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FROM THE SIXTIES TO THE

EIGHTIES

CHAPTER I

CHARACTERISTICS AND PAST TRENDS OF ISRAEL'S ENERGY ECONOMY

Israel, with a population of 3.9 million and GNP of $17 billion is almost totally dependent on the import of crude oil for providing its energy requirements. Total energy consumption in 1980 was about 8.2 million tons of oil equivalent (TOE). Domestic consumption excluding exports, marine bunkers and stock change will amount to 7.4 million tons of oil equivalent. Local crude oil production provides 0.4 percent of the total; local natural gas provides another 0.7 percent; while solar energy utilized primarily for domestic water heating, contributes an estimated 1.2 percent (100,000 TOE).

Approximately 36 percent of primary energy is converted to electricity while the remainder is marketed as distillates and goes to industrial and petrochemical firms; residential, commercial and public users; agriculture and water pumping; and transport, as shown in Table 1.

Table 1: Pattern of Gross Domestic Energy Consumption - 1978

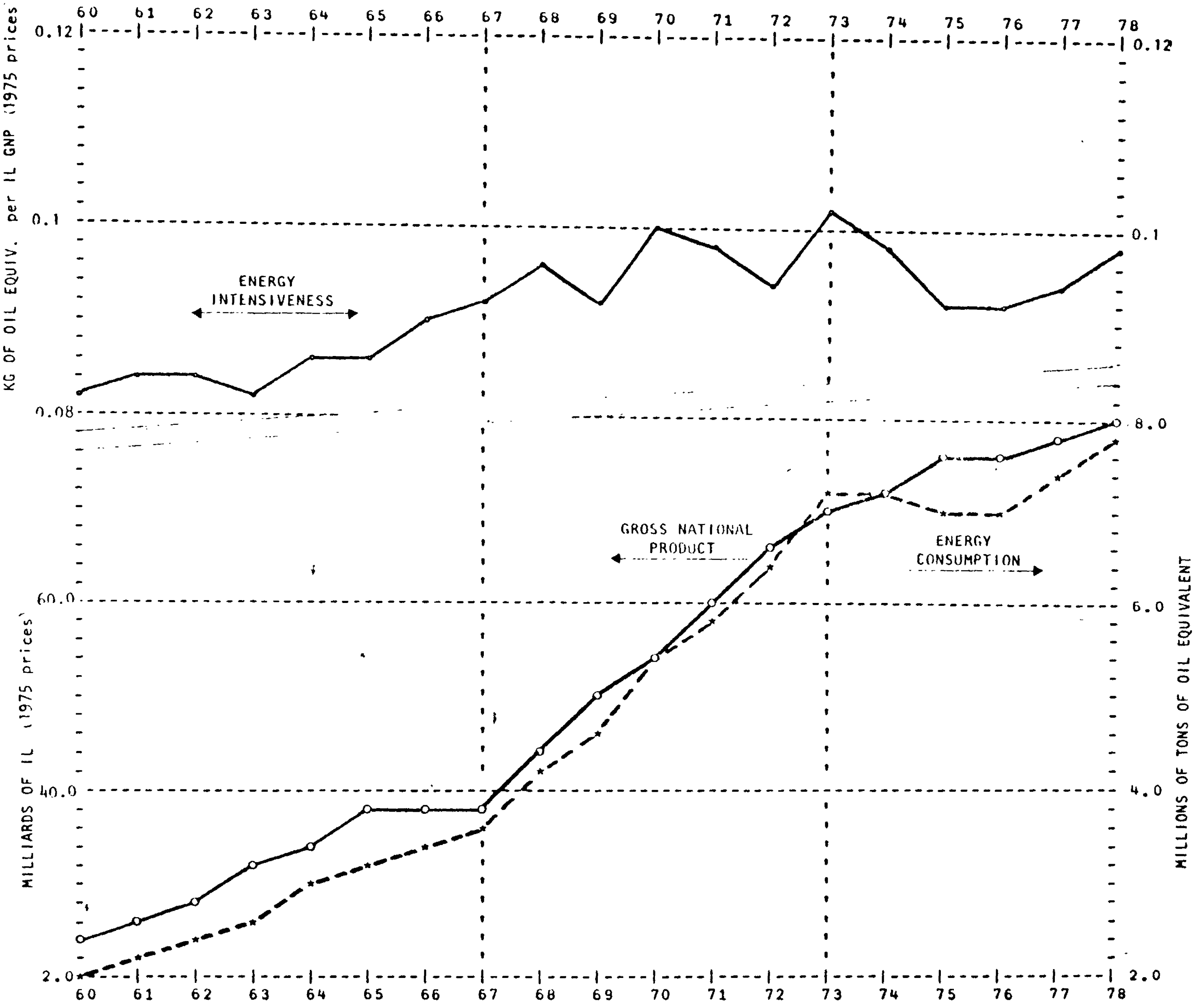
(in percent)

	Oil and Gas	Electricity	Total
Electricity	36.0		
Industry (including petrochemical)	19.9	27.0	29.8
Residential, commercial and public	14.9	43.0	30.1
Agriculture and Water Supply	2.2	18.1	8.8
Transport	19.6	-	19.6
Losses (refineries & elec.generation)	7.4	11.9	11.7
	100.0	100.0	

Energy Consumption Characteristics in Israel

Energy intensiveness in Israel has not changed radically since 1960 although a slight increase of about 10 % has occurred with annual variations, reflecting economic performance (Fig. 1). An energy elasticity of GDP of about 1.1 is thus recorded, which suggests the industrial development stage the country has attained as can be seen in the following figures.

Figure 1 DOMESTIC ENERGY CONSUMPTION, GNP & ENERGY INTENSIVENESS



Electricity intensiveness however has increased significantly by about 45% since the 1960's, making Israel a relatively high electrified country which reflects a long run electricity elasticity of 1.4 - 1.5 (Fig. 2).

These trends of total energy and electricity growth rates per capita are highlighted even more by the comparison presented in Fig. 3 which shows that per capita energy consumption has doubled and electricity consumption almost tripled since 1960.

Since oil still counts for almost all primary energy resources, and almost all of it is imported, the burden on the Israeli economy has increased in recent years, particularly in 1979 and 1980, as can be seen from Figure 4.

It is the question of market vulnerability coupled with these high costs to the economy that stimulate Israel and other highly oil import dependent countries, to search for options that would increase their energy utilization efficiency and break away from oil.

