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Vulnerability Assessment and Possible Adaptation Measures of Energy Sector in Syria

Related to the Project Activity

Programs Containing Measures to facilitate Adaptation to Climate Change

Project Title

Enabling activities for preparation of Syria's initial national Communication to the UNFCCC, (Project Nr.00045323).

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March 2009

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The project implemented in the ministry of local administration and Environment (MLAE)/General Commission of Environmental Affairs (GCEA), in collaboration with Global Environmental Facility (GEF) and United Nation Development Programm (UNDP) in Syria.

Vulnerability Assessment and Possible Adaptation Measures of Energy Sectors in Syria

(INC-SY_V&A_ Energy -En)

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This report has been approved unanimously by the technical committee, during the Technical Workshop which took place on 24/ 03/ 2009 in the Dedeman Hotel Palmyra.

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SUMMARY

In the framework of the UNDP project on ”Enabling Activities for the preparation of Syria's Initial National Communication to the UNFCCC” the vulnerability of Syrian energy sector to climate change and variability will be analysed and assessed.

This final report covers various aspects related to the interaction between energy sector and (GHG; Green House Gas) emissions. The first part deals with the description of the present Syrian energy system by sector of consumption for both demand and supply sides. The second part deals with the estimation of the expected future long-term development of Syrian energy system for a reference energy demand scenario that projects the future final energy demand according to the proposed socio-economic and technological development of the country up to 2030. To meet the projected energy demand, a reference energy supply scenario based on minimal system cost (least-cost of energy unit) is presented taking into account the availability of national energy resources and diversity of supply options. The (GHG) emission of Syrian energy system related to the reference energy supply scenario has been accounted and presented by consumption sectors and type of activity.

In view of vulnerability of energy sector to climate change resulting form the increase of (GHG) emission, an alternative energy supply scenario –(GHG) Scenario- is being developed that reflects the most probable adaptation of this sector to mitigate (GHG) emission. The applied approach in analysing the adaptation strategy relies on accounting and limiting the amounts of (GHG) through the direct change in the type energy conversion technologies of future energy supply in particular the power sector. Compatible with the Kyoto agreement for developing countries, the (CDM; Cleaning Development Mechanism) is being considered for the period up to 2012. In this context the role of renewables and nuclear energy options in the power sector has been evaluated. The resulting structure of the proposed alternative (GHG)-Scenario comparing to the reference scenario could reflect the impact of environmental regulations and mitigation measures on the future structure of energy sources and technologies showing the adaptation of the national energy sector to the proposed changes.

Comparison of both scenarios indicates that the alternative scenario will enable reducing the CO_2 emission of about 3 Mton in 2020 and 7.5 Mton in 2030 that refers to about 4.4% of CO_2 emission reduction in 2030.

Additional issue concerning the adaptation of energy users to climate change can be evaluated on the demand side by enforcing higher costs of energy services and considering energy conservation measures. However, the scenario assumptions should be formulated in respect to the Syrian economic and technological conditions reflecting the expected future evolution of GDP per capita and the energy technology development with its expected market penetration rates.

1. Introduction

Following its international commitments Syria ratified the United Nations Framework Convention on Climate Change (UNFCCC) in April 1996, and the Kyoto Protocol in September 2005. It established the environmental Protection Council and General Commission for Environmental affairs (GCEA) with the main Duties of:

- Integration of environmental dimensions into national legislation and policies;
- Raising awareness among stockholders& public towards environmental issues;
- Developing the national experiences and building national capacities for meeting obligations towards retrieved international environmental conventions;
- Set the national strategy & plans for environmental protection;
- Establishment of environmental monitoring networks.

The Initial National Communication (INC) on (GHG) emission is being prepared in framework of cooperation project between General Commission for Environmental Affairs (GCEA) and UNDP (2007-2009). The Implementation strategy of the project includes:

- Preparing the national (GHG) inventory (Collecting and analysing data related to (GHG) since 1994);
- Analysing potential measures to mitigate the increase in (GHG);
- Analysing potential impacts of climate change in Syria and adapt measures;
- Enabling the Syrian Government to autonomously conduct assessment on climate change impact and to implement adaptive measures according to the INC to different areas of development policies;
- Presenting the INC to UNFCCC.

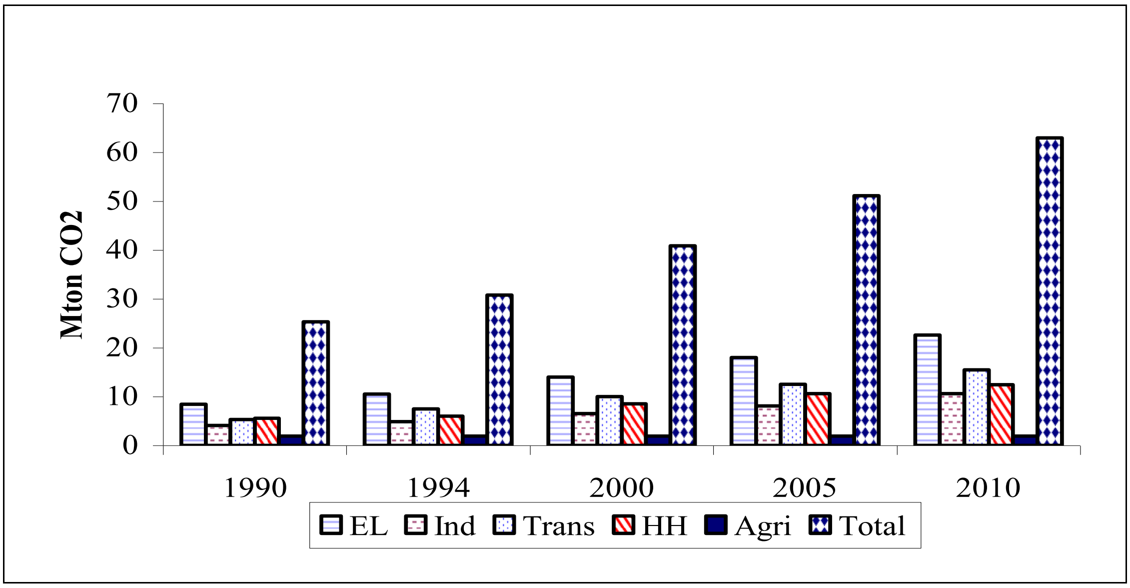

Figure (1): Estimated (GHG) Emissions (in CO_2 equivalent) for the Period 1990-2010.

The first national efforts concerning (GHG)s studies was launched in 1998 when the Environmental Research Center (ERC) prepares a national study on the climate change in Syria in cooperation with GTZ that aimed at assessing (GHG)s inventories and sinks for the years of 1990 and 1994, building main scenario of (GHG) emissions, suggest and estimate the technical and non technical option for (GHG) emissions reduction, [*Jabour et al,* 2005]. Evaluating the contribution of various sectors to the total national emissions of CO2 for the years 1990 and 1994 indicated that the energy sector with its combustion-related activities is dominated with a share of 88% followed by industry and waste with

9% and 3% respectively. Figure 1 presents the estimated development of (GHG) emission up to 2010.

The results indicate that (GHG) emissions will double by 2.3 times and 2.88 times in the year 2005 and 2010 respectively comparing to 25.3 Mton of CO2 equivalents in 1990. The study evaluated the main potential for (GHG) emission reduction in all sectors [*Jabouour et al*, 2005].

2. General Country Overview

The Syrian Arab Republic lies on the eastern coast of the Mediterranean Sea, bounded by Turkey to the north, Iraq to the east, Jordan and Palestine from the south and by Lebanon and the Mediterranean Sea to the west. The total area of SAR is about 185.18 thousand km^2, from which ca. 32% are cultivated land and the remained is desert and Rocky Mountains. The Syrian Desert is suitable for grass growing and is used as pastures during sufficient rainfall.

The climate of the Mediterranean Sea generally prevails in Syria; this climate may be characterised by rainy winter and dry hot summer separated by two short transitional seasons. The coastal region is characterised by heavy rainfall in winter and moderate temperature and high relative humidity in summer. The interior is characterised by a rainy winter season and a hot dry season during summer, the area in the mountains with an altitude of 1000 m or more characterized by rainy winter where rainfall may exceed 1000 mm and moderate climate in summer. The desert region is characterized by small amount of rainfall in winter and hot dry summer [*Hainoun et al*, 2004].

The population of Syria was 4.565 million in 1960, but during the next two decades the number doubled to 9 million, and has kept an increasing trend reaching 13.782 million according to the population census in 1994. According to the population censuses in 1981 and 1994 the Central Bureau for Statistic (CBS) estimated for the period 1981-1994 an average population growth rate of about 3.3%, which was one of the highest growth rate in the world. However, the last decade has depicted continuous decrease of the growth rate as result of different factors influencing the demographical situation in Syria, like changing the life style, increasing of marrying age from 26 to 29 years by male and from 20 years to 25 years by female, increasing the women share in the labour force and other factors[1]. The CBS estimated annual population growth of 2.33% during the period 2000-2006. According to the population census in 2004 the populations mounted to 17.9 millions and the latest estimated population of 2007 is around 19.17 millions [CBS, 2007].

