FINAL REPORT

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"Use of ISED to develop energy sustainable projections in Cuba"

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"Indicators for Sustainable Energy Development"

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1. INTRODUCTION

Between 1959 and 1989, Cuba reached a sustained economic development with social equity as a result of the favorable relationships maintained with the extinct Council of Mutual Economic Help. At the end of those relationships the crisis of the 90´s, which affected the whole society, took place. It was necessary to carry out reforms and economic arrangements trying to maintain basic services to the population (education, health, culture, sports, and social security).

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

Energy imports were a follow-up from 11 million of ton oil equivalent (toe) in 1990 to 5.9 million toe in 1993. Energy consumption decreases in the same period from 13.9 million toe to 7.6 million toe. Electricity generation decreased in 27% in the same period. The blackout was the normal practice. In 1994, there were electricity blackouts in 344 days of the year. Many industries were closed. In 1994, the economy began to recover.

Nevertheless, the Cuban Government dedicated special attention to improve energy situation in this period. In 1993, a National Energy Sources Development Program was approved by the Parliament in order to reduce progressively the energy imports, to obtain maximum benefits from the domestic energy sources and to improve energy efficiency (CNE, 1993). The implementation of the program would also have a remarkable socio-economic and political effect, mainly for its contribution to the stability and energy insurance of the country, and to the reanimation of the economy on a more efficient base, and for its general environmental benefit.

To achieve this objective it is required:

- To increase the use of the domestic crude oil and associated gas for electricity generation in substitution of imported fuel oil,
- To have a more efficient use of bagasse and sugar cane agricultural wastes to enlarge the efficiency in steam generation and in this way, fulfill the energetic requirements of the sugar industry. To increase the electricity delivery to the national electricity system,
- To achieve an extended utilization of hydro energy, wastes (industrial, agricultural and urban), solar energy, wind energy and biogas.

This program was planned in two phases, divided by results not by time. The first phase considers mainly the increase in the production and use of domestic crude oil, energy efficiency and sugar cane contribution. It makes available 700 thousand toe each year additionally. The second phase was planned for a later period when more financial resources can be had for energy sector development. The total contribution of the different actions would change the structure of energy production as follows: 45% sugar industry, 40% crude oil and 15% other sources.

In this period the increases in the production of domestic crude oil and associated gas, the 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 imports dependence, had an important role.

The main purpose of this research contract is to select the priority areas, evaluate the results of the energy police implemented in the country during last decades in economic,

environment, social and institutional dimension using Indicators for Sustainable Energy Development (ISED) and the data series compile by the National Statistic Office.

2. OVERVIEW OF ENERGY SECTOR

In 2001, 74.5% of the total energy supply (primary energy production plus total imports) made up of fossil fuel (crude oil-39.7%, oil products-30.5%, and associated gas-4.2%) and 25.5% renewable (with a decisive weight of sugarcane products), figure 1, (ONE, 2002).

Other resources, such as forest and coffee wastes, wood sawdust and rice shell, have contributed 8339 toe in 2001, what represent 0.07% additional of the total energy supply. The windmills, biogas, hydraulic systems (rams, motor winches, tanks of water, etc.), photovoltaic and wind systems contributed 13232 toe representing the additional 0.1% of the total energy supply (ONE, 2002).

In the electricity generation, fossil fuels are predominant (93.3%), while renewable resources are restricted to 6.7%.

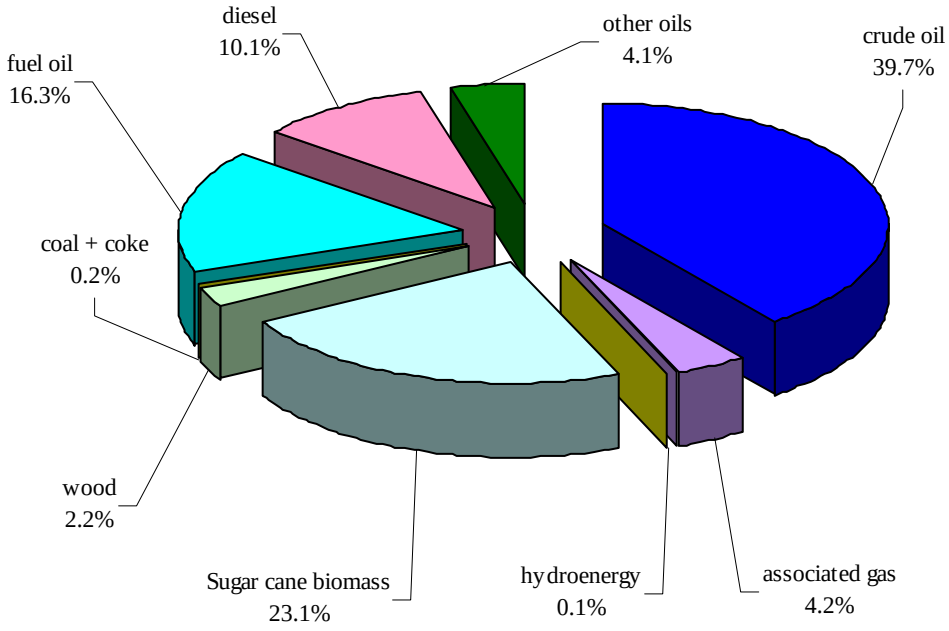

Figure 1. Total energy supply
Source: ONE, 2002

The Cuban energy system is structured as follows (figure 2):

The Parliament or "National Assembly of Popular Power" has an Industry and Energy Commission that represents the legislative power.

On the other hand, the Executive Power - the "State Council" - is made up of Ministries within which are the structures related with energy.

The Ministry of Basic Industry (MINBAS) is integrated by Electric Union (UNE) and Cubapetroleo Union (Cupet), in charge of electricity activities and fossil fuels respectively. Sugar Ministry (MINAZ) comprises sugar mills that co-generate electricity, and enterprises for energy services and energy development. National Institute of Hydraulic Resources (INRH) deals with small, mini- and micro-hydroelectric plants and hydraulic development. Energy sector is also integrated by Energas mixed company, the Independent Producer of the Youth's Island, companies producing windmills from the Ministry of Agriculture (MINAG),

the complex of Electronic Components (where solar panels are manufactured) of the Informatics and Communications Ministry (MIC), companies of the Ministry of Steel and Machinery Industry (SIME) that build hydro-turbines and solar heaters, companies for service and installation of MIC's energy facilities, enterprise operating Turiguanó wind park and biogas plants of MINAG and MINAZ.

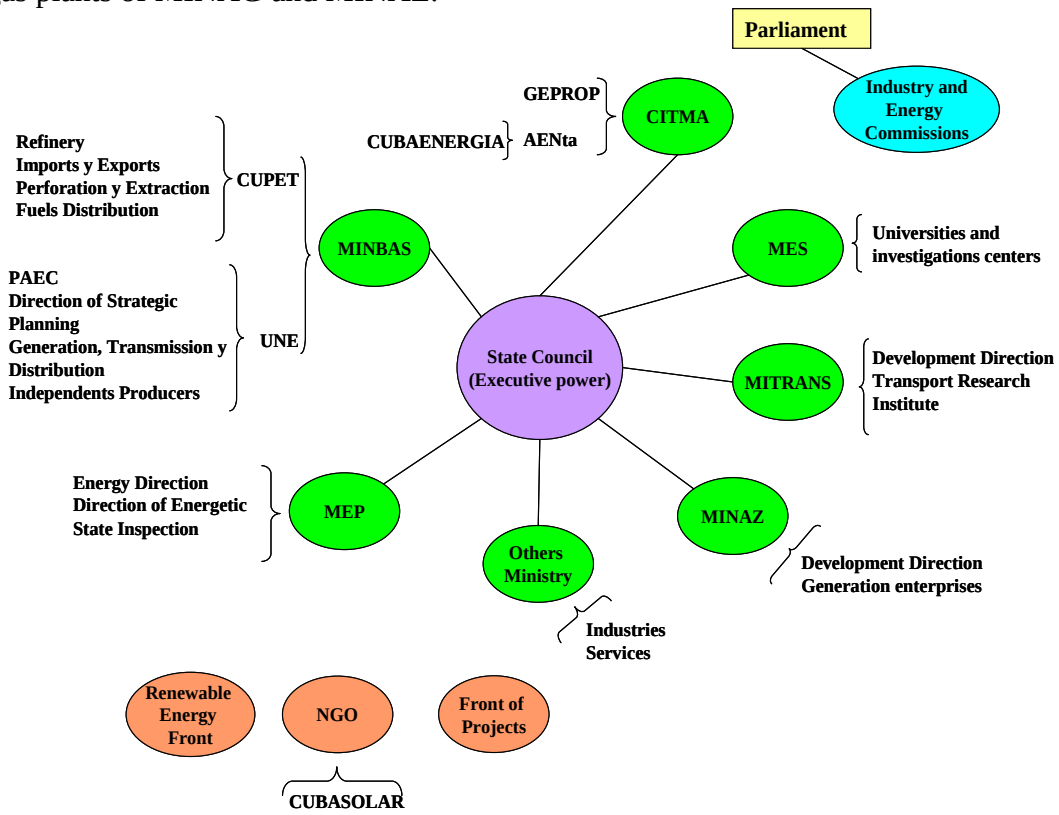

Figure 2. Diagram of Cuban Energy System

On the other hand, the Ministry of Economy and Planning (MEP) governs energy policy and has a group in charge of Energy State Inspection in all the country.

The Ministry of Transport (MITRANS) is responsible for transport development, although every Ministry has its own transport. Universities and research centers of the Ministry of High Education (MES) support energy development. Ministry of Sciences, Technology and Environment (CITMA), through Agency for Nuclear Energy and Advanced Technologies (AENta) and other centers, especially CUBAENERGIA, represents technical scientific support to the country's energy development. CITMA also coordinates Renewable Energy Front that constitutes the government specialized instrument, which coordinates and proposes to the government policies related to renewable energy and its use.

The simplified balance of final energy consumption of the country corresponding to 2001 according to the structure used in the MAED program, Windows version (IAEA, 2002) for modeling energy demand is shown in table 1. As it can be seen, 53.4% of the final consumption corresponds to manufacturing sector, 19.1% - to the transport, 11% - to the residential sector and 9.7% - to services. The consumption of the rest of the sectors is very small; it is 5.9% as a whole. Regarding energy carriers, 56% corresponds to fossil fuels and of them, motor fuel represents 40.4%. Electricity represents only 14.1% and an important role, 30%, corresponds to biomass (table 1).

Table 1. Balance of final energy consumption of 2001, ktoe

Economic sector	Fossil fuel				Electricity	Total Commercial	Non Commercial	Total
	Fossil (substitutable)	Motor fuel	Coke	Total				
Manufacture	1543.4		15.3	1558.7	356.3	1915	2007.6	3922.6
Agriculture	120.9		-	120.9	19.2	140.1	43.4	183.5
Construction	51.8		-	51.8	5.2	57.0	0.1	57.1
Mining industry		259.3	-	259.3	0.0	259.3	0.0	259.3
Transport	-	1404.4	-	1404.4	0.19	1404.4	0.0	1404.4
Residential	403.1	-	-	403.1	386.3	789.4	15.4	804.8
Services	319.2	0.0	-	319.2	265.18	584.4	130.1	714.5
Total	2438.4	1663.7	15.3	4117.4	1032.3	5149.7	2196.6	7346.3

Source: ONE, 2002 and elaboration by CUBAENERGIA energy planning group.

The total final energy consumption index (figure 3) increases in 34% until 1990 with respect to 1970 accordingly to the energy intensive economic and social development of the country in this period. The crisis of the 90´s forced the rapidly decrease of the energy consumption index until 1995 in 35%. During the economic recuperation the final energy consumption index increase in 15% respect previous year and was maintain at the same level, but 30% lower than in 1970, due to saving programs and efficiency improvement.

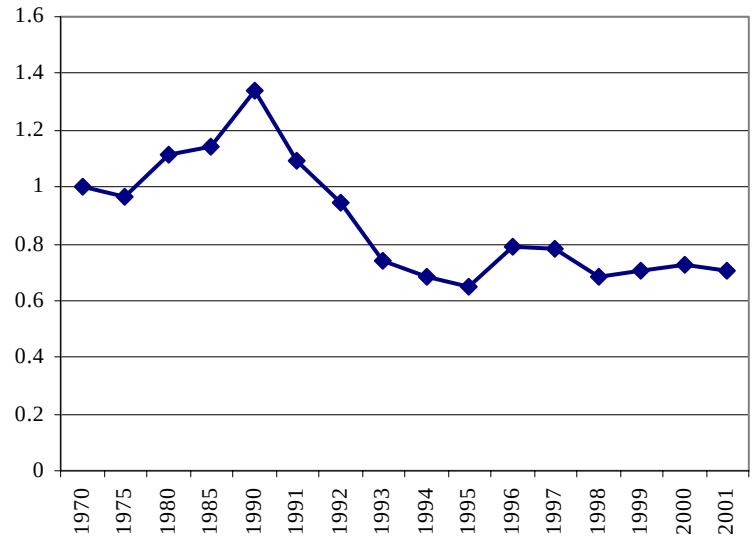

Figure 3. Index of total final energy consumption (1970=1)
Source: ONE, 1985, 1989, 1998, 1999, 2000, 2001 a/, 2002

The final energy consumption index by energy carriers as shown in figure 4 explains the behavior of each of them. The electricity consumption indices increases in 300% in 1990 respect to 1970 (energy intensive economic and social grow period). During the crisis the electricity consumption indices fall-up, but had the rapidly increases to be at 2001 near the level of 1990. Excluding associated gas and electricity consumption index that increases in the last years, all other energy carrier index are lower than in 1970.

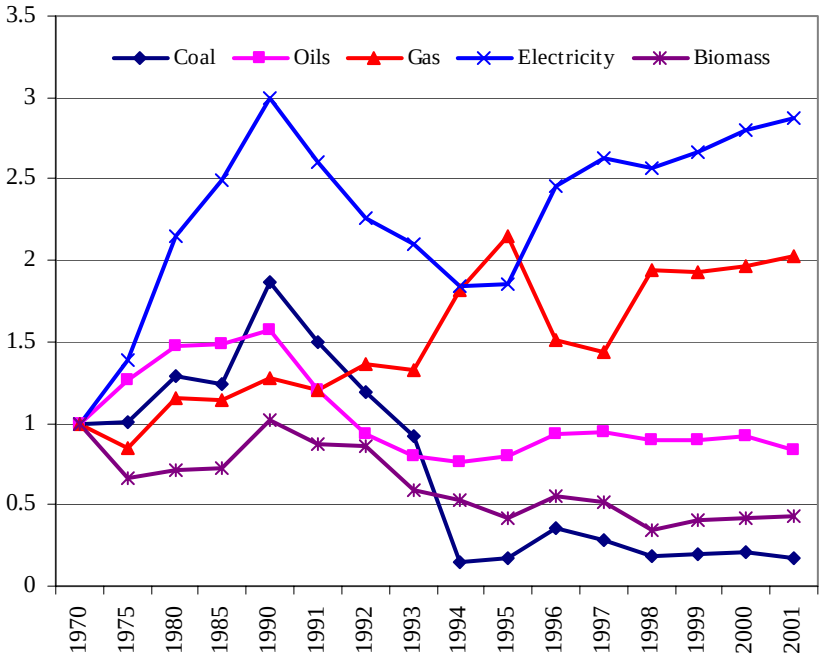

Figure 4. Index of final energy consumption by fuels (1970=1)
Source: ONE, 1985, 1989, 1998, 1999, 2000, 2001 a/, 2002

The final energy consumption by sectors (figure 5) has changed according with the structural changes occurred in the national economy: reduction of the consumption in manufacturing and agricultural sectors and growth in transport, household and mainly in commercial and services sectors, although they are low energy consumers and manufacturing consumption has the fundamental weight (steel, nickel, sugar, cement, etc.).

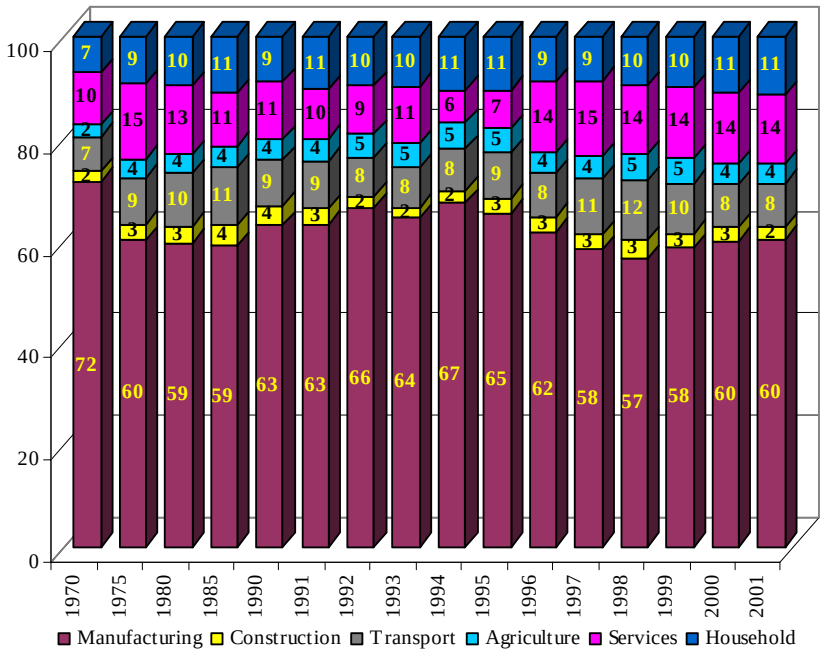

Figure 5. Share of final energy consumption by sectors, %
Source: ONE, 1985, 1989, 1998, 1999, 2000, 2001 a/, 2002

The analysis of the final energy consumption dynamics shows that it fell more than GDP (figure 6), that implies a reduction of the energy intensity of the country, where is considerable the participation of industry sector (manufacturing, agricultural and construction sectors) in this decreased and less important the participation of household and services sectors respect of that they represent within the total consumption (figure 4), this is interpreted as a decrease of the well-being of society, in spite of the government's efforts of affecting social services the less as possible.

