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للأستاذ الدكتور محمد عبد الفتاح شامة

Published Papers (1994-2005)

on Energy and Environmental Protection

by Prof. Dr. M. A. Shama

1- "A Projection on the Future Demands and Capability of Offshore Technology" A.M.R.J. (Egypt-1976), Shama, M. A.,. (100%)

2- "A General Outlook to Offshore Technology", Egyptian Society of Marine Engineers and Shipbuilders, Forth seminar, Alexandria, April, (Egypt-1983), Shama, M. A., (100%)

3- "Costs of C02 Abatement in Egypt Using Both Bottom-Up and Top-Down Appr", Energy Policy, (USA-1994)Yehia El Mahgary, A. F. Ibrahim, M. A. F. Shama, A. Hassan, M. A. H. Rifai, M. Selim, I. Abdel Gelil, H. Kokor, Anhar Hegazi, A. Amin, F. Bedewi and Juha Forsstrom, (8%)

4- "Estimation of GHG Emissions in Egypt Up to the year 2020", World Resource Review, Vol. 6, No. 8, (USA-1994), Yehia El Mahgary, VTT-Energy, A. I. Abdel-Fattah, M. A. Shama, Alexandria, Faculty of Eng., M. Selim, I. Abdel Gelil, Anhar Hegazi, NREA, Egypt, M. A. Rifai, Azhar University, A. Amin, F. Bedewi EEA, Egypt, and J. Forsstrom, (11%)

5- "Technical Evaluation of Transport- Related GHG Abatement Techniques", AEJ, April. (Egypt-1995), Shama, M. A., and Hassan, A. (50%)

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7- "Ship Structural Failures: Types Causes and Environmental Impact", AEJ, July. (Egypt-1995) Shama, M. A., (100%)

8- "GHG Emissions Inventory for Egypt and Emission Mitigation Options",VTT, Energy, (Filand-1995), Yehia El Mahgary, VTT-Energy, Finland, M. A. Shama, A. F. Ibrahim and A. Hassan, Alex. University, Egypt, M. A. Rifai, Azhar University, Egypt, I. Abdel Gelil, M. Selim and H. Kokor, ECPO, Egypt, Anhar Hegazi, NREA, Egypt, A. Amin, F. Bedewi EEAA, Egypt, and Juha Forsstrom, VTT-ENERGY,Finland, (8%)

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11- "Energy and Env. in Eng. Education", AEJ, Vol.36. (Egypt-1997), Shama, M. A. (100%)

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13- "Life Cycle Assessment of Ships", Alexandria Engineering Journal, AEJ, (Egypt-2004) Shama, M.A. (100%)

14- "Life Cycle Assessment of Ships", IMAM 05, Sept. International Maritime Association of Mediterranean Sea, (Portugal-2005), Shama, M. A. (100%)

15- "Environmental Dimension in the Ship's Life Cycle", MARDACON 9, December, Int. Con. "Towards a Cleaner and Safer Maritime Context", (Egypt-2005), Shama, M. A. (100%)

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ESTIMATION OF GHG EMISSIONS IN EGYPT UP TO THE YEAR 2020

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ABSTRACT

Within the frame of UNEP's project on the Methodologies of Determining the Costs of Abatement of GHG Emissions, a case study on Egypt was undertaken by VTT (Technical Research Centre of Finland) in cooperation with the Egyptian Environment Authority Agency (EEAA). Both the bottom-up or engineering models and the top-down or the macroeconomic models were used. In the bottom-up approach, the economic sectors were divided into seven groups: petroleum industry, power generation, heavy industry, light industry, residential and commercial sector, transport and agriculture and domestic wastes. First, a comprehensive inventory for the year 1990 was prepared for all the GHG emissions mainly, but not exclusively, from energy sources. This included CO_2, CH_4 and N_2O.

A base scenario of economic and energy growth of Egypt for business-as-usual alternative was fixed using the results of several optimization processes undertaken earlier by the National Committee of Egypt. GHG emissions of the different sources in this base scenario were then determined using LEAP model and spread sheets.

1 INTRODUCTION

This paper represents a part of the case study on Egypt to determine the costs of the abatement of GHG. It consists of an inventory of the GHG emissions mainly, but not exclusively, from energy production in Egypt in the year 1990; and estimation of the GHG production by the different sectors up to the year 2020. The economic sectors were divided into seven main areas, viz, Petroleum Production, Power Production, Heavy Industry, Light Industry, Household and Commerce, Transport and Agriculture and Domestic Waste.

1.1 Demographic and Economic Summary

The Arab Republic of Egypt has an area of about one million square kilometers with a total estimated population of 55 million inhabitants (end of 1990). The inhabited area along the river Nile at the Delta and along the northern coast represents about 5% of the country total area giving an average population density of more than one thousand persons per square kilometers.

The Gross Domestic Product (GDP) of Egypt in 1990 (the average of the two fiscal years 89/90 and 90/91) was about $49.2x10^9$ L.E. (US\$ $14.78x10^9$) according to price level in 1986/87 and $92.3x10^9$ L.E. (US\$ $27.72x10^9$) according to price level in 1990 (National Bank, 1991). The industrial sector represented about 17.9% of the total GDP, agriculture represented 19.65%, petroleum represented 3.7%, construction - 4.95%, electricity - 1.3%, transport, communication, trade and finance represented 34.2%, and general services including housing, social insurance, governmental and public services represented 18.25%. Figure 1 gives the sectoral GDP of Egypt for the year 1990.