Figure 2: . ISRAEL ELECTRICITY GENERATION, GNP & ELECTRICITY INTENSIVENESS

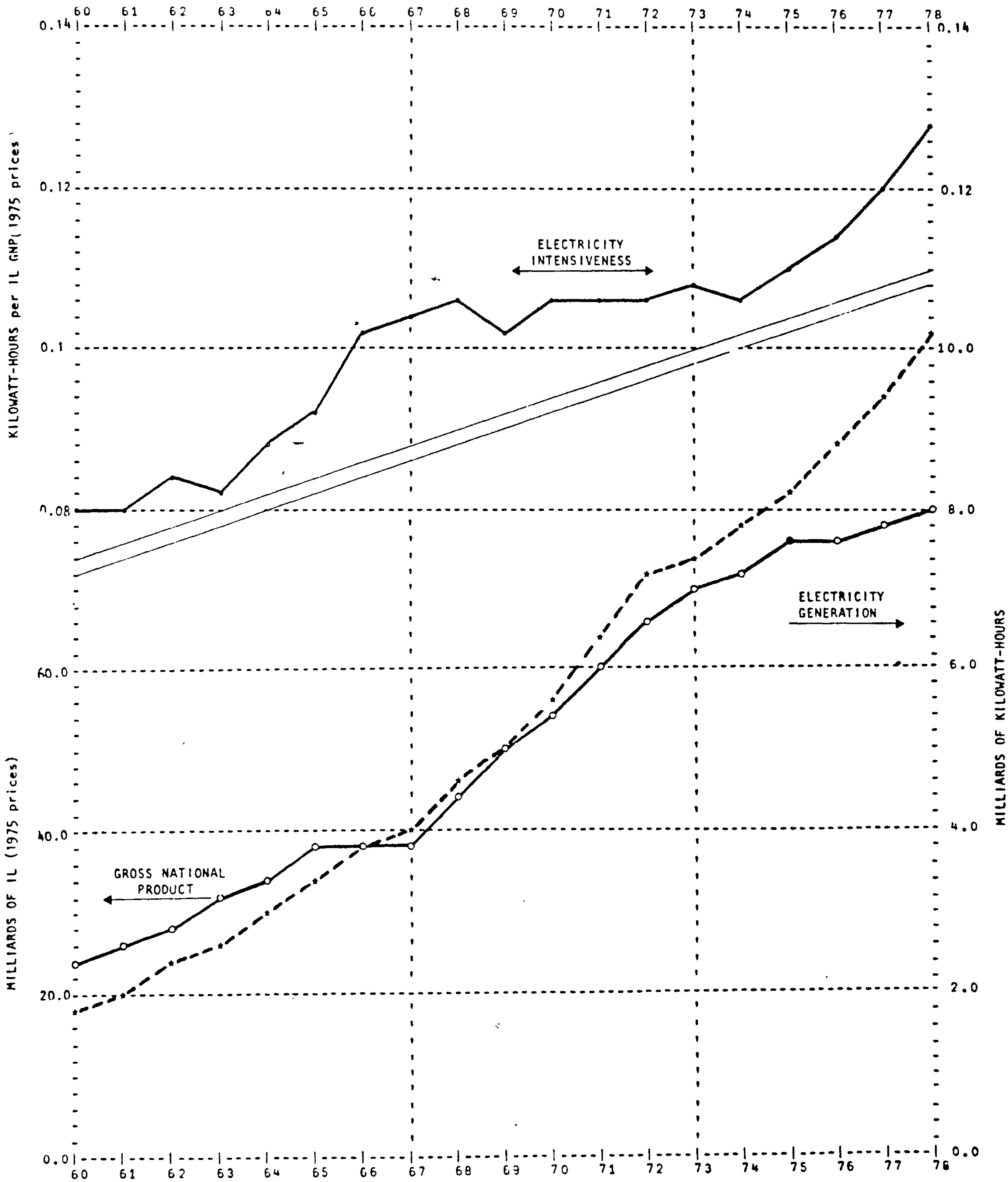


Figure 3: PER CAPITA ENERGY CONSUMPTION & ELECTRICITY GENERATION

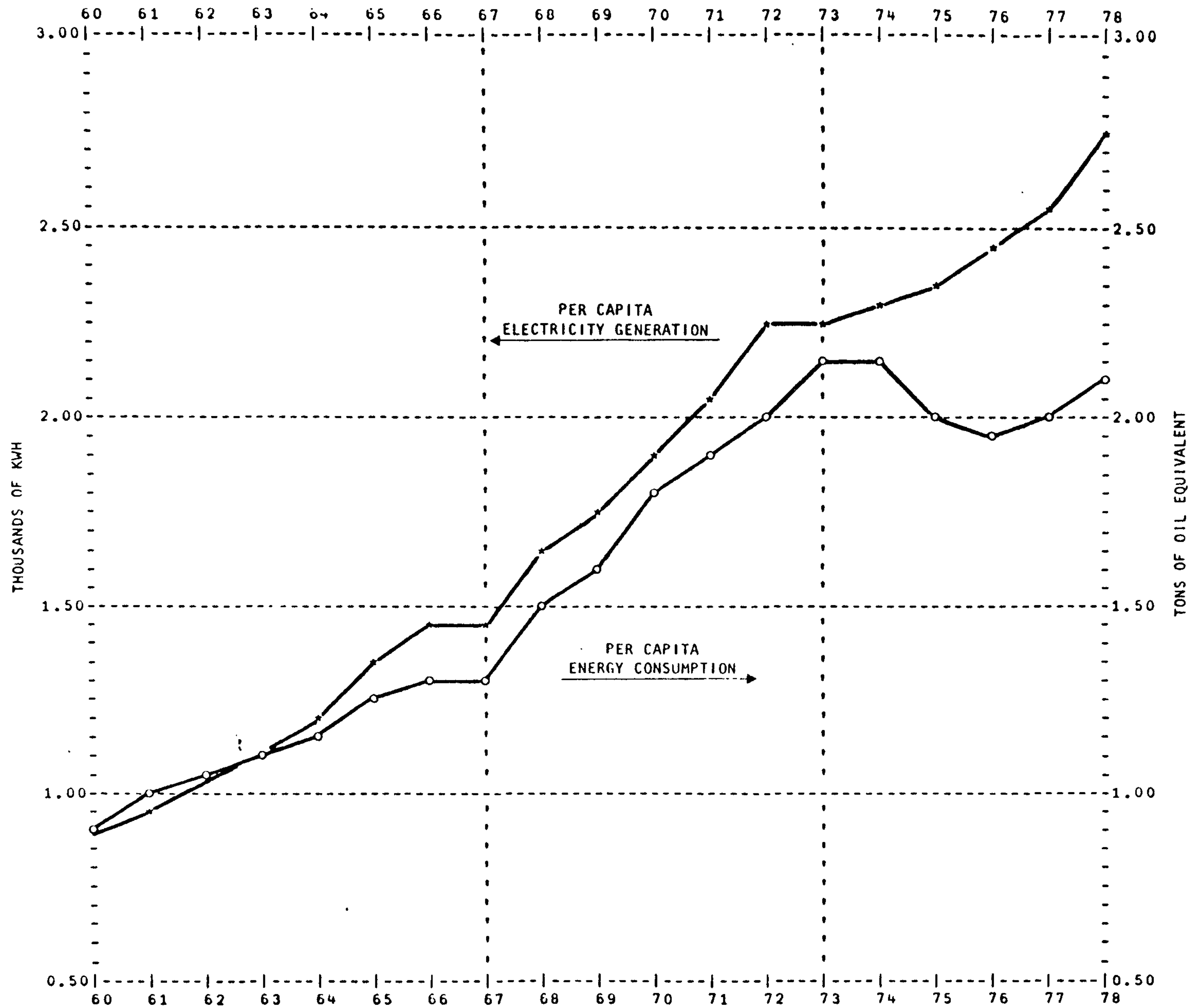
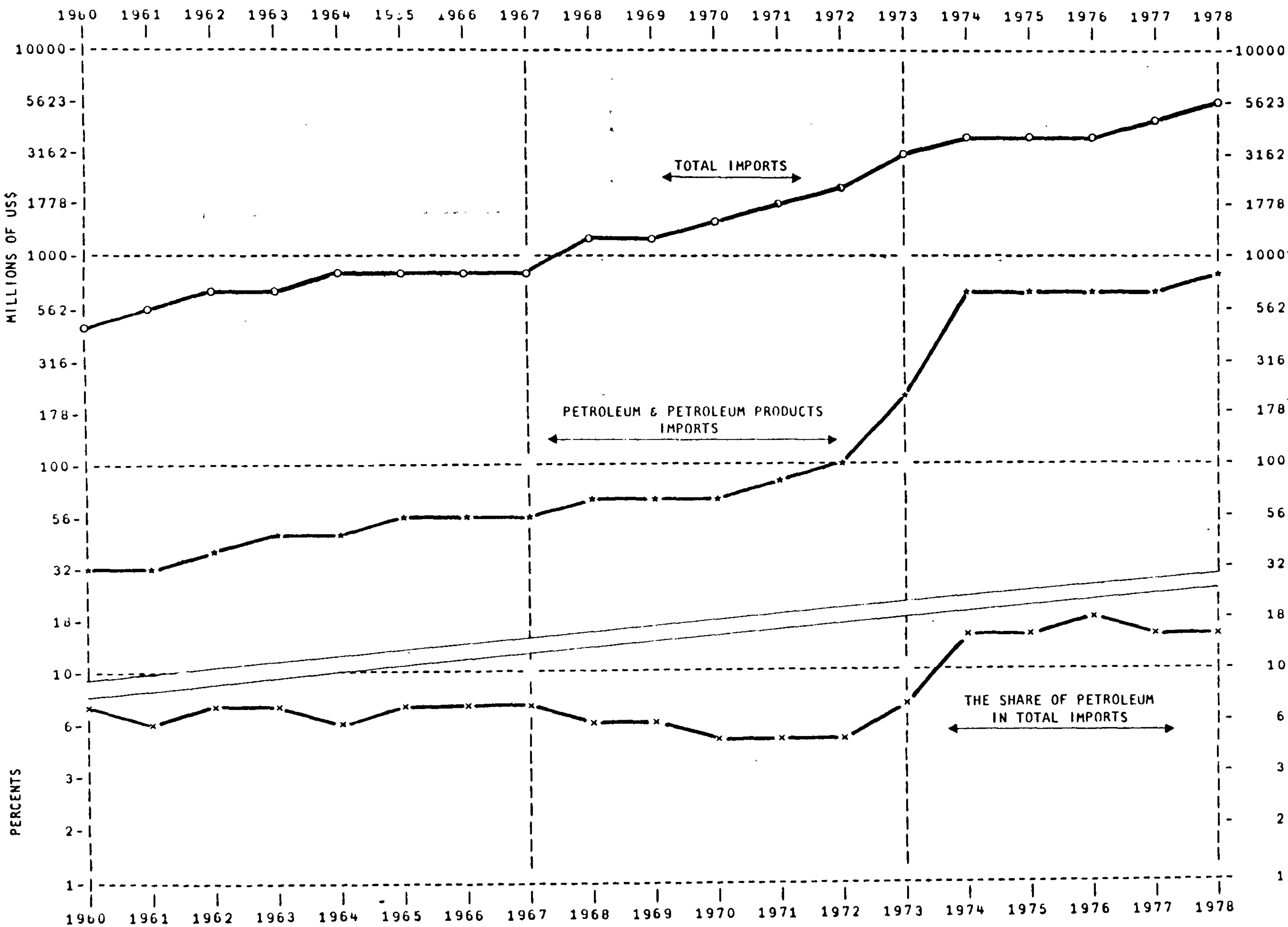


Figure 4: PETROLEUM & PETROLEUM PRODUCTS IMPORTS vs TOTAL IMPORTS



CHAPTER 2

PROBLEMS AND PROSPECTS

Israeli energy policies are based on the following facts:

- Israel's utmost dependency on the import of fuel,
- The relatively high component of fuel purchases on the spot market.
- The severe burden on the Israeli economy in financing these imports.
- The dichotomy of growth: the need for increased energy inputs against the necessity of reducing energy consumption.
- The lack of considerable reserves of fossil resources or significant quantities of techno-economic proven alternatives (hydroelectric power).
- The characteristics and structure of energy consumption: there is no dominant consuming sector, which does not enhance conservation efforts.

In view of these severe problems and constraints, Israel is prudently focussing its national energy objectives on reducing oil imports. In order to reach these objectives, Israel is mobilizing its available resources - the abundance of sun, the low calorific content fossil resources, the highly developed research and development infrastructure and the scientific ingenuity of professionals at governmental, academic and industrial institutions.

Israel has thus adopted the following policy:

- Effective management of all systems through the introduction of conservation measures.
- Diversification of the energy mix by the introduction of coal in all future power generation plants and for energy intensive industrial users.
- Expansion of the use of solar and other renewable forms of energy (hydroelectric, wind power etc.
- Research and development and commercial demonstration of oil shales use.
- Intensification of oil and gas explorations.

Israel is thus determined to adopt any available or developing technology as a substitute for oil to overcome the supply problems of the next twenty years.

SECTION II

THE TRANSITION FROM THE EIGHTIES TO THE END OF THE CENTURY

CHAPTER 3

PROJECTIONS - ECONOMIC - ENERGY SCENARIOS

Since 1960, there have been three distinct kinds of annual growth rates in energy consumption. A high rate of 9.2% between 1960-1967, an accelerated figure of 12.3% between 1967-1972 and a slow growth of about 2.8% between 1972-1978.

These rates correspond with the pace of economic growth in the country, and the impact of the oil crisis since 1973 (Fig. 5).

Electricity generation increased by 11-12% during the first two periods and by a lower figure of 5.5% between 1972-1978, which was still much more than the total energy growth in those 6 years; this reflected again the higher electricity intensiveness and elasticity of the country. (Fig. 6)

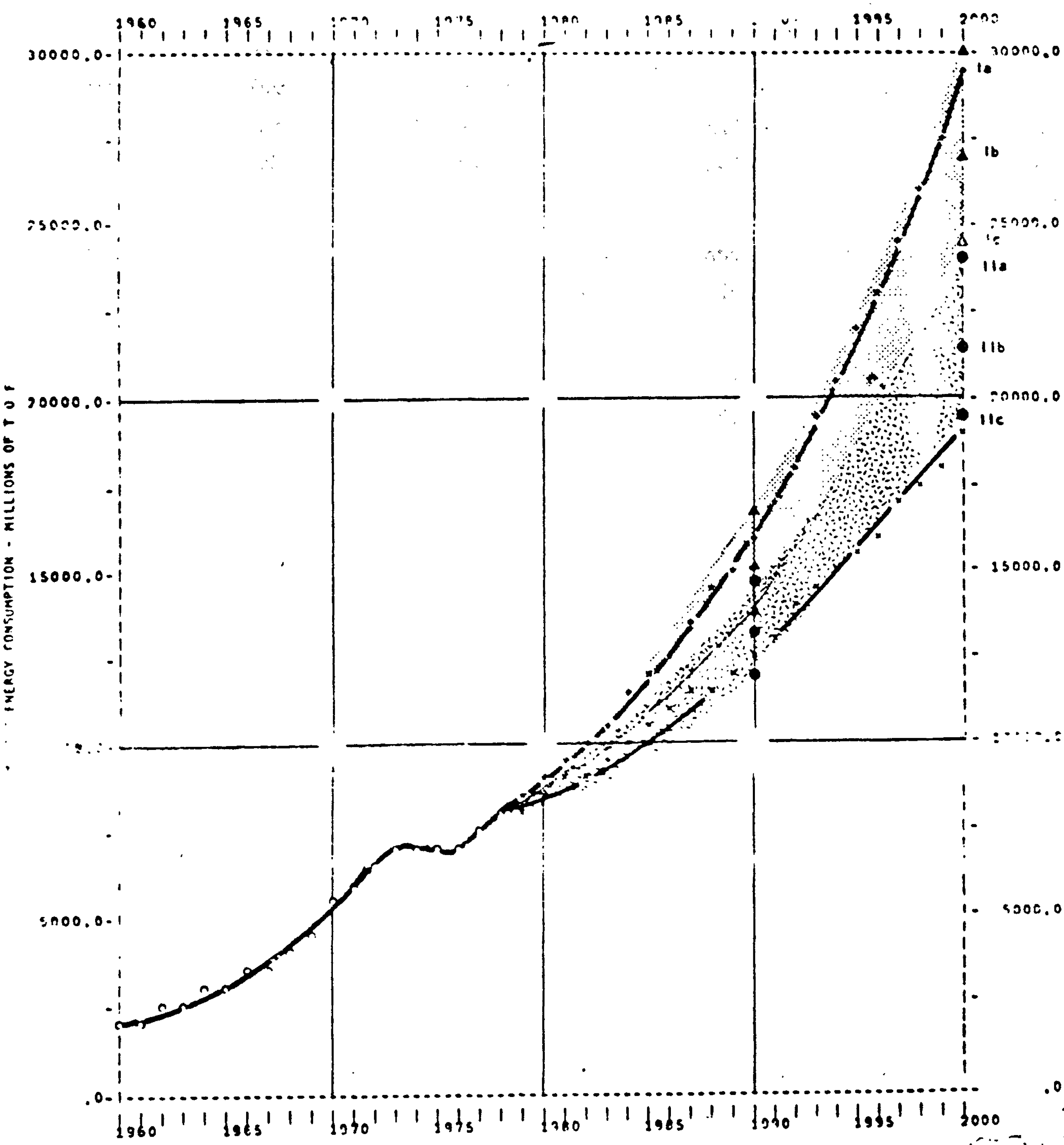
Since energy demand may be roughly assumed to be the product of population, economic activity in terms of GDP and energy intensiveness, different projections have been made as regards the following parameters:

Table 2: Basic Hypothesis on Projections

Annual Population Growth Rate - 2.5%

Annual GDP per capita growth rate	Reasonable 4%		Slow 2%	
	1900	2000	1990	2000
Energy elasticity of income or GDP	1.1	0.9	1.3	1.1
Scenarios	I			II

Figure 5 ISRAEL ENERGY CONSUMPTION OPTIONS UP TO THE YEAR 2000



▲ Scenario I - 4% annual growth of GDP

● Scenario II - 2% annual growth of GDP

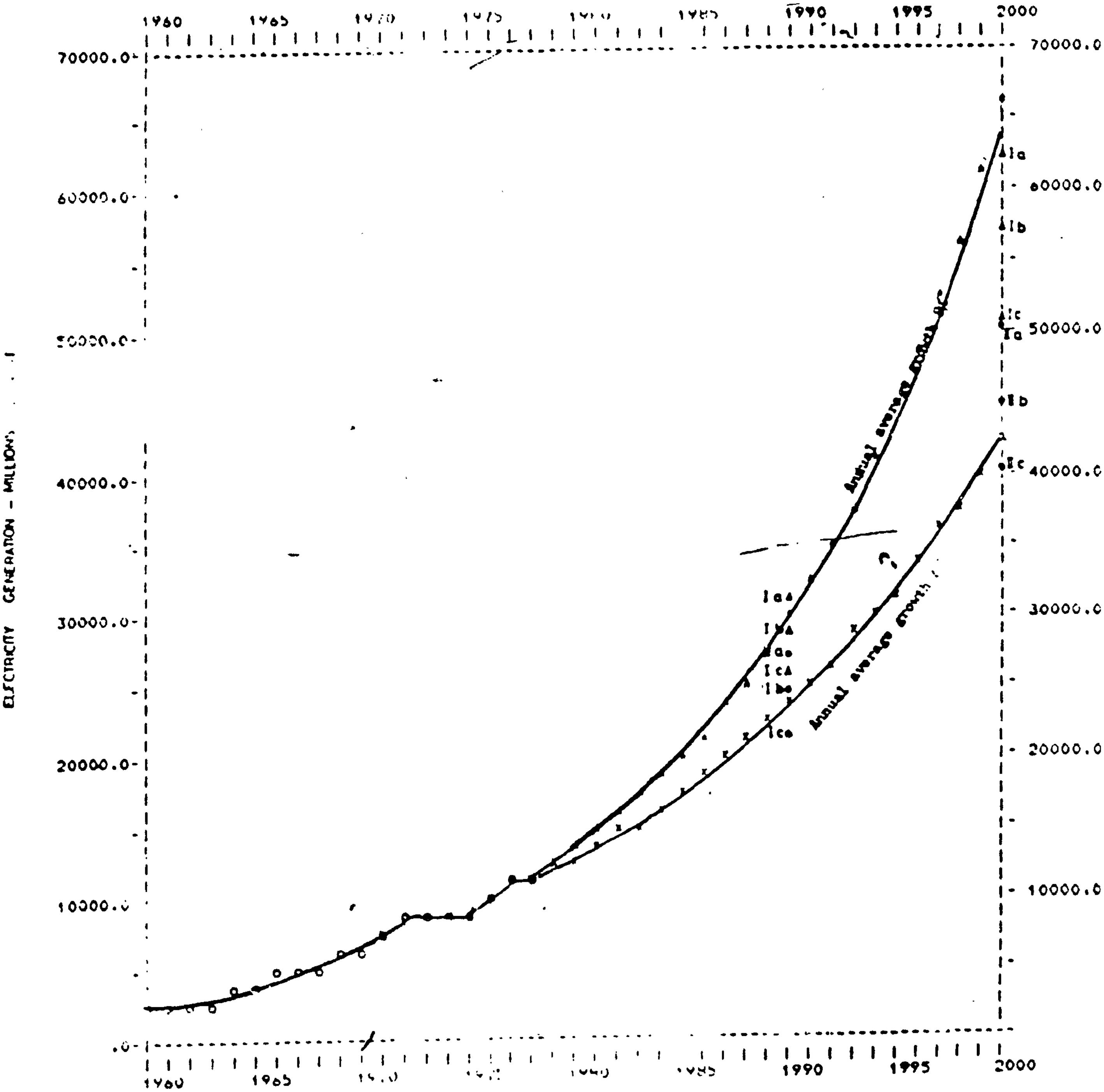
a Basic

b Moderate

c Low

Figure 6

ISRAEL ELECTRICITY GENERATION OPTIONS UP TO THE YEAR 2000



▲ Scenario I - 5% annual growth of G.D.P. per capita

● Scenario II - 3% annual growth of G.D.P. per capita

a) Basic

b) Moderate

c) Low

Three secondary scenarios have been assumed:

(1) Basic scenario - corresponds with the above hypothesis.

(2) Moderate energy scenario - the expected 3% annual rise of real energy prices above all other inputs will reduce total expected basic demand by 10% due to a price elasticity assumption of -0.3.

(3) Low energy scenario - an additional 10% reduction in demand is expected due to the success of various conservation actions.

Any combination of the two last scenarios, may be realized by different weights in the respective components.

The following energy and electricity demands have been projected on the basis of the above.

Table 3: Energy Projections (Million TOE)

Scenario	Year / Secondary Scenari	1978	1990	2000
I	Basic	7.3	17.0	30.0
	Moderate		15.3	27.0
	Low		13.8	24.3
II	Basic		14.7	24.0
	Moderate		13.2	21.6
	Low		12.0	19.5

Electricity projections are based on the expectation that Israel will increase its electricity intensiveness: 45% share of total primary energy resources by 1990 and 50% by the year 2000, estimated as follows:

Table No. 4

Electricity Projections

Year		1978		1990		2000	
Scenario	Secondary Scenario	Million TOE	10^9 KWH	Million TOE	10^9	Million TOE	10^9 KWH
I	Basic	2.67	11.4	7.6	31.7	15	62.5
	Moderate			6.9	28.8	13.5	56.3
	Low			6.2	25.8	12.15	50.0
II	Basic			6.6	27.5	12.0	50.0
	Moderate			5.9	24.6	10.8	45.0
	Low			5.4	22.5	9.75	40.6

The above projections imply that in 1990 energy demand will total 1.6 - 2.3 times the 1978 consumption, and in the year 2000 between 2.3 - 4.1 times.

Electricity is expected to grow 2.0 - 2.8 times by 1990 as compared with 1978 consumption while in the year 2000 the demand will be 3.5 - 5.5 times the 1978 figures.

CHAPTER 4

THE OPTIONS - REDUCING OIL DEPENDENCY

How are we going to supply this demand? What are the prospects of reducing oil consumption subject to these scenarios? What are the options for providing this projected energy needs adequately, reliably and at minimum cost?

How should we act to overcome prospective socio-economic stagnation and reduce geo-political insecurity?

On the demand level we may distinguish two major directions:

- A national and economic efficient price policy.
- An aggressive yet cautious conservation policy.

Demand Level - Pricing Policy

A pricing system which charges consumers the real costs provides the best way for efficient allocation of energy resources. It establishes the correct criterion for making beneficial investments while providing the public with the right signals for their future consumption pattern. Even with relative low, short-term and somewhat higher, long-term price elasticity of demand, the chances are that at the current high level prices, waste will be eliminated, inefficiency in use decreased and total consumption growth reduced.

The government is currently determined to follow as closely as possible this policy: Price equals real cost.

Electricity peak load and shadow pricing in the oil products sector respectively are currently becoming important components of energy pricing policy in Israel.

The introduction of long-term social overhead costs accounting for risk aversion as well as environmental costs will smoothen or levelize the pricing trend, thus providing the consistency to safeguard the economy.

Currently a directive of a 3% - 5% real annual price increase of oil above all other inputs' cost is practiced in Israel to account for future prospects in investment.

Demand Level - Conservation Policy

Secondly, an aggressive conservation policy should be adopted to promote and enforce efficient use of energy where pricing measures do not sufficiently affect consumer behavior. These conservation steps should be directed towards the:

- public sector;
- price regulated industries;
- cases where private benefits from savings do not coincide with social benefits;
- cases where capital outlays for energy saving means competition with other government backed investments.

Yet such a policy should be conducted with the utmost caution, to avoid misallocation of funds, and the introduction of additional distortions in a highly regulated, complicated economy. It is most important not to augment the public sector budget, the major cause of the imbalance between resources and uses in the Israeli economy.

Energy conservation efforts are followed mainly in three directions:

- A most vigorous program to accelerate the spread of solar energy for domestic and industrial use.
- The technological promotion of the use of waste heat in industry.
- Initiated training to eliminate waste in all forms of domestic, industrial and public utilization, by the introduction of technological improvements and conservation awareness.
- Conversion to non-oil uses, wherever possible and economically justified.

Demand management has intrinsic uncertainties, direct conservation means are plagued by the unreliability inherent in mass behavior. Thus the activities should be highly selective and concentrate on:

- Regulating and standardizing energy-saving products, building codes, etc.
- Providing incentives for demonstration plants and pilot projects.
- Disseminating technical and financial information about the saving options available in any of the production processes or consumption practices.

(For specific conservation measures see chapter 7)

Supply Level - Diversification Policy

Diversification policy implies the use of coal as a near-term substitute for oil in future power plants, as well as the introduction of nuclear power stations, oil exploration, the use of solar and other renewable energy forms, oil shale, bio-gas and geothermal energy, as long-term substitutes. All these sources are discussed elsewhere.

Figure 7 summarizes all these options in the form of an action tree.

- Improvement and computerization of the loading program of power generating units.
- Reducing the specific fuel consumption of generating units by introducing new operational parameters, such as higher steam pressures and temperatures and lower flue-gas exit temperatures.
- The somewhat higher wear and tear involved , causing increased maintenance expense, has been well compensated by the savings.
- Close supervision and strict control of operational parameters, which requires high alertness on the part of the station operators and technical personnel.
- Introducing incentive pay programs for operation and maintenance personnel based on those factors in order to enhance economic operation of the power stations.

The changes in operating procedures and design policy introduced after October 1973 had tangible effects. The amount of fuel used for the production of a kWh has dropped due to the more efficient use of available equipment. Moreover, a higher reliability of supply gas has been obtained due to the extra overall availability of the equipment achieved under the new maintenance policy.

During the period 1975/6-1976/7 * the specific fuel oil consumption has decreased from 244.4 grams per kWh to 241.9 grams per kWh. Thus, a reduction of 2.5 grams per kWh has resulted in a saving of about 25,000 tons of fuel oil.

Energy Conservation and Oil Saving on the Consumer Side

- The standard power factor of the electricity consumers has been increased to 0.92. The results obtained so far are very encouraging showing considerable energy savings and improvement of the operational behaviour of the system.
- A program is being prepared to substitute a significant amount of the fuel oil burned in industry by coal.

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* No new unit was added to the system in 1975/6-1976/7.

- Assuming that by 1986/7 all water heating will be achieved by solar energy, a total saving of about $500x10^6$ kWh can be attained, which is equivalent to $120x10^3$ tons of fuel oil. However, as solar heaters replace electric heaters which are operated at off-peak hours, a degradation of the system load factor and the base load unit plant factors is expected. Moreover, on cloudy days the electrical back-up of solar water heaters will increase the winter peak thus lowering the reliability of supply and increasing fuel oil consumption for peaking units. These drawbacks of solar heating can partly be overcome by load management measures.

<u>Diversification of Energy Resources</u> (see elsewhere)

- <u>Coal</u> (see under coal)
- <u>Nuclear Energy</u> (see elsewhere)
- <u>Mediterranean - Dead Sea Project</u> (see elsewhere)
- <u>Pumped Storage</u>

The Israel Electric Corp. has undertaken surveys of potential sites. Three possible sites have been indicated on the shores of Lake Galilee. A preliminary estimate would suggest a power station comprising 2x150 MW.