On the economic side the Syrian economy shows -after an economic crisis during the period (1985-1990)- a high economic growth rate of 8% resulting from the considerable increase in oil production between 1990-1996, foreigner support after the second Golf ware and new investment law. In 1991, Syria passed Investment Law No. 10, encouraging foreign and Syrian private investment through a combination of tax and custom exemptions, the right to repatriate profits and relaxation of foreign exchange controls. Private investors, with financial backing from the Gulf States, have been expanding into various sectors of industry. This has encouraged the development of textiles, pharmaceuticals, food processing (Non-durable) and other light industries, many built by wealthy Syrians from abroad. Tourism appears to be growing as well. The recent economic

[1] According to Human Development Report 2000 (Table 19, page 225), population growth rate in Syrian Arab Republic (SAR) was 3.2% per annum during the period 1975-1998. This report predicts 2.3% p.a. population growth rate during the period 1998-2015 for the Syria. Total population of SAR will be 22.6 million by the year 2015 of which 62.1% will be in urban areas and 3.5% above the age of 65 years.

development prove an average economic growth rate of around 4.7% during the period 2000-2006 (during this period the Syrian GDP grew from 904 to about 1193 billions Syrian Pound). However, the government aim to achieve 6-7% growth rate by the end of this decades. Table 1 shows selected economic and demographic indicators of the country. The official statistics refer that GDP per capita grew from 1108 to 1250 $ during the same period achieving 2.4 % growth rate per year

Table (1): Selected main economic and demographic indicators for the period 2000-2006.

	2000	2001	2002	2003	2004	2005	2006	Growth rate %
GDP(B.SP)[2]	903.9	950.2	1006.4	1017.6	1086	1134.9	1192.7	4.7
GDP ($)	17.7	18.6	19.7	20.0	21.3	22.3	23.4	4.7
Population[3] (Millions)	16.3	16.7	17.13	17.5	17.9	18.27	18.7	2.3
GDP per Capita (SP)	55386.0	56830.1	58750.7	57982.9	60599.3	62121.6	63722.8	2.4
GDP per Capita ($)	1107.8	1122.6	1142.4	1156.1	1200.2	1206.4	1250.2	2.4

(Statistical abstract 2007)

3. Current Energy Sources and Use

According to international statistics the Syrian energy system is characterized by low per capita energy consumption. Table 2 shows selected indicators of energy sector compared with other region for the year 2004. The primary energy consumption per capita in Syria was 0.99 toe (ton of oil equivalent) compared to 1.77 toe of the world average and 2.64 toe of the Middle East (IEA statistics, www.iea.org). The CO2 emission per capita was at the same level of world average.

Table (2): Selected Energy Indicators for the year 2004

	Primary Energy (toe/capita)	Final Electricity Consumption (kWh/capita)	CO2-Emission (tCO2/toe)	CO2-Emission (tCO2/capita)
Syria	0.99	1317	2.59	2.57
Middle East	2.64	2881	2.47	6.51
Asia	0.63	617	1.94	1.22
Africa	0.67	547	1.39	0.93
World Average	1.77	2516	2.37	2.57

- **Institutional Set-up of Energy Sector in Syria**

The energy sector is part of the economic activities being administrated by the office of deputy prime minister for economic affaires. The main contributors in the Syrian energy sector are ministry of oil, ministry for electricity, atomic energy commission (AECS) and the high committee for energy and resources (Figure 2).

The Ministry of Oil & Mineral Resources is responsible for planning and implementation of development programmes related to all fossil fuels like oil and gas and all mineral resources like phosphate, marble, and granite etc. Syrian Petroleum Company (SPC) is responsible for production, transport and distribution of oil and gas. Oil products are extracted in two refineries located at *Banias* and *Homs*. The current total daily production of both refineries amounts to about 242 thousand barrel.

[2] Using 2000 market prices and assuming that 1$ equals to 51 Syrian Pound (SP)
[3] Estimated in the mid year for all years except 2004 when the general census was performed.

The Ministry of Electricity is responsible for investment, tariffs, planning, and policy formulation in the power sector. The power system is managed by the Public Establishment for Electricity (PEE), which is separated into PEEGT (Generation and Transmission), and PEDEEE (Distribution and Exploitation of Electrical Energy). PEEGT is responsible for transmission including the 400-kV and 230-kV levels, while PEDEEE supervises the 66-kV, 20-kV, and 0.4-kV levels. As a result, PEEGT has 230-kV customers, that is, large industries and irrigation. All other customers are under the responsibility of PEDEEE. Recently a new national energy research centre (NERC) has been established at the ministry for electricity. It should deal with energy survey, energy conservation and supporting the development of renewable.

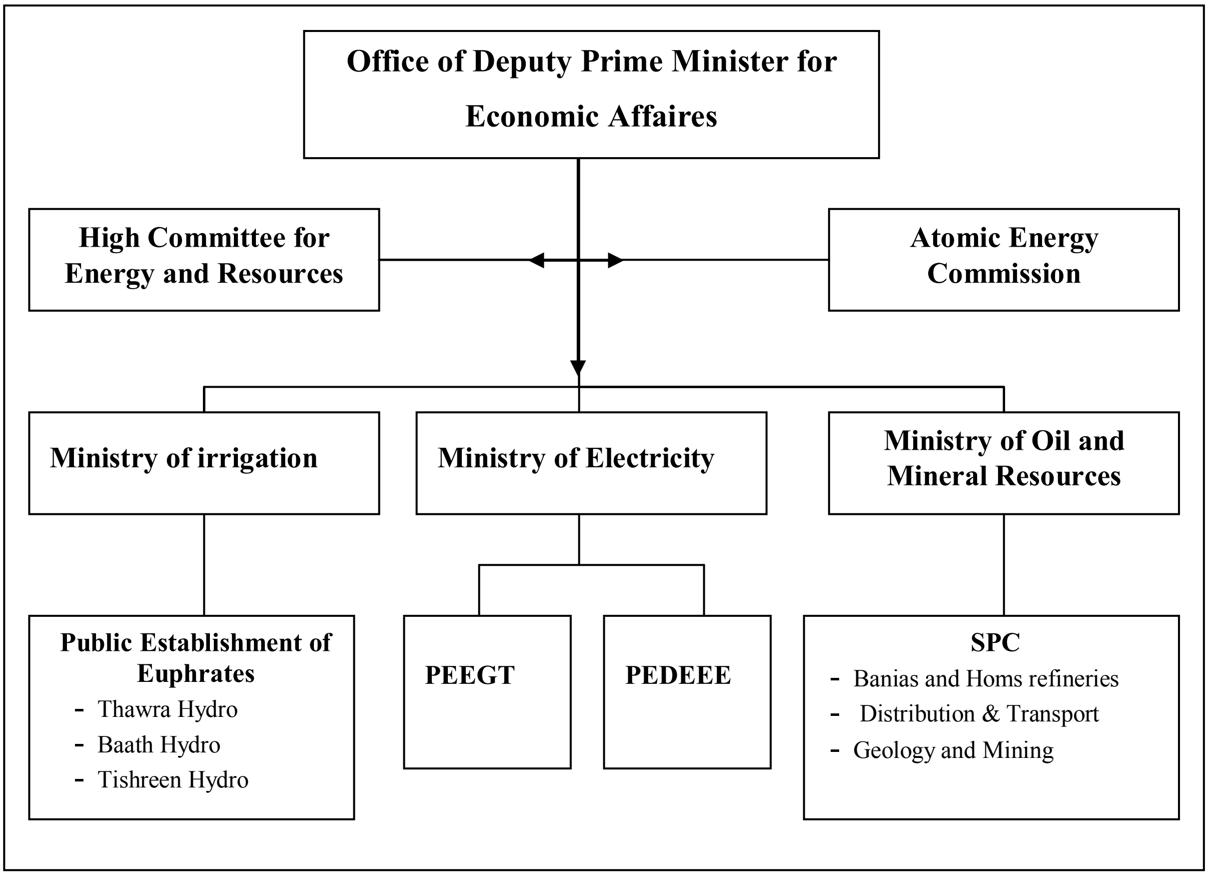

Figure (2): Institutional Organization of Energy Sectors in Syria.

The Ministry for Irrigation is responsible for water resource management and hydro power plants. The Public Establishment of Euphrates is responsible for the three main hydropower plants of *Thawra*, *Baath* and *Tishreen*, all located on the Euphrates River.