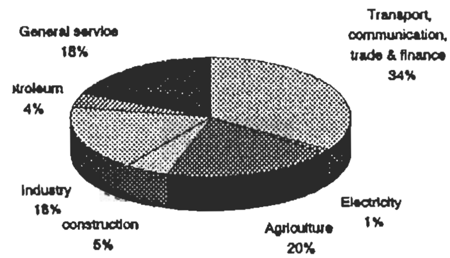

Figure 1 The GDP of the different sectors in Egypt in 1990

1.2 Energy Sector Structure

The main energy sources of Egypt are hydro power, oil, natural gas, coal and non-commercial fuels as firewood, agricultural wastes and dried dung. Oil was first discovered in Egypt in 1868, production started in 1911 and the first refinery was constructed in 1913. The contribution of petroleum sector to the economy of the country is summarized in Table 1.

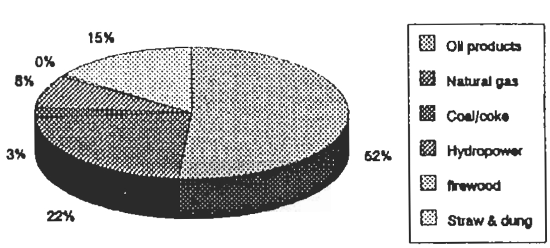

Figure 2 Energy supply by source in 1990 in Egypt

Petroleum consumption has increased drastically from 1975 to 1985, a period sometimes called the explosive petroleum consumption period in Egypt. The annual increase in petroleum consumption during this period reached values as high as 11.3%. This was followed from 1985 to 1989 by sudden decrease in petroleum exports due to collapse of international oil prices. The total production of oil and natural gas increased from 1395 PJ in 1980/81 to 2195 PJ in 1989/1990 with an average annual increase of about 5% (Abdallah, 1992).

Table 1 Petroleum sector contribution to country economy

Year	Balance of petroleum sector in million US Dollars			Local consumption of oil and natural gas (Mt)
	Exports	Imports	Balance	
1970	79	110	- 31	
1975	309	374	- 65	7.46*)
1980	3064	411	2653	13042
1985	3340	710	2630	21831
1990	2288	892	1396	26298

*)About 33 kt of natural gas are included.
Source: H. Abdallah[2].

Natural gas is used as fuel and as raw material in petro-chemical and fertilizer industries. More emphasis is being placed on natural gas production and use as energy source. Coal was discovered in Egypt in 1959 in Sinai. It has not been used so far in power plants.

The total commercial energy demand of Egypt has increased from about 130 PJ (3 Mtoe) in 1950 to about 677 PJ (16 Mtoe) in 1980/81 and to 1069 PJ (25 Mtoe) in 1989/90 with an average annual growth rate of 6.3% in the eighties (Abdallah, 1992). Hydro power played a significant role in satisfying Egypt's energy needs in the seventies by providing more than two third of the electricity demand. In the late eighties the situation was completely reversed with oil and gas providing more than two third of the electricity demand.

The pattern of energy requirement by source in Egypt in 1990 was roughly 52% from oil, 22% from natural gas, 15% from agricultural waste, 8% from hydropower, 3% from coal and less than 1% from firewood (Figure 2).

Petroleum fuels, i.e., oil and natural gas, represent the most important energy sources for Egypt at present and for many years to come. They also represent the main current source of greenhouse gases(GHG). Primary energy consumption by sector is shown in Figure 3.

Proven oil reserves were estimated in 1990 to be about 3.5 billion barrels (Issa, 1990). The present production of oil is in the order of 44 Mt per annum which is roughly 860,00 bbl/day. Hence oil reserves in Egypt would be sufficient, at present production rate, for a little over 11 years. Egypt has been for the last two decades a non-OPEC net oil exporter, and oil exports still represent one of the main foreign currency incomes of Egypt, even though the share of the petroleum sector went down from a maximum of 15.3% in the fiscal year 1984/85 to about 3.7% of the total GDP of Egypt in 1990/91.

The second major primary energy source in Egypt is natural gas, the reserves of which are estimated to be about 368 billion cubic meters (368 km^3). The current level of the annual gas production is in the order of 6.5 Mt (16 billion cubic meters), accounting for nearly 20% of the total consumption of primary energy sources (Abaza, 1989). It is anticipated that natural gas will play an increasingly important role in the country energy mix in the near future, especially for electricity generation.

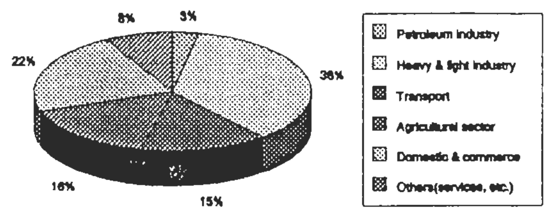

Figure 3 Distribution of primary energy consumption by sector in Egypt in 1990 - Note: Non-commercialsources are included in the agricultural sector

The third major primary energy source is hydro power generated from the High Dam and the two Aswan Dams. About 10 TWh is being produced annually from these three hydropower stations accounting for about 90% of the total available hydro power (Bechtel, 1987).

The electric power sector used in 1990 about one third of the total oil and gas consumption of Egypt, as thermal power plants burned in 1990 about 360 PJ (8.6 Mtoe) of natural gas and petroleum products to generate about 33 TWh. The current fuel mix of thermal electricity generation consists of 51% fuel oil, and 49% natural gas (EEA, 1990 & 1991).

