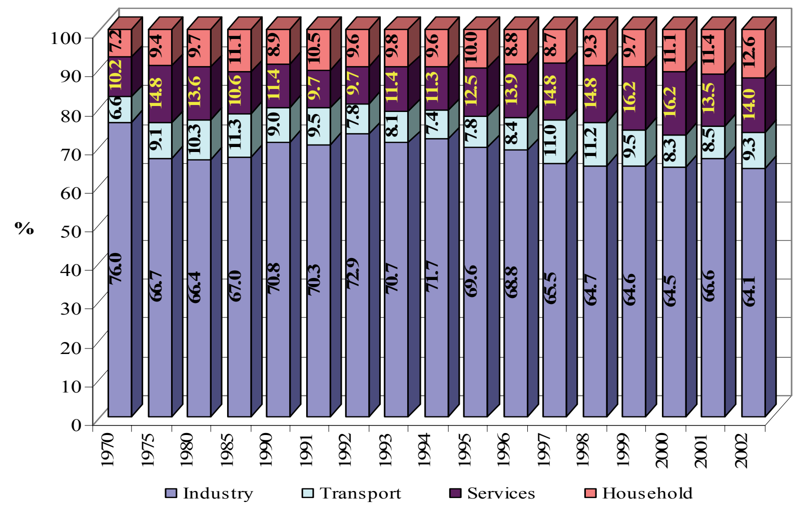

FIG 4.4. Share of final energy use by sectors, %
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003
Note: In 1970 the final energy use in Industry was 7.85 million toe, transport 0.68 million toe, services 1.06 million toe and household 0.74 million toe

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

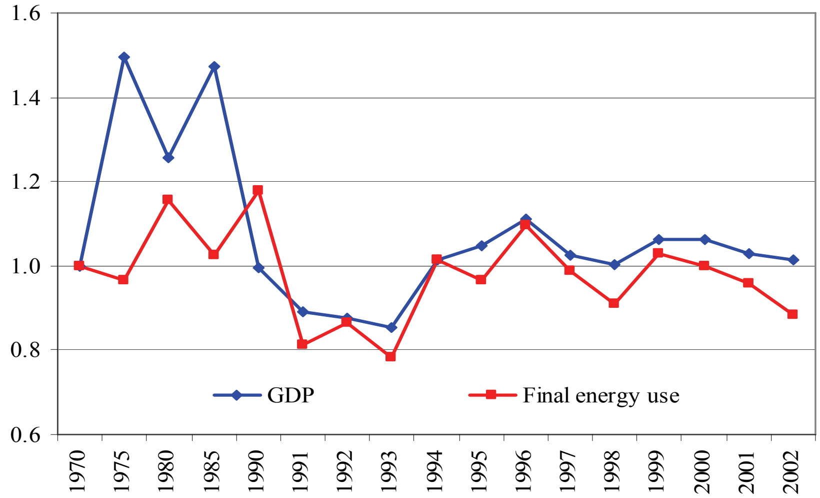

Figure 4.5. GDP$_{1997}$ & total final energy use dynamics
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

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).

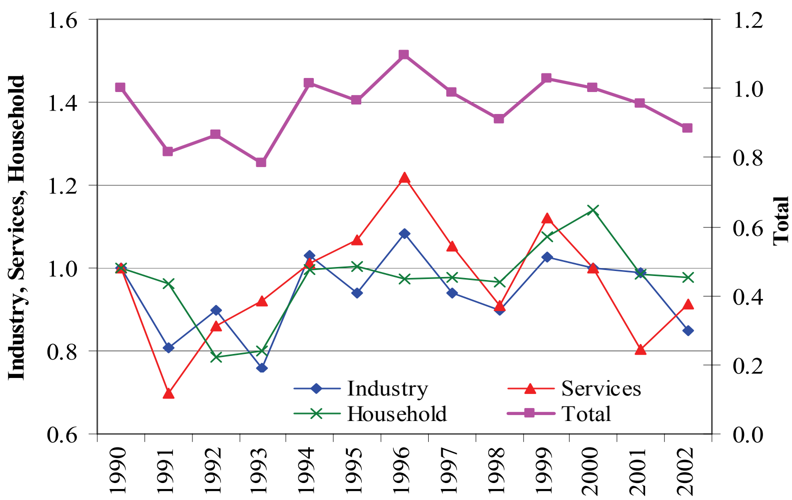

Figure 4.6. Final energy use dynamics by sectors
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

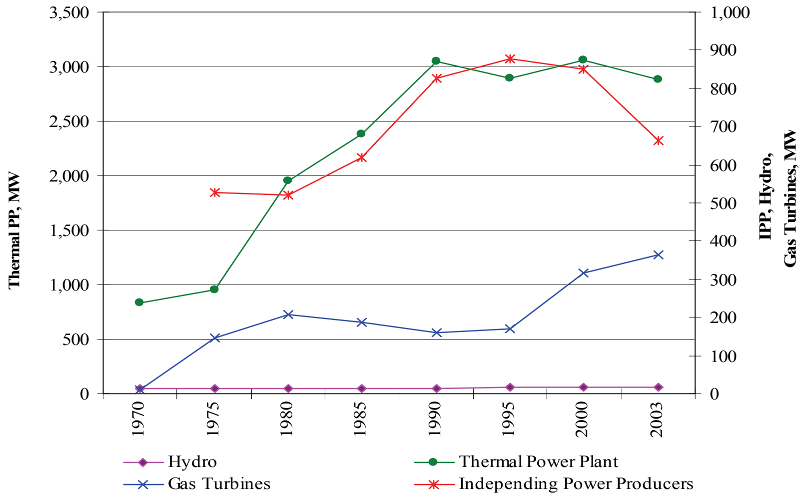

Figure 4.7. Installed capacity
Source: ONE, 2003

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).

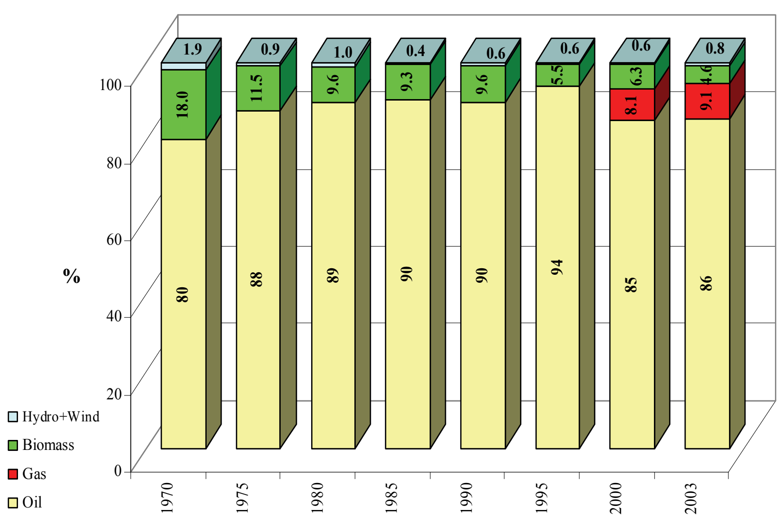

Figure 4.8. Electricity generation mix
Source: UNE, 2003

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.