The peak of the energy consumption dynamics in 1996 (figure 7) is related to the service sector and in particular due to the increase of the tourism, 259 000 visitors more than in 1995.

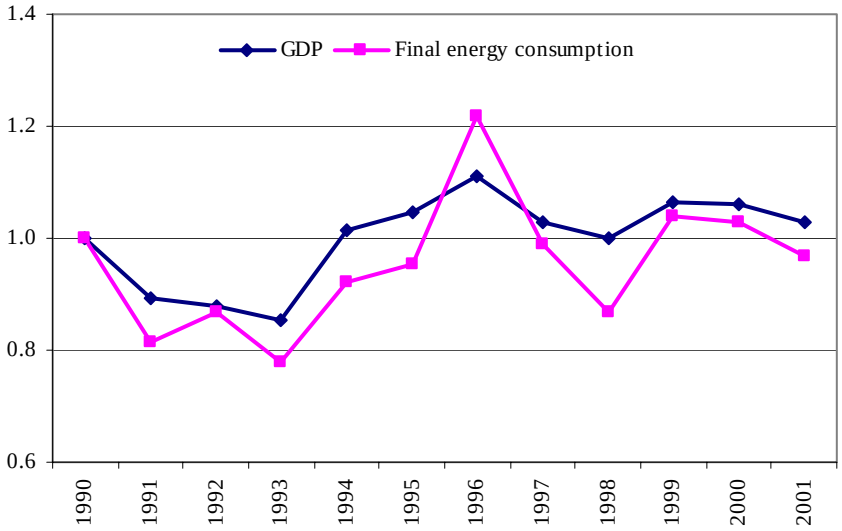

Figure 6. GDP (1997) & Total final energy consumption dynamics (1990=1)
Source: ONE, 1998, 1999, 2000, 2001 a/, 2002

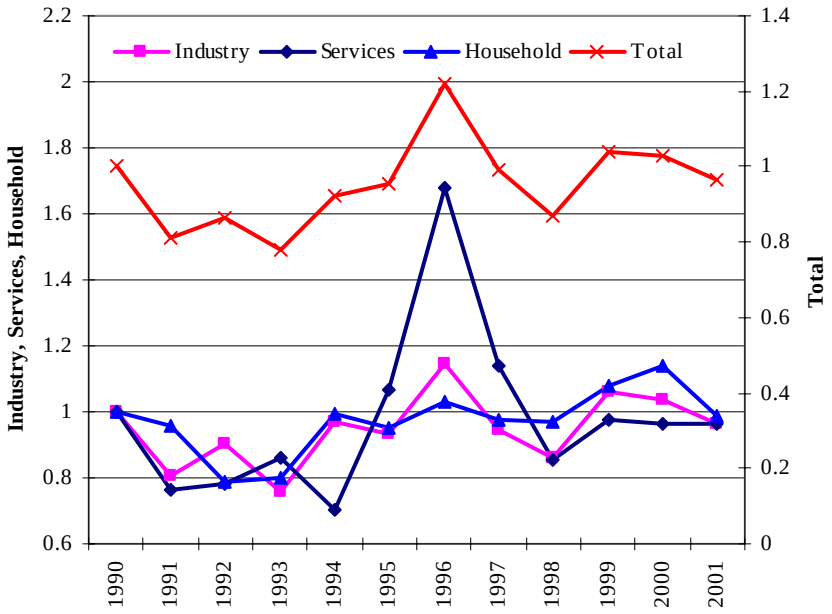

Figure 7. Final energy consumption dynamics by sectors (1990=1)
Source: ONE, 1998, 1999, 2000, 2001 a/, 2002

The installed electricity capacity in the country has rapidly risen to cover the demand of economic and social development. Between 1970 and 1990, 160 MW a year, on average, were

installed. Capacity has continued growing in the last years, although at very low speeds. The biggest growth has been reached based on thermoelectric power plants and cogeneration in sugar industry, although since 1998 gas turbines and combined cycles begun to have an important weight, using associated gas (figure 8). At the end of 2001, installed capacity was 4410.9 MW. More than 90% of these capacities are connected to the National Electric System (NES). Isolated systems and cogeneration plants constitute the rest.

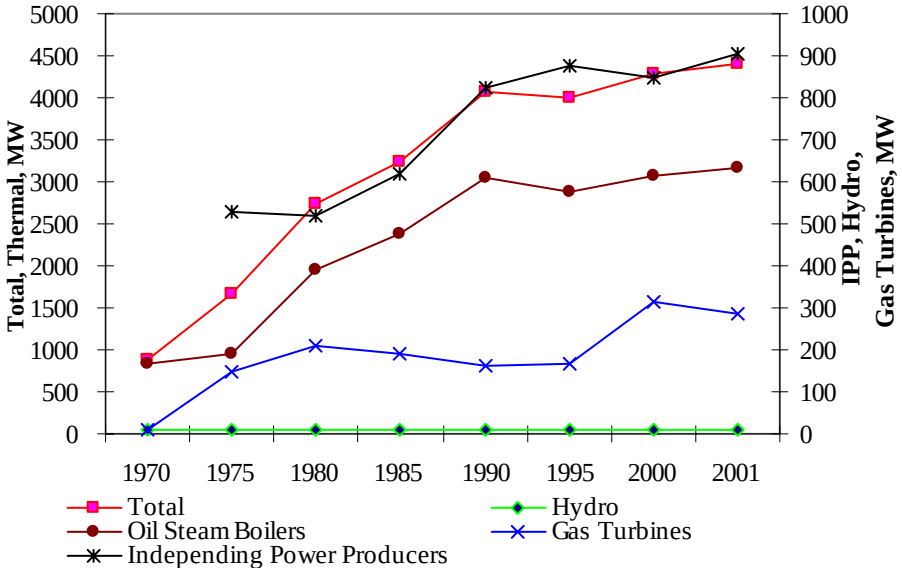

Figure 8. Installed capacity, MW
Source: ONE, 2002

The electricity generation matrix shows that oil byproducts increased their participation from 80% in 1970 to 93% in 2001. In the same period, the biomass reduced its contribution from 18% to 6.1%, beginning the participation of associated gas in 1998 that constituted 6.7% of the country electricity generation in 2001. The hydroenergy contribution is very small and it is bellow 1% (figure 9).

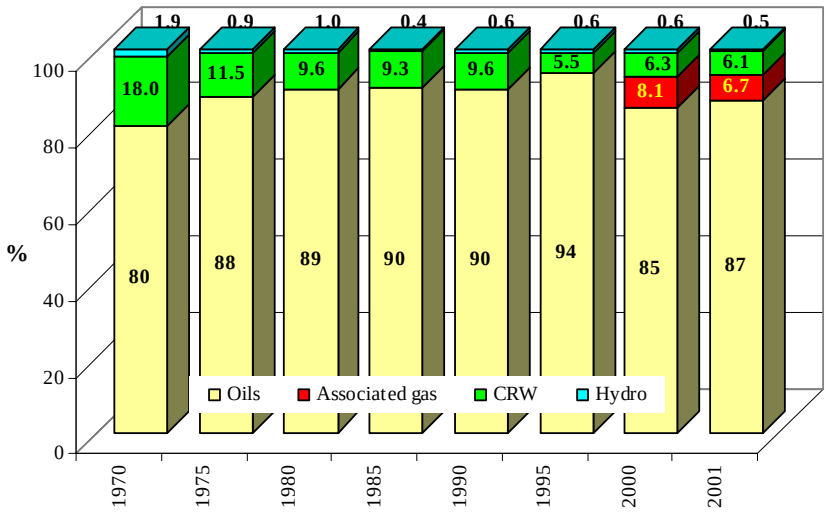

Figure 9. Fuel matrix used in electricity generation
Source: UNE, 2002

There was a rapid growth of electricity consumption (10.5% yearly) in the decade of 70´s, especially because of the high industrial development. In the 80´s, this consumption only increased, on average, at a rate of 4% yearly, but services very slightly raised electricity consumption. However, in the 90´s the crisis affected all sectors, the electricity consumption dropped in all of them, although to a greater extent in service, agriculture and industrial sector. Activities were suspended and industries were closed mainly because of the lack of fuels and electricity, although in other cases it was for the lack of US dollars to acquire the necessary raw materials. The blackouts were a normal practice and they were planned daily. However, the residential sector was affected slightly, and already in 1995 residential electricity consumption was the same as in 1990 (figure 10).

From 1994, with the beginning of the economic recovery the electricity consumption in the commercial sector grew at a greater speed than in the rest of sectors, although the growth rate of residential consumption was determining factor of the overall increases. On average, in the last 5 years the electricity consumption grew 4.2% yearly (figure 10). However, the Electricity Saving Program has made possible that since 1997 average maximum demand remains in the order of 2150 MW and growth rates have been smaller than 2% annual.

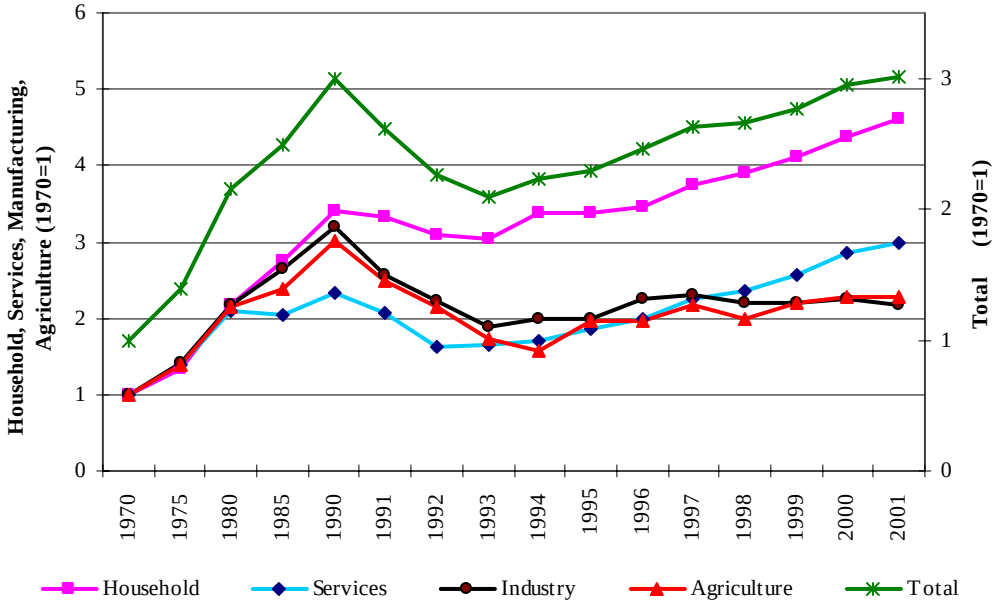

Figure 10. Index of electricity consumption
Source: ONE, 1985, 1989, 1998, 1999, 2000, 2001 a/, 2002

In Cuba energy inequalities are not only restricted to energy access (5.2% of the population, made up of 584,654 people, do not have electricity), neither for the energy prices, although at the moment the tariffs are made to encourage saving, but for the quality, cleaning capacity and efficiency of the energy services. In the specific case of electricity, the residential and government sectors are subsidized, since electricity costs are, largely, paid in hard currencies and despite that fact, in those sectors, it is paid in Cuban pesos[1].

[1] In the electricity sector, at present there is a valid electric tariff in foreign currencies that embraces all sectors of the final use, excluding the residential ones, based on the contracted power and the consumed energy, and that takes into account the different time schedules (dawn, morning and peak hours). As for the residential electricity tariff, the price reform within the general policy of price rise in some considered " sumptuary" consumer goods and public services and elimination of undue free of charges services, to reduce the tax deficit and the excess of circulating money, it suffered the most significant change in the last 35 years (Somoza J. and Garcia A., 1998).

Energy services in the country have a public service character that guarantees to all the citizens in the national territory the right to be clients of these services and to receive them in the stipulated quality and safety conditions. On the other hand, the prices and fuel tariffs and electricity are structured in such a way that the access to them on the part of the whole population is guaranteed. The domestic fuels distribution is rationed to guarantee the minimum necessary to all population.

The residential energy consumption represented 11.41% of the energy consumption in 2001. The main energy used they were: electricity (48%) for lightning, air conditioning, and household appliances, although it is also used for cooking food to a lesser extent (and of which there is no reliable statistics)[2] and continue kerosene (23. 4%) and the LPG and city gas (22.5%). The alcohol used for pre-heating/warm-up of the kerosene stoves constitutes 4.1%, charcoal 1.3% and firewood 0.6% (ONE, 2002).

Electricity consumption in the residential sector has risen as an energy alternative due to the fact of not being sufficient to fulfill the supply of other fuels, to the growth of the population and, although in a limited way, to shortages in the acquisition of household appliances. Other causes that have hindered electricity consumption from being triggered have been the implemented saving programs and the new scheduled price on a step-by-step basis for electricity charges.

The participation of *GLP and the city gas* has grown as a result of the gasification programs, which have displaced part of kerosene and alcohol. This program has benefited 3 million people in its first stage (Somoza J. and Garcia A., 2002). The delivery of gas cookers with two burners and the cylinder of LPG were subsidized by the government, thus allowing even high-risk population to receive this modern service.

The country has created and modernized the production infrastructure and distribution of LPG. The bottling is carried out in 19 Kg gas cylinders (containing 9 Kg of gas) and is distributed to the point-of-sales in trucks and from there the cylinders are distributed to the population in established rationed amounts, depending on the quantity of people inhabiting a house. The price of the cylinder is 7 pesos and, for instance, for a 4-people family, the acquisition cycle is every 19 days. This consumption could be increased if the rationed distribution is eliminated.

Kerosene and alcohol for the warm-up ended up constituting the main energy carriers used in the residential sector between 1970 and 1994, although already from 1985 they begin to diminish their participation. It should be pointed out that the distribution of these energy carriers has always been rationed and the crisis forced to reduce the distribution standards, but even then, in many areas, mainly rural, the distribution did not reach 50% of the established rationed amount. To make up for this deficit the homemade electric stoves (inefficient), the illegal electric network connections, and the diesel diversion from other economic activities and the indiscriminate cutting down of trees proliferated.

Firewood consumption grew abruptly in 1992 arriving at its maximum levels in 1993, when a sustained decrease that took place mainly in the industrial sector began, as a result of the reduction of the charcoal production and consumption.

Methane has begun to be used in an experimental way for the automotive transport. More than 100 cars, mainly taxis have been converted and depending on financing, they could be 1000 at present.

When the electric service passed to the hands of the State, from 1960, the electrification was used for eminently social and economic purposes. They multiplied the rural electric grids

[2] Estimates carried out by PAEC considering 5.4 millions of inhabitants from the main cities of the country showed that among the used carriers for cooking and water heating is around 20%, which means that almost half of the residential consumption is for these uses

and the rural population's electrification grew from 4% in 1960 to 79.4% in 1992 (UNE, several years and ONE, 2002).

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

Taking into account that the majority of rural population lived in isolated houses, the electrification got even more complicated from the practical and economic point of view. For this reason since the decade of the 80´s, policy was focused on providing the electricity only to the population settlements, not only for strictly economic reasons, but also with the aim of promoting, even in the most isolated areas, a life in community that facilitates the access to the social benefits, particularly education and free medical service.

The electrification of social goals has been prioritized, such as 350 doctor's family offices, 5 hospitals, 2364 primary schools, 1864 TV rooms, 150 social clubs, dozens of houses, rural boarding schools, camping facilities, video equipment, telephone exchanges, fishing collection centers and cooperatives (PDFNER, 2003). Special impulse received electrification with the programs for the dissemination of culture, audiovisual programs, among others.

Actions similar to the above mentioned have considerably contributed to improve the quality of life of great amount 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.

On the energy prices (tariff), different theories exist (consideration of the marginal costs, favoring to the poorest, etc.). In Cuba, differentiate electricity tariff for different sectors are applied. They include next main elements:

- ✓ To guarantee the exploitation/operation and the development of the Electric System with efficiency and quality
- ✓ To transfer to the domestic economy the smallest price to increase their competitiveness
- ✓ To get payment from each client according to the costs that he/she causes to the Electric System
- ✓ To provide a price list that stimulates the rational use of the energy

As the electricity is a natural public monopoly, the State is the one that regulates the establishment of the electricity tariff. As it is an international practice the electricity tariff disaggregate costs according to levels of tension 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[3].