1.3 Government Energy Policy

1.3.1 The policy of switching to natural gas

In view of the availability of natural gas and for economic and environmental considerations, the government policy has in recent years favored the use of natural gas in almost all the economic sectors. The combustion of natural gas generates substantially less SO_x, NO_x and CO_2 than the combustion of its competing

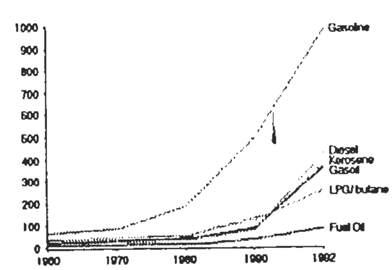

Figure 4 Development of local prices in petroleum fuels in Egypt

oil fuel. The adoption of "natural gas substitution" policy in the Egyptian oil and gas sector since 1975 has resulted in considerable decrease of oil growth rate. The total amount of substituted fuels by natural gas between 1984 and 1991 is shown in Table 2 (Abaza, 1989).

At the macro level, natural gas consumption has increased by 15% per annum while liquid fuels have experienced a growth rate of 7% per annum during the same period (Ministry of Energy, 1991).

Table 2 Amount of liquid fuels substituted by natural gas in Mt (1984-1991)

Gas oil (fuel oil No. 2)	15.7
Fuel oil (fuel oil No. 6)	25.5
Naphtha	8.2
LPG	0.396

Source: Hatata, 1992

1.3.2 Normalization of local prices of petroleum products

The local prices of petroleum products has been, for long time in Egypt, considerably lower than the international market prices to match local incomes and the relatively low cost of life in Egypt. Table 3 gives the local prices of the petroleum products in the course of the last thirty years in local currency LE (Livre Egyptien).

The steep increase in the local prices of petroleum products was accompanied during the same period by a decrease in the value of the Egyptian pound (LE) against the US Dollar. This could be noticed from Figures 4 and 5. This explains partially why the local prices of petroleum product are still lower than the international market prices although some of them has increased by over ten/twenty times. Petroleum prices were practically frozen in the local market since the middle of the seventy's, whereas their international prices have been escalating. The result was the continuous increase in national subsidies in energy and the consequent explosion,

Table 3 Local prices of petroleum products

Fuel / Year	Fuel oil LE/t	Diesel LE/t	Gas oil LE/t	Kerosene LE/t	Gasoline*) LE/t	LPG LE/t
1960	7	15.21	18	22.7	67.2	36
1970	7.5	24.57	30	31.5	81.2	44
1980	7.5	30.42	36	37.8	182	52
1990	50	105.3	120	252	770	120
1992	80	316	360	378	980	250

*) Octane no. 80.
Source: Organization for Energy Planning (OEP).

mentioned earlier, in the consumption of petroleum products from 1975 to 1985. As an example the magnitude of the national subsidies in the petroleum products reached a value of US$3.5x10^9 in 1985 (Abdallah, 1992).

The current policy of the present Government is to bring the local prices to the international market prices by the year 1995. For this reason, the prices of the petroleum products used in this study will be the prevailing international market prices except if otherwise stated.

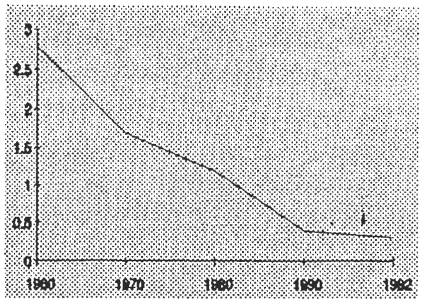

Figure 5 The official rate of the Egyptian Pound (LE) against the US Dollar

2 ENERGY CONSUMPTION AND GHG EMISSIONS IN 1990

2.1 Summary of Energy Consumption and GHG Emissions

A summary of the energy consumption of the different sectors and the corresponding GHG emissions, mainly but not exclusively, from energy activities, in Egypt in 1990 is given in Table 4.

Table 4 Summary of GHG emissions in Egypt, 1990

Energy/EmissionsSector	Energy (PJ)	CO_2 (Mt)	CH_4 (kt)	N_2O (kt)
1. Petroleum	43.50	3.1	51.906	0.121
2. Power Production	464.63[1)]	24.75	0.073	0.89
3. Heavy Industry	144.41	18.81	0.032	0.399
4. Light Industry	138.59	9.30	0.0243	0.351
5. Household & Commerce	134.57	9.34	2.635	0.37
6. Transport	196.6	13.46	9.934	7.091
7. Agriculture & Domestic waste	212.12[2)]	0.67	424.22	33.25
8. Others[3)]	58.82	4.08	1.127	1.579
Total	**1393.24**	**83.51**	**489.951**	**42.629**

1) Generated energy equivalent of hydropower was obtained by assuming an equivalent efficiency equals the average thermal efficiency in that year, i.e., about 33%.
2) About 202.71 PJ of non-commercial energy sources are included.
3) Governmental offices, services etc. (electricity consumption not included).

As could be noticed from Table 4, electricity generation, industry and transport sectors are the major producers of CO_2. Rice paddies are, on the other hand the main producer of CH_4. They are responsible of over 80% of methane production in Egypt. Finally, N-fertilizers and road transport are the main sources of nitrous oxide. The different GHGs have different greenhouse warming potential (GWP). Nitrous oxide, N_2O, has the highest GWP among the three gases and CO_2 has, fortunately the lowest GWP.