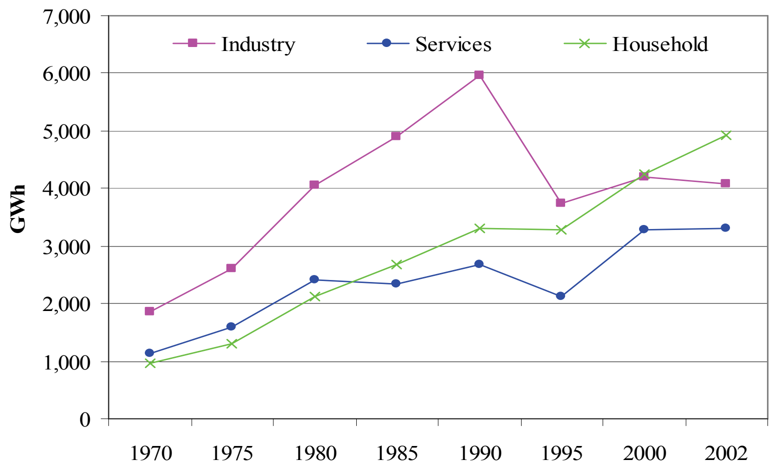

Figure 4.9. Electricity use by sectors
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

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).

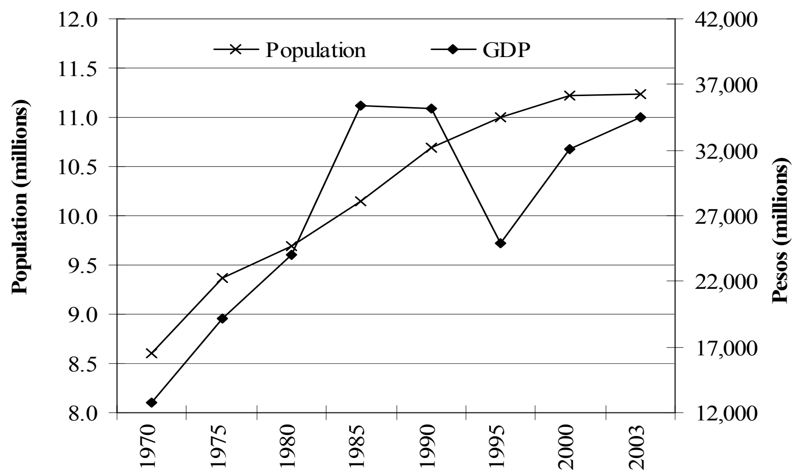

Figure 4.10. Population and GDP_{1997}
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

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.

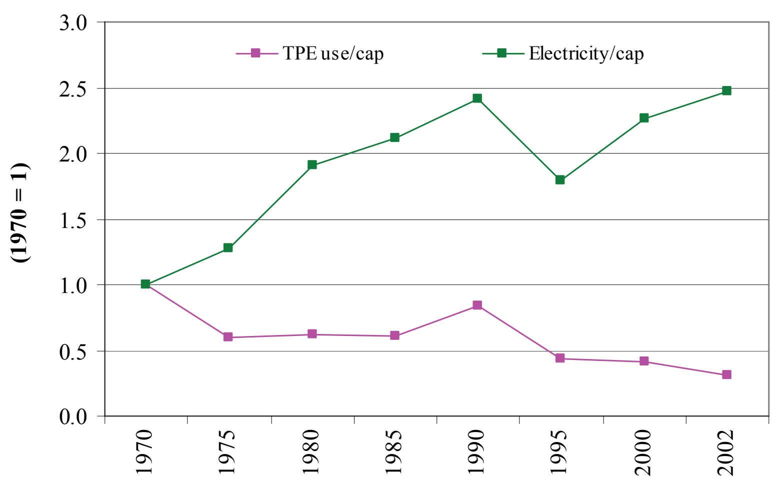

Figure 4.11. Index of Total Primary Energy and electricity use per capita
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003
Note: In 1970, the TPE/cap was 0.585 toe/cap and the Electricity/cap was 0.463 MWh/cap

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.

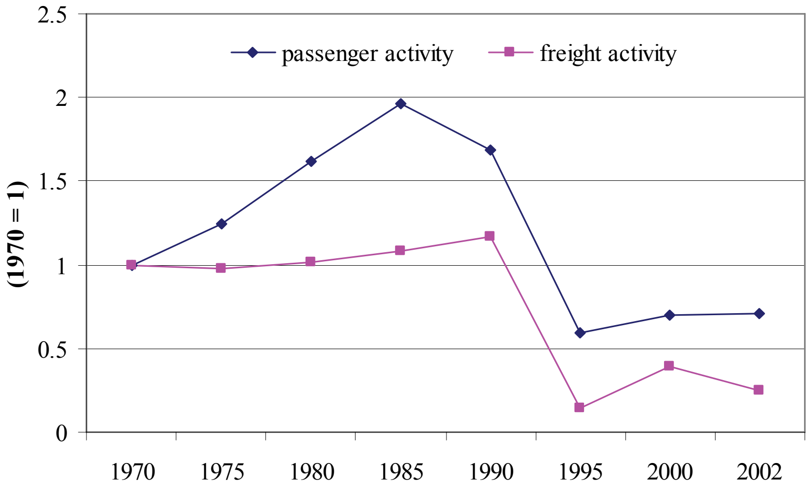

Figure 4.12. Index of Freight and Passenger transport activities
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

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.

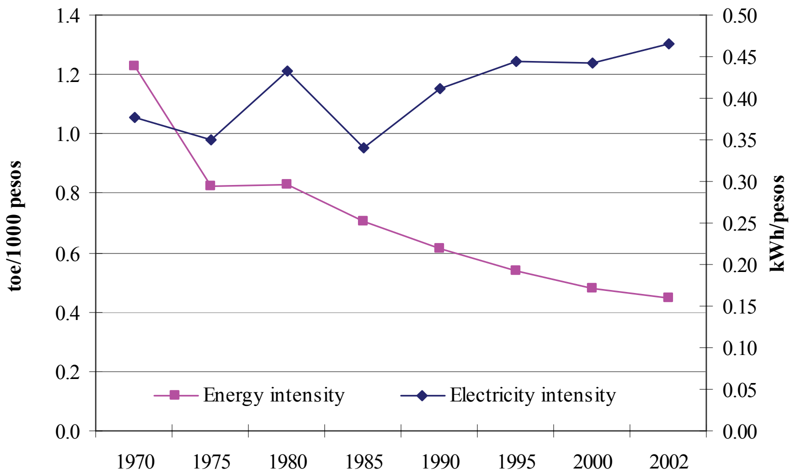

Figure 4.13. TPES and electricity intensities
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

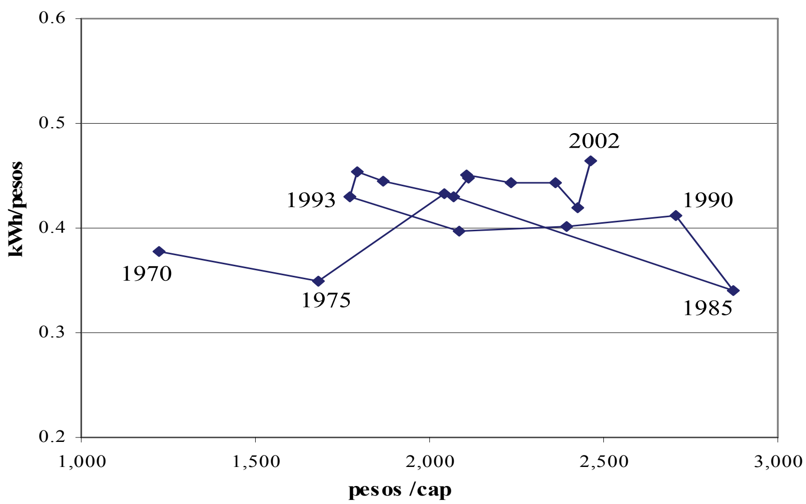

Figure 4.14. Electricity intensity and GDP per capita
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

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.