- **Main Features of National Energy Policies**

The overall target of Syrian energy policy aims at ensuring supply security by providing energy services to all segments of society at cost effective and affordable prices appropriate to Syrian economic conditions. To accomplish this goal Syrian energy policy is faced with three challenges, namely expanding the gas market, sustaining the oil production and developing country's power capacity [*Hainoun et al*, 2004]. To manage these challenges ***following general implementation measures are considered:***

– Reducing the technical losses and illegal consumption
– Improvement of energy efficiency

– Encouraging the use of renewable
– Establishing costing oriented price policy
– Saving oil and substituting it by gas
– Attracting foreign investment in oil, gas and power sectors

A key challenge for the Syrian natural gas (NG) industry is logistical, with gas reserves located mainly in north-eastern Syria, while population is centred in western and southern Syria. SPC currently is working to increase Syria's gas production through several projects aiming at expanding and developing the NG network.

The electricity production policy consists in substituting gas by oil in the existing stations and building new stations suitable for gas alone (at present 90% of generated electricity is thermal origin, from which 44% is gas origin). The Government is in process to relax state monopoly over power sector. There are many efforts to reinforce the transmission and distribution of networks, and to improve the quality of customer services.

- **Final Energy Consumption**

The Syrian energy sector is characterized by fossil fuel dominance, absence of renewable role and exploitation of the hydro resources, low energy efficiency and very low contribution of clean fuel technologies.

Figure 3 shows the distribution of final energy demand (including and electricity) by sector of consumption (*Hainoun et al*, 2006).

The total final energy consumption amounted to 14.4 MTOE. The transportation sector (Trans) shows the highest share with 26%, followed by house hold (HH) with 24% and industry with 20%. The consumption shares of agriculture (Ag), construction (Cons), and mining (Min) and service (Serv) amounted to 11%, 7%, 7%, 5% respectively. The final consumption by fuel type is distributed to 72.1 % for the oil derivatives, 10.3 % natural gas, 2.63 % traditional fuel, and 15% for electricity.

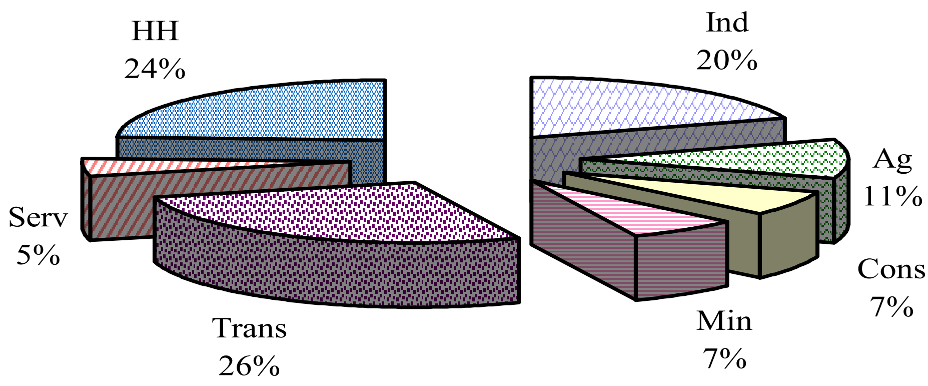

Figure (3): Sectoral Consumption of Final Energy in Syria in the Year 2005.

- **Electricity Consumption**

According to the ministry of electricity, the peak load demand grew from 5770 MW in 2004 to 6008 MW in the year 2005, which mean 4.12 % growth rate comparing to an average growth rate of 7.8 % as for the period 2000-2005.

As a motive force in the development process, electricity sectors achieved a huge jump during the last two decades, resulting in duplicating the total generated electricity three times between the years 1991 and 2005 from 12.2 TWh to 34.8 TWh respectively. This corresponds to an average annual growth rate of 7.8 % [TSR, 2006]. The secondary electricity production per capita grew from a 1545 kWh in 2000 to around 2000 kWh in 2006 (Figure 4, 5).

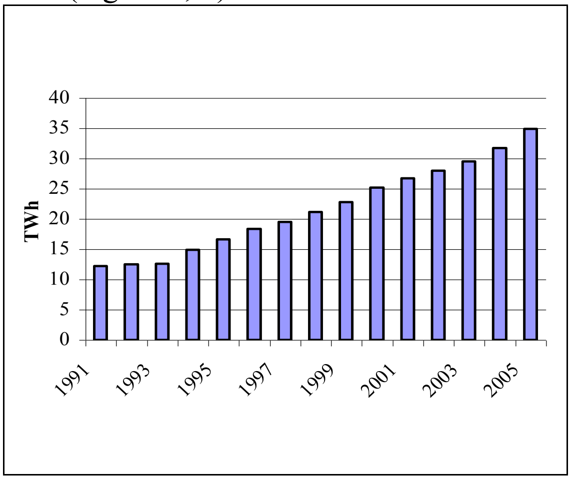

Figure (4): Development of electricity production in the period of 1991 to 2005 (TWh) [TSR, 2006]

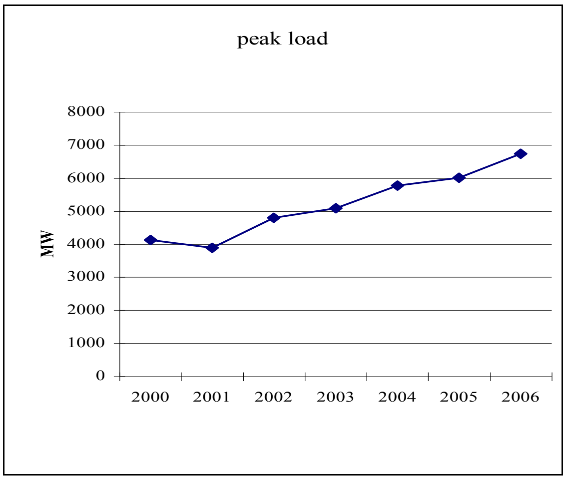

Figure (5): Peak Load Development 2000-2006 [TSR, 2006]

Figure 6 presents the structure of the Syrian electricity generation system by generation type in the year 2005. The total installed capacity amounted to 7160 MW whereas the available installed capacity was 6008 MW distributed to 24% for Hydropower and 76% for fossil fired power plants [TSR, 2006]. The total gross electricity generation in 2005 amounted to 34.9 TWh, whereas the total final electricity consumption amounted to 26.81 TWh that's about 76.82 % of the total generated electricity. The sectoral electricity consumption is shown in figure 6. The house hold sector had the highest share with 47%, followed by industry (31%), service sector and agriculture with 14 % and less than 6% respectively, while the remaining 3% went to mining, construction, and pipeline transporting with less than 1 % for each.

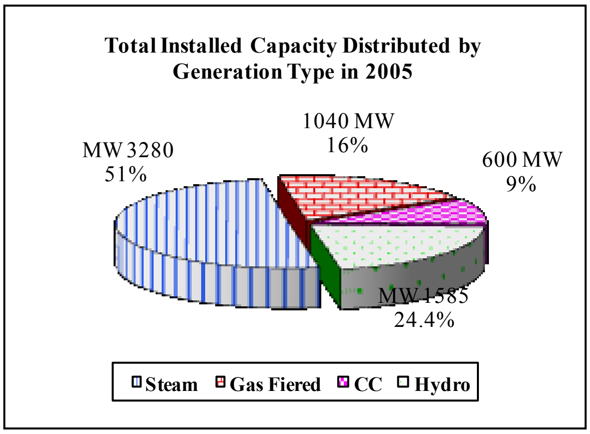

Figure (6): Total Installed capacity by Generation Type

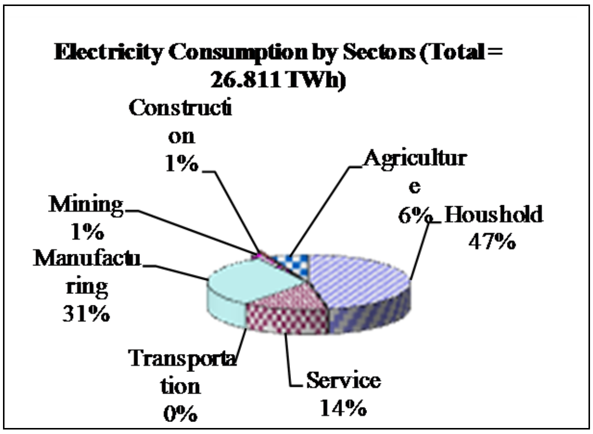

Figure (7): Electricity Consumption By Sectors

- **Primary Energy Supply and Energy Sources**

This level considers all energy carriers allocated for internal consumption consisting of oil derivatives, natural gas, renewables and traditional fuel. These carriers are either consumed directly by the end consumers or used partially in the power sector for electricity generation where the new energy carrier "electricity" appears. Table 3 shows the distribution of [4]primary energy by fuel types before electricity generation (total fuel including thus allocated for electricity generation). Subsequently the primary energy supply during the period 2003-2005 was covered mainly by oil derivatives, and natural gas and small amounts of renewables (hydro power). It is apparent that diesel occupied the main share followed by fuel oil and natural gas that are mainly consumed in the electricity generation. The share of hydro energy in the total primary supply decreased from 3% to almost 2.4%.