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

Thus, risk population[4] that usually has smaller electricity consumption than the population with higher living standards, pays less for the electric service, since it does not reach 100 kWh per month because of the scarce electrical appliances and the electricity is used basically for lighting. However, many families exceed the 300 kWh per month. As

[3] Indeed, the variable component of the electric tariff is based on a fuel price that is yearly established, being it the reason why any fuel price variation as compared to the foreseen prices is transferred to the tariff by using an adjusting coefficient K that is nothing more than the relation real fuel price / basic price.

[4] The studies on poverty carried out in the country coincide in differentiating the Cuban poverty from the one that is observed in Latin America and the Caribbean and suggested to use the term "Population in Risk" to denote the population with insufficient revenues to acquire basic food products and other goods, but having at the same time a qualitatively higher protection than that received by the Latin American poor.

average in the country the electric consumption for residential consumer was 131 kWh/month in 2001 (ONE, 2002), what is equal to an average monthly price of 17.46 pesos/month per house that would be equal to the current change rate for US dollar for the population by CADECA[5] (1UD$=26 pesos), to 0.67 US $.

However, it is necessary to point out that the electricity generation has a high component in foreign currencies that far exceeds the prices the population pays for this service.

Table 2. Annual average prices of domestic fuels

Products	Unit	1995	2001	% increment
City gas	Pesos/10^3 m^3	155.8	180	15.5
Electricity	Cent/kWh	12.45	13.33	7.1
GLP	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/

The energy demand projection for the reference scenario developed using MAED (Windows version) are presented by energy carriers' en table 3 and by sector in table 4.

The main assumptions in this scenario are: a moderate economic and social development, 4.16% yearly increases of GDP, atmosphere for foreign investment is favorable in tourism and mining, moderate rhythm of oil extraction grew, energy intensity of industries fall-up in 1%, revenues per capita increases until 5000 $/cap in 2020, car per capita increases, inhabitant per houses decreases, urbanization level reach 80%, limitations to acquire domestic appliances are eliminated, but they are more efficiently, etc.

Table 3. Final energy demand projections by energy carriers, ktoe

	2001	2005	2010	2015	2020
Non commercial	2196.5	2743.2	3405.6	4154.0	5050.9
Electricity	1032.5	1276.7	1583.2	1945.3	2378.7
Thermal use	0.0	3.0	4.5	7.4	14.5
Fossil fuel	2438.4	3119.4	3800.2	4605.8	5620.2
Motor fuel	1665.9	1860.4	2139.5	2462.3	2808.7
Feedstock	15.3	21.1	27.1	34.0	42.9
Total	7348.6	9023.7	10960.1	13208.9	15915.9

Table 4. Final energy demand projections by sectors, ktoe

	2001	2005	2010	2015	2020
Industry	4422.3	5683.6	7129.5	8796.4	10746.6
Freight transport	602.8	664.7	724.3	789.1	846.4
Passenger transport	804.0	910.0	1062.8	1238.5	1438.8
Residential	805.0	927.3	1113.7	1376.9	1787.3
Services	714.5	838.0	929.8	1007.9	1096.8
Total	7348.6	9023.7	10960.1	13208.9	15915.9

[5] CADECA, Bureau of exchange, is an institution subordinated to the Central Bank, the main objective of which is to collect dollars (although it also changes the so-called "convertible pesos") that are coming from different sources into the hands of the population. This is a "parallel" house of exchange, to avoid the "flow" of foreign currencies to the black market. However, it would be worthwhile clarifying that the official rate of exchange dollar - peso valid for economic-mercantile operations among companies is 1:1.

3. REVIEW OF ENERGY STATISTICAL DATA CAPABILITY

The National Statistical Information System (NSIS) collects economic, demographic and social data. This information is interesting to the State and government for planning, control, economic analysis, international compromise and public information. The National Statistical Office (NSO) has 14 provincial and 169 municipal delegations in the country. The NSIS has central and territorial level for administration control. NSIS used different questionnaires to collect energy information on indicators of energy consumption, electricity generation balance, fuel consumption, electrification, use of renewable resources, supply and distribution of energy sources, territorial energy efficiency, etc.

The main limitations of the NSIS are: it is exhaustive, but not very agile; poor quality of some data, complicate organization flows, difficulties in use. The major enhancement projections of NSIS are: it reduces the volume of data collection; enhances the data validation, provides statistical verification; integrates all the information systems, and uses modern information supports.

After a detailed analysis of complete ISED lists (disaggregated), the table 5 shows the ISED which are not applicable to our country. We do not use space heating; coal and nuclear in electricity generation, abatement technologies and we not import gas and electricity.

Table 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 imports 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 fuels reserves: for coal** **(37) Life time of proven recoverable fossil fuels reserves: for coal** **(38) Proven uranium reserves** **(39) Life time of proven uranium reserves**

In the year 2002, the following indicators were not accounted in the national statistics:

- ✓ Energy mix (heat) : In the sugar cane production process steam is used, but it is not accounting
- ✓ (15, 15.2.3) Expenditures on energy sector and hydrocarbon exploration
- ✓ (21.3) Fraction of disposable income/private consumption per capita spent on fuel and electricity by a group of 20% poorest population
- ✓ (19) Income inequality

- ✓ (20) Ratio of daily disposable income/private consumption per capita of 20% poorest population to the price of electricity and major household fuels
- ✓ (23.1.3, 23.3.3) Quantities of particulate emissions from energy and transport activities
- ✓ (24) Ambient concentration of pollutants in urban areas
- ✓ (28.1) Storm water discharge
- ✓ (28.3) Discharges of oil into coastal waters
- ✓ (29.1) Generation of solid waste from energy activities
- ✓ (29.2) Generation of solid waste from thermal power plants
- ✓ (36) Proven recoverable fossil fuel reserves
- ✓ (37) Life time of proven recoverable fossil fuel reserves
- ✓ (40) Intensity of use of forest resources as fuelwood
- ✓ (41) Rate of deforestation

We do not have poor population, we use the denomination "population in risk" to differentiate this situation with the poorest in Latin America and the Caribbean, but no enough statistic exist nowadays.

As a results of the first year research contract the lack on some statistic were pointed out and an important work was carried out to enhance the statistic system.

The main modifications introduced in the statistic system are:

1. Reduce, but concentrate the information collection.
2. Establishment of three new surveys (on environment management, use and distribution of water and survey on wastes).
3. Incorporate the concept of hydro basins in the analysis of investments.
4. Reduce the desegregation of information on investment, but compile more information on the effect on hydro basins and the environment.
5. Introduction of data verification.

This way it is expected to initiate the collection of the majority of previous indicators.

4. MAJOR ENERGY PRIORITY AREAS

The major priority of the country, particularly during the economic crisis of the 90´s was to improve the economic situation.

Taking into consideration the objectives of the National Energy Sources Development Program approved by the Parliament in 1993 and priorities of research and development for next five years in the country the selected major energy policies for evaluation are:

- Reduce energy dependence
- Increasing the renewable energy source's participation in the solution of social issues
- Energy efficiency improvement

In table 6 appears the indicators used to evaluate these polices. The main data related to the priority policies not allowed now are:

- (15, 15.2.3) Expenditures on energy sector and hydrocarbon exploration
- (23.1.3, 23.3.3) Quantities of particulate emissions from energy and transport activities

- (28.3) Discharges of oil into coastal waters
- (36) Proven fossil fuel reserves
- (37) Life time of proven recoverable fossil fuel reserves
- (40) Intensity of use of forest resources as fuelwood
- (41) Rate of deforestation

Table 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 traveled 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 Consumption per capita 17. Indigenous energy production 18. Energy Net import Dependency
Social	**Direct Driving Force** 21. Fraction of disposable income/private consumption 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 emission 35. Fraction of technically exploitable capability of hydropower currently not in use **State** 24. Ambient concentration of pollutants in urban areas

5. IMPLEMENTATION OF ISED FRAMEWORK

The drastic changes that affected to the Cuban energy system, described previously, were due to the economic changes that took place by the crisis that affected to the country, the urbanization, the decrease of the demographic growth rates, the educational and health system development and to the increment of life expectation. Before 1990 is not available information on GDP at constant 1997 prices. For this reason all the indicators related to GDP are from 1990 until the present.

5.1 Analysis of economic situation

- **Activity effects**

The Cuban population has been duplicated in the last 50 years. The annual growth rates (by 1000 inhabitants) were superior at 10 up to 1990 (figure 11). The crisis of last decade, together with the increment of the educational and cultural levels, improves of the medical attention, sexual education programs, migrations, etc. made that this rate continued falling to being 2.3 in the 2001, value corresponding to highly developed countries.

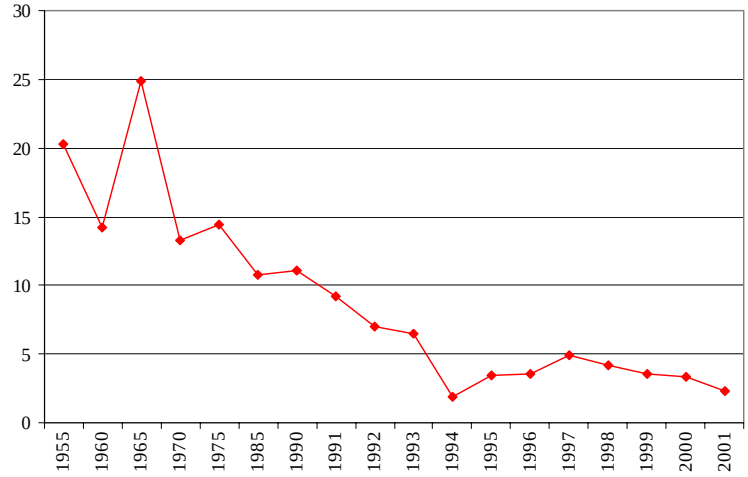

Figure 11. Annual population growth rate (by 1000 inhabitans)
Source: ONE, 1985, 1989, 1998, 1999, 2000, 2001 a/, 2002

The economic crisis forced to the country to close industries and trade and to reduce all the activity levels trying to affect the less possible the areas of health, education, sports, etc. From 1990 to 1993, the GDP fell in 25% (figure 12). The economic recovery began in 1994, between 1995 and 2001 the yearly growth averages of GDP has been 4.85%, although the levels of 1990 have not still been reached, being still a 6% smaller.

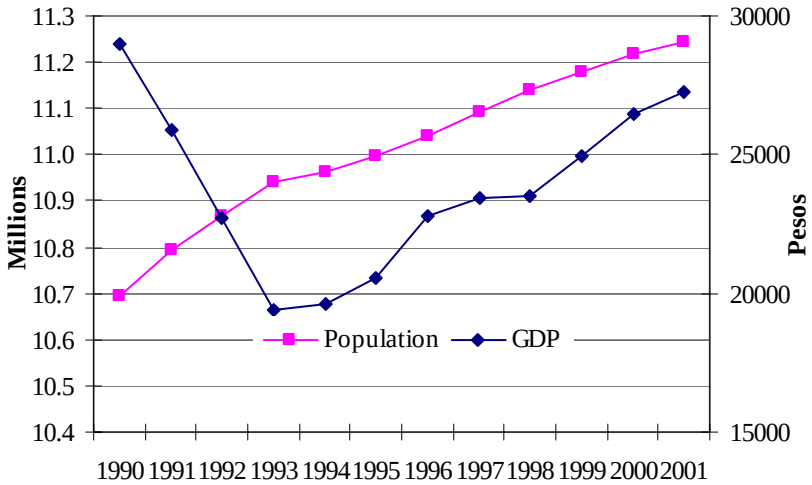

Figure 12. Population and GDP (1997 constant prices)
Source: ONE, 1998, 1999, 2000, 2001 a/, 2002

The effects of these activities are reflected in a different way in the main indices of energy consumption per capita. The electricity consumption per capita rapidly increases until 1990, but the primary energy consumption per capita reduces due to more rapidly increases of population than biomass production. Among 1990 and 1993 all the consumptions per capita fell (figure 19), as a result of the crisis. Although the electricity consumption is lightly bigger in 2001 than in 1990 (figure 10), the electricity consumption per capita is smaller, due to the population growth (figure 13). It is observed increases of primary energy consumption per capita in last years (crude oil and gas).

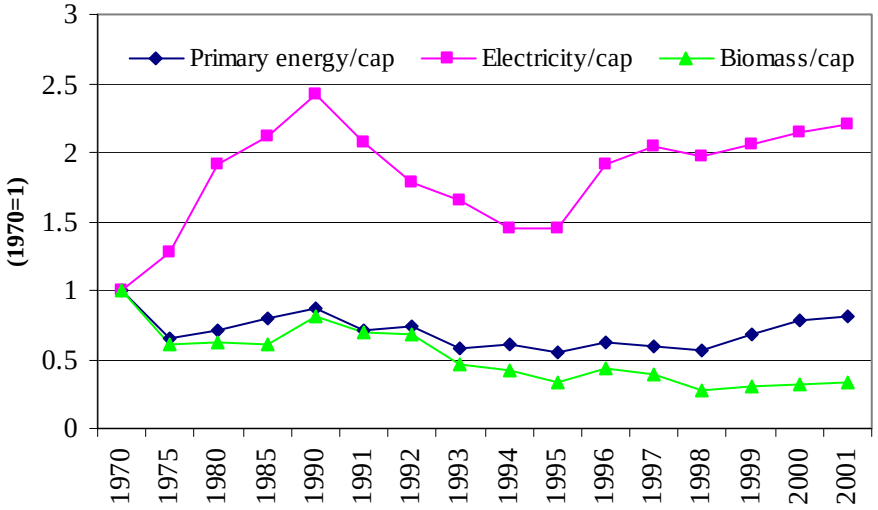

Figure 13. Energy consumption index per capita
Source: ONE, 1985, 1989, 1998, 1999, 2000, 2001 a/, 2002

However, the production of sugar cane increases from 1970 to 1990 (figure 14), the energy use of bagasse decreases in 1975 and had in the same period the lower increases due to non-energy use of bagasse (production of pulp, bagasse panels, etc.).

After 1990 the sugar cane biomass had a constant reduction due to the decreased of sugar cane availability (figure 14) fundamentally caused by the low prices of sugar in the world market, the lack of financial resources and fertilizers that produced an important reduction of the productivity (figure 15).

In 2002, a restructuring process of the sugar sector was implemented, which had been postponed in the past due to its social implications. 45.5% of the 156 sugar mills existing in the country were closed, and half of the surface given over to sugar cultivation was used to substitute food imports and to plant timbers. 25% of the labor force was reoriented to other production activities, after its re-qualification and/or professional reorientation.

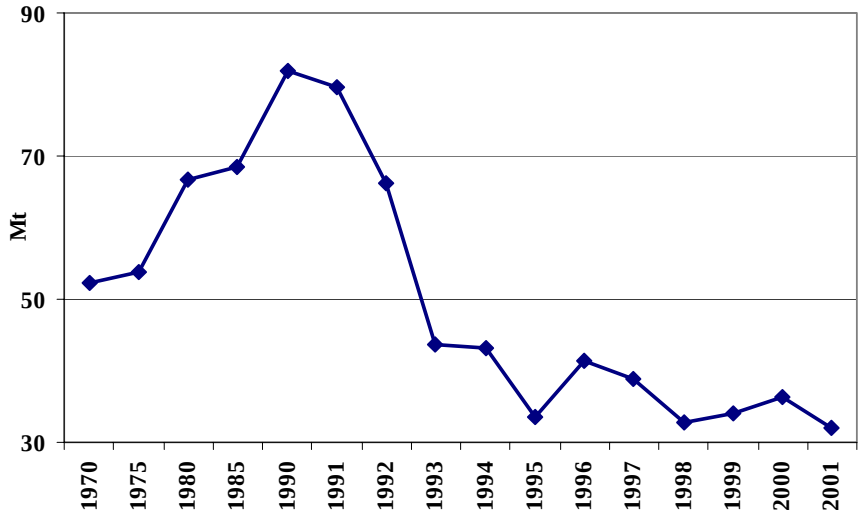

Figure 14. Sugar cane production
Source: ONE, 1985, 1989, 1998, 1999, 2000, 2001 a/, 2002

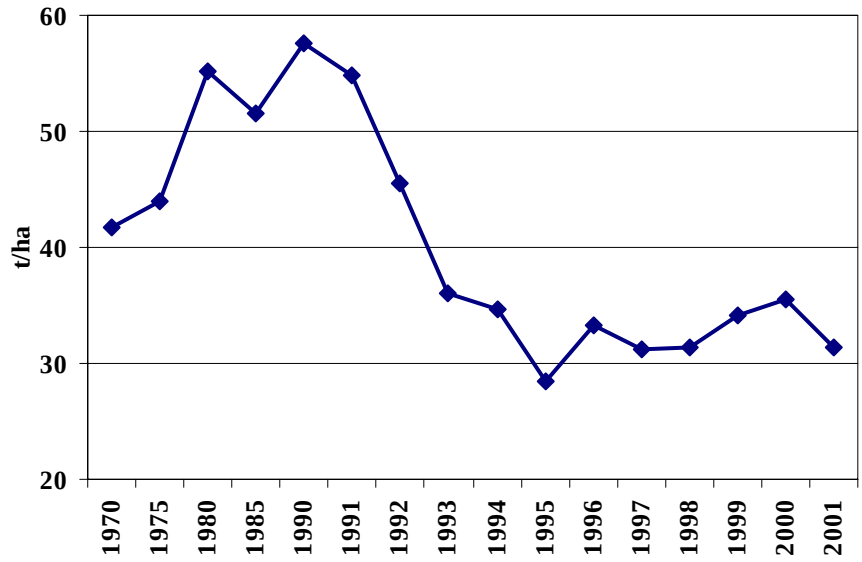

Figure 15. Productivity (sugar cane production per hectare)
Source: ONE, 1985, 1989, 1998, 1999, 2000, 2001 a/, 2002

The consumption per capita of biomass has not reached the levels that it had in 1990 due fundamentally to the decrease of the sugar cane biomass production by the causes that were explained previously and to the increment that has existed in the production of other fuels (LPG, city gas and electricity) to cooking in substitution of the firewood consumption and charcoal to this use. The consumption per capita of primary energy has increased since 1999 with the important increment in the consumption of domestic crude oil and associated gas.