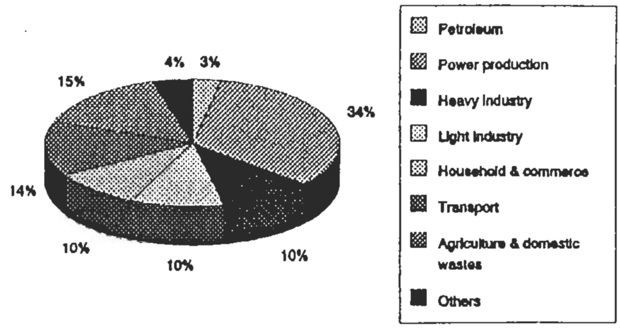

Figure 6 Primary energy consumption by the different sectors of the present study in 1990

Figure 6 shows the distribution of energy consumption of the different economic sectors of the present study. This distribution which is slightly different than the conventional one given earlier in Figure 3 was found more convenient when considering the actions and measures that could be taken in these sectors to decrease GHG emissions.

The corresponding distribution of GHGs emissions, taking into account the GWP of each gas, is given in Figure 7. It is of particular interest to compare the Figures 6 and 7, and to note that Figure 7 is not a mirror of Figure 6. The share of the power production sector is less in the GWP sources than in energy consumption thanks to the effect of hydropower. The share of heavy industry has, on the other hand, increased mainly because of additional CO_2 emissions from constructional industry and also because of the coal used in metallurgical industry. The share of petroleum industry in GHG emissions is more than its share in energy consumption mainly because of gas

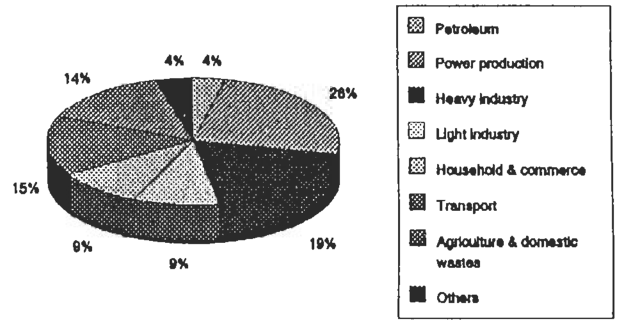

Figure 7 Corresponding GWP of the different sectors in 1990

leakage. The shares of the other sectors have roughly remained the same or changed slightly.

The transport and agricultural sectors which consumed about 14% and 15% respectively of the prime energy of Egypt have contributed roughly similar share to the GWP of the GHG emissions of Egypt in that year. The GHG emissions from transport sector are totally caused by burning petroleum fuels, whereas those of the agricultural sector are mainly caused by N_2O from N-fertilizers and CH_4 from rice paddies. Emissions from biomass burning were not included as it is mainly caused by emissions from straw burning, which is being taken up again by new plantations.

2.2 GHG Budget of Egypt in 1990

As a matter of fact, part of the straw is being continuously used in paper and pulp industry. This was estimated to be about 12.5% of the annual production of straw. A part of the paper produced is again burned or dumped in landfills, hence re-cycled to the atmosphere. The balance is stored in libraries or on bookshelves, thus representing a small sink of CO_2. In the absence of exact statistics on these figures, it was assumed that half the amount of the straw used in paper and pulp industry was re-cycled and the other half was stored in the form of books, periodicals, etc. The amount of CO_2 taken up by this sink in 1990 is thus 4.8 Mt.

The final budget of the GHG emissions in Egypt in 1990 is given in

Table 5 The final budget of GHG emissions in Egypt for the year 1990

GHG Source/Sink	CO_2 (Mt)	CH_4 (kt)	N_2O (kt)
Emissions	83.51	490	42.6
- Straw used in pulp & paper indust.	- 4.8	-----	-----
- Desert	-----	- 193	-----
- Farm land	-----	-----	unknown
Balance	78.71	297	≤ 42.6

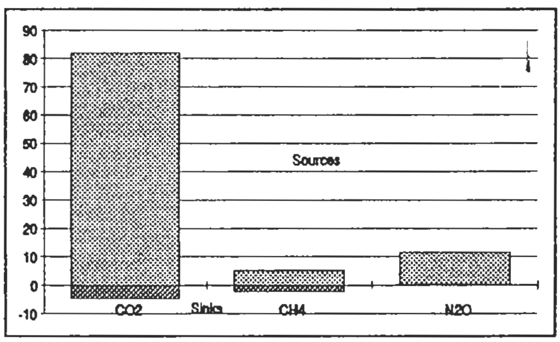

Figure 8 Sources and sinks of CO_2 in Egypt in 1990

Table 5, and their GWP is shown in Figure 8. The effect of the desert as sink of CH_4 is also shown in the same figure.

The main sources of CO_2 in Egypt in 1990 were fossil fuel burning and construction industries including cement, bricks, lime, etc. (Figure 9).

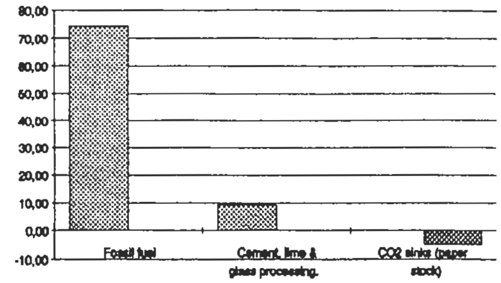

Figure 9 The sources and sinks of GHGx (including their GWP) in 1990 in Egypt

Figures 10 and 11 show the sources of CH_4 and N_2O in Egypt in 1990, including desert consumption of CH_4, through oxidation by methylotrophic bacteria, and rice paddies and landfills production of CH_4. N-fertilizers are the main source of N_2O in Egypt.