The pumped storage system is envisaged after the commissioning of nuclear units. It has been calculated that 213 million kWh can be produced per year at a rate of 300 MW, with an overall efficiency of 78%. The construction will take 7 years and it will cost $1000/KW.

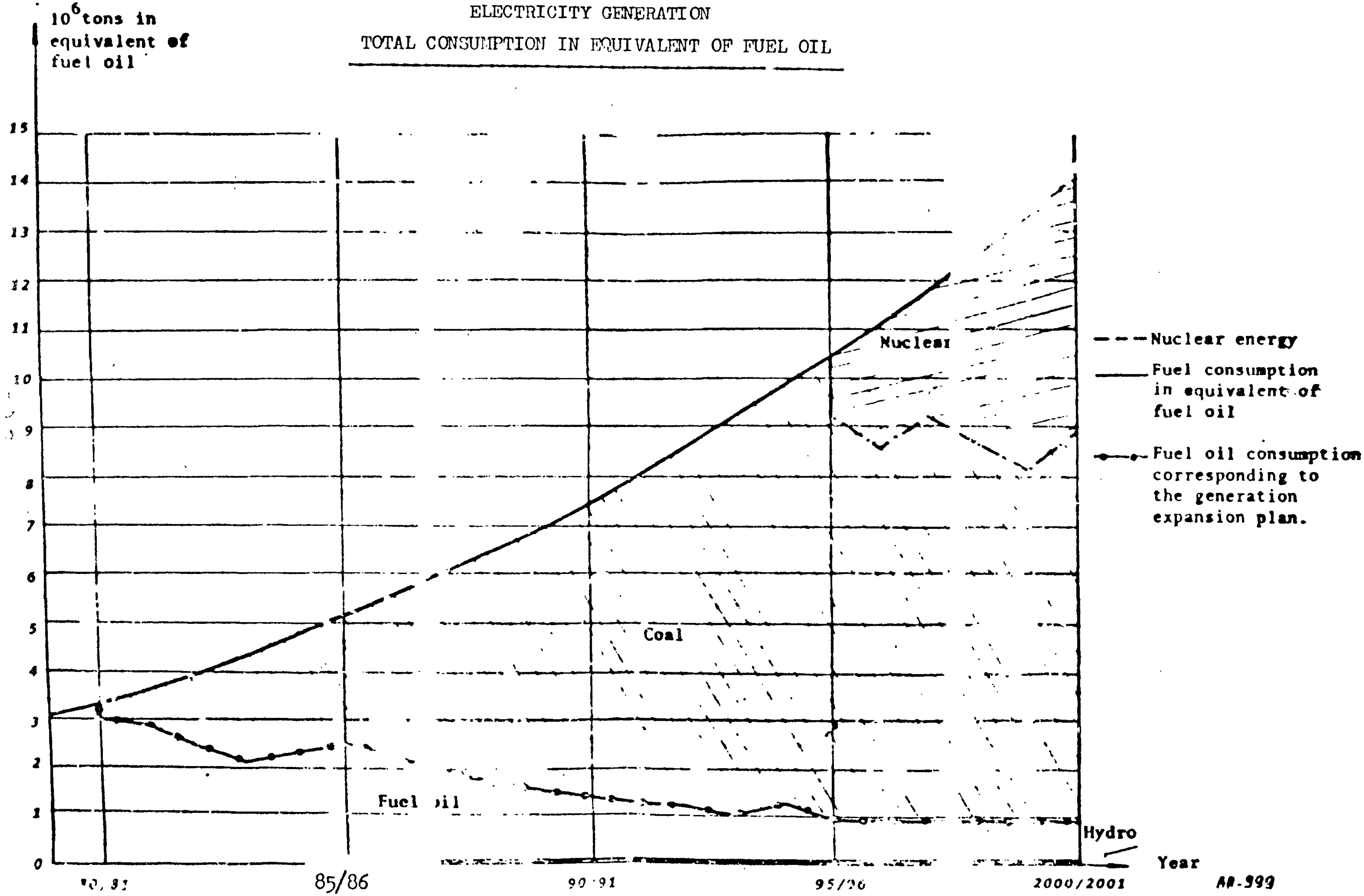
This plant could replace the equivalent of 59,000 tons of fuel oil per year.

<u>Low Heating Value Fossil Fuels</u>

- <u>Lignite</u> (see under lignite)
- <u>Oil shales</u> (see under shale)

ELECTRICITY GENERATION

TOTAL CONSUMPTION IN EQUIVALENT OF FUEL OIL



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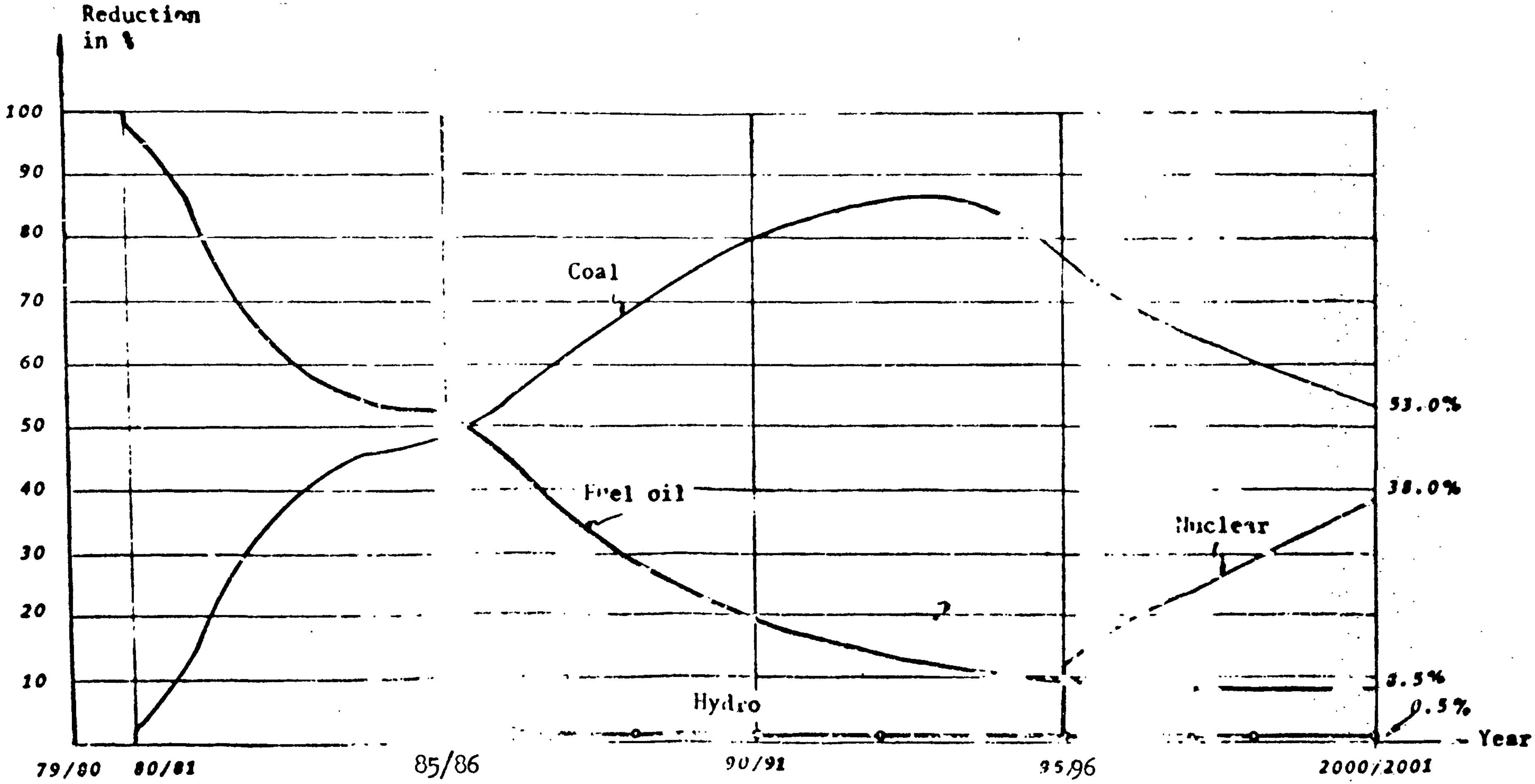
REDUCTION OF IEC'S DEPENDENCE
ON FUEL OIL



The Generation Expansion Plan for the Years 1980-2000

Taking into account the available energy sources for electricity generation, the following assumptions have been made:

- Fuel oil is not to be used for base load electricity generation.
- As nuclear power will not be available before the nineties, the base load should be supplied by coal fired power plants till then.
- Peak load power will be generated by hydro-electric plant whenever feasible, gas turbines and combined cycle units.

The generation expansion plan, based on the above assumptions and on IEC's official, low alternative demand forecast leads to the results shown in Figs. 8 and 9 and the following conclusions:

- Were IEC to depend on fuel oil as the whole energy source, the fuel oil consumption would increase from less than 3 million tons in 1978/9 to over 14 million tons in the year 2000.
- According to the present expansion plan, the demand for fuel oil will decrease rapidly, at a rate of about 5.6% per year, reaching 1 million tons in the year 2000.

The successful execution of the expansion plan will enable a considerable decrease in the dependence on fuel oil consumption accompanied by significant economic benefits.

The reduction of IEC's dependence on fuel oil is shown in figure 9. The cumulative (1979/80 equivalent) quantities of fuel oil substituted by coal will total 7.5, 21 and 59 million tons in the years 1985/6, 1990/91 and 2000/2001 respectively.

The Shift to Electric Energy

Apart from the consideration that electric energy is the main method for significant utilization of alternative energy sources, there are other factors in favor of its broader use, namely:

- Ecological considerations encouraging the use of electric energy in highly populated areas.
- Technological developments allowing controlled automatic and efficient processes in the use of electric energy.

If the national goal is to speed up the reduction of the dependence on oil, an intensive shift to electric energy is mandatory.

The major areas where electrical substitution for oil and gas seems possible are:

- Transportation (passenger cars, trains, industrial vehicles.)
- Space heating (heat pumps)
- Process steam (combined electricity - steam generation)
- Direct heat
- Cooking
- A thorough investigation should be carried out in all energy sectors in order to determine their potential shift into electricity.
- In each case, the economic and technical feasibility, and the suitable timing of such a shift, should be studied.
- The forecasts for electricity demand should be modified to account for the additional potential, so that the generation expansion can meet the requirements.

CHAPTER 6

MARKET FORCES - PRICING POLICIES

Prices of energy products and services should reflect the real economic marginal cost to the economy, in order to ensure efficient allocation and consumption.

The Ministry of Energy considers the market mechanism as a major means for the efficient use of energy and conservation efforts in the country. For this purpose a modified price system is currently under consideration in order that prices to the consumer will reflect marginal costs. Even if the objective of identity between prices and costs cannot be achieved completely, it is absolutely necessary to adopt as far as possible the relative prices of energy products in relation to their marginal costs.

Over the whole period from 1972 to the end of 1980, the burden of the increasing costs of imported oil to the country has not been fully transferred to the consumer. However, in the last two years, the objective of full transfer has been largely achieved, as can be seen from the following table:

Real Price Increases of Oil Products, Electricity and Crude Oil

	1/1/1972 -31/12/80 %	31/12/1978 31/12/1980 %
Weighted average of real price annual increase for all oil products	13.7	24.5
Weighted average of real price annual increase for electricity	9.9	19.0
Annual price (C.I.F.) increase of imported crude oil	26.8	34.0

While the concept of price equals cost has merits for economic efficiency, it may present problems with respect to the income distribution of the population, and the impact on the consumer price index. On the other hand, the sensitivity of the industrial consumers to prices is reduced due to the tax regulations which do not give enough credit to conservation efforts. All these become impediments in realizing the potential benefits of such a price policy.

However, even with these problems the price equals costs policy is currently being implemented.