Table (3): Distribution of primary energy by fuel type for the period 2003-2005

	2003	2004	2005
Diesel	32.3%	32.2%	33.0%
Gasoline	6.9%	6.8%	6.9%
Fuel	23.2%	25.3%	24.7%
LPNG	4.4%	4.4%	4.5%
NG	23.1%	22.1%	21.6%
Asphalt	3.7%	3.6%	3.6%
Heavy products	2.3%	2.2%	2.2%
Hydro power	3.1%	2.5%	2.4%
Traditional	1.0%	1.0%	1.0%
Total Annual (Mtoe)	**18.13**	**19.00**	**19.41**

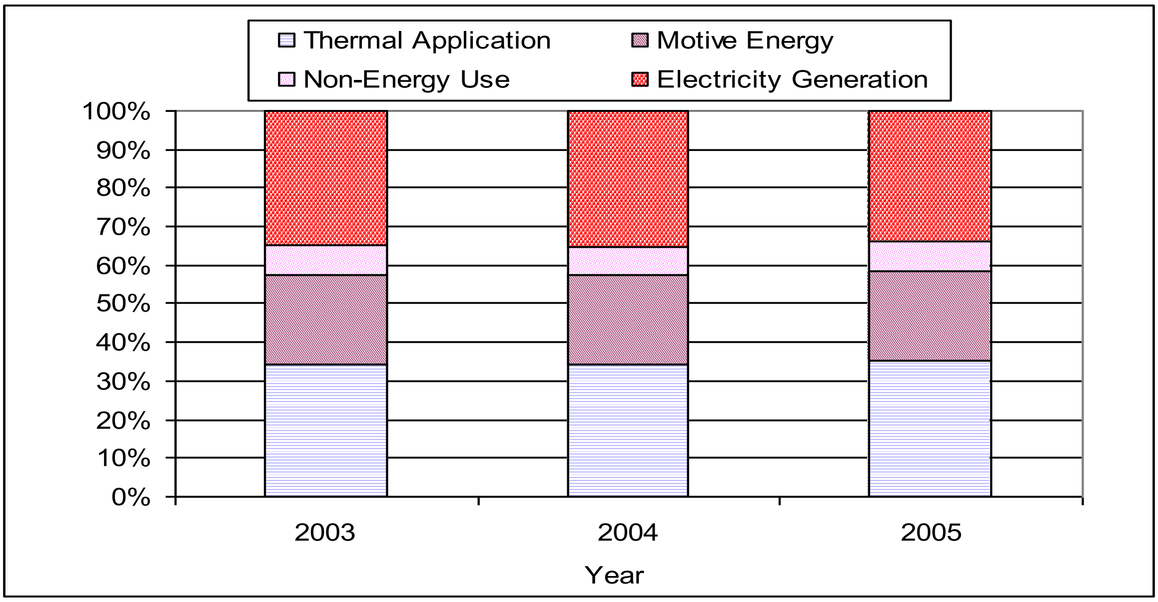

Figure (8): Distribution of primary energy by type of consumption.

[4] Usually a secondary energy level is defined by conversing oil, NG to oil derivatives. However, for simplification both levels are considered to be equal.

The distribution of primary energy by type of application is presented by Figure 8. Thus, the secondary energy has been devoted to cover thermal, motive and non-energy application in addition to electricity generation. During the study period the share of thermal application in the total primary supply amounted to around 34.5%, for electricity generation 35%, for motive energy between 23% and for non-energy application (including Asphalt and heavy products like coke) about 7.5%.

4. Inventory of Greenhouse Gas (GHG) Sources

The (GHG) sources comprise the combustion processes of energy sector, non-combustion processes of industrial processes, agriculture, waste management, forestry and others.

The assessment of (GHG) sources and their emissions is essential for evaluating the potentials of the (GHG) mitigation and its impact on the various economic sectors. The assessment is designed to fulfill the methodology adopted by UNFCCC, and International Panel of Climate Change (IPCC) protocol of Non-I countries. Starting from the year 2005 being considered as base year -compatible with the national energy studies to analyze future energy demand and supply [*Hainoun* et al, 2005], [*Hainoun* et al, 2008]- the (GHG) sources and their future emissions have been evaluated by performing a comprehensive analysis of future development of the energy sector including both, supply (resources extraction, refineries, electricity generation) and demand side (i.e. industrial process, transportation, residential and commercial activities). The study focuses mainly on (GHG) emission of the power sector that typically represents the main producer of (GHG) emissions [IPCC, 2006]. Furthermore, in order to evaluate the most favorable adaptation measures and mitigation strategies towards realistic reduction of (GHG) emission of energy sector the study comprises the analysis of reference and alternative supply scenarios.

4.1. (GHG) Emissions of Energy Sector

The present energy conversion technologies rely mainly upon combustion of fossil fuels. During combustion the carbon and hydrogen of the fossil fuels are converted mainly into carbon dioxide (CO_2) and water (H_2O), releasing the chemical energy in the fuel as heat. This heat is generally either used directly or used often to generate electricity or for transportation. This sector includes two main combustion-related activities, namely Stationary combustion and Transportation.

A. Stationary combustion:

Stationary combustion is responsible for about 70% of the greenhouse gas emissions from the energy sector[5]. Practically stationary combustion comprises all energy consuming activity except transportation sector (in addition to petrochemical and fertilizer industry). About half of the emissions of the stationary combustion are associated with combustion in energy industries mainly power plants and refineries. This source category includes:

- Energy industries like energy extractions, energy production and transformation including energy generation and petroleum refineries;
- Manufacturing industries and construction: include activities like iron and steel production, chemical manufacturing, pulp, paper, food industries, beverages and tobacco, …etc
- Other sectors such as commercial and residential.

[5] 2006 IPCC Guidelines for National Greenhouse Inventories.

B. ***Transportation***

Mobile combustion (road and other traffic) causes about one quarter of the emissions in the energy sector [IPCC, 2006].

4.2. (GHG) Emissions of Industrial processes

This (GHG) source encompasses the following:

- Industries that give rise to CO2 emissions from non-combustion processes – notably calcinations of lime within the cement industry and reduction of irons and within the steel industry;
- Industrial Processes that give rise to Non-CO2 emissions: notably, those involved with insulation, refrigeration and switch gear;

4.3. Agriculture

Including both dairy and other pastoral farming;

4.4. Forestry

Encompassing both harvesting obligations and implications of sink credits.

4.5. Waste Management

Encompassing solid waste disposal and wastewater treatment (including industrial wastewater).

The annual (GHG) emissions by sectors have been calculated using the IPCC Bottom-up methodology based on quantities of fuel combusted and the specific emission factors that are related to Syrian fuel characteristics. The results are summarized in Table 4 for the energy sector only.

Table (4): Total (GHG)s Emissions of Energy Sector for the Year 2005.

(GHG) Inventory of Energy Sector 2005

	Consumed Energy (Mtoe)	CO_2 emissions (Mt)	Ton CO_2 (per toe)	CH_4 (kton)	N_2O (kton)
Total (combustion processes)	**22.3**	**57.2**	**2.55**	**12.35**	**0.510**
1. Energy Industries	9.36	27.79	2.97	0.81	0.14
• Public Electricity	6.9	21.7	3.14	0.62	0.107
• Refining & Extraction	2.46	6.09	2.48	0.19	0.033
2. Industry & Construction	1.55	4.64	2.99	0.15	0.039
3. Transport	4.4	12.46	2.81	1.71	0.125
4. Other Sectors	7.032	12.3	1.748	9.680	0.206
• Service (Ser)	0.432	1.2	2.783	0.190	0.011
• Household (HH)	4.8	6.91	1.43	7.23	0.145
• Agriculture (Agr)	1.8	4.18	2.34	2.26	0.05

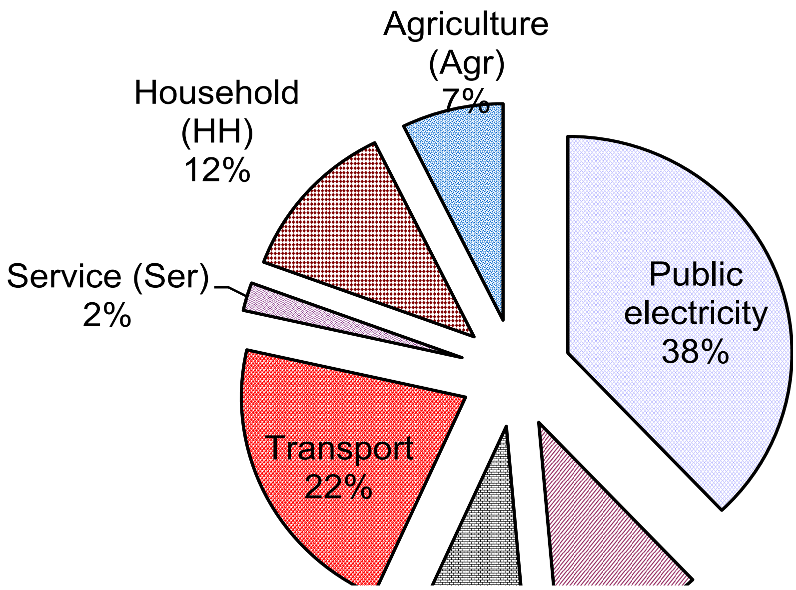

Figure (9): Distribution of CO2 Emissions of Energy Sector by Type of Activity (2005).