2.3 Energy and GHG Production in Egypt in Comparison to Other Countries

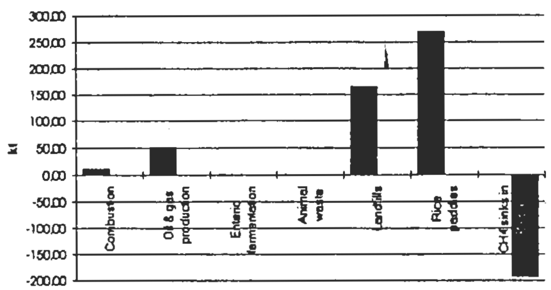

Figure 10 Sources and sinks of CH_4 in Egypt in 1990

It is of particular interest to compare the results obtained so far in this study on Egypt with those of similar studies on other countries. Table 6 summarizes selected energy and CO_2 emission factors of Egypt, Brazil, China and some of the OECD countries.

The first row of Table 6, primary energy consumption per capita, gives indication of the country's stage of development, effectiveness

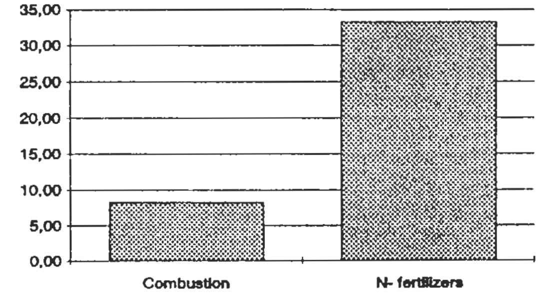

Figure 11 Sources of N_2O in Egypt in 1990

Table 6 Energy and CO_2 emission factors for some countries in 1990

Country	China 1)	Egypt 3)	Brazil 2)	Poland 1)	Finland 1)	France 1)	Japan 1)	USA 1)
GJ/capita	22.3	25.3	55.6	108.5	246.7	156.1	146.5	320
kg CO_2 /GJ	76.5	59.18	34.91	66.8	42.4	41.64	58.32	60
t CO_2 /capita	1.71	1.5	1.94	7.24	10.46	6.5	8.55	19.2

Sources: 1) CEC, 1993 2) Pinguelli, et al, 1993 3) Present Study.

of energy efficiency and particular weather conditions, etc. Industrialized countries have higher energy consumption per capita than developing countries. But the higher energy consumption per capita indicates also a low energy efficiency in case of similar GDP and weather conditions. Japan, e.g., had a higher GDP/capita than USA in 1990, still Japan's energy consumption per capita is less than half that of USA, thanks to the successful energy conservation programme in Japan and to the wasteful energy consumption manners in USA. Even though Finland has colder climate and it needs more heating in winter, its energy consumption per capita is still far lower than that of the USA.

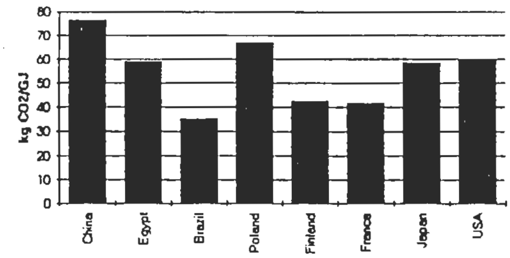

Figure 12 CO_2 production per unit of primary energy in different countries

The second row of Table 6 has been mistakenly used by some authors to indicate the efficient use of energy. This is not the case as one tonne or one GJ of primary energy of a certain fuel will produce the same amount of CO_2 irrespective of the efficiency of the process used. This raw indicates more or less the energy mix of the country. The lower the figure the higher is the share of non fossil fuels, as renewables and nuclear (Figure 12). Brazil has considerable hydro power resources of over 40 GW, in addition to an effective programme of using renewables to substitute gasoline. France covers a great part of its energy needs by nuclear energy. Finland has a good mix of hydro, nuclear and fossil plants, each type provides roughly one third of the energy demand. Egypt renewable energy sources (hydro plus non-commercial) provided in 1990 about 23% of the total energy demand, still they have pronounced effect on the CO_2 per unit energy. USA seems to have the highest share of fossil fuels in its energy mix.

The third row of Table 6 (see also Figure 13) is a mixture of the effects in the two preceding rows; still the effect of the level of energy consumption per capita is more pronounced.

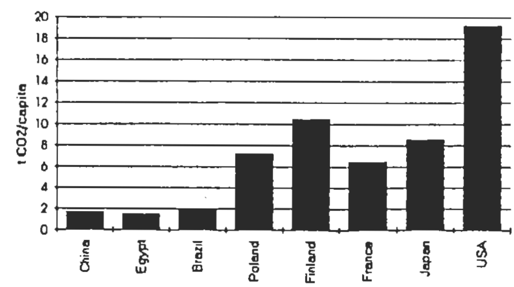

Figure 13 The emissions of CO_2/capita in different countries

3 GHG EMISSIONS UP TO THE YEAR 2020

The next and most important step was to establish, to the best of our present knowledge, a realistic scenario of the energy demands of the different economic sectors and that of the whole country, and to satisfy these demands using available sources up to the year 2020. Fortunately, a number of energy forecasting studies of that type was undertaken in Egypt using several international models. This made the problem a bit easier.