Electricity rates are in the process of adjustment to reflect not only complete coverage of costs, but also the pattern of loading that the consumer imposes on the system. The time of day, tariff system (on peak load pricing) together with load management practices may cause significant changes in the consumption patterns, improve the electricity system load factor, "share off" peaks and consequently save energy and reduce the capital and operational costs of the system.

Likewise. marginal costing for oil products is under preliminary investigation employing mathematical optimization techniques for joint production.

These principles of pricing policies in the energy field should always be subject to the general lines of economic policy and the determination of the political level to implement them.

CHAPTER 7

REGULATIONS AND INCENTIVES

SPECIFIC CONSERVATION POLICIES

Legal Action

In January 1977 the Knesset adopted the National Energy Authority Act, which gives a broad base for regulating energy activities in all sectors of the economy. New regulations and legislation are currently being introduced. Some of these are listed below:

- Mandatory use of solar energy for water heating in all new homes.
- Mandatory metering of hot water in all new apartment houses (all cold water is metered).
- Expanding the use of diesel engines for most commercial vehicles (currently, the use of diesel engine is restricted to buses, taxi cabs and heavy trucks only.)
- Mandatory automobile engine tune-ups twice a year.
- Increasing local taxes on large, heavy gasoline consuming cars, to promote the use of smaller and economic vehicles.
- Requirement to maintain water pumping units efficiency above a specified level.
- Reducing local taxes on energy-saving devices.

Several new laws and regulations relate specifically to conservation in the industrial sector. These include:

- Requirement to maintain industrial boilers thermal efficiency above a specified level.
- Mandatory preparation of annual energy audit on all industrial plants consuming above 50 tons of oil or 100.000 kilowatt tons per month.
- Capital investment in energy saving measures will be recognized as eligible for special concessions awarded under the Law for the Encouragement of Capital Investments in Israel and the Law for the Encouragement of Industry.
- Government approval of investments in new, or the expansion of existing, industrial plants will be conditional upon the efficient use of energy.

- Government approval of price increases of controlled products will be conditional upon the presentation of energy audit and the efficient use of energy in the applicant's plant.

Incentives

Incentives and financial assistance are provided for:

- Demonstration projects of an innovative nature
- Large or communal solar water heating projects
- Potential energy saving surveys for industrial plants. Among the demonstration projects are:

- Solar water heating in swimming pools, and sport institutions.
- Solar pre-heating of feeder water for steam boilers in the textile industry, hatcheries and laundries.
- Solar water heating in hotels.
- Solar drying of spices.
- Passive solar utilization in hothouses.
- Waste heat utilization to generate electricity in the refineries and chemical industries.

Financial assistance is provided at the rate of 10% of total investments for centralized solar water heating systems in large apartment houses, 30% participation in the demonstration projects, and 15% grants or 40% - 50% loans during 6 - 10 years for the production of energy conservation measures in industrial plants, following feasibility surveys which are financed by the Ministry at 50% of the expenses.

Information and Training

A major part of conservation activity is carried out by:

- Provision of technological information through the mass media and publishing of printed matter for technical staff.
- The establishment of advisory bureaux for individuals in the area of home heating and industry to increase the efficiency of energy uses
- Operation of mobile teams to examine the efficiency of steam boilers and improve the exploitation of water pump stations.
- Introduction of a person responsible for energy in factories, institutions, offices etc. for the purpose of follow-up and improvement in energy use.

- Introduction of energy conservation as a study subject in the school curriculum.

It is expected that following these direct measures and the impact of the pricing policy, within 10 years we may realize the following savings, as compared with a "business as usual" attitude.

	Expected Savings (MTOE)	Percentage Savings %
Industry	500 - 600	13 - 17
Agriculture and Water Pumping	100 - 140	10 - 15
Residential, Commercial and Public	400 - 600	12 - 16
Transportation	200 - 250	15 - 20
Energy Sector	175 - 250	5 - 7
Total	1375 -1840	9 - 13

With an energy elasticity of 1.1 in Israel, a reduction to an elasticity of 0.7 - 0.9 within the next 20 years should be attainable.

CHAPTER 8

OIL EXPLORATION - THE BIG CHALLENGE

In the framework of the efforts to get away from absolute dependence on imported energy sources, there has to be a concentrated professional and financial effort to explore for oil in Israel that would make the prospect of finding oil in the country reasonably certain.

Oil exploration has been going on for 30 years. So far 288 drills have been carried out including 105 experimental and production bores in the Heletz and Zohar areas and 183 exploration drills. (excluding Sinai).

So far oil exploration has yielded three relatively small discoveries of oil and gas, the main one being the Heletz field, from which 16 million barrels have been extracted and the gas field at Zohar. Geophysical data, geological surveys and findings from drills carried out in Israel have provided a picture that indicates a good prospect of discovering oil and gas.

As far back as 1962, the unofficial report estimated that there were reserves of between 500 and 2000 million of barrels of oil in the country. Another report carried out in 1973 confirmed these estimates.

The above evaluations were recently reinforced by two further estimates of Israel's oil potential which concluded that Israel's oil and hydrocarbonates reserves totalled 330 million barrels on land (excluding the Dead Sea area. From the geological point of view, the Dead Sea basin is unique and the oil reserves there are tentatively estimated at several hundred million barrels more).

One of these estimates was carried out by oil and geological experts led by the well-known American geologist James Wilson. The other work was carried out by the U.S. Company Neptune, which acted as a contractor for oil searches and extraction in South Sinai. These parties re-evaluated all existing data in Israel concerning oil exploration. There was also a revaluation of the data from the point of view of the prospects of maintaining economic oil and gas reservoirs in Israel.

SECTION IV

TRANSFORMING THE SUPPLY BASE

EXPLORATION AND DIVERSIFICATION

In the wake of government decisions in 1975, oil exploration work was intensified, with the stress being placed on searches in the Gulf of Suez area in the Sinai. As a result the Alma field in South Sinai was discovered and developed. When it was handed over to the Egyptians, it was producing about 40 thousand barrels of oil a day, about 20% of Israel's oil consumption. Other exploration work was focused on the coastal plain and as a result gas fields were detected at Sadot and Shikma and indications of oil and gas at Gan Yavneh and Ashdod. Similarly, a number of initial searches were carried out in the Mediterranean continental shelf. These discoveries, not all of which were checked or developed, still indicate prospects of finding this important source of energy in the country's soil.

Policy Guidelines

a) Oil exploration in Israel during the next 4 or 5 years is starting to be recognized as a national project to boost the financial, technological, professional and human infrastructure.

b) Fast implementation of a comprehensive oil exploration program that includes the whole coastal area particularly the southern coastal zone and the Dead Sea basin.

c) On the background of this approach, the necessary budgets for carrying out a multi-annual plan will be assured at the rate of about 20 - 25 drills a year at an overall annual investment of 30 - 35 million dollars during the next four to five years.

d) Development of scientific, management, financial, and organizational tools for processing current data, extension and updating of geological and geophysical data as well as repeated and current checks of the estimated potential for finding oil sources in the country.

CHAPTER 9

COAL THE INTERMEDIATE SOLUTION

Israel, a country without domestic coal resources, is determined to convert its electricity generation and some industrial production processes, from fuel oil to coal because of its anticipated higher dependability, lower purchase prices per unit energy input, and the diversification objective of primary energy supplies.

Following the October 1973 war, Israel Electric Corp. initiated thorough examinations of all the aspects involved in using coal for electricity generation in Israel. As coal technology has not been used so far in the country, it was necessary to study very carefully all the implications.

The 1981 will mark the beginning of the coal era in Israel, with the operation of the first of four generating units of 350 M.W. at the new Hadera power station. This will be followed by the use of coal in industrial production processes, initially in the cement industry.

Currently, it is planned to use about 9-10 million tons of coal by the end of the decade according to the following time schedule:

Year	1981	1982	1983	1984	1985	1987	1990
Coal use (1000 tons)	500	1200	2500	3300	4000	6000	9000
Share of electricity of total coal consumption (%)	80	77	83	85	82	85	80

The conversion to coal program is thus conceived along the following lines of action.

- Implementation of the development program of the electric power sector based solely on coal-fired generation stations within this decade. This conversion will follow a dual technology of coal and fuel oil so as to secure maximum flexibility as a response to the changing conditions of the world oil and coal markets.
- In 1985 the coal-fired M.D. power station will be able to provide a net capacity of 1400 MW, thus achieving a significant reduction of the dependence on fuel oil, as about 45% of the electric energy will be generated from coal.
- Initiation of cogeneration-regional combined heat and power stations which will burn coal and save 15 - 20% of the direct fuel inputs in industrial plants. In this way, another 300,000 tons of oil used directly in industry will be substituted by coal.
- Promotion of gradual conversion to coal of industrial factories, first the more energy intensive ones - the cement, potash and phosphates industries and later on medium-sized plants. The expansion of the usage of coal in industry, subject to strict environmental control, is nothing but the fast implementation of the required infrastructure - inland transportation, technological know-how, and managerial skills - which makes coal a feasible energy source for its potential users. The amount of coal in industrial use in 1990 may reach about 1 million tons.
- Adaptation of proven coal technologies which are available elsewhere and can be employed in the country subject to a relatively short period of study and training. These technologies include the introduction of medium and small size boilers for steam generation, a coal-oil mixture as an option for expansion of coal usage in modified oil-fired power generation units, and coal slurry technologies for the transportation of coal by pipes.

- Finally, establishing a research and development program for the liquification and gasification of coal in order to introduce future technologies of coal utilization for additional expansion in the next decade.

Coal is the immediate option for Israel and will remain the major substitute for oil, on an interim basis, as long as nuclear power does not materialize and new and renewable resources are not technologically available and economically feasible.

Lignite

Low quality lignite is available in the Hula valley below the surface, under a top layer of peat, which is younger than lignite and contains much more water in it. Peat also has a low fuel content.

Lignite was first found in drills carried out in 1952. Since then, several proposals have been made to examine its fuel possibilities, but it was only in the mid-seventies that it was decided to check the potential economic and technological exploitation of lignite. Three drills were carried out in the Hula valley in 1976 and in the wake of the findings a team was entrusted with the task of preparing a preliminary evaluation of the potential for establishing a power plant run on lignite.

The geological reserves are estimated at 500 million tons and the mineable quantity of lignite at about 440 million tons. The ratio between the amount of unusable material and the lignite is 1: 3.22. A power plant based on lignite would contain three 200 megawatt units and use up ten million tons of the brown coal during 5,000 operating hours annually. In 30 years of operation, about 305 million tons of lignite would be consumed. The net electricity output during the 5,000 hours of operation annually would be 2.705×10^9 per kilowatt hour.

Investment in the Hula lignite project would amount to $1 billion and the average production costs per kilowatt hour are 60% higher than in a coal-fired plant. A significantly real increase in the cost of coal of 3% or more per annum during the lifetime of the project would influence its feasibility and attain the economic break-even point.

The first unit could be introduced in the early 1990's,if the fuel prices justify the project and if ecological and cooling water problems are solved in the meantime.

CHAPTER 10

NUCLEAR ENERGY - A PROBLEMATIC NECESSITY

Nuclear power is conceived as a major part of the program for diversification of energy resources. Nuclear energy will be one of the components of the "energy basket" of Israel starting in the middle of the next decade.

Nuclear energy is not new in Israel, since a primary technological infrastructure has already been developed at the I.E.C. and the Atomic Energy Commission. However, it is necessary to update the expertise available in the country and the assessments involved in the introduction of nuclear power stations in Israel.

The policy of the Ministry and like agencies is based on the following principles:

1) The preparation of an appropriate structure of manpower and know-how by use of the existing frameworks such as the Electric Corporation and Atomic Energy Commission and the creation of joint or new set-ups.

2) The preparation of physical conditions by laying the groundwork of power plant sites including solutions for appropriate cooling means and study of the vulnerability of unprotected atomic plants and their influence on the population.

3) The preparation of an infrastructure for nuclear fuel, the extraction of uranium from phosphates and production of fuel rocks. The Ministry is also aiming at developing safe sources of nuclear fuels.