Table 4 depicts that the total CO_2 emissions caused by energy sector (combustion processes) in 2005 amounted to about 57.18 Mt. Compared to the estimated emission of the year 1990 (see Fig. 1) the annual average growth rate of CO_2 emissions of the energy sector for the period 1990-2005 amounted at 5.4%.

The distribution of CO_2 by sector of emission is presented in table 4 and figure 9. It is obvious that the energy industry (electricity generation, refinery and extraction industries) shared by more than 49% of the total CO_2 emission. This results from the high energy consumption of combustion processes in this sector that amounts to 42% of the total available primary energy in 2005. Transportation sector emits more than 12.4 Mton of carbon dioxide (about 22% of total emission) and ranked at second position followed by residential, industry and construction, agriculture and services corresponding to 12%, 8%, 7% and 2% of total CO_2 emissions respectively.

The contribution of other (GHG) gases, namely CH_4 and N_2O, amounted to 259 and 158.2 kton of CO_2-equivalent respectively. Main CH_4 emissions origin from residential (household) sector follows by agriculture and transportation with 58%, 18%, and 14% respectively. Energy industry adds less than 7%. N_2O is emitted mainly by Household sector followed by energy industries, transport and agriculture with 28%, 27, 24.5% and 10% respectively.

In general CO_2 emissions depends on the fuel characteristics and heat content, while CH_4, N_2O emissions are determined mainly by the combustion process and its boundary conditions (like combustion technology, apparatus efficiency, post-combustion controls,…etc) in addition to the gas contents in the fuel. For this reason the highest non-CO_2emissions come from residential application like small stoves, open burning and from the transport sector.

- **(GHG) Emissions of the Power Sector**

The power sector (electricity generation) consumed in the year 2005 about 4051 kton fuel oil and 3385 Mm^3 natural gas, which amounted to 78% and 68% of the total consumed fuel oil and natural gas respectively [FEB, 2005]. Figure 10 shows that the CO2 emission of electricity generation amounted to ca. 40% of the total CO2 emission in energy sectors. The historical development of (GHG)-emission (given in CO2 equivalent) of the power sector for the period 1996-2005 is presented in figure 11.

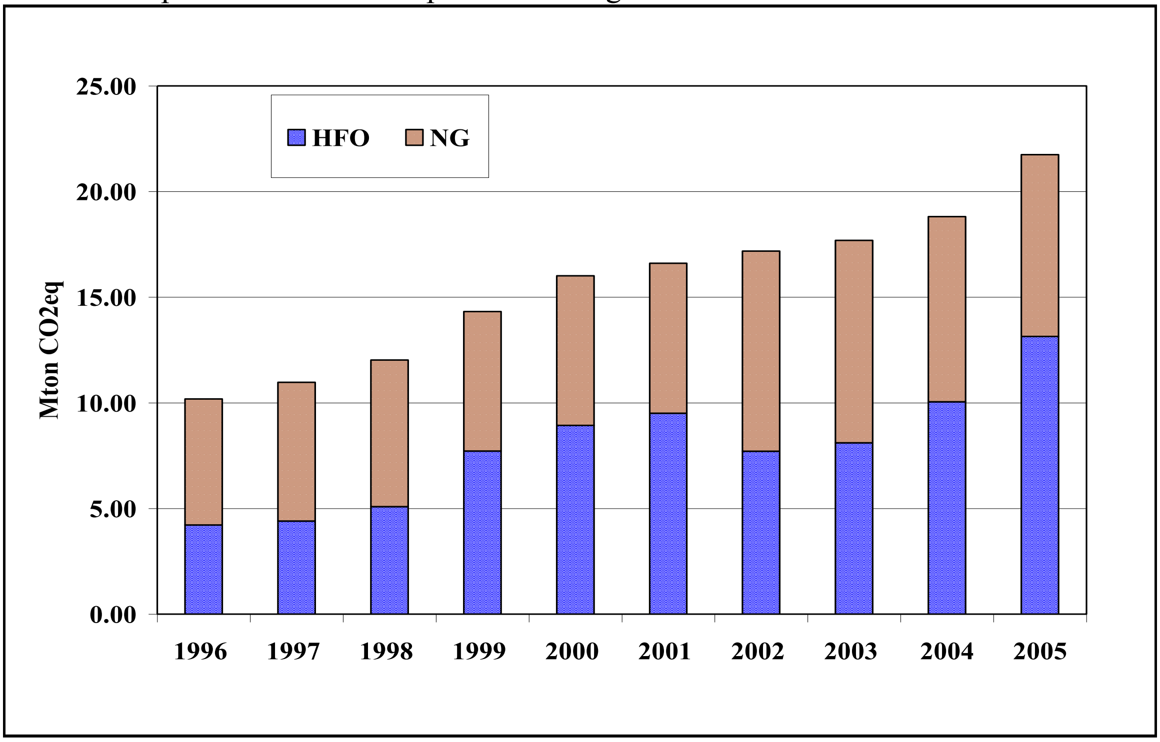

Figure (10): Development of (GHG) emission of the electricity generation by fuel type for the period 1996- 2005

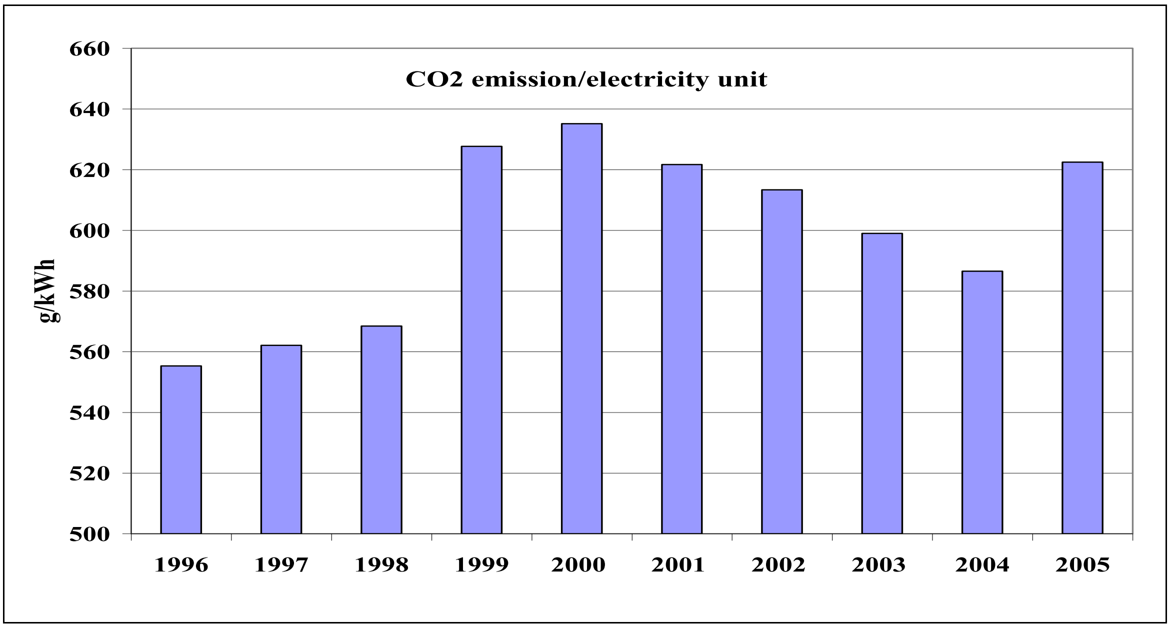

Figure (11): Development of CO2eq-emission per kWh of generated electricity for the period 1996-2005.

It can be deduced that the average annual emission growth rate amounted to 8.8 % starting from 10.7 to about 21.7 Mton of CO2eq respectively. Along with this steady increasing in (GHG) emission, the CO2 emission per kWh increased from 555 g/ kWh to 630 g/ kWh during the first period and declined later to 590 g/ kWh in 2004 in order to increase again to 622 g/kWh in 2005 as presented in figure 11. The observed variation results from the changing shares of NG and fuel oil in the generation process. Higher NG share relates to lower CO2 emission.

5. Sub-Sectors Most Sensitive to Climate Change

Due to the comprehensive nature of climate change impacts on different socio-economic activities, it is most likely expected that all consumption sectors can be affected. This can include residential sector (house hold and service), transportation, agriculture and industry. However, the residential sector will be very sensitive to climate change (CC). On the other hand the electricity generation and water supply seem to be the most sensitive production sector to CC. Following are some arguments for the expected sensitivity.