3.1 Basic Sectoral Assumptions

3.1.1 Petroleum sector

Natural gas production was planned to increase steadily in the business-as-usual scenario. In the year 2000, natural gas production was estimated at 15 Mt increasing to 23 Mt in 2010 and to 27 Mt in 2020. Oil production was, on the other hand, assumed to increase with a much lower rate in view of the dwindling oil resources of Egypt. Oil consumption was assumed to reach 28 Mt in 2000, 31 Mt in 2010 and 35 Mt in 2020. If oil consumption outstripped local oil production, it was assumed that the balance will be imported.

3.1.2 The power production sector

The main assumptions of the base scenario, as far as the power production sector is concerned are as follows:

3.1.2.1 Rate of growth of energy production:

Among the several forecasts suggested for future power production a realistic option with the following growth rates was selected:

* From 1992 to 2000 an annual growth rate of about 5% was assumed
* From 2000 to 2010 an annual growth rate of about 4% was assumed
* From 2010 to 2020 an annual growth rate of about 3.5% was assumed.

It is worth mentioning that those rates are of the same order as the actual rate for 1991/1992 which was about 4.7 % .

3.1.2.2 Hydropower growth:

The hydro power capacity of 2715 MW at 1990 will be increased through the introduction of mini-hydro power plants as follows:

* 1993/94 80.0 MW from Essna
* 1996/97 80.0 MW from Nag Hamady and other sites
* 2001/2002 20.0 MW form other different sites
* 2006/2007 20.0 MW from other different sites

With the construction of these plants whose total power is 200 MW no other hydro power plants are considered for the base case.

3.1.2.3 New and renewable energy sources:

The projected contribution of New & Renewable Energy Resources (NRES) to electrical generation will be either directly through electricity generation by wind energy or PV systems, or indirectly through replacing electric appliances by appliances using renewable energy. The total projected production of NRES according to the current plan is given in Table 7.

It will be further assumed that the contribution of the renewable energy will

Table 7 Plans of NRSE's contribution

YEARS	1991	1995	2000	2005
NRSE contribution (GWh)	70.0	332	1310	3295
%	0.1%	0.5%	1.6%	3.2%

increased annually by about 10% from 2005 to 2010 and by 7% annually from 2010 to 2020.

3.1.2.4 Nuclear plants and grid interconnection:

According to present prospects, the base scenario will not include any nuclear power plants nor considerations for grid interconnection with other countries.

3.1.2.5 Coal power plants:

The equivalent fuel consumption of coal power plants will be assumed in accordance with EEA projections (Abdallah, 1992). They are supposed to start operation in 1997.

3.1.2.6 Energy conservation prospects:

It is further assumed that the fuel consumption rate will decrease by about 1% annually due to the improvement in energy efficiency. The lowest realistic value to be achieved in this scenario was assumed to be about 240 gfoe/kWh (gram fuel oil equivalent per kilo Watt hour) at 2005 and 230 gfoe/kWh at 2015.

3.1.2.7 Thermal Power Plants:

The fuel mixture for thermal power plants will be mainly natural gas, fuel oil and coal. Natural gas provides currently about 53.5% of the total fuel consumption, fuel oil accounts for 46.3%. It was assumed in the base scenario that natural gas will provide 60% of the equivalent fuel at 2010 and be kept frozen at that level due to resource shortage possibilities. Coal power plants will be constructed as explained in item 3.1.2.5 above.

3.1.3 Industry Sector

The steep growth in energy consumption of the industrial sector cannot be missed as Egypt has an ambitious industrialization programme, which seems realistic taking into account the population growth and the planned growth in GDP. Oil is the fuel most used in industry in the business-as-usual scenario followed by natural gas, but coal still plays an important role.

3.1.4 Household and commerce sector

The domestic and commercial sector is a major electricity, kerosene and LPG consumer. The estimation of the consumption of this sector is rather difficult and depends to a great extent on the economic growth and the well-being of the country. The scenario proposed for this sector is not entirely based on the assumptions of the NCE's scenario (National Committee, 1992), in which the energy demand of the domestic and commercial sector will double in 2000 and treble in 2010 with respect to the demand of 1990. This was found to lead to too steep an increase in energy; instead, the demand of the domestic and commercial sector was assumed to increase by a factor of 1.7 in the year 2000, by a factor of 2.4 in the year 2010 and by a factor of about 3 in the year 2020, with respect to the demand in 1990.

3.1.5 Transportation sector

For the transportation sector, the determination of the energy consumption and consequently the traffic-related GHG emissions until the year 2000 was based on the development of the transport demand in Egypt. For both passenger and freight transport (intercity and short distance traffic), it was assumed that the expected increase in demands matched the foreseen population growth. Otherwise the progress of the demands will be affected by the evolution of the number of vehicles. Based on the specific energy consumption and emission rates of the different transport modes as well as the expected transport demands until 2020, the total energy needed for the transport sector and the corresponding traffic-related GHG emissions were calculated using a model constructed by Alexandria Faculty of Engineering (ElMahgary *et al*, 1994).