4) The installation of plants in the framework of electricity production systems will be based on the use of proven technologies, by purchasing or adapting existing plans. The policy aims at involving Israeli planners in the work with maximum involvement in the production of components and systems.

5) In the short and medium run, nuclear energy cannot serve as a supplier of electricity for the Israeli grid, mainly because of the long time it takes to build a nuclear power plant (10 to 12 years). During the next 10 years, there will be a need to deepen the infrastructure and decide on further preparation for the introduction of nuclear plants. However, it is still planned that by the middle of the next decade, the first nuclear unit of 900 MW will be operating.

6) Other energy sources with a large-scale potential utilization for the beginning of the next century are the breeder and fission reactors.

SECTION V

TRANSFORMING THE SUPPLY BASE

NEW AND RENEWABLE ENERGY RESOURCES

INTRODUCTION - THE RATIONALE FOR AN INTENSIVE R & D PROGRAM

It is unlikely that R & D in alternative energy resources, can solve the problem of energy supply completely. But there is no doubt that a proper R & D policy can help in furthering five national energy goals:

a. Creation of indigenous energy sources that will substantially reduce dependence on imports.

b. Introduction of sufficient flexibility in the national energy system to allow the use of alternative resources.

c. Development of high professional capability to allow the proper selection and cooperation of new technologies developed elsewhere.

d. Development of processes and equipment to facilitate entrance into the expanding world energy market.

e. Minimization of environmental damage.

The R & D projects and the allocations of manpower and budgets are examined in relation to the following criteria:

a. A substantial potential contribution to the national energy balance. (Larger potential contribution will carry higher preference).

b. Compatibility with Israeli technical, economical, organizational and industrial capabilities.

c. The measure of innovation.

Perhaps as compensation for the lack of indigenous fuels, Israel is endowed with plenty of sunshine. The average solar insulation over Israel ranks among the highest in the world. This probably supplied the early drive for research, development and application of solar energy.

CHAPTER 11

HYDRO-ELECTRIC POWER

A. The Mediterranean Dead Sea Canal

Historic Background and Physical Considerations

Some 1,200 M cubic meters per year of sweet water, used to be fed into the Dead Sea by the Jordan River system, prior to the pumping of water from the Sea of Galillee into the Jordan-Negev pipeline, the diversion of the Yarmukh waters into the Ghor canal (in the Hashemite Kingdom of Jordan), and the extensive agricultural development of the Jordan Valley itself. Nowadays, the yearly inflow has been reduced to some 25% of that amount, and this way be further cut down to 150-200 M m^3 p.a., if and when the Jordanian Maqarein High Dam is built. The level of the Dead Sea has thus dropped from about -393 meters below "Sea Level") to approximately -402 m., and may reach -410 m. by 1990.

Economic Considerations

A detailed economic analysis has shown that a hydro-electric power project, based on a sea-water 35-50 m^3/sec canal from the Mediterranean to the Dead Sea, utilizing that 400 meters difference in levels between the two seas and making full use of the evaporation capacity of the Dead Sea surface - would be economically justified and physically feasible. This conclusion holds good for several routes and in various versions. The direct energy benefits are the installation of some 600 MW, applied at peak load - an especially suitable role for hydroelectric power stations.

In addition, there may be several attractive secondary benefits, particularly as regards the Southern (Qatif-Massada) route. These would considerably enhance the overall profitability of the project.

The conclusions with respect to the hydro-electric project itself are based on an estimate of $ 497 M to $ 946.6 M overall capitalized benefits in fuel savings, in the various versions, and an additional $306 M through economics in projected construction (all sums capitalized at 6% to Jan. 1, 1990). Fuel savings are estimated over a 50 year period, but would accrue mainly in the first 20 years. An increase of 1-3% per annum (in real terms) has been assumed in the price of all fuel categories, in excess of the Jan.1, 1980 prices of \$ 290/ton for jet fuel, \$160/ton for heavy oil and \$46/ton for coal. Total investments are estimated between \$ 583 M and \$ 685 M depending on the choice of route. The scheme is planned to produce 1220 million kWh/year at a rate of 546 MW during the first 12 years and 725 million kWh year at a rate of 337 MW afterwards. The construction will take 8 years and the capital cost total \$1,200/KW.

The earliest possible year of exploitation is 1990. This plan would save the equivalent of 300,000 tons per year during the first 12 years and 175,000 tons of fuel oil in the following period. The SCIC is having these figures re-examined by international experts.

Routes

Initially, a variety of routes were considered, including a conduit originating in the Red Sea. Several schemes (including the latter) were eliminated for economic and other considerations. More detailed studies have centered upon the following:

- A Northern route, through the Jezreel and Jordan Valley, including the truncated version, consisting of a Jezreel canal and the channeling of the sea water to the Dead Sea through the Jordan River bed.
- A Southern route involving a canal-tunnel combination, from Qatif to Massada. or from Ziqim to Massada if the Gaza area is bypassed.

The economic analysis is based upon a dynamic model of future power generation in Israel, developed by the Israel Electric Corporation Project Working Group (PWG) under a Ministry of Energy contract. The PGW has also graded the alternative routes and versions economically. The Qatif-Massada plan takes first place at an estimated investment of \$ 550 M at 1977 prices (or \$ 685 M at 1980 prices).

It is therefore proposed to focus, at this stage, upon the southern route by further studies and more advanced planning, unless unexpected technical difficulties or new factors arise. The final report will include more definitive recommendations.

Solar Energy from the Dead Sea

The development of electrical energy production in solar ponds in Israel opens up the possibility of utilizing all the Mediterranean water supplied by the canal to generate up to 1500 MW of Solar Energy, thus exploiting the Dead Sea as a "Solar Lake". This possibility depends upon the results of further R & D, relating to the development of large (2.5 km^2) ponds, as compared with the existing ones (0.007 km^2). Solar Ponds require for their operation a 1-2 meters upper layer of less dense water, and the solar lake project is conditional upon the cutting of an Interseas canal.

Cooling of Thermal (Nuclear or other) Power Stations

The impossibility of building new sites for thermal power stations along the Mediterranean coastline (where all present units are situated) has created an interest in prospective inland sites, involving the pumping up of some 35-40 m^3/sec. per 1000 MW for cooling purposes. The Mediterranean Dead Sea canal could thus provide important savings and much simplification, in the next stages of the country's energy development program, should the siting involve the North-Western Negev. This region is especially suitable for nuclear power stations, due to safety considerations.

Importance of the Project for Israel's Energy Program

It is thus possible that some 3,000 MW of future installed power will depend on, or be strongly coupled with the canal. Supply in the year 2000 is expected to reach a figure of 10,000 MW as compared with the present 2,600 MW. We are thus dealing with some 30% of Israel's installed power capacity in the not-too distant future (20-30 years from now).

Effect on the Dead Sea (Potash) Works

Dilution of the highly concentrated soft water in the Dead Sea by the inflowing sea water from the Mediterranean may lead after some years of operation to a slight reduction in the output of the existing potash plant. Such a decrease might only occur if complete mingling of the two kinds of water should take place throughout the full depth of the Dead Sea - an extremely unlikely eventuality that would anyway have to be prevented in implementing the solar-lake project. The upper limit of such a temporary production loss is estimated at some 300,000 tons of potash per million, which amounts to about 15% of the present annual production, or about $ 20 M p.a. (at 1980 prices).

Should the mixing take place as conjectured in a relatively thin upper layer only, very simple technological solutions for prevention losses coule be applied, e.g. drawing quasi-original and "normally" concentrated Dead Sea water for the potash plant from a greater depth (in the northern part of the Dead Sea).

The Committee has initiated an appropriate research program and a more precise evaluation may be available in the final report.

Long-Term Investigations

Some investigations may take years years to complete owing to the long-term nature of their data collection and interpretation. An example is provided by the "whitening phenomena" that might occur through the precipitation of gypsum in the Dead Sea as a result of the inflow of Mediterranean water. Other examples include studies of evaporation rates and the stratification of the Dead Sea: effects of nutrients contained in Mediterranean water on biological processes in the Dead Sea, etc. It is assumed that the results of most of these studies will become available in 1982.

Establishing a New Steady Level for the Dead Sea

The final level at which the Dead Sea will reach its quasi-steady state (in the year 2010) has been tentatively set at -393 m below sea level to suit the crest levels of the dykes of the Israeli Dead Sea Works, now in the process of being raised to -391.0 m. A further rise is planned in about 20 years time. The ground level of the production plant proper lies between -388 m and -389 m.

It is possible that the rate at which the Jordanian Potash Works dykes will be raised will force a 5-10 years delay in attaining the final (steady-state) level of -393 m. This should not seriously affect the economics of the project. The Committee has also examined the possibility of adopting a steady-state level of -400 m, for the sake of economic comparison. This level might be prolonged, if progress in the normal operation of the Jordanian plant should come to a stop at an early stage, a rather implausible eventuality.

Future Jordanian Co-operation

The above-mentioned 5-10 years delay in reaching the -393 m may be obviated should the Jordanian Potash Works be willing to raise their dykes earlier.

A proposal for a Binational Park along the Jordan river provides for the development of the unique fauna and flora of the deeper Jordan River valley, with extensive touristic, ecological, scientific and historical programs, in addition to co-ordinated agricultural development on both banks.

With Jordanian co-operation it should also become possible to undertake in the nineties a joint feasibility study of a gradual raising of a dam across the Lissan strait, so as to allow for some further rise of the water level in the northern part of the sea. This would increase the evaporation area and ensuing power production, without damaging the potash works and other facilities in the southern area (though flooding the lower Jordan Valley in both Israel and Jordan and possibly losing agricultural areas). Surveys of the sea bottom and the Lissan area and specific engineering studies are required in view of the geological and seismic conditions.

B. Almagor Plant

The idea of exploiting the Jordan River for electricity generation is based on the shifting of the river bed north of the Galilee Sea.

A 1.6 million m^3 basin at an altitude of 251 m (which is the difference in latitudes between the Jordan River and the Sea of Galilee), could supply 265 million kWh per year at a maximum rate of 100 MW. This plant could save about 65,000 tons of fuel oil per year, and its construction is about 5 years.

CHAPTER 12

SOLAR ENERGY

Interest in solar energy began on a small scale in the late forties and early fifties. Prof. Robinson of the Haifa Technion was running a solar laboratory, studying solar radiation and collection and experimenting with possible applications. A substantial step forward was taken with the pioneering research of Dr. Tabor, then the Director of the National Physical Laboratory, who in 1955 developed the first selective surfaces for solar applications. Soon systems of solar water heaters began to appear on roof-tops, in the beginning on single homes and later on large apartment buildings. It must be noted that this process proceeded on a commercial basis with no special government incentives.

Today, a visitor in Israel would be impressed by the large number of houses and buildings equipped with solar water heaters. Over 500,000 households get their hot water from solar energy. That accounts for approximately 50% of total domestic water heating. From an energy balance point of view, solar water heating saves over 5% of the electricity generation and accounts for more than 1.5% of the total primary energy supply. This makes Israel a front runner in the use of solar energy.

As early as 1958, Dr. Tabor and his group started research on non-convective solar ponds. Two experimental solar ponds were constructed in the early 1960 at the same time, turbines using organic vapor were developed for utilization of solar energy. Competition from cheap and abundant oil brought most of the research to a stop in the late 1960; but the foundation was laid for subsequent work.

Solar R & D picked up considerable momentum after 1973, with the escalation of oil prices. An extensive program for research and development of solar and other alternative energy sources was adopted. In 1977, the new Ministry of Energy and Infrastructure took over responsibility for all the energy programs, including solar ones.

At present, there are several groups in industry, universities, and research institutions which are actively engaged in research development and applications of solar energy.

THERMAL SOLAR SYSTEMS

Thermal systems have, so far, made the largest impact on solar energy utilization. No wonder that a big variety of programs fall under this heading.

Flat Plate Collectors

Flat plate collectors are used extensively in Israel. There are a few dozen firms that produce and market collectors or systems incorporating them. There is, however, still a margin left for improvement of performance, design and costs.