- Residential sector: the most important requirements of this consumption sector are electricity and water. As both services are expected to face big challenges in dealing with CC, the residential sector will suffer a lot under the new conditions. The most sensitive parts are the low income households as the direct results will be increased electricity and water price that can not be delivered ***at affordable price for all segments of the society.***

- Electricity generation sector: As this sector is currently by more than 80% depending on fossil fuel, it will face a big challenge to reduce this dependency for the purpose of mitigating CO_2 emission. This target can be realized by:
  - Technology enhancement in term of efficiency improvement and adding CO_2 capturing technology,
  - Introducing alternative clean technologies by shifting to renewables and nuclear options.

  Both alternatives need a lot of investments that will be translated in significantly higher electricity generation cost.

- Water sector: due to the increased scarcity of water for the various applications. This will affect all production sectors like power, industry and agriculture sectors and consumption sectors like residential sector that are deeply depended on water supply. Besides, in the current technological infrastructure a strong feed back effect between power and water sector can be identified. The dependency of power sector on water supply arises form the huge amount of water required for cooling process. The water sector need in many cases electricity for pumping, transport and distribution. However, the above mentioned increase in electricity price will limit the water availability for various consumption sectors.

6. Coping Capacity of Energy Sector to Climate Change

To deal with the expected future climate change, various development trends are probable. However, the feasibility of the assumed development trend should be evaluated in respect to the energy indicators for sustainable development in social (accessibility and affordability of energy services), economic, environmental and institutional dimension. ***This means that the adopted future energy supply strategy should assures adequate, reliable and efficient energy services to all segments of society at affordable costs, compatible with local conditions, in an environmentally congenial manner.*** According to these requirements, the Syrian energy sector possesses wide potentials to deal with the expected climate change. The coping capacity of this sector varies from conservation measures to efficiency improvement (shifting to modern alternatives) up to reducing the dependency on fossil fuels, its share amounts presently at more than 95% of total primary energy demand in Syria. The coping capacity of the energy sub-sectors can be classified as follow:

- Power sector: the potential of this main sub-sector comprises following
  - Efficiency improvement by shifting to combined cycle power plants,
  - Substituting fuel oil by natural gas,
  - Reducing the technical and illegal consumption in the electricity distribution,
  - Increasing the share of renewables and nuclear options.
- Transportation sector:
  - Shifting to modern public transportation like metro,
  - Shifting to train mode for freight transportation,
  - Replacing old cars by new alternatives with higher efficiency; including modern hybrid cars (for the far future)
- Industry sectors:
  - Efficiency improvement of industry processes mainly in heat application,
  - Rehabilitation and modernization of energy intensive industries like cement industry.
- Agriculture sector:
  - Efficiency improvement for water pumping,
  - Adopting innovative measurements for water demand management,
  - New machines for agriculture process,
  - Reducing the share of water intensive agricultures like cotton cultivation (due to both, high energy and water requirements).
- Residential:
  - Conservation measures in all residential applications (behavioral),
  - Developing alternative heating devices,
  - Increasing the share of solar energy for water and space heating,
  - More insulation in the building sector,
  - Efficiency improvement for air conditioners and refrigerators.

The coping capacity of energy sector to Climate Change is reflected in the ability of this sector to undergo the required restructuring and technological change and improvement. On the technological side the choice of clean technologies (like renewables and nuclear in the power sector and efficiency improvement in other sub-sectors) are most possible and favorable. The restructuring ability of the energy sector, that presently seems to be obsolete, is a realistic and promising choice. The burdens are financial and structural nature. Recent results of national energy supply strategy indicate that both wind energy and nuclear option are promising alternative in the future energy supply mix [Hainoun et al, 2008]. However, the increased share of renewables (coming mainly from wind energy) requires significantly higher installed capacity –due to low availability factors of renewables-. The evaluation results show that the factor of replacing one capacity unit of fossil fired with renewables amounts to about 2.

7. Possible Policy and Adaptation Measures to Lessen Climate Variability and Change Impacts

To alleviate the expected impact of climate change on the energy sector various policy and adaptation measures can be assessed. The feasibility of the imposed policy and/ or measures should be evaluated on the basis of cost and time efficiency. The lower the cost and faster the impact, to reduce (GHG) emission and alleviate its impact, the more favorable is the measure. Thus, following measures can be considered in case of Syria:

- Encouraging renewables and nuclear in the power sector;
- Conservation measures: both behaviorally and technically;
- Encouraging the introduction of clean technologies in all energy conversion process: mainly for future candidates;
- Introducing mitigation techniques: CO2 capturing and storage;
- Energy price: removing subsidy in energy sector will reduce the total consumption due to the expected reduction of specific consumption and triggered technology improvements;
- Imposing limits on CO2 emissions (Tax and penalties).

To evaluate the impact of adaptation measures in the future energy supply policy on the (GHG) emission two different energy supply scenarios are presented. Beside the business as usual reference supply strategy (base line scenario) an alternative supply scenario based on enforced future share of the renewables are presented below. This represents the first adaptation measure in the above presented alternatives and is the most favourable energy policy to mitigate national (GHG) emission.

- **Reference Energy Supply Scenario**

The main features of the proposed reference energy supply scenario are presented according to the optimal supply strategy developed in reference [*Hainoun et al*, 2008]. For this scenario the CO2 emission of the energy sector has been calculated and considered as base-line for further alternative scenarios of CO2 mitigation. In particular case of power sector, the baseline CO2 emission trajectory depends greatly on the choice of power generation technologies satisfying the projected future electricity demand. In a previous step for evaluating the future supply strategy Syrian future final energy demand has been projected in a previous analysis using the end-use approach [*Hainoun et al*, 2005], [Hainoun et al, 2004]. Table 5 presents the future development of final energy demand distributed by form of consumptions up to 2030.

Table 5: Projected final energy demand by type of consumption [Mtoe].

Year	Electricity		Thermal Uses	Motor Fuel	Non-energy uses		Total
	MWyr	Mtoe			Asphalt[6]	Feedstock[7]	
2003	2420	1.823	6.218	4.212	0.672	0.308	13.233
2004	2567	1.933	6.512	4.372	0.692	0.316	13.825
2005	2722	2.050	6.822	4.538	0.713	0.323	14.446
2007	3010	2.267	7.508	4.979	0.756	0.343	15.853
2010	**3501**	**2.637**	**8.673**	**5.723**	**0.826**	**0.375**	**18.235**
2015	4524	3.408	11.114	7.337	0.958	0.421	23.237
2020	5878	4.427	14.197	9.493	1.111	0.486	29.714
2025	7638	5.753	18.010	12.286	1.288	0.581	37.918
2030	**9985**	**7.520**	**22.699**	**15.870**	**1.493**	**0.777**	**48.359**

To meet the projected future final energy demand given above a reference supply scenario has been developed that ensures optimal national supply strategy characterized by minimal total costs of the energy system over the study period. The national resources and available energy conversion technologies have be exploited wisely, and import & export options as well [Hainoun et al, 2008]. Figure 12 shows the development trend of primary energy supply. The results of reference supply scenario indicate that Syria will still rely mainly upon oil products and natural gas to cover its primary energy supply.

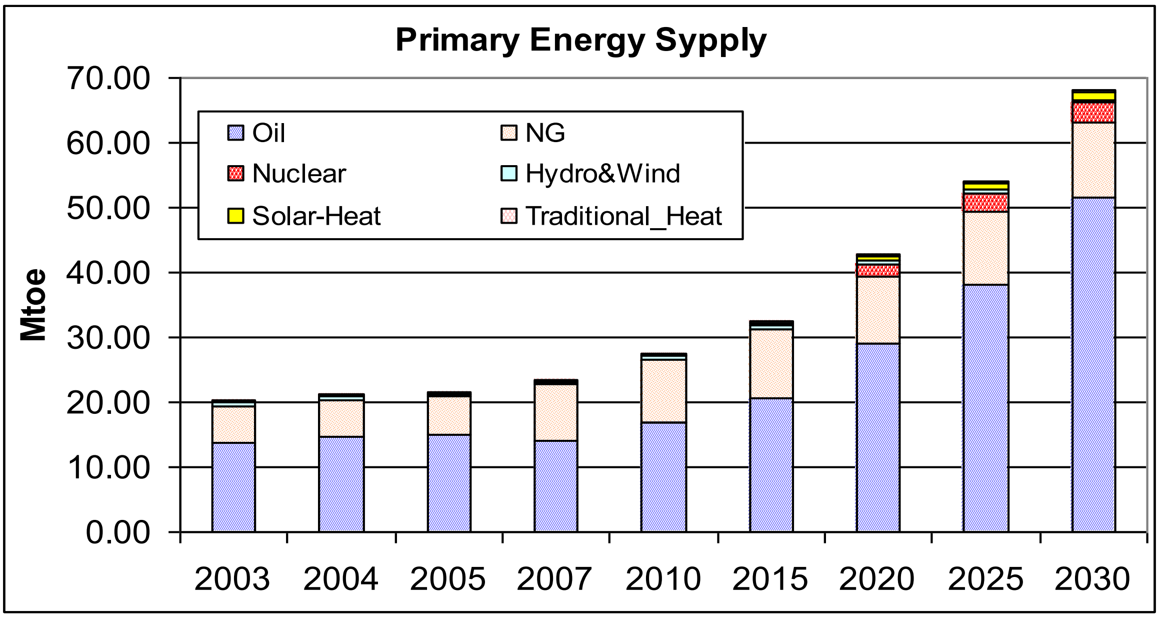

Figure (12): Development of future primary energy by fuel type (reference Scenario).