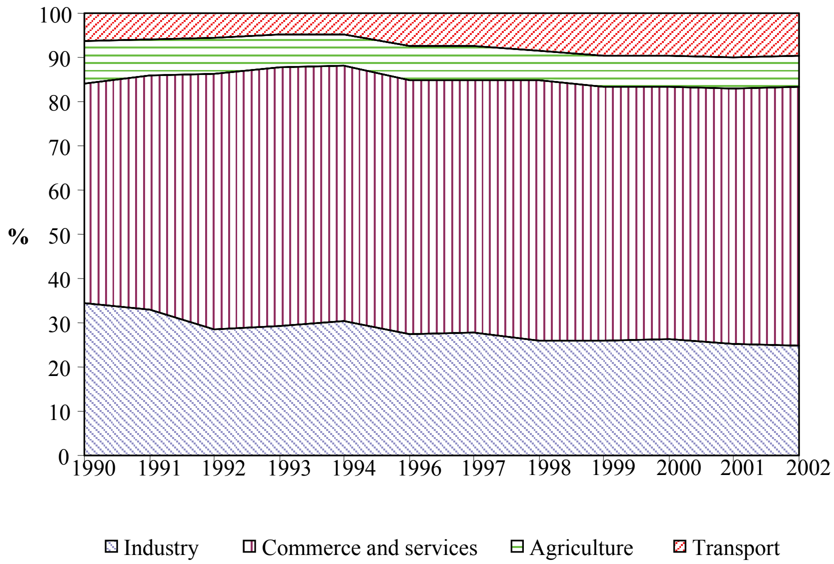

Figure 4.15. Share of added value by sectors
Source: ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

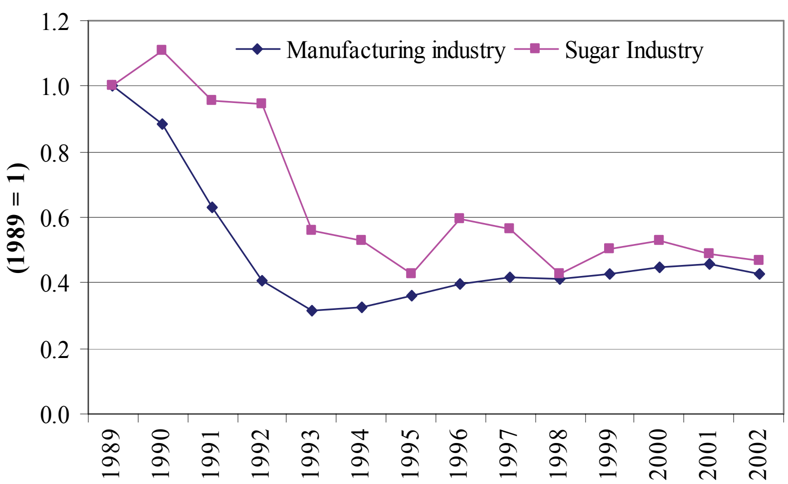

Figure 4.16. Indices of manufacturing and sugar industries production
Source: ONE, 1989, 1998, 1999, 2000, 2001 a/, 2002, 2003

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.

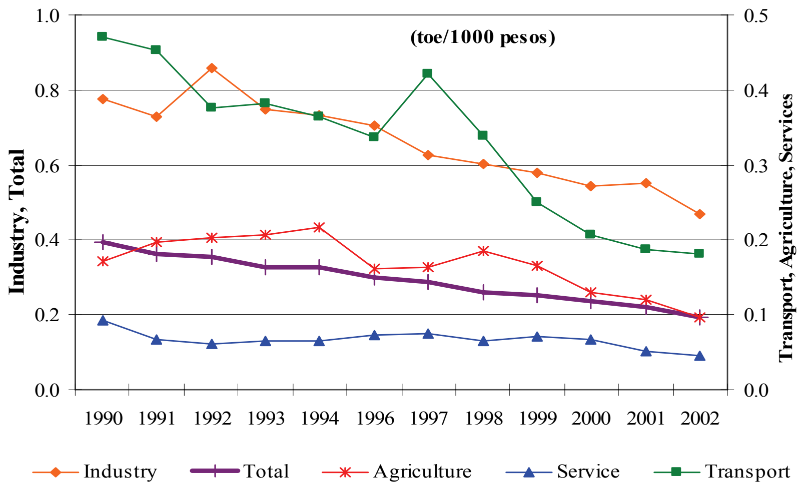

Figure 4.17. Final energy intensities by sectors
Source: ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003
Note: Data for 1995 are not available

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.

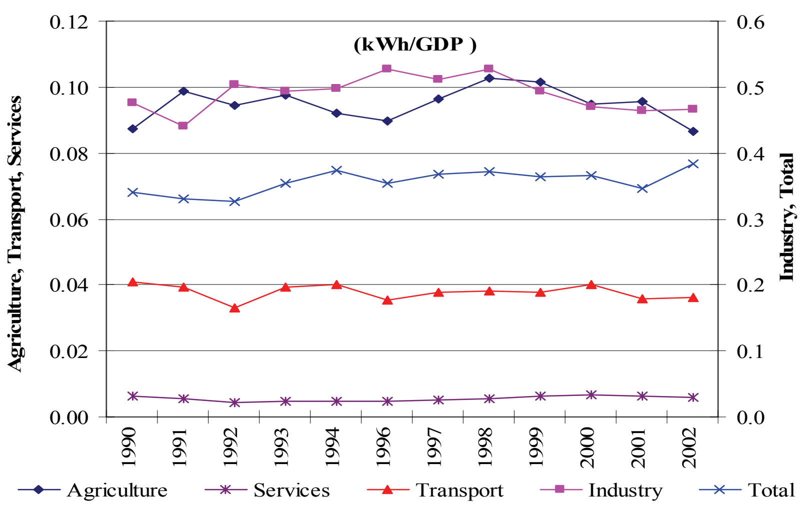

Figure 4.18. Electricity intensities by sectors
Source: ONE, 1998, 1999, 2000, 2001 a/, 2002
Note: Data for 1995 are not available

4.5.1.3. Technological effects

Supply side

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.