Research is carried out in universities and scientific institutions with the aim of fully understanding the flow characteristics of the collector both under thermosiphonic free convection and under forced convection.

Israel was first to market commercial collectors with selective coated surfaces. Since then it has become common practice. Research is still continuing on improving the coating so that a more uniform layer will be formed with better stability against heat and corrosion. Attention is also given to glass coating to reduce the reflection in the visible light region while increasing the reflectivity in the far infra red. A reduction of solar reflectivity from 8% to 2% was attained in laboratory tests.

Considerable effort is made, mainly in industry, towards development of new designs of collectors, for example:

Such is an interesting fine copper tube collector which acts as a solar radiation trap, even for rays with large incident angle.

Another novel idea is the free flow collector. It replaces the usual internal fluid passages with a thin film of light oil flowing freely down an inclined surface, covered by a black thin aluminum foil, which acts as the absorbing surface. The good contact between the oil and the foil ensures high collection efficiency while the absence of tubes allows much lighter weight and less corrosion.

Several other designs claim advantages of low costs and long service life. Research continues towards lower cost per calorie collectors.

Shallow Solar Ponds:

Shallow ponds are made of large plastic bags with black bottom and transparent top. They are filled with approximately 10 cm of water which is heated during the day and stored at night. Such ponds are studied at the Weizmann Institute, with a view to applying them to central water heating in large buildings. Indications are that it may offer considerably less expensive heat than the usual flat plate collectors.

Concentrating Collector:

The main interest is in the development of essentially non-tracking or partially tracking collectors. At the Technion, a concentrating collector having a stationary spherical reflector was developed and is now in the process of commercialization.

The reflector which constitutes the major part of the structure is stationary, making it easier to design, with less problems in wind storms. The sunlight is always focused into a radius which is in line with the sun and the center of the sphere. A small absorber arm is made to track this focal radius allowing a concentration ratio of 50:1 and over. In a test where water was used, a temperature of 150°C was reached with 50% efficiency. The temperature was limited by the saturation pressure of the water. Tests to allow utilization of higher range of temperatures by using liquid metal in the absorber are now being conducted. These collectors, which can be produced at a reasonable cost, may offer a good source for domestic heating and air conditioning as well as electric power generation.

An inexpensive low concentration stationary collector (with a ratio of approximately 3:1) which can supply medium temperatures was developed and is being tested at the Weizmann Institute.

Air Heaters

Air heaters have many advantages for space heating. Special designs which minimize the heat losses are being investigated at the Technion and at Ben-Gurion University.

Another concept of integrating the solar air heater as part of the roof structure was developed in cooperation with Miromit, a company which has 20 years experience in solar energy.

Standards of Testing

Proper standards and testing facilities are essential counterparts of solar energy industry. The Israel Standard Institute is engaged in developing (or adapting foreign) standards to suit the local conditions and export purposes. Several test facilities are available to the industry. The Standard Institute itself offers such services. The Technion has a lab used mostly for research. The Weizmann Institute has developed a sophisticated test facility. These aids are used by the local manufacturers.

Storage

Thermal storage is of a major importance for most solar energy applications. It is used to bridge the gap between demand and supply.

In addition to hot water tanks and pebble bed storage for hot and cold air, more sophisticated systems are being investigated.

Systems of paraffins and salt hydrates, which change phase at appropriate temperatures are under study at the Technion and Ben-Gurion University. Special attention is given to the heat transfer mechanism and the proper distribution of the tubes in the heat exchangers. Additives that suppress the tendency of the salt hydrate to crystallize are being investigated.

A novel system, making use of changes in muscibility gaps with temperature, is the subject of a research program in Tel Aviv University. The idea is to select a mixture that mingles in any proportion at a given temperature but separates into two phases at somewhat higher temperature. The division is achieved by using solar energy and each phase is stored separately. When heat is required, the two phases are made to mingle, thus releasing the heat of mixing. Such a system may offer a long-term storage since there is no need for insulation.

Seasonal storage systems, using the ground soil as a medium are being studied at Ben-Gurion University.

Finally, a research program has begun investigating the possible use of large aquifers as a cooling medium for large power plants while using the heat during the winter for agricultural purposes.

Water Heating:

Increasing the use of solar water heating, to cover more than 60% of the households by the mid-eighties, is a declared policy of the Ministry of Energy. This step implies a greater use of centrally applied hot water, and other services in larger buildings, as well as the improvement of the systems and the installation.

A major thrust has been in expanding the normal individual installation to central systems supplying hot water . Problems of flow distribution in the collectors field, minimization of plumbing and control had to be considered. Various methods of supplying the hot water have been devised. At present there is slow but increasing penetration of the central system market on a commercial basis. The largest system, involving 144 m^2 of collector area, has been installed in a hotel at Eilat.

Heating & Cooling (Passive and Active Systems)

Desert climate is most suitable for passive systems since there is a large differential between day and night temperatures, and plenty of sunshine. Properly designed night cooling can keep buildings comfortable during summers, while solar trapping can keep the buildings warm, day and night, during winters. A research program on passive systems is being conducted at Sde-Boker (B.G.U.). Several experimental small houses were built to allow the data acquisition and comparison of various methods.

Another group is interested mostly in fenestration and proper shadowing. Work is also being done on thermal modelling of buildings.

Space Heating:

Only a few places in Israel are actually heated by solar energy. The Mechanical Engineering Department library at the Technion is the first attempt at solar space heating. The heat transfer medium is water, and two days shortage is supplied by hot water tanks. Also in the space heating domain, the Miromit prefabricated roof panels concrete collectors create a continuous absorbing surface. The heated air is transferred from the solar panels to a rock-heat storage, or directly into the house. The structural roof member includes selective surface absorbing plate, cover glass, insulation and architectural finish. The ratio of collector area to total floor area is 1:2 to 1:1, depending on the specific house layout, design, insulation and other parameters. Following field tests made at the Building Research Station at the Technion, a commercial demonstration program was initiated, comprising three homes in which space heating will be provided by roof panels concrete collectors.

No detailed cost analysis has yet been made, and therefore it is premature to predict the impact of such development on the primary energy balance.

Climate Control Systems:

The largest project in heating and cooling is conducted at Tadiran. It was initiated in 19[illegible]4 with the specific purpose of marketing in Israel and abroad, climate control systems, supplying hot water, space heating and air conditioning, whose major energy source is the sun. To meet the performance requirements it was necessary to develop a flat plate solar collector yielding its energy at a higher temperature than the state-of-the-art flat plate collectors. The second major component is a hot water fired lithium-bromide absorption chiller, designed to operate at an inlet temperature range of 65 to 95 degrees C and still maintain a high coefficient of performance. The third major component is the control subsystem to balance the solar energy input, the conventional energy drawn from the backup, and the building load. The fourth component is the combination of energy storage, hot and cold, and conventional backup. Following the development effort, a 50 ton proto-type was completed in 197[illegible], with performance exceeding those of comparable machines. It was still operating with a good coefficient of performance even with a low generator temperature of [illegible]°C., thus demonstrating the viability of the system.

A full-scale commercial type demonstration has been completed in December 1980 comprising a 200 ton unit to supply air conditioning space heating and hot water to a hospital ward near Tel Aviv. As an energy source it serves a 3500 m^2 array of Tadiran developed collectors.

Economic analysis of around the clock solar climate control systems, with conventional back-up, including allowance for components and installations cost reductions with increased volume of sales, show that such systems will be competitive with conventional, electrically driven climate control methods. The full-equivalent consumption for industrial, commercial and institutional climate control systems is estimated, annually, at 200,000 tons, or 2.5 percent of Israel's total energy consumption. It is assumed that in the latter part of the eighties an increasing portion of new industrial, commercial and institutional buildings will go solar for their climate control, as well as some retrofit on existing buildings. The impact on the primary energy balance, allowing for fuel oil consumed for back-up, may be approximately one to one and a half percent. It should be stressed that airconditioning is used primarily during peak hours. The saving here, therefore, is not only fuel, but also in electric peak loads.

Cooling with Desiccants

Yet another method of producing cold air is by an extension of the desert cooler to conditions of higher humidity. The basic process involves four steps.

- Drying the air by using desiccants.
- Cooling the dried air to outside temperature.
- Wetting the air adiabatically, thus bringing it to the desired temperature and humidity.
- Regenerating the desiccant using solar energy.

A research program to develop the system is being carried out at the Technion.

Industry

Some application of solar energy has been made by the Food Processing Industry especially spice drying. Recently some interest was indicated in applying solar energy to supply low temperature heat requirements, such as for plating baths and low temperature steam. Possible utilization of newly developed concentrating collectors is being considered and some demo systems are to be erected next year.

Agriculture

A greenhouse in Israel will require an average of 25 kg of fuel annually per m^2 to master the cold winter nights. At the same time there is excess heat during the day when the sun shines.

Research is being done to store the daytime heat for use at night, thus saving fuel. One system is to make the water flow through the roof of the greenhouse and then through the ground underneath, thus cooling the greenhouse during the day and heating it at night. The ground acts as a heat storage.

Solar Ponds

Work on non-convective solar ponds is probably the most exciting and significant R & D in solar energy that is being conducted now in Israel. Proper application of solar ponds may allow large scale utilization of solar energy and thus probably has the potential of substantial contribution to the national energy balance.

The idea of non-convective solar ponds for collection of solar energy was first suggested more than 20 years ago by Prof. Bloch. It came from observing nature.The phenomenon of a natural solar pond exist at several places in the world including a few miles south of Eilat. Temperature differential between the bottom and the top may exceed 40°C. Artificial solar ponds essentially replace the metal, glass and plastic of conventional collectors with a mass of water, thus reducing by order of magnitude the cost per calorie collected. It also has a large inherent storage ability, up to months of storage, depending on the design of the ponds.

Normal bodies of water can support only small temperature differences under solar radiation since convection currents mix the water. By creating and maintaining a density gradient, by differential dissolution of salts, with increasing concentration from top to bottom, the usual convective currents that occur in homogeneous ponds can be reduced greatly. The result is that hot water can accumulate at the bottom with the top layer acting as an insulator. Temperatures close to boiling point can be reached. The only loss mechanism is by conduction through the stagnant layer of water, and therefore, it is kept at a low value. The average collection efficiency may exceed 20 to 25% .

The research and development of large scale solar ponds is by its very nature a slow process. It takes more than a year until a long-term steady state of the pond is attained. Also, many problems are yet to be solved, such as methods of construction and sealing, maintenance of the salinity gradients, effects of wind, ground conduction, opacity created by dust and algae growth. None of these problems seem unsolvable however.

At present, there are three experimental solar ponds under investigation. A 1,500 square meters pond, at Ormat plant in Yavneh, was put into operation in 1978. It is now providing a heat source, from the bottom layer at 88°C, and a heat sink, from the top layer at approximately 30°C, to an organic fluid turbine generating up to 8 KW day and night. A second pond was constructed in Eilat by compacting the local clay soil without any additional sealing agent.

The third and largest pond, 6500 m^2, was completed in June 1978, at Ein Bokek on the shore of the Dead Sea. A year later a 150 KW organic fluid turbine was installed and the combined system inaugurated in December, 1979. In addition an experimental flash chamber for producing low pressure steam to be used for desalting water has been installed and operated.

The successful operation of this pilot system has prompted a decision to go for the next stage of substantial upscaling. A two year program has been approved to build and operate a combined system of a 250,000 sq. meters pond with a 5 MW turbine. The system will be operational in 1983. Up to 1500 MW of solar energy could be potentially generated from the Dead Sea and such a program would also fit nicely with the Mediterranean Dead Sea project (see elsewhere).

It is too early to present an accurate economic evaluation of the solar pond for there are still many imponderables. However, it is estimated that the cost per installed KW, including pond and conversion system, would be $1,700 - $2,200 and this figure can probably be reduced even further. This, coupled with low requirements for maintenance, make the solar pond competitive with other means of electrical generation from solar sources. Moreover, the production of low temperatures heat would become economic even earlier.