The automotive fuel consumption has fallen, due to the decrease of transportation activities in the country during the last decade (figure 16). This behavior during the last years do not reflect the reality of the increases of transport in service sector, mainly related to the tourism development, because the statistics do not include the automotive fuel consumption in other ministries (Ministry of Tourism and private sector).

In 1994 the passengers and freight transportations had decreased in 80% and 88% respectively respect to the values of 1990 (figure 16), from this year a slight recovery begins, still reaching in 2001 smaller values in 64% and 63% respectively than the values in 1990.

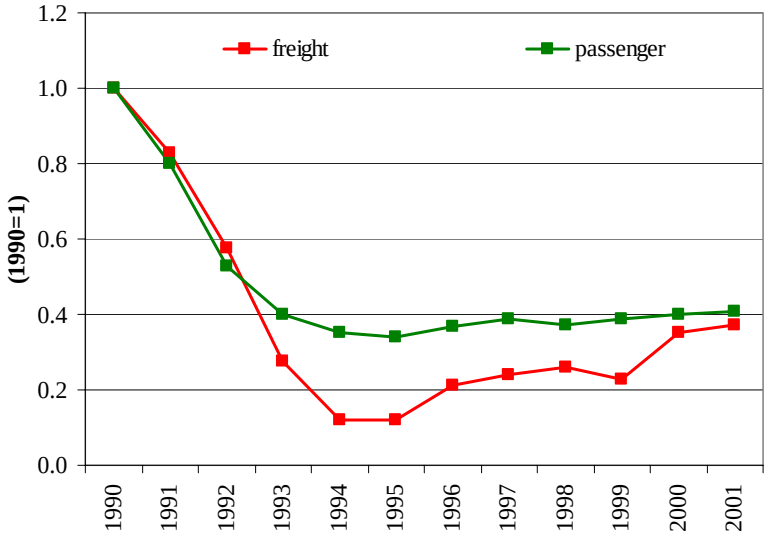

Figure 16. Index of Freight and Passenger transport activities
Source: ONE, 1998, 1999, 2000, 2001 a/, 2002

The electricity intensity in the last decade (figure 17 and 18), excluding fluctuations that happened in 1993 and 1997, it was conserved practically constant due to the programs of electricity saving, substitution of fuels to cooking, reduction of losses and increments in the efficiency of the thermal power plants by modernizations. However, the energy intensity of the total primary energy supply (figure 17) had a chaotic behavior caused first by the lack of fossil fuels for cooking that provoked the indiscriminate use of biomass, later on for the substitution of fuels (firewood and charcoal by gas and electricity) and finally for the important savings obtained from the saving and efficiency programs.

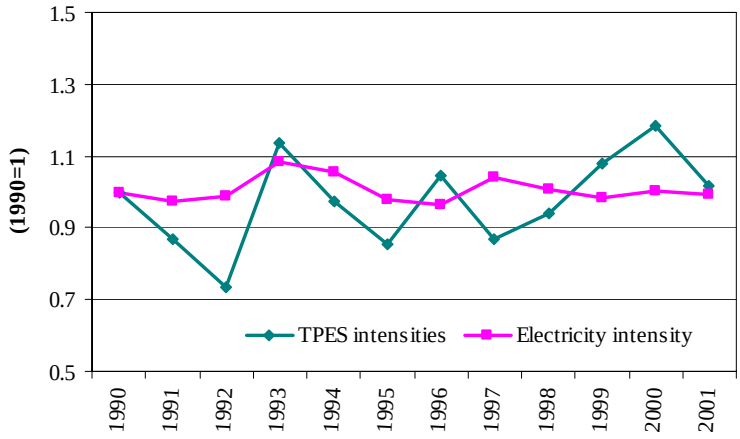

Figure 17. TPEs and electricity intensities
Source: ONE, 1998, 1999, 2000, 2001 a/, 2002
Note: In 1990, the TPES intensity was 0.39 toe/1000 US$-ppp 2000, and the electricity intensity 0.34 kWh/1000 US$-ppp 2000

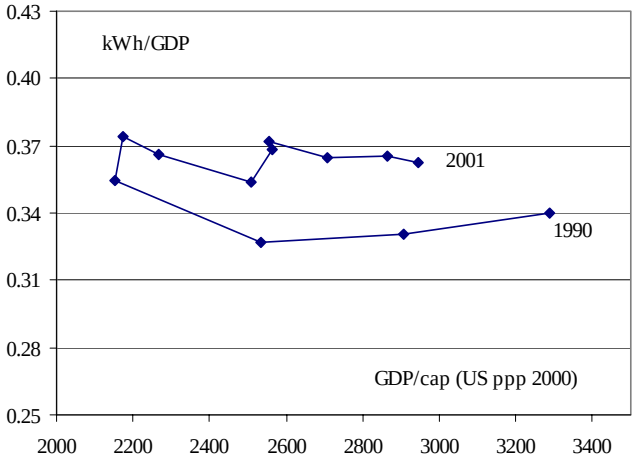

Figure 18. Electricity intensity and GDP per capita[6]
Source: ONE, 1998, 1999, 2000, 2001 a/, 2002

- **Structural effects**

The Cuban economy has had important structural changes. Until half of last century, the country was practically farming with a moderate industrial development only in the related to the sugar industry. Since 1959, an industrialization process begins, being developed industries of great energy consumption like nickel, steel, cement, machineries, etc. The weight of the commercial and services sector also grow notably.

During the crisis of the 90´s a contraction of the manufacturing sector took place (figure 19) due to the fall of the added value generated by the sector within the total added value, the partial closing of industries, the decrease of production (figure 20) due to the lack of raw materials, etc. However, the commercial and services sector occupy a more predominant role. The participation of agriculture in the GDP decrease whiles the participation of transport sector increase.

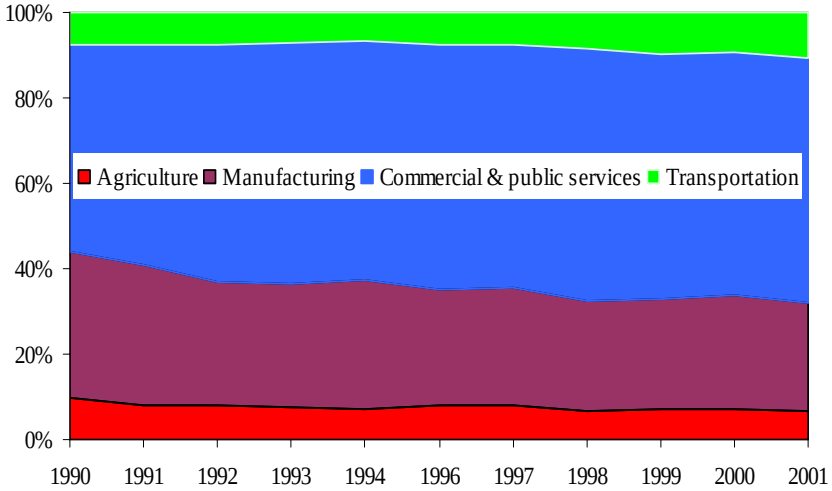

Figure 19. Share of added value by sectors

[6] The Purchasing Power Parity (PPP) is under development by the National Institute for Economic Research. In this paper the PPP, reported by the International Energy Agency (IEA) was used in the absence of domestic data.

Source: ONE, 1998, 1999, 2000, 2001 a/, 2002

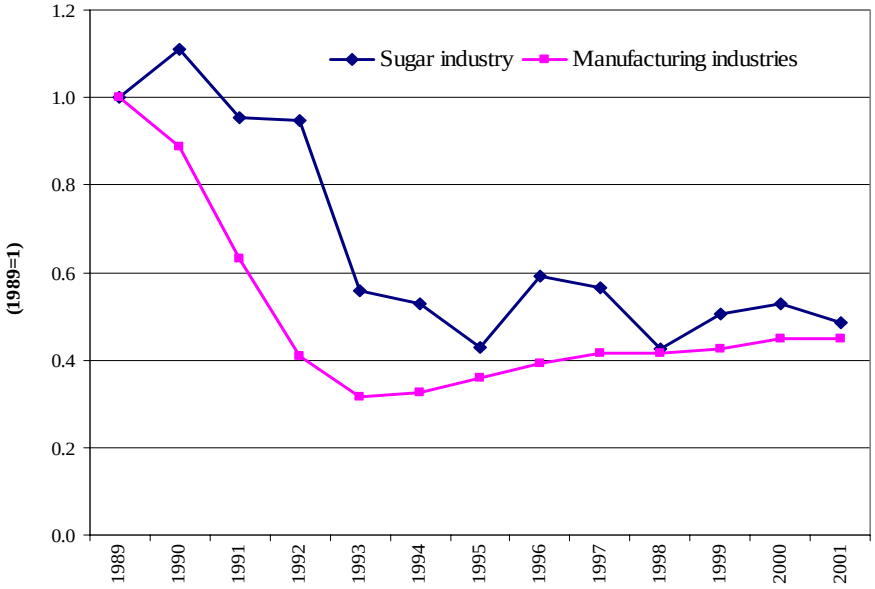

Figure 20. Index of industry production
Source: ONE, 1989, 1998, 1999, 2000, 2001 a/, 2002

The total energy use per unit of GDP or aggregated energy intensity indicates the general relation of energy consumption to economic and social development. The analysis of reduction of this aggregated indicator can provide an incorrect view of the economic and social development. It is necessary to analyze more desegregated indicators to see the real situation.

Manufacturing is the more energy and electricity intensive sector (figure 21 and 22) that consumes 60% of the total energy and 32% of the total electricity consumption of the country. The energy intensity was drop during the firsts years of the crisis, but later on, except during 1993-1994 that had a slightly increases, continue the decreases due to effect of energy saving and efficiencies programs.

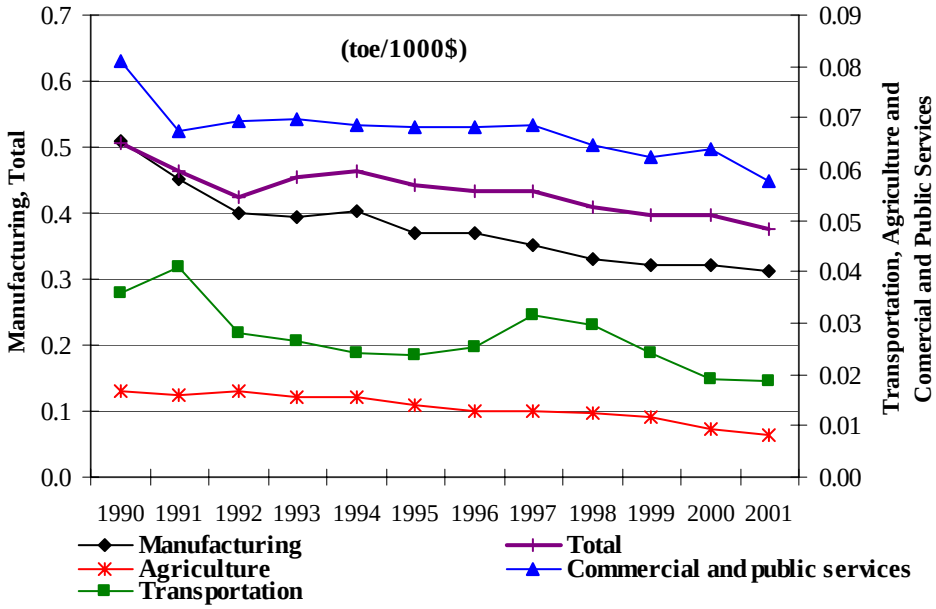

Figure 21. Final energy intensities by sectors
Source: ONE, 1998, 1999, 2000, 2001 a/, 2002

The total electricity intensity, except with fluctuations that occurred in 1993 and 1996, slightly increases and was managed to keep practically at the same level due to energy saving programs, fuel substitution for cooking, loss reduction, and increases in efficiency because of modernization and changes in industry and services. The electricity intensity reduction in the manufacturing sector was compensated by it increases in the services sector.

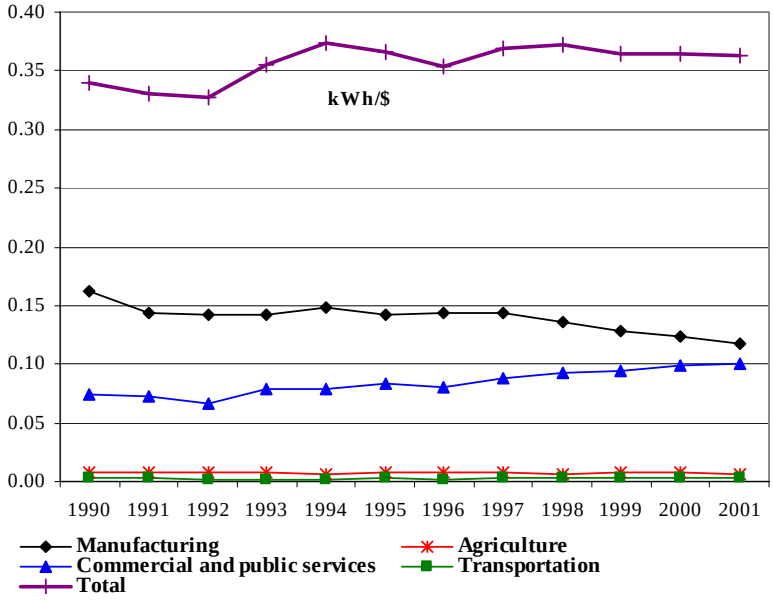

Figure 22. Electricity intensities by sectors
Source: ONE, 1998, 1999, 2000, 2001 a/, 2002

- **Technological effects**

<u>Supply side</u>

The increment of the production and use of the domestic crude oil to electricity generation and cement production has been important, allowing that in 2003 the whole electricity generation is carried out with national fuels, that has meant an important result of the police taken by the Government in the elimination of the external dependence in this strategic activity of the national economy.

The associated gas (that was burned without energy use) began in 1998 to be used for the electricity generation and the city gas production. On the other hand, the modernization and adaptation of the thermoelectric power plants have allowed reducing the specific fuel consumptions; the maintenance and investments in electric grids and the measures adopted to reduce the commercial losses have allowed decreasing the total losses up to 18.1% (figure 23). Nevertheless, they are still higher than in 1985.

The refinery production was increased until the crisis to drop in 4.3 times in 1995 and was maintaining at this level more or less. Slightly recuperation occur during the last two years, although they are 2.8 times lower than in 1990 (figure 24). Beside, it carried out important improvements in the transportation of fuels with the construction of pipelines that communicate the supply and more important consumption points.

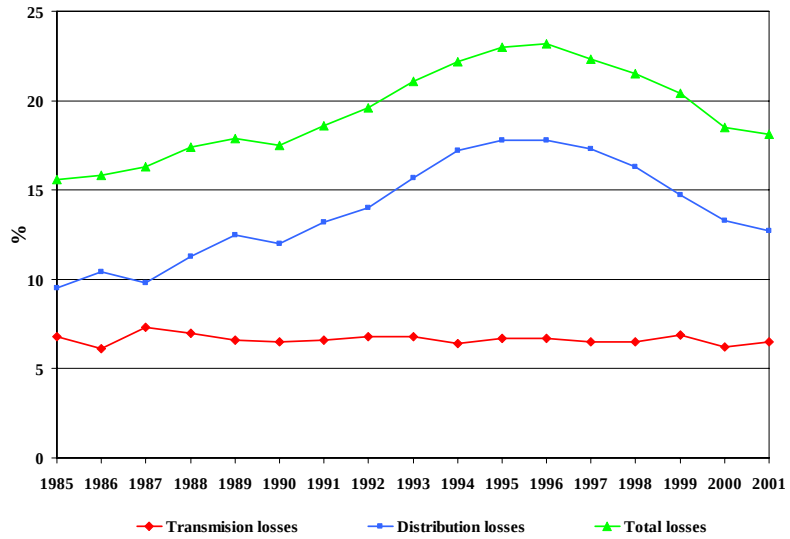

Figure 23. Electricity losses
Source: UNE, 1990-2002

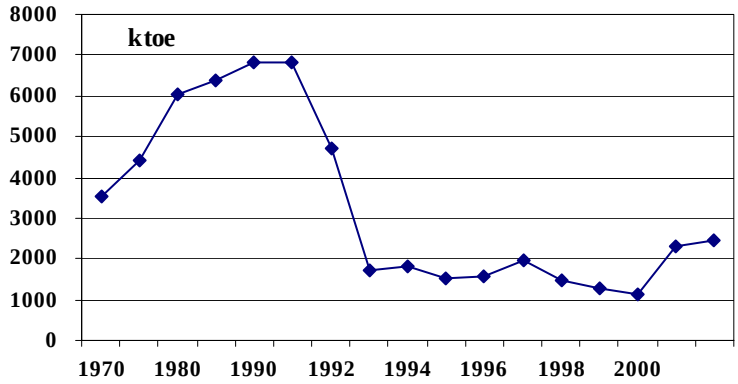

Figure 24. Refinery production
Source: ONE, 1985, 1989, 1998, 1999, 2000, 2001 a/, 2002

Demand side

Since 2002, a new electricity tariff system enters into effect (MFP, 2002). It propitiated the electricity saving, although exist part of the public sector that paid it in national currency and it does not cause the necessary incentive.