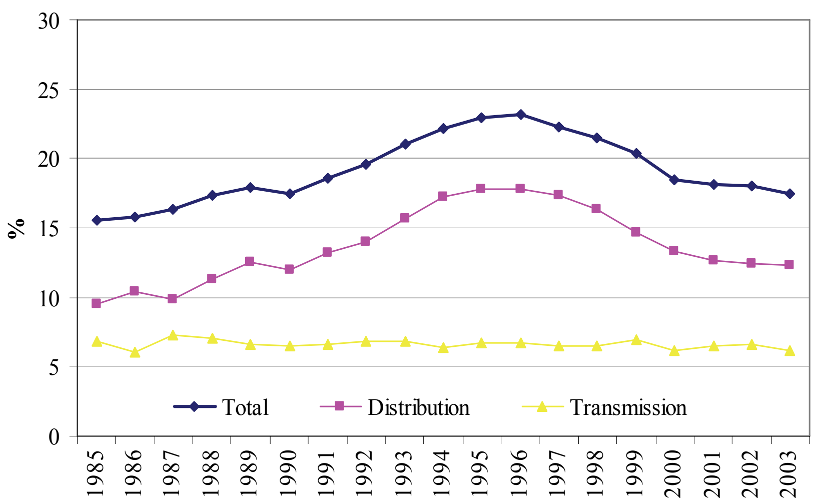

Figure 4.19. Electricity losses
Source: UNE, 1990-2003

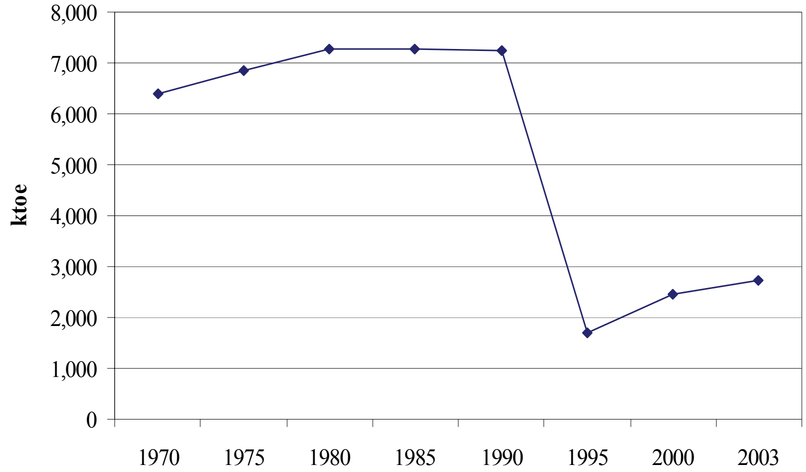

Figure 4.20. Refinery production
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

Demand side

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.

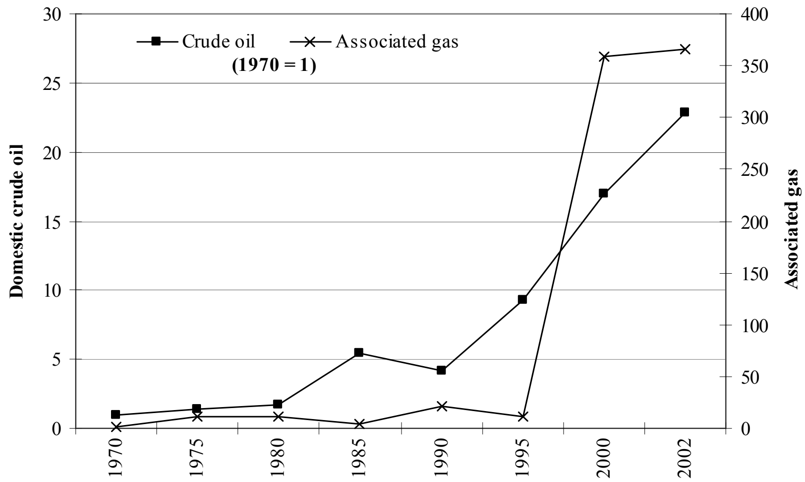

Figure 4.21. Crude oil and associated gas production
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

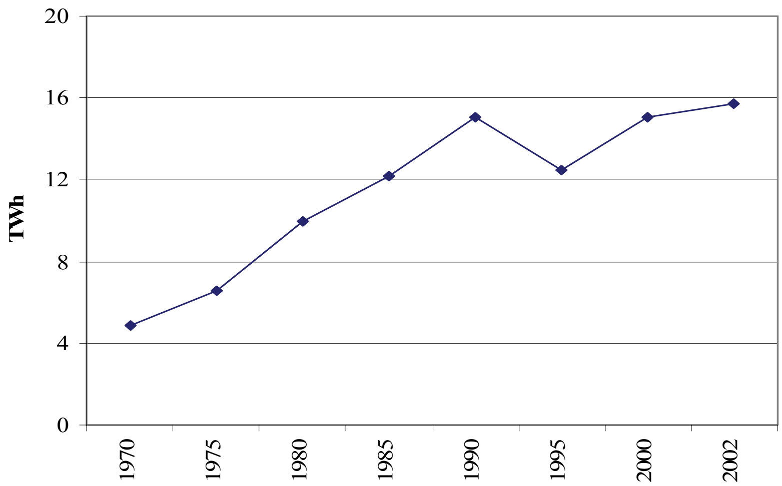

Figure 4.22. Electricity generation
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

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).

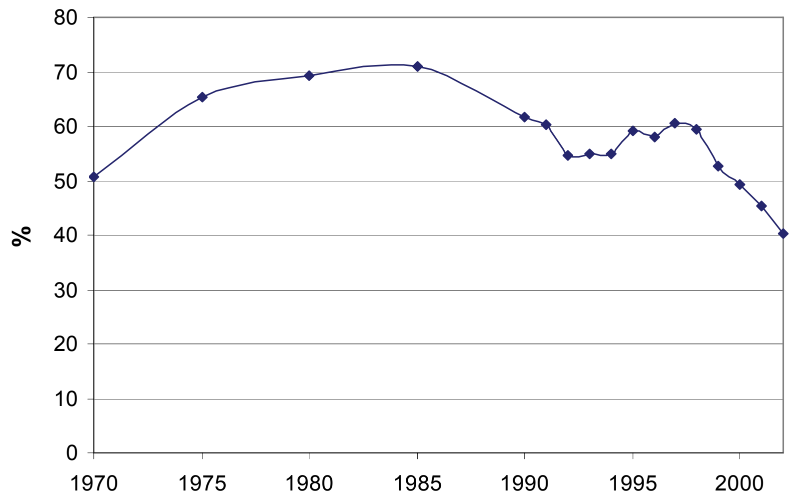

Figure 4.23. Net Energy Imports in TPES
Source: Authors' elaboration from CEE, 1986, 1990; ONE, 1998–2003a and 2004

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.

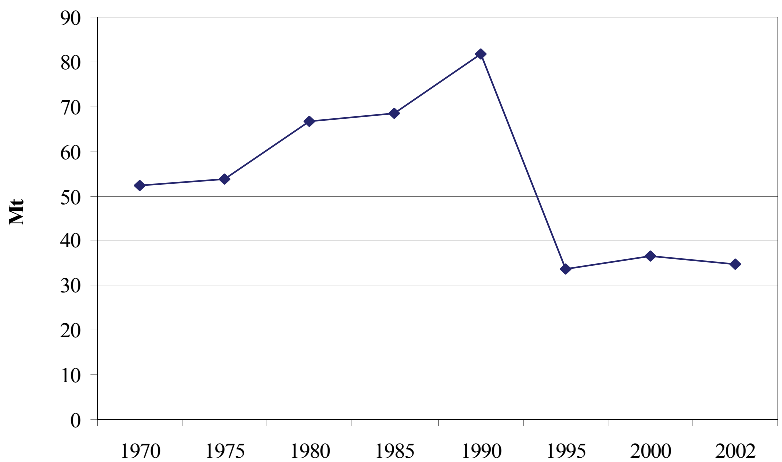

Figure 4.24. Sugarcane production
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

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.