3.1.6 Agriculture and domestic wastes

The emissions of GHGs in the agriculture sector are based mainly on the development plan for reclamation of land. The scarcity of cultivated land and water makes it difficult and expensive to expand the cultivated area. The land

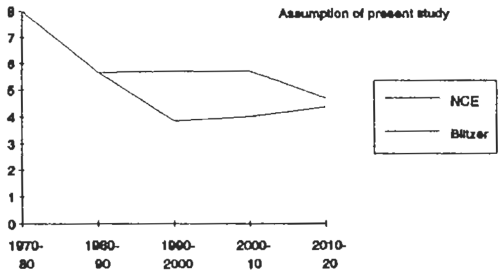

Figure 14 Growth rate assumptions of GDP of Egypt in different studies

master plan (EEA, 1991), shows the possibility of reclamation of 1.245 Mha and additional 0.229 Mha in Sinai and Western Desert up to year 2020, depending on availability of surface and ground water. The rate of annual reclamation according to the experience of the last 2 five-year plans, 1982/1987 and 1987/1992, was 0.295 Mha/5 years.

In addition, the green areas, public gardens and tree plantation inside and outside all private and public building of Egypt may reach 2000 ha in 2010, increasing at a rate of 100 ha/year. The area cultivated by rice paddies was assumed constant after a slight increase in 1991-1993. In case of calculating the N_2O from N-fertilizers, the total planted area was increased according to existing plans of land reclamation. Agricultural machineries are expected to increase rather fast due to the mechanization process assumed in that sector.

3.2 The Base Scenario

In preparing the base scenario, the earlier energy studies of Egypt were consulted as well as other economic and energy forecasts. The latest forecast was the one prepared by the National Committee of Egypt (NCE) for the World Energy Council. It also presented the official national energy data profile for Egypt. A summary of this study was presented at the 15th W.E.C. Congress 1992, held in Madrid last Sept. (National Committee, 1992). Another forecast was presented in a paper written by C. Blitzer, et al. (Blitzer *et al*, 1992). The main assumptions in the two publications are rather different. The average annual growth of the GDP, e.g., was more or less extrapolated in the NCE's estimations based on the growth rates in previous decades. In the paper published by Blitzer, et al., the growth in GDP was generated in the model as a result of different constraints on the Egyptian Economy, including capital and labor availabilities, petroleum and natural gas reserves and the international borrowing constraints. Figure 14 shows the two assumptions of the growth of the GDP. It is of course difficult to give preference to one approach over the other as each one is based on certain assumptions, but it was felt that as a developing country, Egypt is facing a stage of economic improvements and reforms, hence, the growth rate in the GDP of the last decade may not fall down but rather continues at least at the same pace until the year 2010, after which it may decrease slightly. The horizon of the study published by the National Committee of Egypt (National Committee, 1992) was the year 2010. The annual economic growth of the GDP from 1980 to 1990 based on the local currency was 5.66%. Accordingly, an annual increase in the GDP of about 5.7% was assumed between 1990 and 2000, a similar annual increase was assumed from 2000 to 2010. A slower growth of about 4.7% was assumed from 2010 to 2020 to cope with the relative high rate of population growth.

Estimating the population growth of Egypt is not less difficult than estimating the GDP. If the present rate of growth were extrapolated, Egypt populations in 2020 would be over 110 millions. But if account is made for birth control the present rate of birth would decline and the populations would be about 92 millions in 2020. This figure is in good agreement with the United Nations estimation predicting that Egypt populations in 2025 would be about 95 millions. Table 8 gives the population and GDP growth rates used in the present study.

Table 8 Population, real GDP (local currency 1990) and energy growth rates of Egypt

Egypt	Year			
	1990	2000	2010	2020
Population (millions)	55	68.38	81.84	92
GDP (billions LE)	93,300	151.98	247.55	391.86
GDP (billions US$)[1]	27,700	45.64	74.34	117.68
GDP/Capita(LE)	1680	2222.58	3057.11	4259.35
GDP/Capita(US$)	500	667.45	908.36	1279.1
Primary Energy demand (PJ)	1392	2016	2644	3586
Primary energy/Capita(GJ)	25.31	29.48	32.31	38.98

1) A constant value of the US dollar with respect to the LE was assumed.

The forecast of energy demand/supply in Egypt up to the year 2020 is a long optimization process governed by several factors, as the economic growth of the country, the demands of each sector, the availability of resources, etc. Undertaking such an exercise in the present study was completely out of question in view of time and resources constraints. A realistic and reliable scenario was thus sought to form the base scenario of the present study.

Reference was made again to earlier studies. The primary energy

Table 9 Energy consumption in case study's sectors in the base scenario (PJ)

Source/Year	1990	2000	2010	2020
Petroleum	43.50	52.81	59.04	64.75
Power generation	464.30	711.37	993.23	1358.50
Heavy industry	144.41	227.23	322.52	468.72
Light industry	138.59	212.71	313.81	467.86
Household & com.	134.57	208.97	299.43	367.90
Transport	196.60	240.92	280.29	309.09
Agriculture	212.12	281.71	350.63	420.56
Others	58.82	91.39	130.95	160.89
Total	1392.84	2028.12	2755.03	3623.35

forecast of the NCE, which was obtained through optimization processes using different planning and forecasting models, was selected again to form the base scenario of the present study. The outlines of the primary energy demand according to the forecast of the NCE are given in Table 8. Hydro electricity, which was given in the NCE's estimations (Abdallah, 1992) in PJ at the end use has now been transferred, according to UN practice, to primary energy in PJ using the average efficiency of the thermal power plants at that year. Some guidance was taken from the NCE paper as to the breakdown of the primary energy in the difference sectors. But a great deal of freedom was given to the principal investigators responsible of each sector to fix up the energy demands in their sectors within these guiding values.