The Cuban Electricity Saving Program has had an important influence in the reduction of the demand and electricity consumption, that it has allowed the non-installation of more than 150 MW, the reduction of the maxim demands growth rhythm, etc. In this program, load regulators were dedicated to the main consumers, achieving adjustments and reduction of their demands. With the obtained savings it was subsidized the sale of lamps, fluorescent tubes and thrifty bulbs to the population.

5.2 Reduce the energy dependence

As a result of implementation of the National Energy Sources Development Program in 2001 respect to 1991 was possible to increase in more than 6 times the domestic production of

crude oil and in more than 17 times the associated gas (figure 25), that are used to cover in 2003 the 93% of the whole electricity generation of the country, allowed to decrease the use of naphtha in city gas production and is used in cement production. This availability of fuels allowed to increase the electricity generation since 1994 (figures 26) after the abrupt decreased occurred between 1990 and 1993.

These actions permit to reduce the import dependence. It can be lower if the sugar cane agro-industry will not continue depressed.

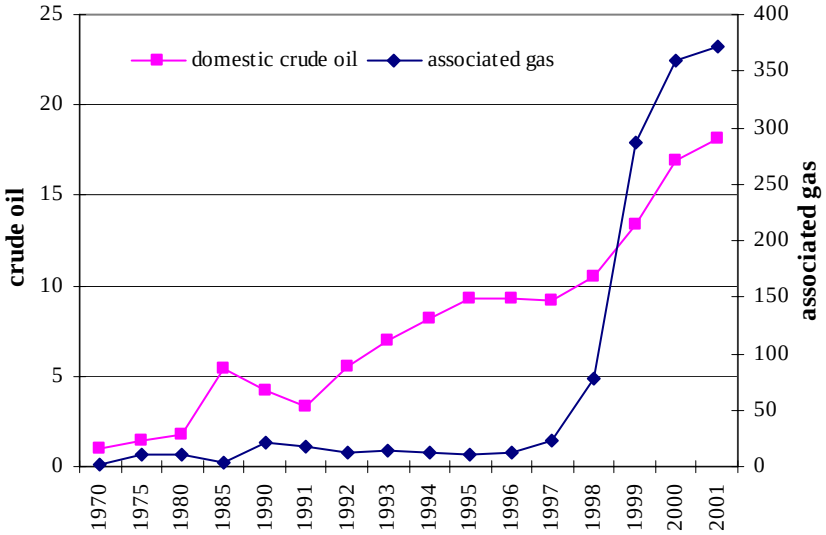

Figure 25. Index of crude oil and associated gas production
Source: ONE, 1985, 1989, 1998, 1999, 2000, 2001 a/, 2002

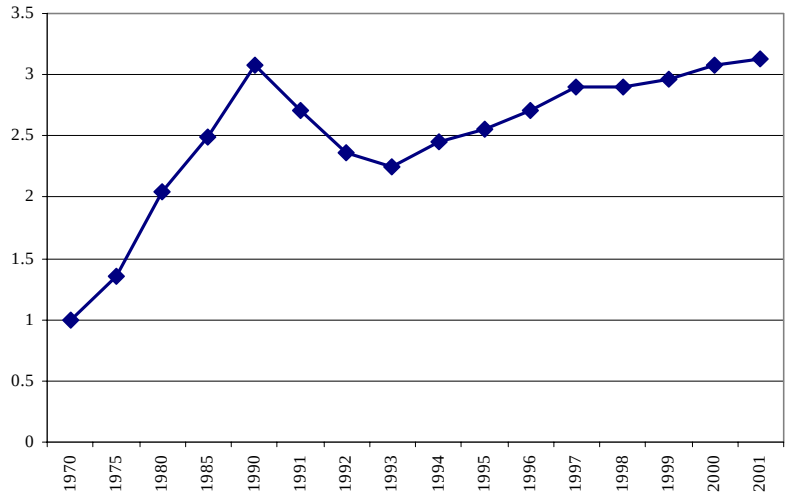

Figure 26. Index of electricity generation
Source: ONE, 1985, 1989, 1998, 1999, 2000, 2001 a/, 2002

The energy dependence of the country (total energy imports) rose smartly from 50% in 1970 to 71% in 1985 with stable supply of crude oil and hydrocarbons at preferential prices, from the former Soviet Union. Later on a decrease begun because of economic changes that took place.

The reduction of energy dependence became stronger with the crisis of the 90´s, which together with the lack of financial resources for the import of fuels, saving programs developed by the country, substitution of fuels and mainly with the increase in the production

of national crude oil and associated gas, enabled to diminish up to 45% in 2001 that it is inferior to the dependence of the 70´s (figure 27). However, this dependence could have been smaller if the sugar industry did not continue depressed.

A detailed assessment of energy dependence shows that up to 1990 the levels of primary energy imports were in the order of 40%, but then they decreased up to 15% (because of the increase in the national production of crude oil and associated gas). However, the imports of petroleum products rose up to 47% in 1995 due to low levels of refining, which then increase. Crude oil and petroleum product imports increased among the years 1990 and 1997 reaching 48.8%, they decreased since this year up to 29.7% in 2001, having a decrease of 7.3% for the whole period (figure 27).

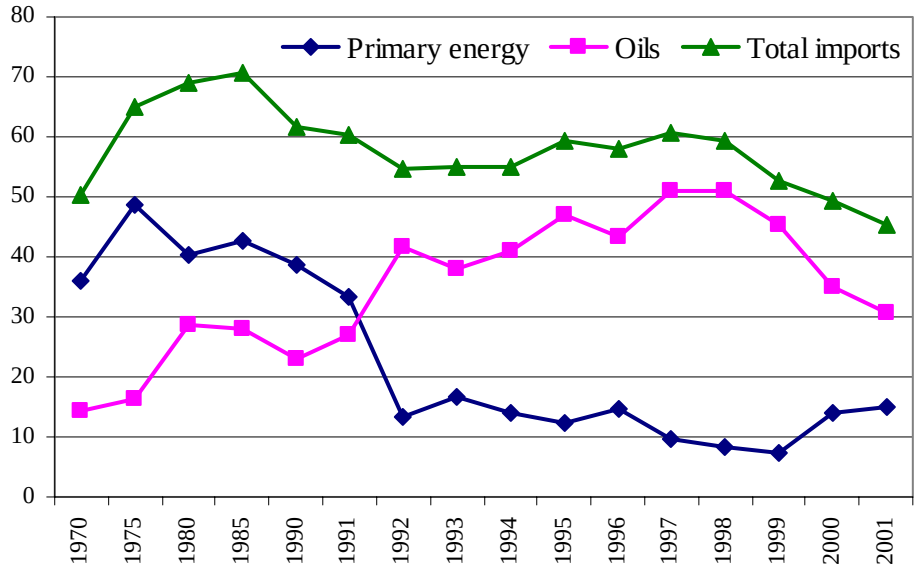

Figure 27. Energy imports dependence, %
Source: ONE, 1985, 1989, 1998, 1999, 2000, 2001 a/, 2002

5.3 Increasing the renewable energy source's participation in the solution of social issues

Before 1959, only the 56% of the total population had access to the electricity, not for the possibility of physical access, but for lack of revenues that allowed it to them. The Government took the electricity up to where economically it has been possible achieving that in 2001 the 94.8% of total population had access to it (figure 28), while it is in execution a program to achieve 100%, evaluating the feasibility of the different supply sources for it: extension of the grid, photovoltaic panels, mini-hydroelectrics, wind generators, hybrid systems and biomass.

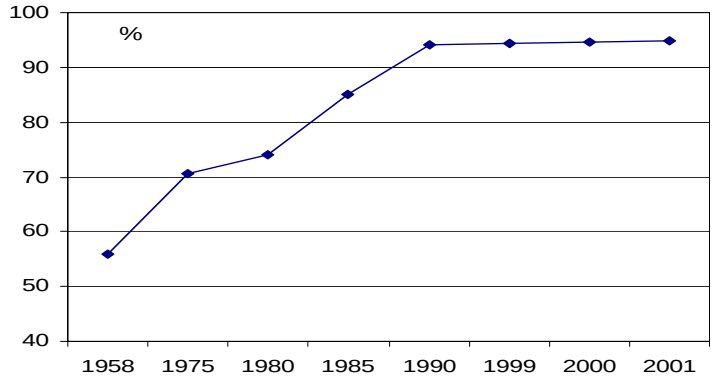

Figure 28. Electrification level
Source: ONE, 1985, 1989, 1998, 1999, 2000, 2001 a/, 2002

In Cuba the 5.2% of the total population depends on the non commercial sources of energy (population that doesn't have access to the electricity) and they live in isolated rural zones and mainly in mountainous areas, although is possible to obtain a bigger precision of this value when the results of the census of 2002 are available. For the geography of Cuba the oriental area is the most mountainous and it is considered that there the 87% of population only has electricity.

In this electrification process at the end of 2002 a capacity of 1.49 MWp (Wp-peak watt) was installed in photovoltaic systems, with which 350 medical clinics, 5 hospitals, 2364 primary schools, 1864 television rooms, 150 social centers, houses, rural boarding schools, camping centers, television broadcasting stations, phone rooms, fishing storing centers and cooperative communities (small enterprises dedicated to agriculture) have been electrified.

The average electricity consumption in the residential sector grew from 82 kWh/house/month in 1970 up to 131 kWh/house/month in 2001, as a result of the increase in the living standards (1.3 times the value of 1990). The electricity consumption growth in households has been limited by restrictions imposed in the acquisition of electric appliances, although other factors have also had a considerable effect of the introduction of highly energy-saving appliances, subsidized programs for changing the refrigerators' rubber seals, the change of lighting bulbs for energy-saving bulbs, the broadcasted energy saving campaigns, the gradually increasing electricity charges, etc.

The figure 29 shows the electricity consumption in residential sector. It increases, except reduction of the 90's crisis with the rapidly increment in the last years.

The manufactured gas, LPG and firewood have had an important increase in the households energy consumption: 2, 2.5 and 7 times respectively in 2001 with regard to 1990, although it is part of the supply reduction of kerosene 56%, alcohol 32% and charcoal 55% which is used mainly in rural areas for cooking.

The behavior of the residential energy consumption and population by year and by energy resources (figure 30) shows the substitution of fuels occurred in the period: kerosina, alcohol, and wood by GLP, city gas and electricity. At the level of 10.8 million inhabitants can be observed the effect of the crisis of 90´s. The figure 31 shows the indices of the final energy consumption per capita in household sector during evaluated period.

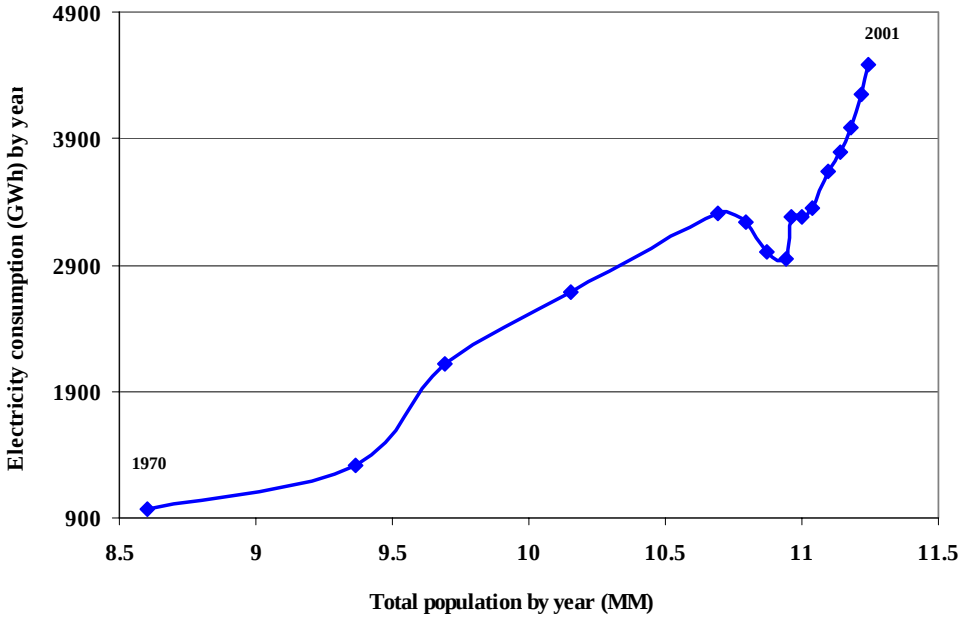

Figure 29. Electricity consumption (household sector) and total population
Source: ONE, 1985, 1989, 1998, 1999, 2000, 2001 a/, 2002

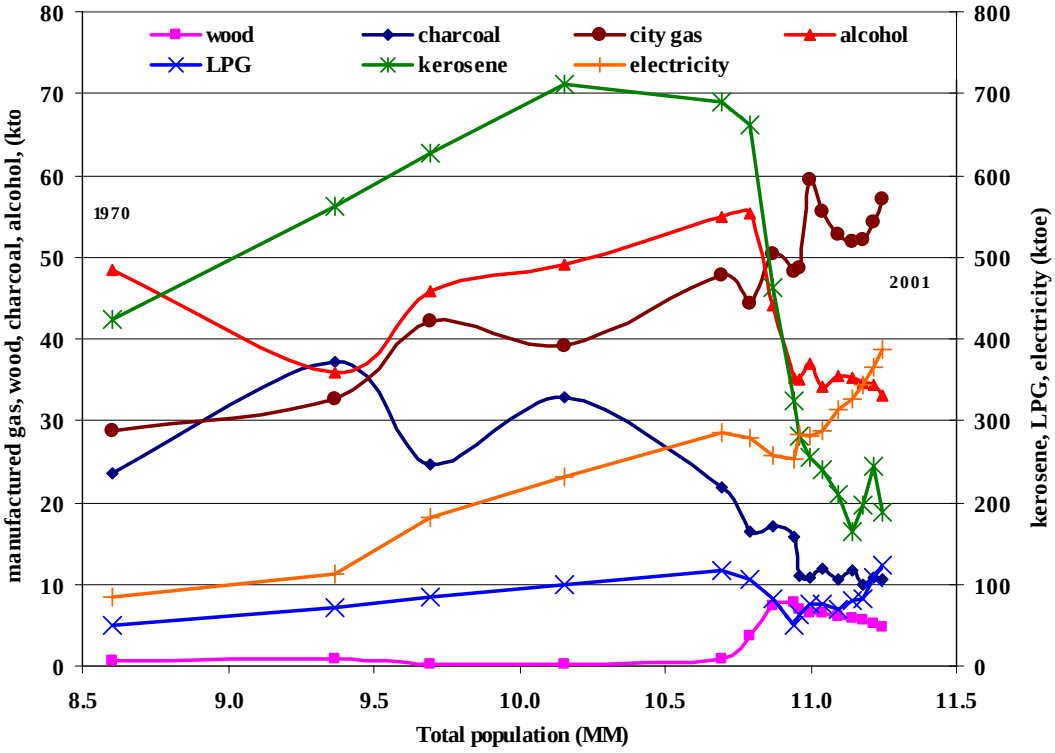

Figure 30. Energy consumption in residential sector and total population by year
Source: ONE, 1985, 1989, 1998, 1999, 2000, 2001 a/, 2002

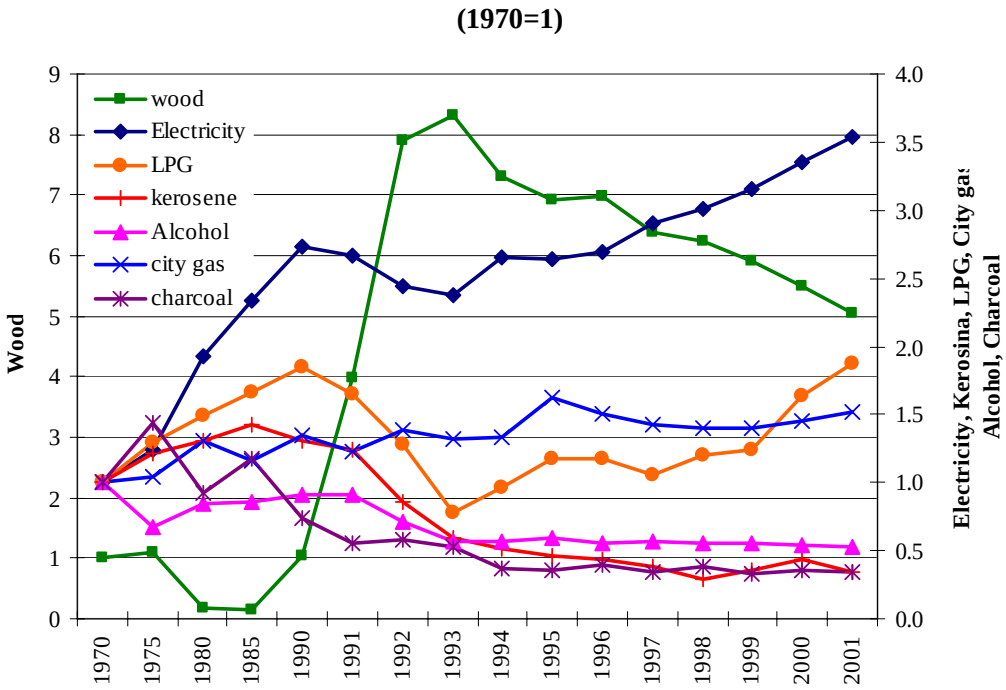

Figure 31. Final energy consumption per capita in household sector
Source; ONE, 1985, 1989, 1998, 1999, 2001 a/, 2002

The covering of supply and healing of water have a high social impact and has increased its reach sustainable. In the 80´s decade, the volume of water given to the population grew 4 times, increasing in three times the communities with access to this service and its quality. These achievements allowed that in the 90´s decade the objectives in this service were to improve the services of the rural, near of urban and subjected to extreme conditions of drought areas. With the lack of resources during the crisis, these objectives were postponed and were added to them, at the end of this decade, as primordial objective the recovery of the appropriate levels of potability of the water that had been reached with the program begun in the 60´s decade. The potability levels in this moment have been increased but it continues being a high-priority task.