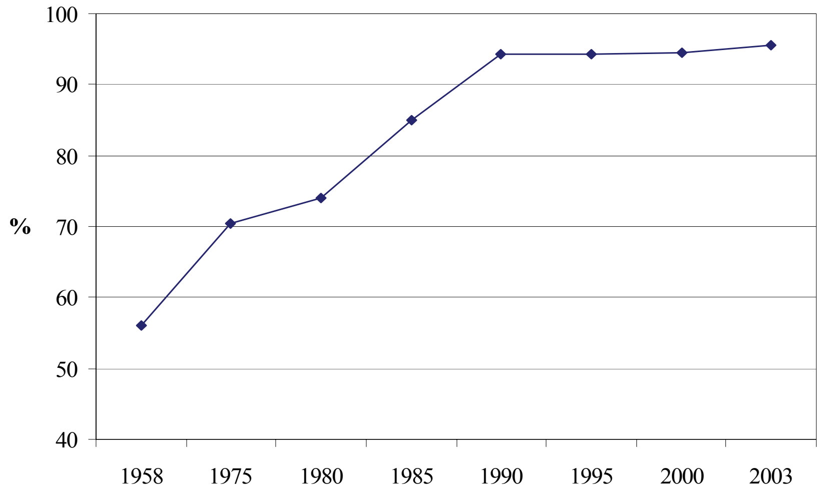

Figure 4.25. Electrification level
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003, 2004

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.

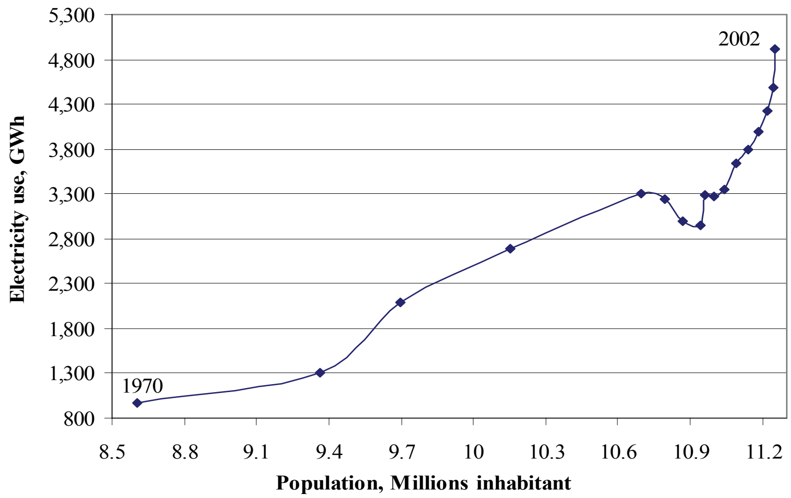

Figure 4.26. Electricity use in household sector versus population
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

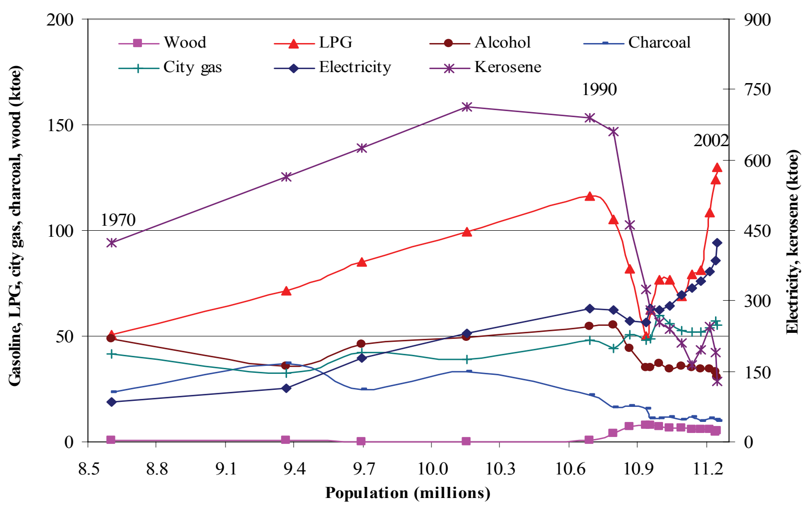

Figure 4.27. Energy use in household sector versus population
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

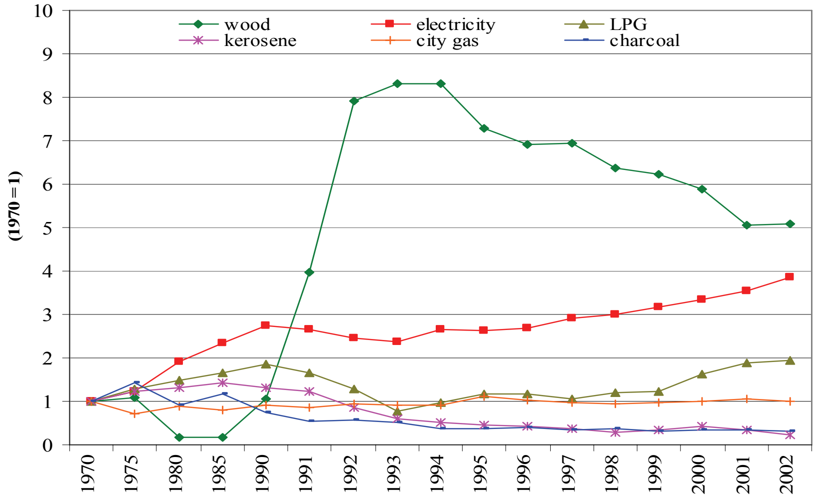

Figure 4.28. Indices of final energy use per capita in household sector
Source: CEE, 1986, 1990; ONE, 1998, 1999, 2000, 2001 a/, 2002, 2003

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).

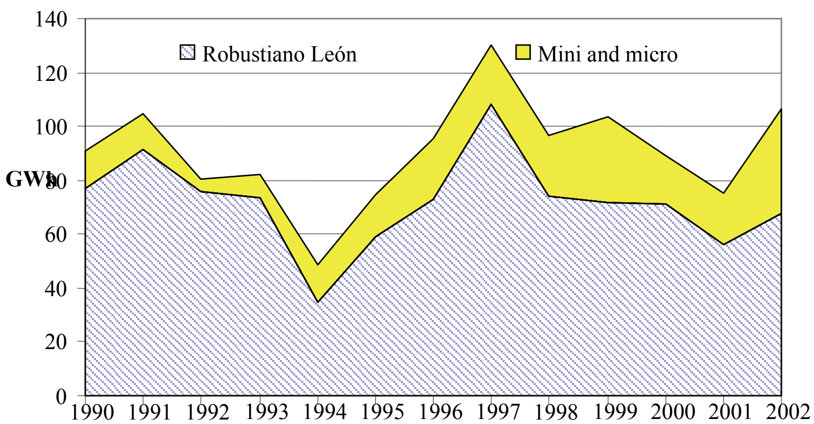

Figure 4.29. Hydropower Generation
Source: ONE, 2003

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).