[6] Asphalt data not included in MAED results. The data up to the year 2010 refer to official estimation, for the following years an annual growth rate of 3% has been assumed.

[7] For fertilizer and petrochemical industry

- **Renewable Energy Supply Scenario**

The adaptation of environmental friendly energy policy fulfils the requirements of sustainable energy development. Thus, the objective of a renewable supply scenario is to analyse both, increasing the supply security by reducing national dependency on fossil fuel and mitigating the emission of CO_2 in the energy sector. Furthermore, the analysis of renewable supply scenario provides a useful tool to estimate the costs of emission reduction by comparing the total energy costs (investment and fuel cost) of this scenario with the reference case.
The Renewable Scenario is designed to analyze the impact of increased use of selected renewable options that seem to be most promising according to international development. The pre estimations refers that only three renewable types present promising potential to penetrate in to the national energy system, namely wind energy, photo voltage and solar energy for thermal use. ***The main scenario assumptions are:***

- Increasing the share of renewable sources in total electricity generation starting from 1% in 2010 to 10% in 2030;
- Solar uses achieve share of 10 % of the total thermal uses by 2030.

Figure 13 shows the impact of increased renewables in the power sector on the future trend of fuel consumption. Thus, the imposed 10% renewables in the total electricity generation will help in saving around 2.5 Mtoe (million ton of oil equivalent) of fuel oil in 2030 Syria.

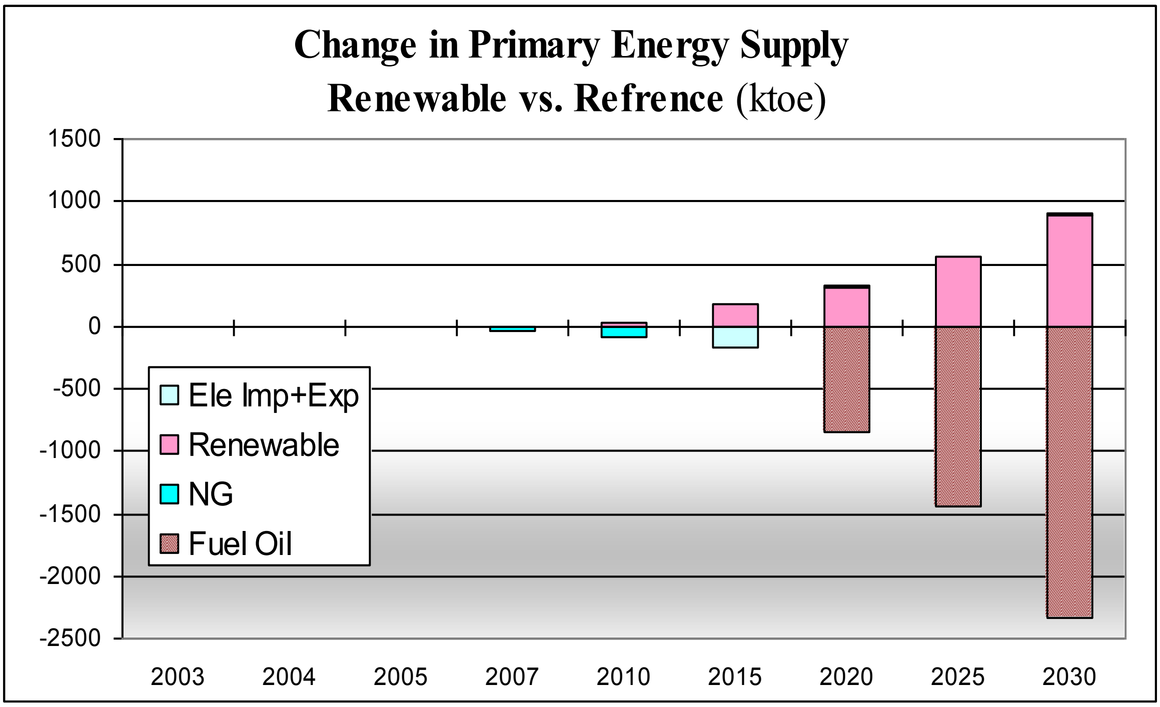

Figure (13): Development of the Difference between Primary Energy Supply of Renewable and Reference Scenarios.

- **Results Comparison of reference and Renewable Scenarios**

The comparison below focuses mainly on the power sector due to its dominant role in the energy supply and as main (GHG) source. The development trends for the electricity generation for both scenarios are presented in Fig. 14 and 15. The total installed capacity in 2030 amounts at 19000 MW for the reference case. The new installed capacity over the study period will amount to 16040 MW. The addition consist of 2400 MW CC (unit size 300 MW), 1500 gas turbine (unit size 100 MW), 10400 MW fuel fired steam turbine (unit size 200 MW), 1600 MW nuclear (1000 MW in 2020, 600 MW in 2025) and 40 MW wind turbines (in 2020). Photo voltaic and solar power plants have been considered as candidates but they weren't selected in the optimal solution due to their high overnight costs.

In comparison, the renewable scenario shows that the total installed capacity mounts at around 24000 MW in 2030. This means an additional installed capacity of 6000 MW compared to the reference case, that will be required to produce 10% of the total electricity from renewable (mainly wind energy). Hence, the new installed wind capacity jumped from 240 MW (2.7% of the total installed capacity) in 2010 to 5850 MW (more than 24% of total installed capacity) in 2030. In this year the renewables will generate more than 10 TWh. No doubt that building this capacity of wind_PP will affect the structure of the generation system, and one can guess that wind will replace the most expensive power plants comparing to reference scenario, namely fuel oil fired power plants. Natural gas fired power plants capacity increased by 1.6 times (2400 MW comparing with 1500 MW in Ref_Sc) while CC_PP and Nuclear capacity remain the same (2400, 1600 MW respectively).

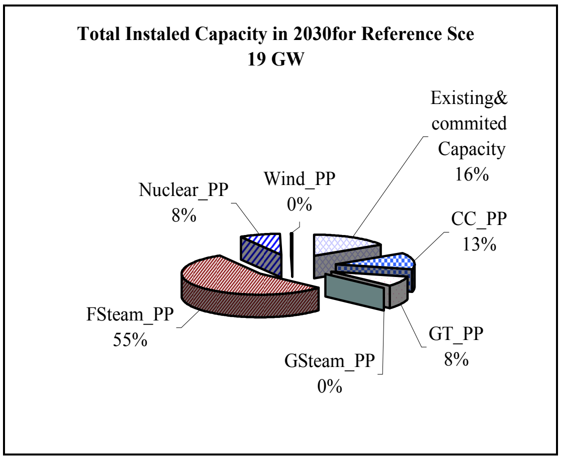

Figure (14): Distribution of the new Installed Capacity in 2030 by power plant type for reference scenario

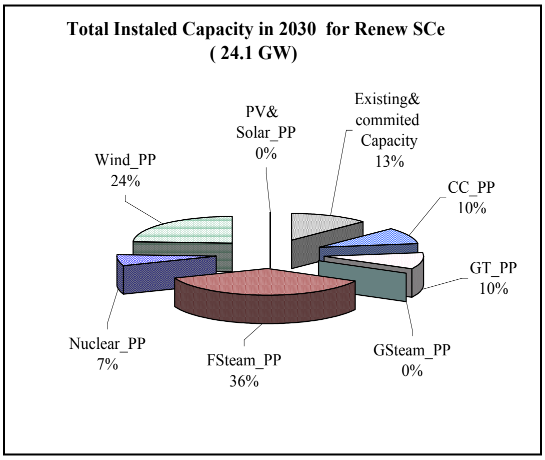

Figure (15): Distribution of the new Installed Capacity in 2030 for reference scenario by power plant type

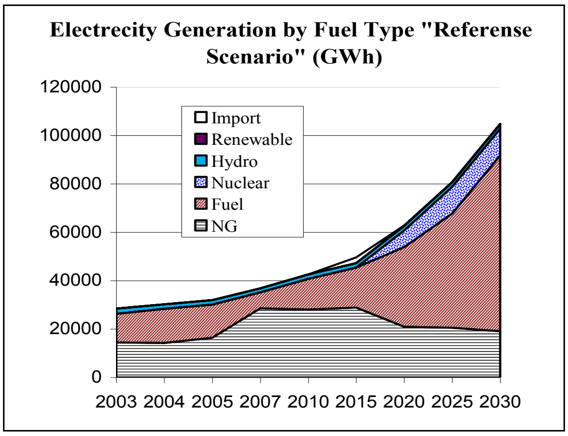

Figure (16): Electricity generation development by fuel type between 2003 and 2030 in Ref _Sce