In the 2001, the 85.3% of total population had potable water and 83.9%. Where is possible, mainly in rural areas the service of supply potable water are used renewable energy.

In 1995, the program of using the capacities of different reservoirs for electricity generation started. Also, very small hydroelectric power plants were built mainly for electrification of isolated regions. Figure 33 shows the reduction in the existing hydropower capabilities that are not in use. The estimated hydroelectric potential is roughly 650 MW. Only 57.4 MW of this potential are exploited at present. Around 50% of the theoretical potential is in the Toa-Duaba basin, which is a protected area due to the number of endemic species that it has. Owing to the implications to the environment, this potential will not be exploited.

Hydropower generation fluctuated during the period depending of the rain levels (see figure 33), but small hydroelectric plants increased their share. At the end of 2002, 169 hydroelectric power plants were in operation. Their installed capacity reached 14.7 MW (ONE, 2003).

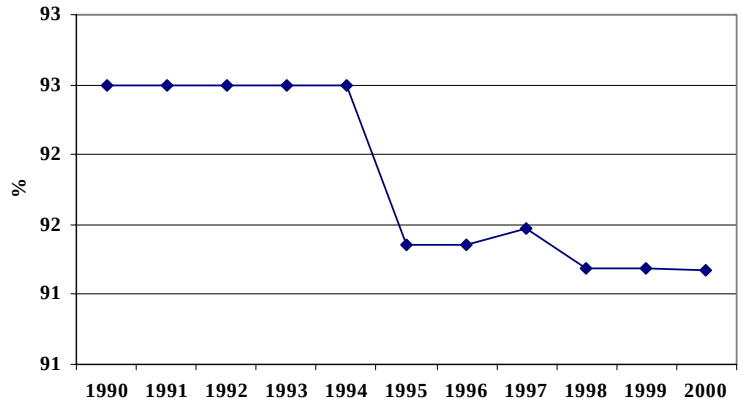

Figure 32. Fraction of technically exploitable capability of hydropower currently not in use. Source: ONE, 2003

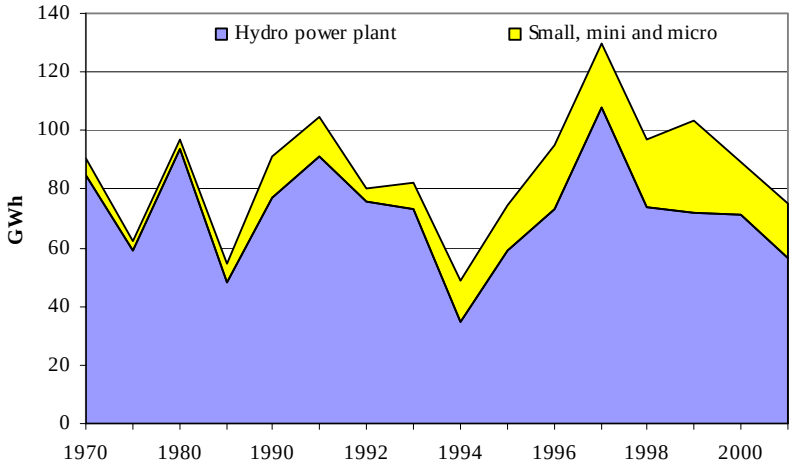

Figure 33. Hydropower Generation
Source: ONE, 2003

In 2000, the intensive Social Program of Rural Electrification began. It included the electrification of isolated schools (more than 2300), rural hospitals and other social objectives. At the end of 2002, 5318 photovoltaic systems were installed (ONE, 2003).

Considering other renewable projects, at the end of year 2002: 6767 windmills were used for water pumping, 139 biogas digesters, 7 wind generators and 45 hydraulic ram pump were installed in the country (ONE, 2003).

The participation of biomass was discussed in previous paragraph.

5.3 Energy efficiency improvement

The efficiency analysis is very difficult to do during the crisis period. The influences of some factors are contradictory. At the beginning, the introduction of new power plants in the 70´s and 80´s reduce the specific fuel consumption, but the use of crude oil in power plants in 1992-1993 (designed to use fuel oil) reduced the efficiency of the electricity generation and increased the specific fuel consumption as shown in figures 34 and 35. The implementation of different organizational measures, in the operation of the electric system, and the connection of two new units (250 MW and 100 MW) to the grid enable: to reduce the operation of less efficient power plants, to increase the average efficiency of the system, and to reduce the

specific consumption in 1996-1997. During 1997-1998, the Safe Electricity Program, the modernization process of 100 MW units, and the conversion program of power plants to use domestic crude oil contributed to increasing efficiency.

In 1998, associated gas was used in electricity generation. It reached 6.7% of the total generation in 2001, as shown in figure 9. These actions continued the efficiency increase and reduced the specific fuel consumption in electricity generation. Nevertheless, the specific fuel consumption was lower than in 1990, but the fossil fuel efficiency in 2001 is higher than in 1990 in more than 1%.

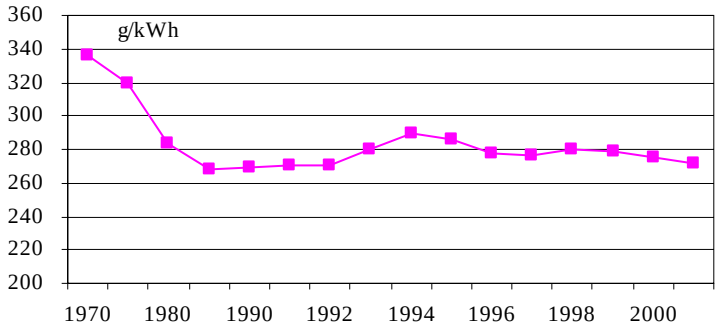

Figure 34. Specific fuel consumption in electricity generation
Source: ONE, 2003

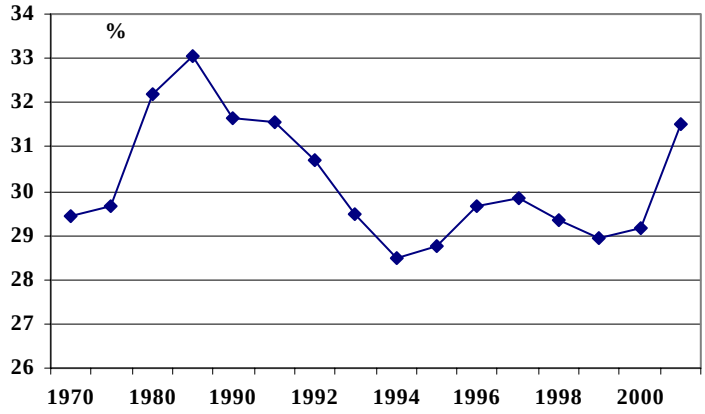

Figure 35. Fossil fuel efficiency in electricity generation
Source: Authors elaboration from ONE, 2003 and UNE, 2002

The efficiency of transformation of primary energy supply to final energy carriers delivered to consumers is measured using different indicators. The ratio of total final energy consumption to the total primary energy supply (TPEs) had a chaotic behavior (figure 36). In the 80´s, the TPEs increases (mainly in sugar cane industry) and the enhancement of the efficiency in electricity generation predominated. During the 90´s crisis, the transformation efficiency was decreases drastically and the ratio of total final energy consumption to TPEs increases. Later on this indicator was affected by the overall reduction of TPES (sugar cane, substitution of imported crude by the increases the domestic production), but at the same time the increases in petroleum by products imports.

From 1997, this indicator continuously was reduced due to increases in the TPEs (crude oil and gas).

The participation of the electricity supply from cogeneration heat and power plants (CHP), sugar cane industries in case of Cuba, decreased during the intensive period of

economic and social development 1959-1989 due to rapidly increment of the power sector based in thermal power plants. Nevertheless, the cogeneration of the sugar sector increases in 65% (figure 37), but after 1990 this participation was substantially reduced accordingly the sugar cane production changes.

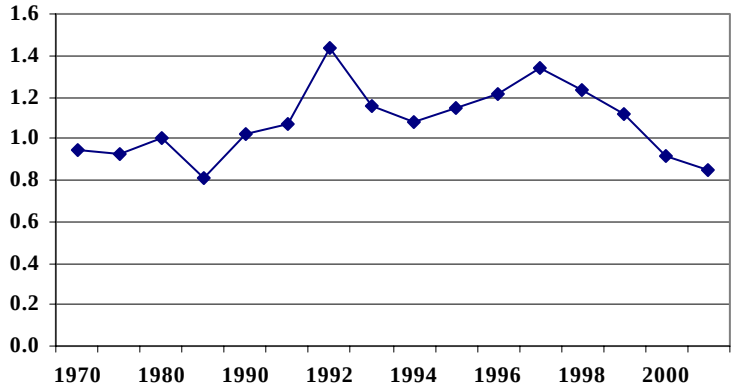

Figure 36. Ratio of total final energy consumption to total primary energy supply
Source: ONE, 2003

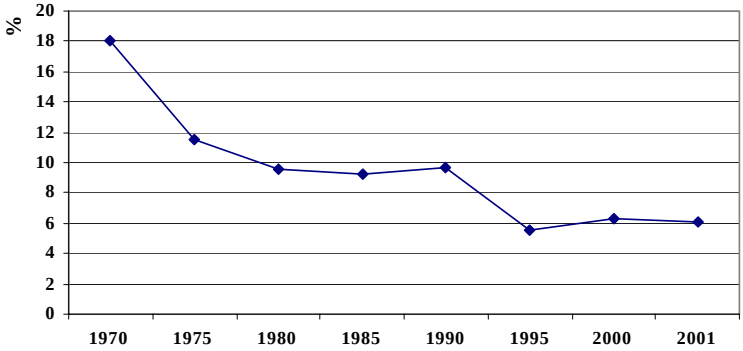

Figure 37. Electricity supplies from CHP
Source: ONE, 2003

Oil refining efficiency (figure 38) calculated as a finished light product output per unit of crude oil fed at the refineries had the overall tendency to increases after the changes suffer during the 90´s crisis, where the refinery production was reduced substantially.

The oil refining efficiency behavior was mainly due to changes in the share of output products. The gasoline and LPG production was increase, but the share of heavy products production (fuel oil) on the average decreased. The overall refinery production was decreased (figure 39).

The economic crisis did not allow adequate maintenance of transmission and distribution (T&D) lines. Half of them have more than 20 years of exploitation. The gauge change of electric lines was stopped. Inadequate distribution of power plants (far from consumption centers) requires increasing the electricity transfer. Illegal connections to the electricity grid were increased during economic crisis. These implicated the rapid increase of the electricity losses (mainly the distribution losses) as was shown in figure 23.

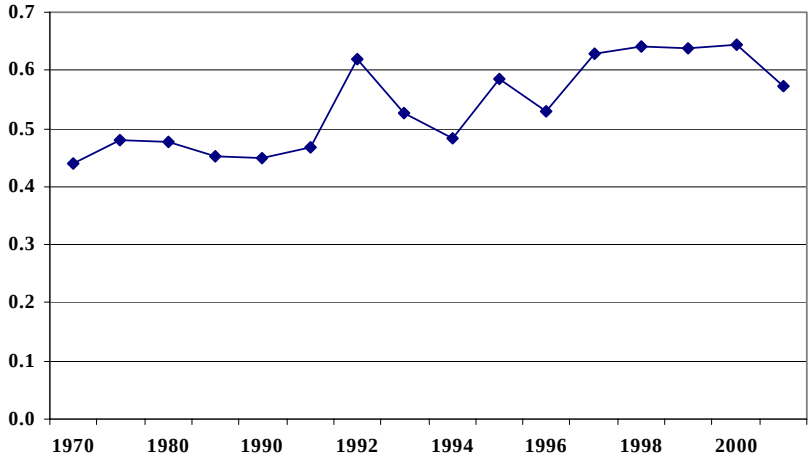

Figure 38. Oil refining efficiency
Source: Authors elaboration from ONE, 2003

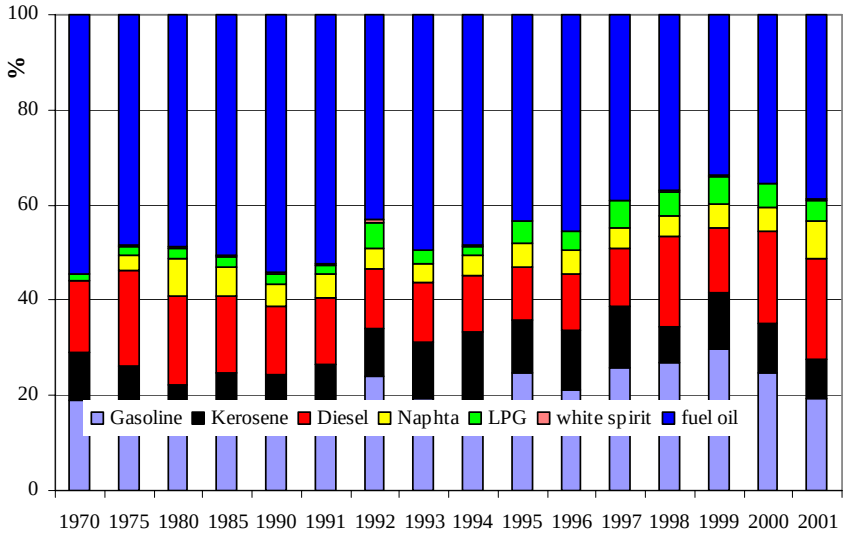

Figure 39. Share of refineries output products
Source: Authors elaboration from ONE, 2003

After 1997, the illegal electricity consumption was cut. Thousands of electricity counters were installed and organizational arrangements were implemented. The maintenance of transmission lines was reestablished. These actions and the changes in the tariff system initiated the reduction of T&D losses.

The Energy Not Served (ENS) shown in figure 40 indicates the critical situation of the electricity supply mainly during 1992-1995. The ENS in 1993 accounted for the 12.4% of electricity served this year.

The Electricity saving program, the demand side management program and the new tariff system, as can be observed in figures 41 and 42, increased the electricity demand outside peak hours and did not increase the peak demand while the consumption was increased.