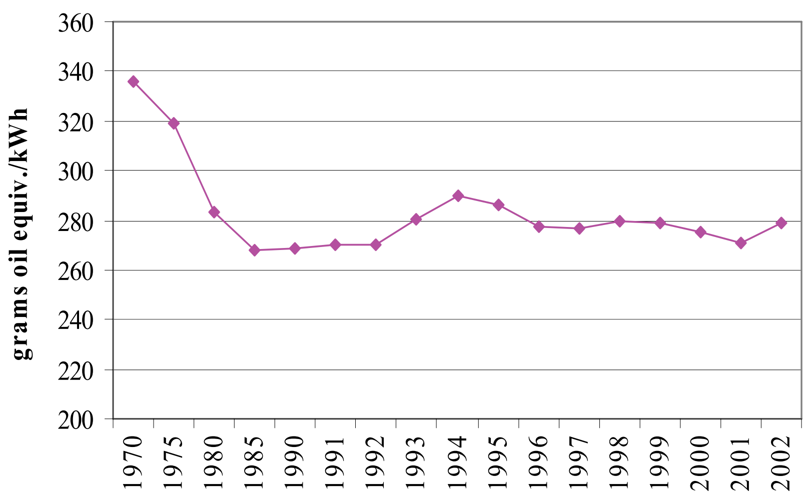

Figure 4.30. Fuel use in electricity generation
Source: ONE, 2003

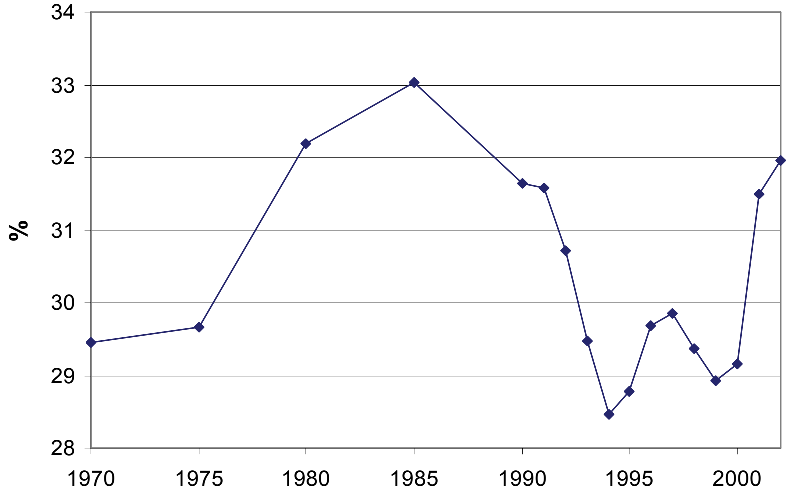

Figure 4.31. Fossil fuel efficiency in electricity generation
Source: Authors elaboration from ONE, 2003 and UNE, 2003

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).

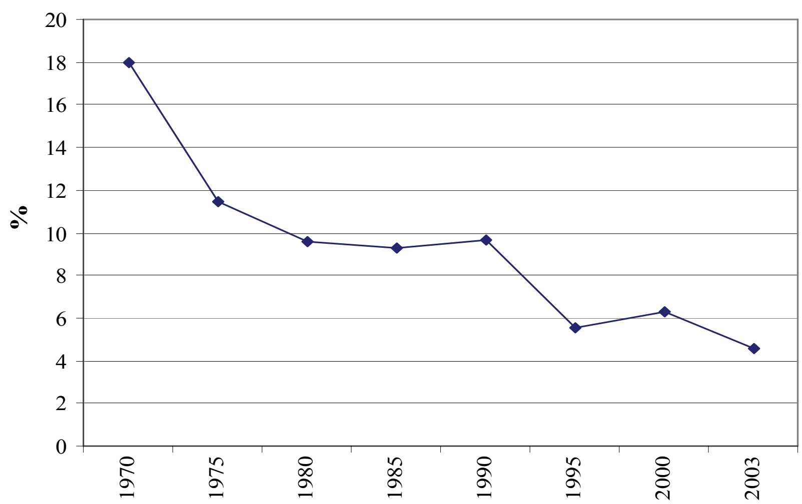

Figure 4.32. Electricity supplies from CHP
Source: ONE, 2003

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.

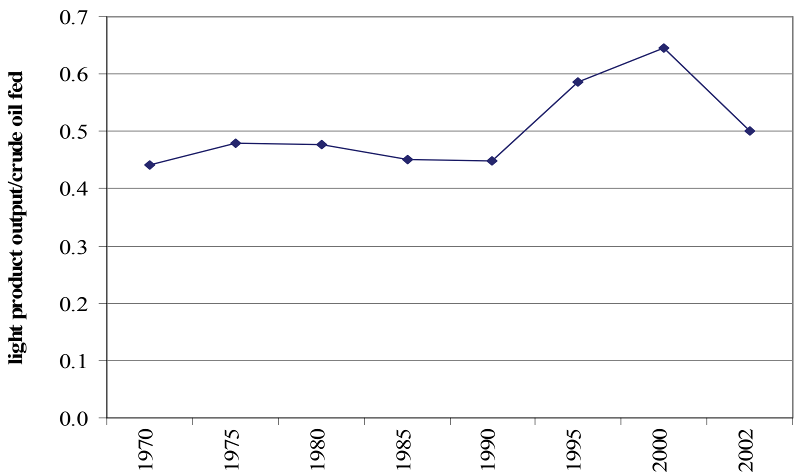

Figure 4.33. Oil refining efficiency
Source: Author's elaboration from ONE, 2003

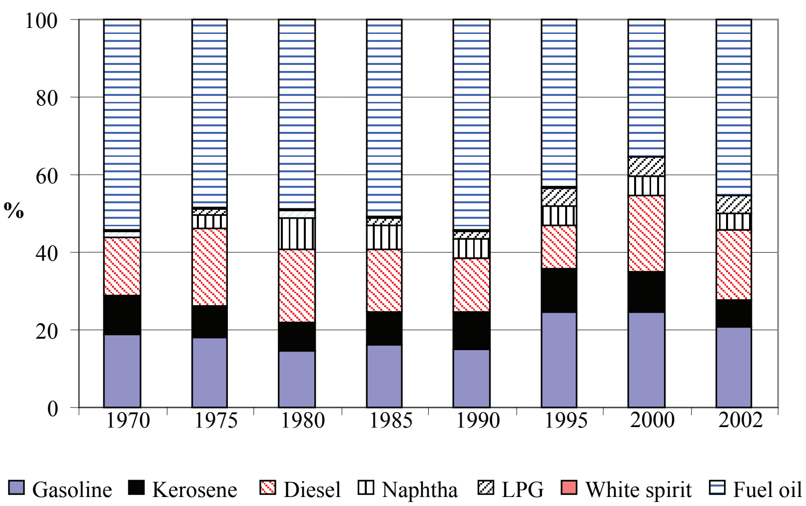

Figure 4.34. Share of refineries output products
Source: Authors' elaboration from ONE, 2003

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.

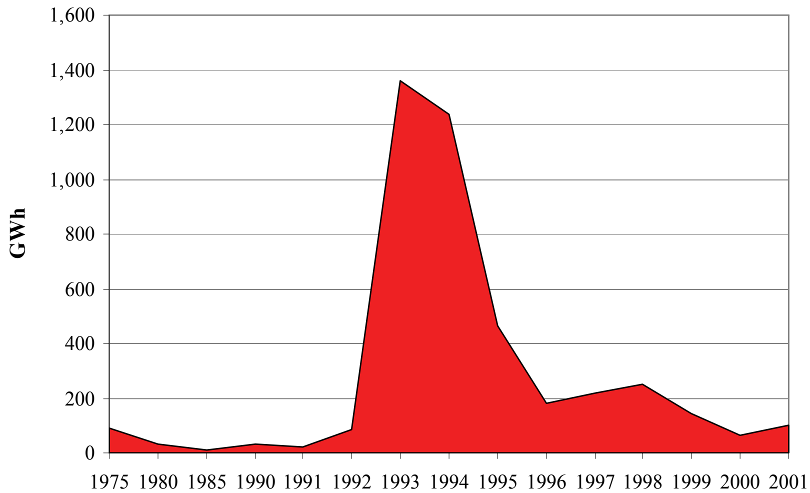

Figure 4.35. Energy Not Served due to loss of generation capacities
Source: DNC, 2000-2004