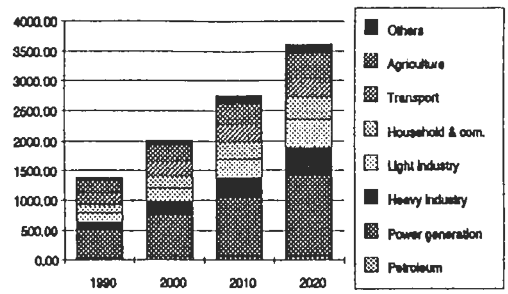

Figure 15 Energy consumption in the different sectors in the base scenario

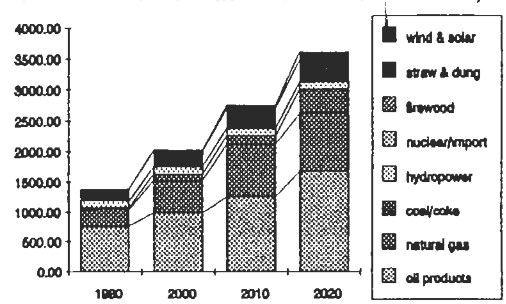

Figure 16 Energy consumption in the different sectors in the base scenario

Table 9 and Figure 15 give the forecast of the primary energy consumption of the different economic sector according to the present study. The largest consumer of primary energy is power production sector followed by industry. This is also clear from Figure 15. On the other hand, the energy consumption by sources in the base scenario are shown in Table 9 and Figure 16.

Renewable energy sources include, in addition to

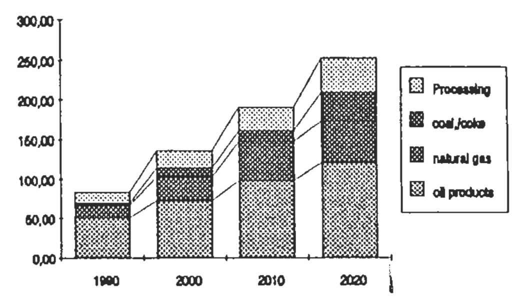

Figure 17 Energy consumption by source in the base scenario

wind and PV already mentioned for electricity generation, solar water heating in houses and for low-grade heat industry. Electricity produced from renewable energy sources was multiplied the same factor as hydro electricity to obtain the primary energy given in Table 10.

Table 10 Energy Consumption by source in the base scenario (PJ)

Year	1990	2000	2010	2020
Oil products	753.37	988.80	1253.05	1674.60
Natural gas	296.79	532.25	867.28	955.79
Coal/coke	33.59	115.64	140.17	384.33
Hydropower	106.38	116.64	118.38	118.38
Nuclear/import	0	0	0	0
Firewood	5.61	6.64	7.83	8.99
Straw & dung	197.1	254	311	368.5
Wind & solar	0	14.15	57.32	112.75
Total	1392.84	2028.12	2755.03	3623.35

3.3 Estimations of GHG Emissions

As far as the CO_2 emissions are concerned, the four main sources, viz, oil, gas, coal and industrial processing are increasing by similar rates in the base scenario (Figure 17). In spite of the fact that the amount of energy generated from coal is less than half that generated from natural gas, CO_2 produced from coal is of the same order as that produced from natural gas.

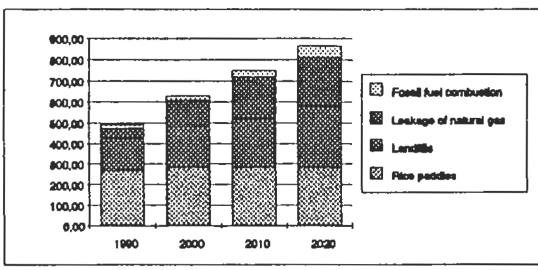

Figure 18 CO_2 emissions up the year 2020 in the business-as-usual scenario

Figure 18 shows that the main sources of CH_4 emissions are rice paddies, land fills and leakage from natural gas. The emissions from the first source are roughly constant as the area cultivated with rice will practically remain unchanged. Emissions from landfills will increase in view of the increase in population, and those due to leakage of natural gas will also increase as a result of expansion in natural gas utilization.

The situation with respect to N_2O emissions is rather different. Figure 19

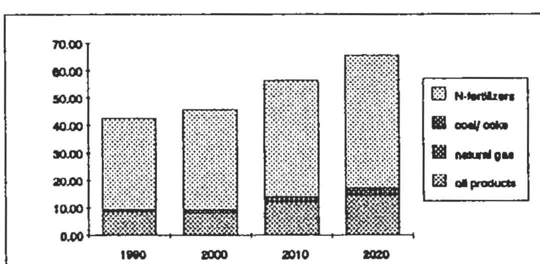

Figure 19 Emissions of N_2O by source in the base/business-as-usual scenario

shows that the main sources of N_2O emissions are N-fertilizers and oil products particularly from the transportation sector. Both are increasing as a result of increasing the area of cultivated land and the number of vehicles on the roads. The use of N_2O in Egypt has increased drastically after the construction of the High Dam as it held in front of it the silt which had been reviving the Egyptian soil for millennia.

The different actions/measures to decrease GHG emissions in Egypt, together with their costs, were considered in details in the case study report (ElMahgary *et al*, 1992).

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