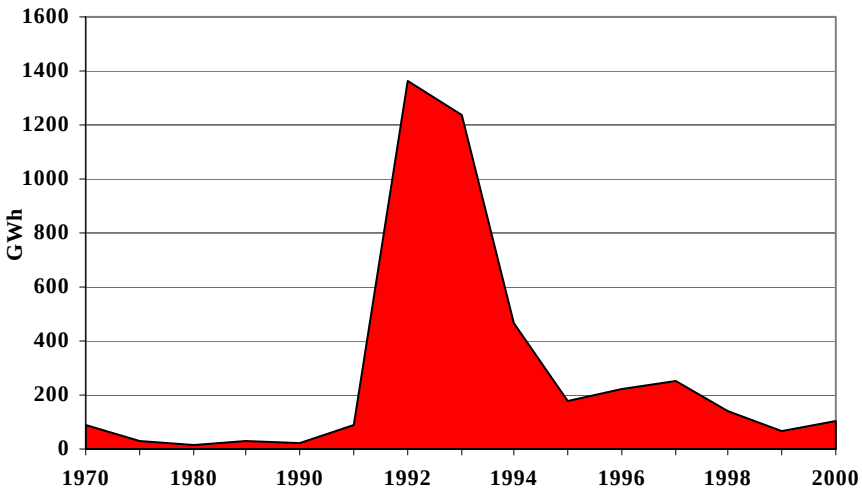

Figure 40. Energy Not Served
Source: ONE, 2003

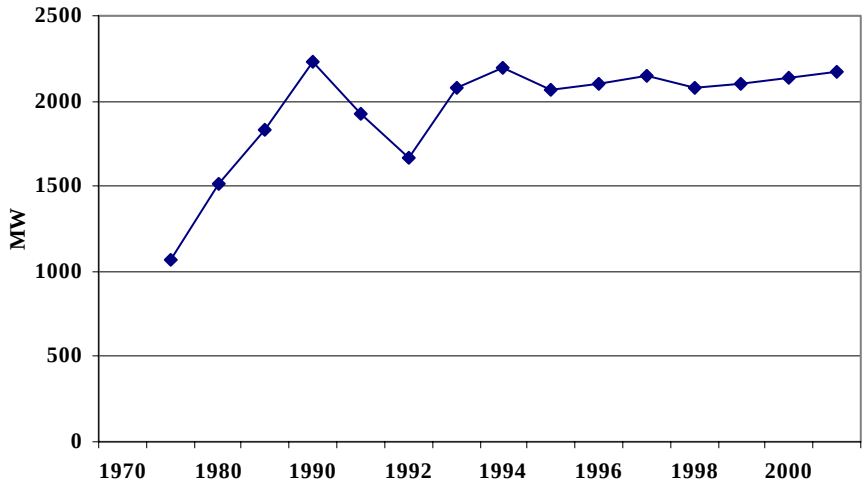

Figure 41. Electricity peak demand growth index
Source: UNE, 2001

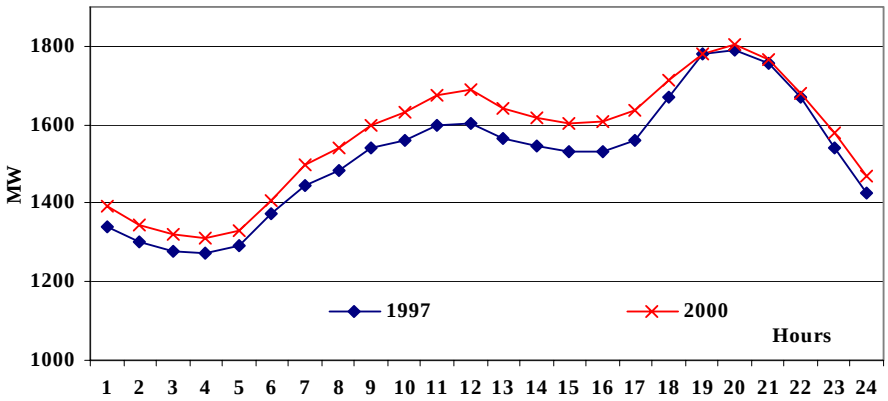

Figure 42. Average hourly demand
Source: UNE, 2001

5.5 Influence of the energy policies on the environment

The environmental implications of the Cuban energy development will be analyzed by the local and global influence of the pollutants emission, taking into account the prevalence of the fossil fuels in the energy system. On the other hand, the local effects of SO_2 emissions from national crude oil use are considerable.

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

- **Greenhouse Gases (GHG)**

The CO_2 emissions from the energy activity constitute around 95% of the total emissions of CO_2 of the country (figure 43)[7]. The main sources of these emissions are the energy industries and the manufacturing and construction industries.

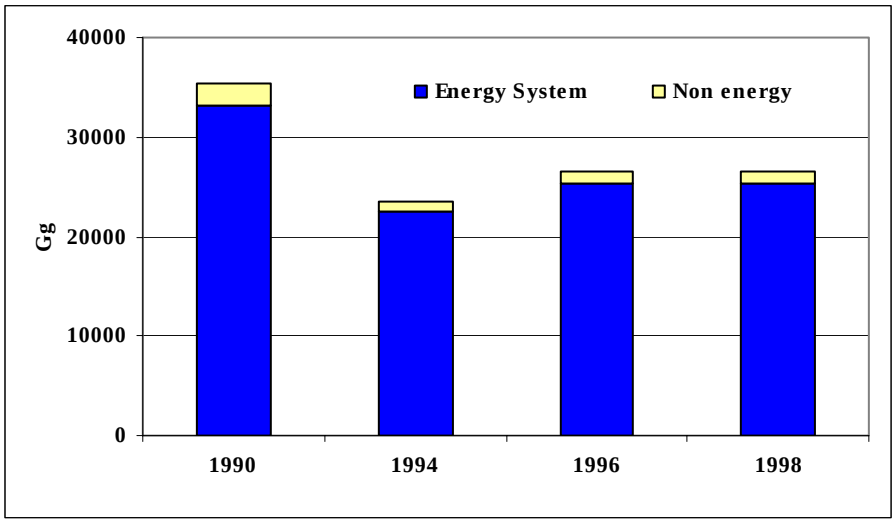

Figure 43. Contribution of energy sector to the total CO_2 emissions
Source: CITMA, 2002; CITMA 2003.

In 1990, the total CO_2 emissions from energy activities were 33155 Giga-grams (Gg) of CO_2. That year, 17527.36 Gg of CO_2 constituted absorptions for the change in the land use[8] (figure 44).

In 1994, due to the economic crisis, the consumption of fuel in the country diminished in 43.8% compared with 1990. The emissions of CO_2 from energy sector decreased in 31.8% and the absorptions increased 13.3%.

From 1994, with the economic recovery, the emissions of GHG from energy sector were increased reaching in 1998, 76.4% of the CO_2 emissions reported for the year 1990. The absorptions have been increased; overcoming during 1998 the figure reached in the year 1990 in 50%.

[7] 1998 estimations are under review
[8] Protected areas are not included

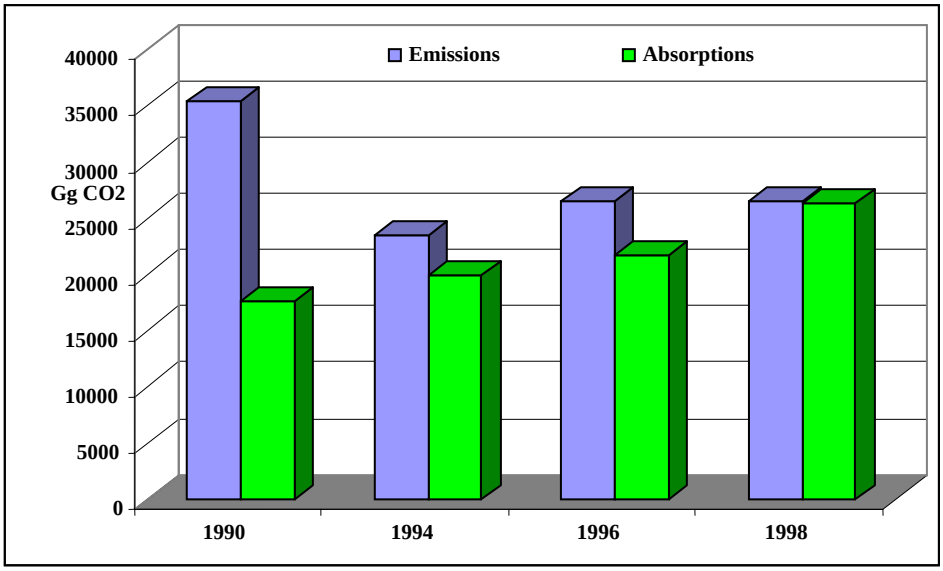

Figure 44. Emissions and Absorptions of CO_2 in the country
Source: CITMA, 2002; CITMA 2003

The contribution of the energy sector to the emissions of CH_4 is lower in comparison with the CO_2. For the years 1990 and 1994, this contribution was 0.6%. However, from 1996 an increase takes place due to the increment of the petroleum and the associate gas activities, reaching in 1998 4.5% (figure 45).

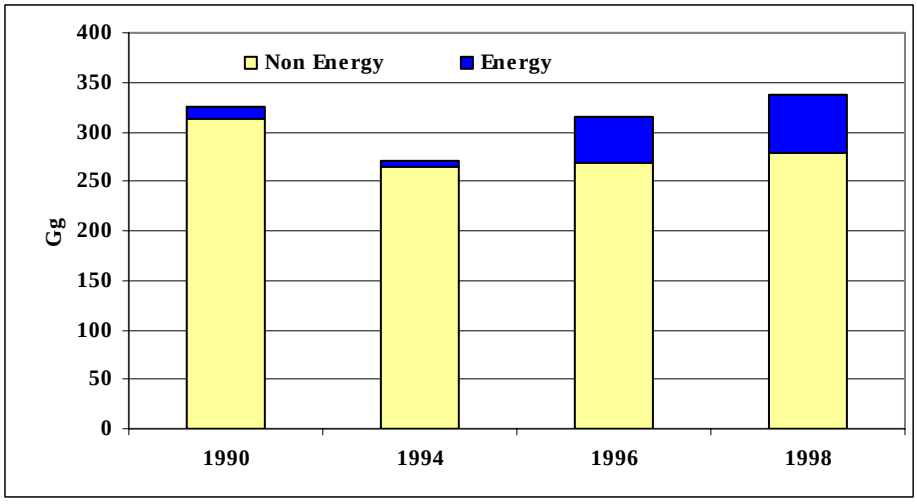

Figure 45. Contribution of energy sector to total CH_4 emissions
Source: CITMA, 2002; CITMA 2003

The N_2O emissions from the energy sector are small, constituting in average 0.98% of the total emissions of the GHG in the sector (figure 46).

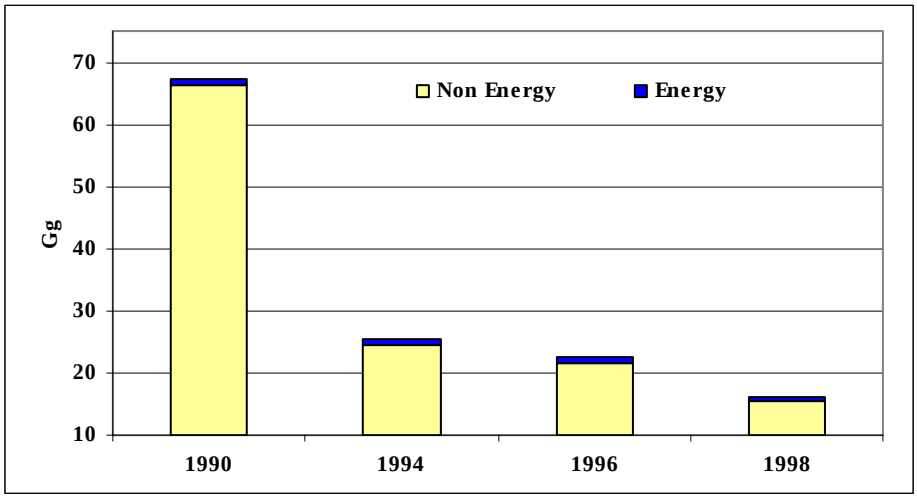

Figure 46. Contribution of energy sector to total N_2O emissions
Source: CITMA, 2002; CITMA 2003

- **Air pollutants**

The emissions of SO_2, NOx, CO and COVDM coming from the energy activities diminished in 1994 due to the decrease in the fuel consumption (figure 47). From 1996, these emissions begin to grow but only the SO_2 reaches the levels of 1990 due to the national crude oil use. The emissions of SO_2 of 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 industry.

The CO emissions in the energy system are fundamentally associated to the transport and to the bagasse burn. In 1996, the emissions of CO reached 63.5% of 1990 emissions.

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

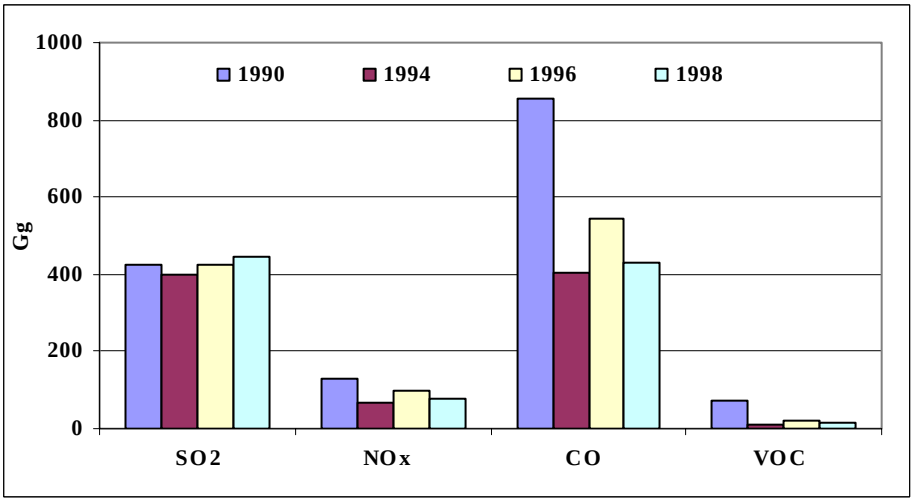

Figure 47. SO2, NOx, CO, VOCDM emissions from energy sector
Source: CITMA, 2002; CITMA 2003

- **Affectations to the air quality**

In the last years an increase of the mean concentrations of gaseous oxidized compounds has been observed (CIGEA, 2001; CIGEA, 2003). These compounds are the main precursors of the rainfall acidity, and they can cause diverse harmful effects in the terrestrial and aquatic ecosystems. The emissions caused by the industrial and agricultural sources are the main responsible for this increment. The concentrations of these compounds have increased in correspondence with the recovery of the economy (figure 48).

The data of the mean annual concentrations of pollutants are obtained in the main monitoring stations of the country and these data correspond to different existent polluting sources (not only from energy activities). For this reason, we consider more useful the results of local studies that are made in areas where energy industries are located.

Due to the economic crisis the monitoring systems in the country have suffered a deterioration which has influenced in the quantity of studies carried out. On the other hand the results of this type of studies are not included in the national statistics which hinders the access to them.

In the country are areas where the quality of the air is seriously affected. Among these areas is the area miner-metallurgist of the north of Holguín, the area of Mariel (thermal power plant, cement industry), and the City of Havana.

A study carried out in the year 1999 by Cuesta O. et al. (2003), of the Atmospheric Environment Research Center, Meteorological Institute, in the eastern area of Havana Bay, where important urban areas converge with a great industrial concentration (thermal power plant, refinery, food industry, port activities, constructions and naval repair), determined that the emissions associated to the refinery process and the rest of the polluting sources are affecting the quality of the air in the area. The H_2S is the main pollutant, reaching concentrations that surpass between three and twenty seven times the acceptable maximum concentration established in the Cuban Standard of Air Quality.

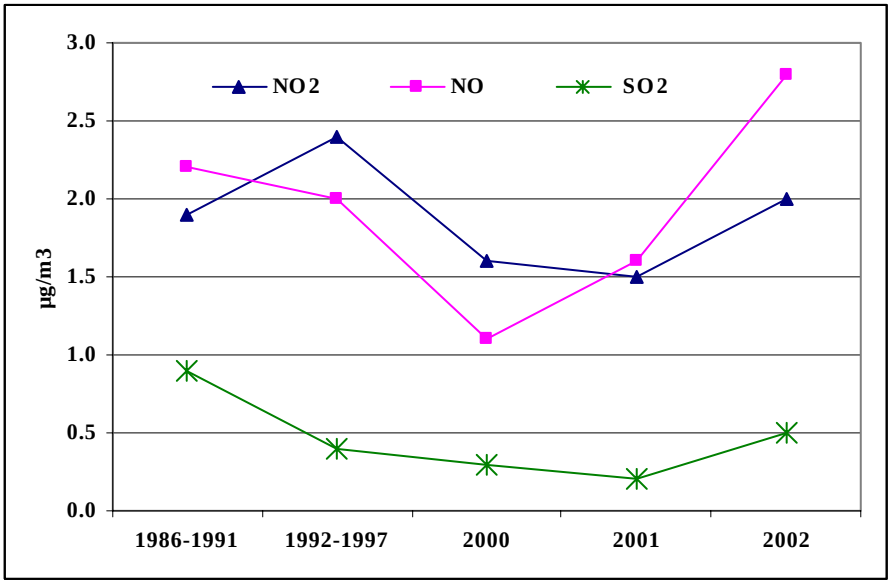

Figure 48. Annual mean concentrations of gaseous compounds at regional level
Source: Instituto de Meteorología, 1999, 2003

In relation to the superficial ozone (O_3), it is observed typical means concentrations of 30 µg/m^3 (from April to September) and 120 µg/m^3 (from October to March), coinciding with the

optimal development season of the main cultivations of the country, which are affected with concentrations of 70 µg/m^3. For these reason is applying in some provinces the Early Alert System to prevent the producers about the danger of affectation to the crops for the presence of this pollutant (CIGEA, 2001).

- **Electricity generation**

The 93.3% of the electricity generation in the year 2001 was carried out using fossil fuels, what has a decisive effect in the emissions of this sector.

The main pollutants from electricity generation in the country are the CO_2, the SO_2 and the NO_x. The emissions of CO_2 represent 99.3% of the total GHG from the electricity generation (figure 49).