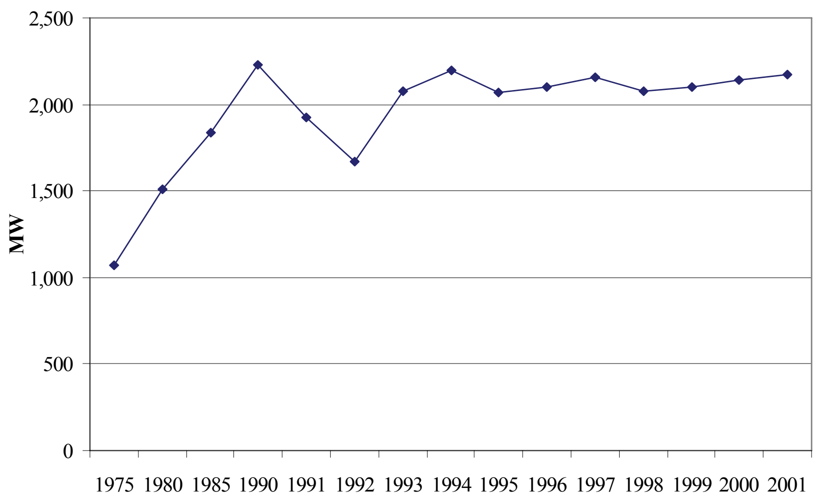

Figure 4.36. Electricity peak demand
Source: UNE, 2002

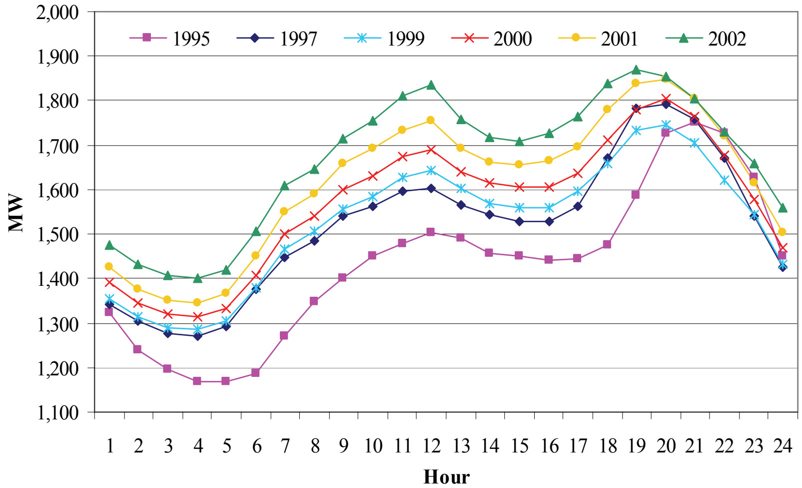

Figure 4.37. Average hourly demand
Source: DNC, 2000-2003
Note: Data before 1995 are not available

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.

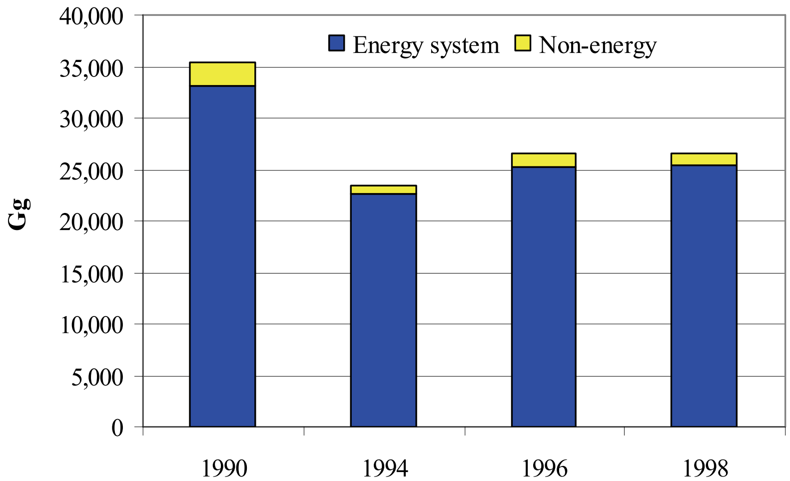

Figure 4.38. Contribution of energy sector to the total CO_2 emissions
Source: CITMA, 2002; CITMA 2003.

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.

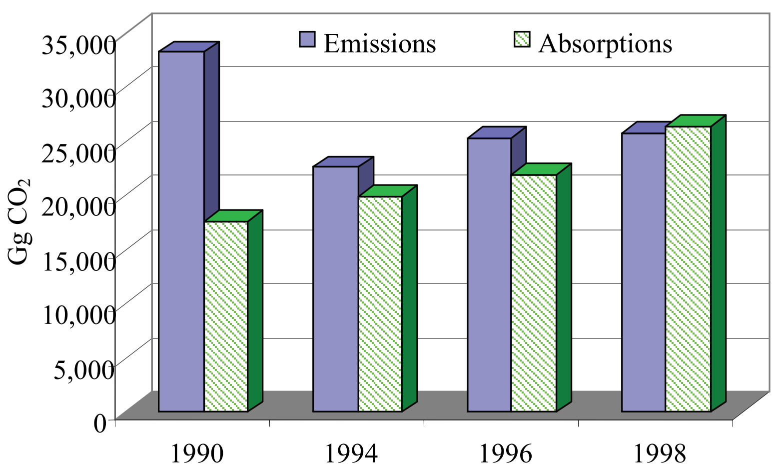

Figure 4.39. CO_2 Emissions from energy sector and absorptions of CO_2
Source: CITMA, 2002; CITMA 2003

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).

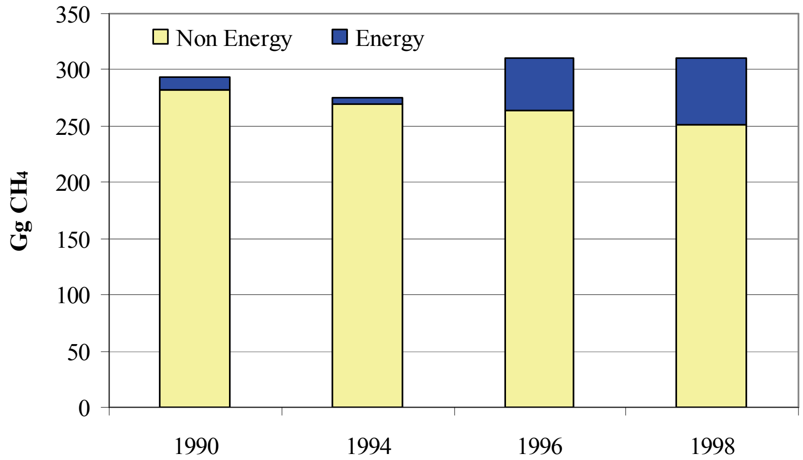

Figure 4.40. Contribution of energy sector to total methane emissions
Source: CITMA, 2002; CITMA 2003

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).

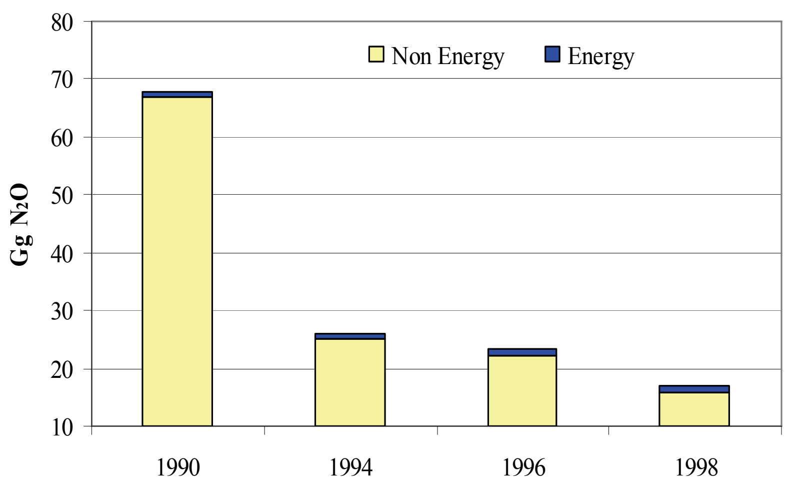

Figure 4.41. Contribution of energy sector to total N_2O emissions
Source: CITMA, 2002; CITMA 2003

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.