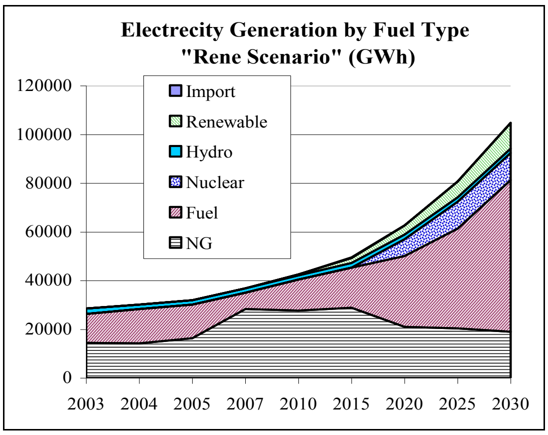

Figure (17): Electricity generation development by fuel type between 2003 and 2030 in Ren_Sce

Fig. 16, 17 present the mix of electricity generation from 2003 to 2030 in the two scenarios. To satisfy the electricity demand the electricity generation jumped from 28.49 TWh in 2003 to 104.8 TWh in 2030 achieving annual growth rate of 5%.The proportion of fossil fuel in Ref_Sc rises from 92 % (50% NG, 42% Fuel oil) to 96% (66%, 30% for NG and fuel oil respectively) during the first years then, dropped gradually to 87.5% (18.2%, 69.3%) by the end of study period due to building new nuclear power plants whose shares arrives 10.6% of the total generation in 2030. Comparing with Ref_Sc the share of fossil fuel in Renw_Sc shows similar fluctuation but the percentage will drop to 78% in 2030 due to the increased share of wind power plants.

As a result of the previous change in the electricity generation mix the required quantities of NG and HF for the two scenarios are shown in table 6. The saving HF quantities in Ren_Sce rise from 850 ktoe (11.5%) in 2020 to 2338 kton (14%) in 2030 resulting directly from the declining of heavy fuel (HF) shares in total generation from (46%, 59%) comparing with (52%, 69%) in Ref_Sc for the same two years respectively.

Table 6: Comparison of fossil fuel consumption for electricity generation in reference & renewable scenarios for the period 2003-2030 (ktoe)

Year	NG		HF		
	Ref_Sc	Ren _Sc	Ref_Sc	Ren _Sc	HF Saving
2003	3255	3255	2704	2704	0
2004	3208	3208	3229	3229	0
2005	3194	3194	3150	3150	0
2007	5117	5078	1501	1501	0
2010	4656	4576	2891	2891	0
2015	4576	4576	3771	3771	0
2020	3296	3296	7433	6582	850
2025	3210	3210	10688	9253	1436
2030	3020	3020	16432	14094	2338

- **Comparison of (GHG) Emissions for both Scenarios**

Comparing with Ref_Sc, the cumulative amount of CO_2 emission in Ren_Sc is decreased; Starting with around 3 Mton in 2020 and arriving more than 7.5 Mton in the year 2030 that refers to about 4.4% of CO_2 emission in this year.
Depending on the consumed quantities of fossil fuel, the CO_2 emission from electricity generation was about 18 Mt in 2003, distributed by 52% for NG combustion shared and about 42% for HF.

Table 7: Comparison of CO_2 Emissions of Reference and Renewable Scenarios

Emission (Mton)	2003	2005	2007	2010	2015	2020	2025	2030
Reference Scenario	47.8	51.7	55	63.5	77.3	99	127.4	168.2
Renewable Scenario	47.8	51.7	55	63.3	77.3	96.2	122.8	160.7
CO_2 Reduction	0	0	0	-0.2	0	-2.8	-4.6	-7.5

The development of annual emission of CO2 for the two scenarios over the study period is presented in Fig. 18. The effect of renewables appears first after 2020.
According to Ren_Sce, CO2 emission from electricity generation is doubled 3 times during the study period comparing with 3.4 in Ref_Sce, rising from 18Mt in 2003 to 54 Mt in 2030 achieving growth rate of 4.7% annually.
The calculated cumulative emissions of CO2 indicate that the total CO2 emission over the study period will mounts at 895 Mt in Ren_Sce compared to 970 Mt in Ref_Sce, which mean that the potential CO2 reduction during the study period is more than 74.5Mt (about 7.7% of the total CO2 emissions).

For non-CO2 emissions (CH4 & N2O), Fig. 19 presents a comparing between the cumulative emissions over the study period for both scenarios. In general CH4, N2O quantities can be neglected compared to CO2 emissions as their shares from the total emissions during the study is less than 1%. However, CH4 and N2O emissions amount at 10.25 and 25 kton $CO2_{eq}$ at the begin of study respectively. According to Ren_Sce results they will be doubled by 4, 4.5 times rising to 39.114 kt of $CO2_{eq}$ respectively by 2030. This means a reduction of more than 61, 180 kton of $CO2_{eq}$ compared to the Ref_Sce where the two gases emissions are expected to amount at more than 46, 132 kton of CO2eq respectively in 2030.

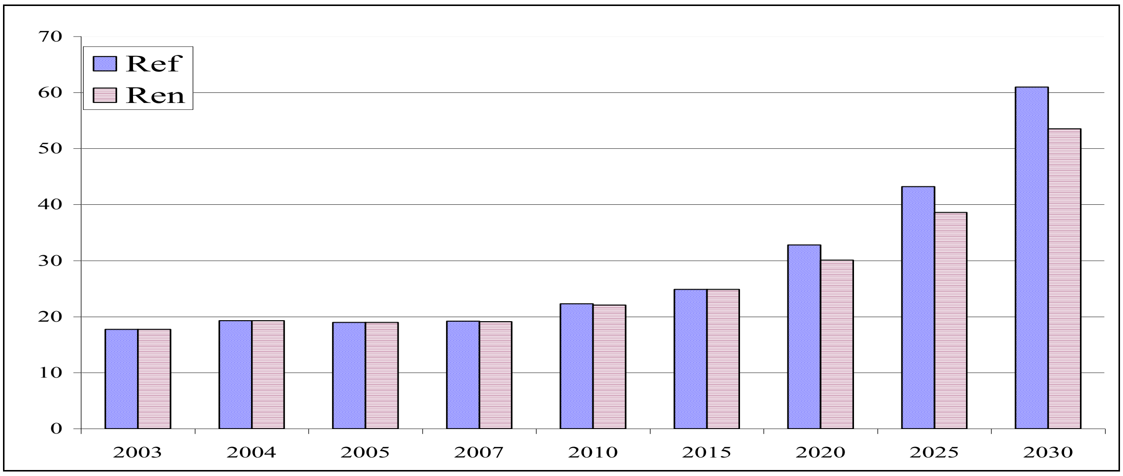

Figure (18): Comparison between the CO2 emissions of power sector in Ref & Ren scenarios during the study period (Mt)

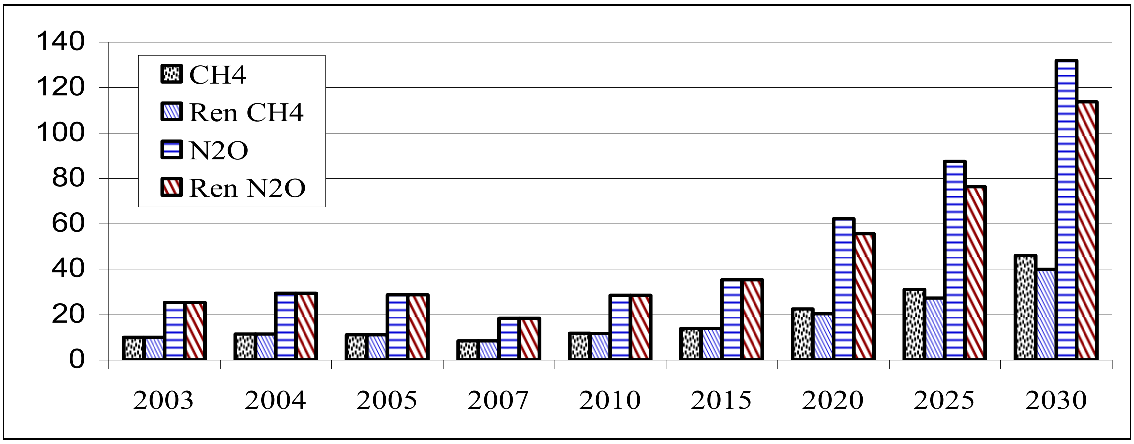

Figure (19): Comparison between CH_4 & N_2O emissions from electricity system in Ref & Ren scenarios during study period (kt CO_2eq)

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