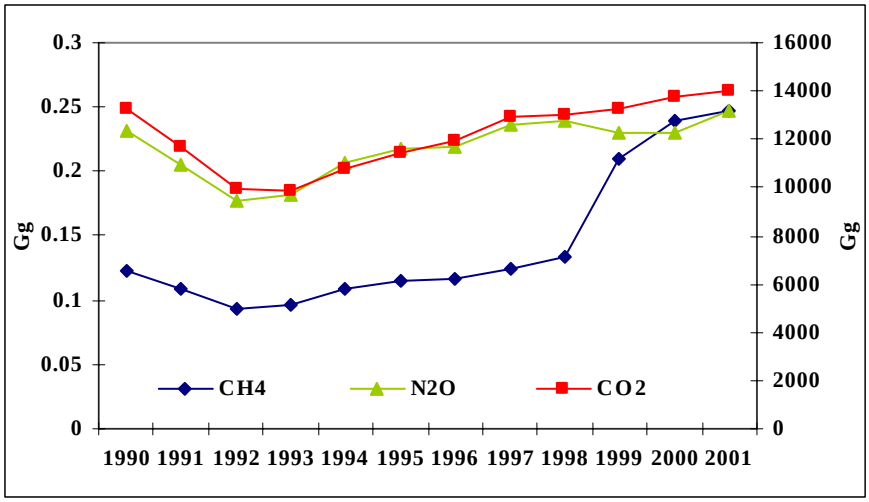

Figure 49. GHG emissions from electricity generation
Source: Authors estimations

During 1991 and 1992, the emissions of CO_2, SO_2, and NO_x from the electric sector diminished due to the forced decrease of the electricity generation owing to a lack of financial resources to buy fuels. The emissions began to grow in 1993, even when the generation continued falling up to 1994, due to the increment in the use of domestic crude oil. This fuel has a high sulfur content (around 7%), and the power plants were designed to use fuel oil. The lack of financial resources made the plants was not adapted to use crude oil and the maintenances were inadequate, diminishing the efficiency (figure 50).

In 1997, the CO_2 emissions reached the levels of 1990. From 1998 the rhythm of growth of the emissions diminished due to the use of the associated gas in more efficient turbines of gas, to the modernization of the units of 100 MW of the system and the incorporation of new units of 250 MW, with an increment of the efficiency. The electricity generation reached the levels of 1990 in the year 2000.

The electricity generation is one of the main sources of the SO_2 emissions in the energy sector (figure 51). Due to the increment of crude oil participation in electricity generation, the SO_2 emissions increased considerably during the whole period. The 1990 levels were exceeded in 1993 in 7.3%. The SO_2 emissions in the year 2001 surpassed the emissions of 1990 in 59%.

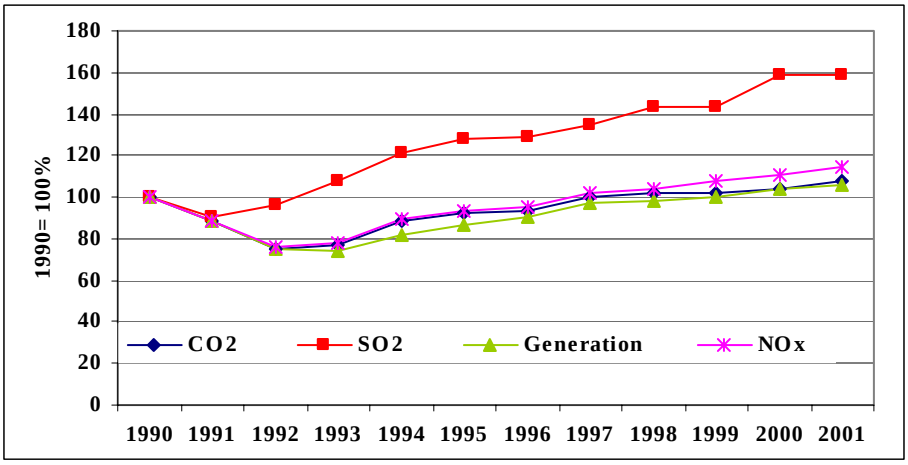

Figure 50. Indices of CO_2, SO_2, NOx emissions, and electricity generation
Source: Authors estimations

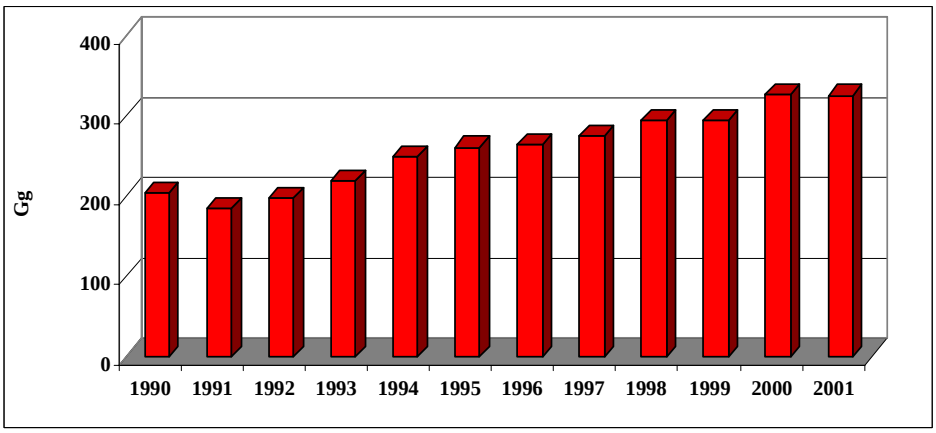

Figure 51. SO_2 emissions from electricity generation
Source: Authors estimations

At the end of 1998, associated gas started to be used in electricity generation. In 2001, the generated electricity using the associated gas represented 6.8% of the total electricity generated in the country (ONE, 2002), which is reflected in SO_2 emissions. However, in the year 2000 an increase of the emissions took place although the consumption of gas increased 20% in relation to the previous year. The reason is the increment in 37.7% of the crude oil consumption in relation to the previous year.

The estimated values of CO and VOC emissions from electricity generation are shown in Figure 52. Since 1993, these emissions have increased proportionally to the use of domestic crude oil.

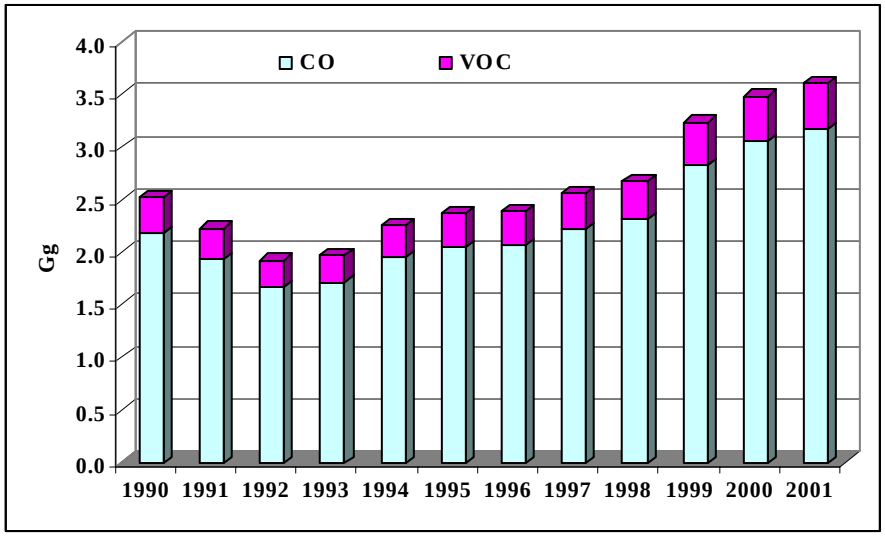

Figure 52. CO and VOC emissions from electricity generation
Source: Authors estimations

6. ASSESSMENT OF CURRENT ENERGY POLICIES IN PRIORITY AREAS

To show if the results of implemented energy polices positively affect economy, society or the environment using a set of indicators an important amount of data are needed. The major objective of main implemented energy police during the evaluated period was to reduce import dependence, increase the renewable energy participation in the solution of social issues and to increase energy efficiency.

The action of increasing expenditure on hydrocarbon exploration and development, increase expenditures on energy sector (Indicator 15 Direct Driving Force Economic Dimension), and increase the indigenous energy production (Indicator 17 State of Economic Dimension) and reduce net energy import dependence (Indicator 18), but affect the proven recoverable fossil fuel reserves (Indicator 36) and lifetime of proven fossil fuel reserves (Indicator 37). The absence of data series for indicators 15 (expenditures on energy sector), 36 (Proven fossil fuel reserves), and 37 (Life time of proven recoverable fossil fuel reserves) did not enable the complete analysis of effects of this action.

The action of diversifying energy mix influences on properly energy mix and expenditure on energy sector (Indicator 11 Indirect Driving Force Economic Dimension and Indicator 15 Direct Driving Force Economic Dimension respectively). This positively reduces net import dependence as was shown in the previous paragraphs.

On the other hand, the action of increasing share of associated gas in fuel mix influences on energy mix and energy supply efficiency (Indicators 11 and 12, Indirect and Direct Driving Force respectively, Economic Dimension). This action has a positive effect and reduces the net import dependence and ambient concentration of pollutants in urban areas (Indicator 24, State Environment Dimension). In the local area of using associated gas for electricity generation, the concentration of sulfur compounds was substantially reduced taking into consideration the population, tourist's opinions and the quantities of clean sulfur produced.

The use of associated gas for electricity generation started in 1998. Before that, the associated was burnt in flare without any energy utilization and provoked the contamination of an important tourist zone. The action of increasing share of associated gas in fuel mix reduces the growth rate rhythm of the quantities of main air pollutant emissions from electricity generation (Indicator 26, Direct Driving Force, State of Environment Dimension) as was shown in the previous paragraph.

The action of increasing efficiency of energy supply affects the overall energy supply efficiency (Indicator 12, Indirect Driving Force, Economic Dimension), Energy use per unit GDP and Expenditure on energy use (Indicators 14 and 15, Direct Driving Force, Economic Dimension). This contributed to reduce the rhythm of growth of pollutants emissions.

The action of increasing the participation of renewable sources in fuel mix modifies energy mix (Indicator No. 11, Indirect Driving Force, State of Economic Dimension), increase the expenditure in the energy sector (Indicator 15, Direct Driving Force, State of Economic Dimension) and reduces net import dependence (Indicator 18, State of Economic Dimension). The non-electrified population in Cuba is not associated to the income inequality. It is associated to the geography of the regions where some rural populations live. The electrification of these populations is the Government's social program: The electrification was made with photovoltaic panels and very small hydroelectric power plants. This program starts with the electrification of more than 2300 schools. In the next 5 years it is expected to electrify 167 000 households.

7. STRATEGIES FOR IMPROVEMENT IN PRIORITY AREAS

In the energy sector, very affected by the crisis in the last decade, were carried out structural changes and reforms that were already reflected in the Law of Foreign Investments. This law foresees the private capital participation in the energy industries, which were materialized in the electricity generation and in the exploration and production of petroleum and associated gas.

At the end of last decade, the oil production was equally shared between CUPET and the private sector. In the electricity generation, there are four gas turbines and a combined cycle that work as a joint venture between UNE-CUPET-Sherrit Utilities Inc. and a completely private power plant in Youth's Island.

Now the new Electric Law that defines the regulatory framework of the electric industry is in its final stage of conciliation, because the Law nowadays in force dates from 1975.

On the other hand, in 1998 a special tributary system was applied for the recovery of the sugar cane agriculture. This new fiscal procedure comprised exemptions, deductions and allowances according to Law 73 of the Tributary System, and the price of the sugar cane was doubled.

In 2002 as it was previously stated, there was a process of restructuring of the sugar sector.

- **Electric Sector**

After 1959, there are three clearly defined stages:

First stage: up to 1989 there was an expansion based on technology transfer (although not very efficient) and a reliable supply at preferential prices of fuels, the installed capacity grew in about 2600 MW (based on fuel oil) and tripling the refinement capacity.

Second stage: from 1990 up to 1995 characterized by strong restrictions on fuel supplies. All the national economy was seriously affected.

Third stage: starting from 1996 until the present characterized by economic recovery.

Institutional reforms

- ✓ Creation of the National Energy Commission. The actions taken by this commission were elimination of the fuel oil consumption in raw sugar production, reduction of energy consumption indexes in the sugar refinement process, in thermal power plants, in cement production, textiles, etc.
- ✓ Development Program for National Energy Sources (CNE, 1993).
- ✓ Increase of the electricity tariff (stage tariff) for the residential sector.
- ✓ Introduction of the obligatory payment in foreign currencies for oil products and electricity in self-financed companies.
- ✓ Controlled fuels distribution.
- ✓ Reorganization of the big industries, which are highly electricity consumers (textile industry, construction materials industry and food industry); promoting the general and intensive use of bicycles; using trucks with trailers and railroad cars for the passengers transport.
- ✓ Implementation of the Cuban Electricity Saving Program; distribution of lamps and subsidized thrifty bulbs; substitution of refrigerator's seals and promotional videos and advertisements on energy saving.
- ✓ Law No. 260 issued on December 1998 penalizing the illicit acquisition of electricity due to altered power meters or illegal connections made.
- ✓ New electric tariff differed for the non-residential sector by voltage levels, schedule of consumption and type of consumers (MFP, 2002).
- ✓ Implementation of sector's programs of efficiency improvement specially in Nickel, cement, sugar cane, steel, and machinery industries and in tourist and agriculture sectors.

- **Oil and Gas sector**

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

The extraction of oil and associated gas has grown in 2001 in 6 and 20 times as compared to 1991, respectively.

The refinement capacity is of 5.9 million tons in four refineries.

Institutional reforms

The Gasification Program mainly in Havana City and in Santiago de Cuba with the financing of foreign companies enabled to provide a service to a greater number of consumers and substitutes the kerosene and alcohol as domestic fuel. In Havana City, the domestic supply is expected to be 50% with manufactured gas and the other 50% with LPG. The LPG stoves and gas bottle (9 Kg of gas capacity) are sold at subsidized prices.

In 1998, the remotorization and change of fuel from gasoline to diesel took place to improve efficiency, fuel consumption and the environmental impact of transportation. In addition, the renovation of the vehicles existing in the country is carried out with implementation of import standards to achieve more economic and less polluting transports.

Recently the national banks start financing the energy efficiency programs in foreign currencies.

Risk exploration of oil and the implementation of the Law of Foreign Investment permit the rapidly development the sector and increase the crude oil and associated production.

- **Other energy sources**

Cuba has developed capacities and experience in the production of solar heaters, photovoltaic systems and the solar cells production, turbines for mini-hydroelectric, windmills and different hydraulic applications as water pumps, solar dryers and distillers and controlled-climate chambers, etc. Jointly with the high capacities, the availability of highly qualified technical scientific personnel and infrastructure, the country has been able to electrify relevant community objectives and mainly to be able to provide the electrification of more than 2300 schools, so that television and computers are accessible in far away areas (mountains and difficult access places), medical care and social centers.

At the moment there is a project that is aimed at providing electricity to 100% of the population in the next 5 years using systems which are economically, environmentally and sustainable in a more appropriate way for each place: from the expansion of electric grids, photovoltaic systems, the mini or micro-hydroelectric power plants, wind generators, combustion systems and biomass gasification, biogas, urban solid wastes, the use of residuals for energy and environmental purposes, as well as hybrid systems wherever it is considered necessary for reliability reasons.

To have intellectual capacities for all projects cycle, from integral energy planning, its environmental impact and sustainability, until its implementation constitutes the main potential of the country related to energy, environment, and sustainable development.

Institutional reforms

Development Program for National Energy Sources (CNE, 1993)

Creation of the Renewable Energy Front (October 14, 2002) as a specialized state organization to coordinate and integrate the different institutions involved in renewable energy issues.

- **Environment**

In the last period some actions for the solution of the problems detected in the atmospheric contamination have been undertaken (CIGEA, 2001).

- ✓ Law 81 of the environment (1997) establish the corresponding responsibilities on the technological processes and the import of technologies with respect to the emission of gases and particles
- ✓ To promote the renewable source development, instead of the use of fossil fuels.
- ✓ To develop the National Program "The global changes and the evolution of the Cuban environment" that contains important research projects from the environmental and socio-economic point of view.
- ✓ To establish relative dispositions to the conservation of the layer of ozone and the prevention of the climatic change.
- ✓ To elaborate standards relate to the quality of the atmosphere.
- ✓ The application of taxes to the sources of residuals and emissions is analyzed.
- ✓ The national team on climate change elaborates the National Strategy for Climate Change Framework Convention Implementation integrating the main economy sectors, universities, research centers and NGOs.
- ✓ Environmental license is necessary for any investment.
- ✓ Exclude for taxes the renewable energy projects.

8. CONCLUSION AND RECOMMENDATIONS

ISED framework methodology is an appropriate tool to perform the analysis of different associated to energy policies considering their social, economic, environmental and institutional dimension.

The absence of some data does not enable performing the complete analysis of all the implemented energy policies in the country with the necessary detail. Nevertheless, with the collected data, possible analyses were performed with appropriate results.

Relevant was the results of the use of ISED framework methodology to enhance the statistical capabilities of the country. It was possible in short period to introduce appropriate changes in the National Statistic System. Three new surveys were introduced in the system.

It is recommended to use ISED framework methodology to evaluate the sustainable energy development scenarios that are under construction in the country.

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