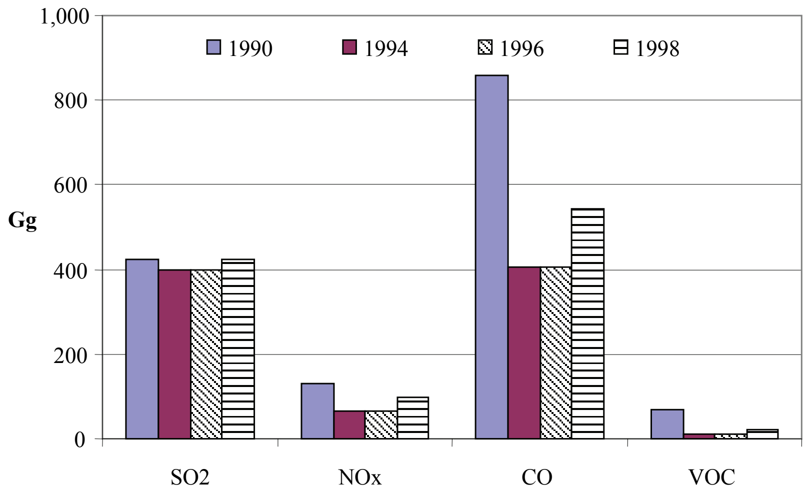

Figure 4.42. SO_2, NO_x, CO, NMVOC emissions from energy sector
Source: CITMA, 2002; CITMA 2003

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).

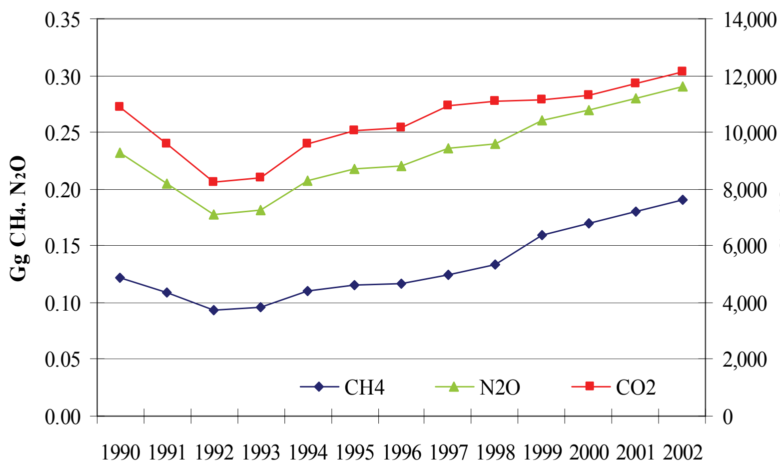

Figure 4.43. Greenhouse gas emissions from electricity generation
Source: Authors' estimations

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%.

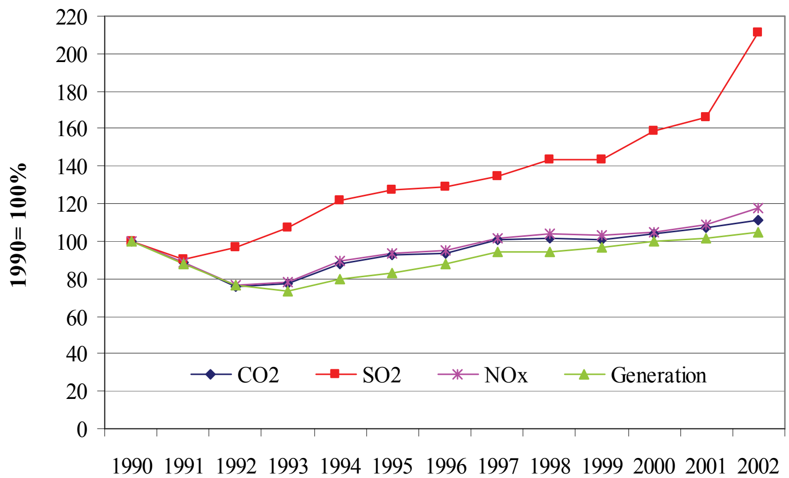

Figure 4.44. Indices of CO_2, SO_2, NO_x emissions, and electricity generation
Source: Authors' estimations

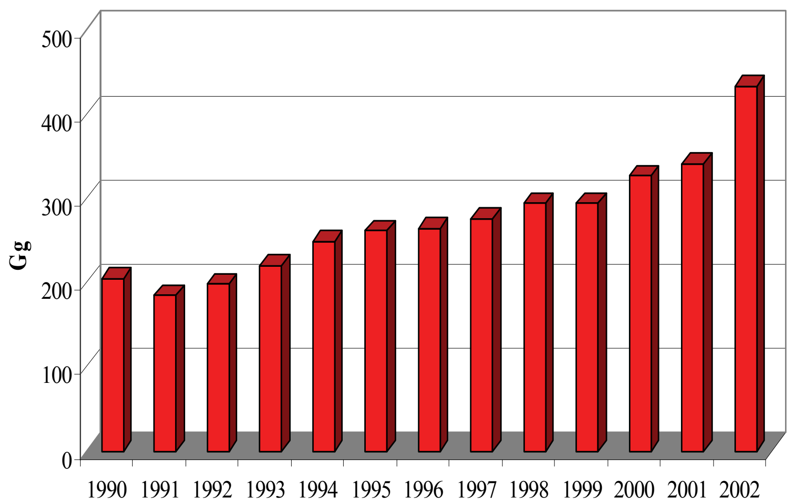

Figure 4.45. SO_2 emissions from electricity generation
Source: Author's estimations

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.

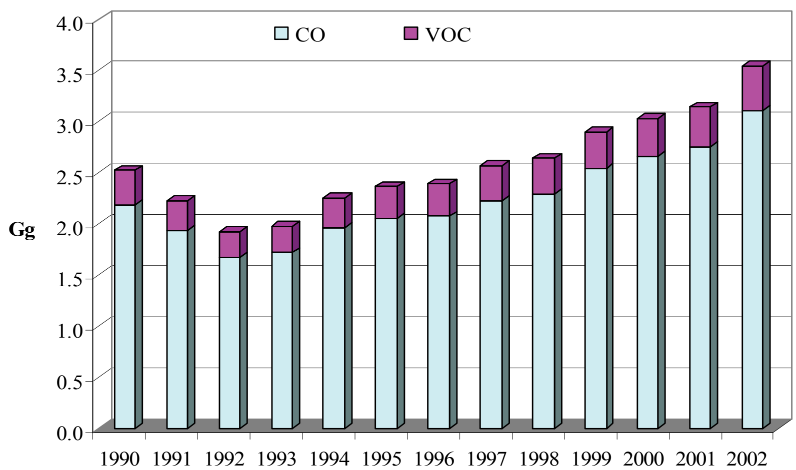

Figure 4.46. CO and VOC emissions from electricity generation
Source: Authors' estimations

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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