Indeed, it is hoped that if the program is successful, solar ponds will be used extensively to supply domestic, commercial and industrial hot water, generate electricity and provide desalted water. It may contribute significantly to the energy balance of Israel in the nineties.

Thermal Conversion

There is no question of the importance of efficient and dependable means for converting low temperature heat to electricity.

A sealed organic fluid Rankine cycle, turbo-generator was developed back in the 1960's at Ormat. Originally they were meant for using solar energy, but, again due to the availability of cheap petroleum, were actually used on conventional fuels. They were marketed as small (up to 3 KW), dependable, maintenance-free turbo-generators for use in remote locations where professional people were not available. Millions of maintenance-free running hours accumulated at installations all over the world from Africa to Alaska have earned unique reputation for these units. Now, with a return to solar, turbo-generators from 2 KW to 5 MW are being developed on the basis of the long experience gained in this subject.

A novel idea of making use of a magnote-hydro-dynamio (MHD) generator to produce electricity from low temperature sources is being researched at Ben-Gurion University. It consists of a dual cycle of liquid metal heated by solar energy and mixed with an organic fluid. The mixture is then accelerated in a specially designed two phase nozzle, due to the evaporation and expansion of the organic fluid, and is made to flow through the MHD generator, producing electricity directly. The organic fluid in the gaseous phase is then separated from the liquid metal, condensed and pumped back to the mixer. The liquid metal is made to go through the solar collector to complete its cycle. First stage theoretical and experimental work has been completed and in the next year a pilot system should become operational.

Direct Conversion

Photovoltaic

The current world approach to the utilization of photovoltaic is that it is a very large scale sophisticated and expensive technology, beyond the means of a small country like Israel. Therefore, there is no real effort towards large scale production of solar cells.

The research in this subject concentrates on the physical and chemical development of new types of surfaces and cells, and on system integration, with and without concentration.

Surfaces and Cells

A research program, for producing inexpensive photovoltaic surfaces, is being carried out at Tel Aviv University. It was found that an oriented crystalline film may be obtained by evaporating silicon, under high vacuum, on to a suitable single crystal substrate. After detaching the film an inexpensive photovoltaic surface is obtained.

Photo-electro-chemical cells are developed at the Weizmann Institute. The cells consist of semiconductor electrodes in a suitable electrolyte. Upon illumination, electric current is produced. The cell provides controllable built-in storage, so that excess electricity may be stored for periods of no sunshine, thus allowing a constant load independent of the instantaneous illumination.

Systems

A small 10W photovoltaic battery charger is produced by Tadiran mostly for military purposes. It uses conventional silicon cells.

Development is underway at the Weizmann Institute, of a solar cell system where Fresnel lenses are used to concentrate solar light, by a factor of 50:1, on special silicon cells greatly enhancing the production of electricity per cell. A tracking system which takes the signal from the sun is also being developed. This system requires much less photovoltaic cells per unit of electricity thus reducing the cost of the most expensive component; however, it has the added complication and cost of a concentrating and tracking system.

Application of the spherical stationary concentrator to electricity generation by solar cells is being investigated at the Technion.

An exciting new method for improving the utilization of solar cells is under study at the Hebrew University. Solar cells can convert only a narrow band of wavelength into electricity. The rest of the radiation only heats the cell. When a specially doped glass is exposed to sunlight, excitation occurs inside the glass and the re-emission is essentially in a narrow gap that may be made to fit the silicon cell. Moreover, most of the re-emitted light is at such angles that it is reflected back from the glass surface and eventually emerges from the side of the glass plate at a greatly increased intensity in the suitable range. Thus, if silicon cells are to be placed on the side of the plate, they enjoy effectively higher illumination with very little heating effects.

Hydrogen and Fuel

A research program to produce hydrogen from water by using solar radiation is under way at the Hebrew University, Jerusalem. By adding solar sensitive chemicals to water and exposing it to the sunlight, a chain of reactions takes place resulting in a reduction of the water to hydrogen and oxygen with good theoretical efficiency. This research is in its initial stages, and so far with meager results.

Another idea of producing fuels and chemicals from carbon dioxide using solar energy is being studied both at the Hebrew University and the Weizmann Institute.

BIOMASS

Agricultural Wastes

The abundance of organic wastes, manures and vegetation, coupled with environmental problems and high energy cost, have led to a project aimed at the introduction of a novel approach to the ancient idea of producing methane gas from agricultural wastes. This project is directed by the Research and Development Institute of the Kibbutz Industries. Bioconversion by anaerobic digestion is the basic process whereby organic wastes are affected by bacteria which are active when no oxigen is present. The resulting biogas contains 60 to 65 percent methane, 30 to 35 percent carbon dioxide and some traces of sulphides.

The project team concentrated its efforts on solving four problems:

- The collection of the wastes.
- The improvement of the digestor efficiency.
- The transport and utilization of the gas.
- The proper disposal of the slurry.

It turned out that the kibbutz agricultural structure is suitable for resolving the collection, gas transport and slurry disposal problems. An energy survey, currently in progress, indicates that a kibbutz can meet 65 to 90 percent of its energy needs by properly utilizing its agricultural wastes.

The residual slurry could be used as fertilizer, fish food, cattle and other livestock food, soil conditioner, hard boards, and insulation. An intensive program is being carried out aimed at ascertaining the uses and values of the slurry. It is apparent that its value as food is higher than its use as fertilizer, fill or conditioner.

The project is now in its sixth year. A substantial improvement was achieved in the digestion process, causing a reduction of the required residence time coupled with a substantial increase in the gas production rate. A rate of 5 volumes of gas per day per volume of digestor can be routinely obtained and the rate can probably be pushed upwards to 8 - 10.

Sixteen bench scale digestors allow testing simultaneously of various combinations of conditions and feeds, while eight systems of pilot plant size of one cubic meter give important information on the operation of the system. Demonstration units of twelve up to two hundred cubic meters have been completed and the technology is considered ready for commercialization.

The investment cost for the construction of a biogas plant for a kibbutz with a cowshed of 500 heads of cattle is estimated at 250,000 U.S.Dollars. Saving in fuel and electricity is estimated at 40,000 U.S. Dollars per year. Utilization of the slurry would be an added advantage. The impact of biogas conversion on Israel's energy balance is somewhat difficult to estimate. It certainly could not exceed 1% by far. However, this project should be looked upon as an all around solution to several problems and as such may make an important contribution.

<u>Algae</u>:

Much research on algae is carried out in Israel. Algae are studied as a source of protein, as a means of purifying sewage water and as a source for chemicals and fuel.

Extremely interesting research programs resulted from the discovery of certain halophillic algae that grow in highly saline water and contain over 30% of their dry weight as glycerol. Their rate of growth depends on solar energy and the environmental conditions.

One group is interested in the production of glycerol which may turn out to be cheaper than that produced by alternative methods.

The other group aims at the production of liquid fuel which can be extracted by pyrolitic processing of the algae.

Both groups study the growth rate with and without CO_2 addition. Problems in concentrating and harvesting of the algae still need to be resolved.

CHAPTER 13

OIL SHALE

To date, oil shales are the only known and identified fossil energy source indigenous to Israel. High priority is placed on the development of oil shale as a potential replacement for imported oil.

Early work on oil shale was carried out in Israel in the 1950's, when bitumen from Ein Bokek was used for various experiments of material handling and grindability as well as combustion characteristics. The work was discontinued mostly due to the cheap competition of crude oil.

The interest in oil shale was renewed in the mid 1970's and it picked up more momentum in the last 2 years.

A program has been undertaken by the Ministry of Energy and Infrastructure (MOEI) whose objectives are a commercial exploitation of Israeli oil shale at a rate of 20,000 - 40,000 bbl/day by 1990.

Several avenues are being considered:

(a) Retorting to produce synthetic fuels (oil and gas)

(b) Direct combustion for the production of steam and electricity.

(c) Ash utilization (cement, building materials and aggregates).

The program involves resource and exploration evaluation, an estimate of adaptation of existing technologies to Israel's conditions and R & D for new improved technologies. It is carried out by contract with government and industrial companies and universities.

Geological Survey and Exploration

Oil shales were encountered in Israel in early water drillings and at several other locations. In the past few years more efforts have been made in identifying the resources, quantities and qualities.

The recoverable reserves in the 5 major fields, already identified are:

	Efé	0.6×10^9	tons	
	Oron	0.6×10^9	"	
	Hartuv	1.0×10^9	"	(minimum)
*	Bigat Zin	0.7×10^9	"	"
*	Znifim	1.5×10^9	"	"
	total	4.4×10^9	tons	

All these deposits are of similar nature with an overburden ration of 0.5 - 1.0, an average kerogen content of approximately 15% and Fisher Assay yields of 15-18 GPT. This oil yield accounts for only about 40-45% of the oil organic matter, an additional 20% is obtained as gas and the rest is fixed carbon.

These known reserves could potentially produce over 200 million tons of oil with additional quantities of gas and other products.

There are good indications that more fields exist even though they have not been completely investigated.

DEVELOPMENT PROGRAM (Retorting)

The program for the near future can be divided into 3 phases:

Phase 1 - Technology selection (continuation)

" 2 - Industrial Module

" 3 - Commercialization

Technology Selection (in Progress)

Objectives: - Adoption of a technology for the retorting of the oil shale
- Adoption of the method and technology for improvement of the oil to make it suitable for refining into commercial distillates.

Estimated Duration: 2 - 3 years

This phase of the program, started last year, is concentrating on the evaluation of the existing technologies with respect to retorting the Israeli oil shale. The criteria for the evaluation will be:

- Yield oil and gas
- Quality of the oil and gas
- Degree of utilization of the fixed carbon
- Technical suitability, reliability, maintenance and operations.
- Possibility of beneficiation of the oil
- Costs

Production tests will be carried out at existing pilot plants in the U.S. and elsewhere after a preliminary study and evaluation of the technology and its potential for retorting Israeli oil shale.

An evaluation of the required modifications or improvements in existing plants, to better fit the above-stated criteria, will be made. Repeat tests may be required.

It is hoped that an existing technology, possibly with some modifications, will be found to give adequate answers to the requirement. However, an R & D program for the development of a new technology as part of the total project, will continue. During this phase a construction of a small pilot plant may be indicated as a substantial aid in the selection of the technology.

Industrial Module

Objectives:- Demonstration of the Technology applicability to industrial scale of production

- Design, construction and operation of an industrial retort module with the accompanying equipment (mining material handling, pretreatment, disposal of spent shale, oil beneficiation etc.)

Estimated duration: 4 - 5 years.

This phase is crucial in the development of a viable technology for oil shale utilization. A module of an industrial scale (2000 - 8000 bbl/day) which could be repeated in a commercial plant will be constructed, operated and evaluated. This phase will supply all the necessary information (technical, operational, economical and environmental) for the factory.

A detailed plan depends on the results of phase 1.

Commercial Plant

Plants with a capacity of 20,000 - 40,000 bbl/day are considered as most suitable for the size of fields found in Israel. These factories will consist of a number of modules as required for full production.

This phase will be based on the demonstrated technology and could be considered mostly as a commercial enterprise beyond the scope of R & D.

It is expected that by the end of the 80's, one full-scale production plant will be operating.

CHAPTER 14

WIND POWER

The development of wind power is currently under study, as new evidence with regard to it's techno-economic feasibility has been established. Although implimentation is still far from realization, some experts believe it could ultimately save between 5 and 10% of the fossil fuel used by the Electric corporation.

Most people in the field estimate that wind power generators can be economical in locations where wind velocities average 6 meter/seconds (about 13.5 mph) or more. Several areas in Israel qualify under these terms. The Hermon mountain slopes (9 m/sec.), the mountains of Upper Galillee (7 m/sec.) the Negev plateau and the Sdom area (6 m/sec.). In each instance, the wind velocities occur at a point only about 10 meters above ground level; they increase as one goes higher.

Under these conditions, wind power generation will be economical, once equipment becomes available at $ 750 or less per installed kilowatt capacity. That stage has not yet been reached. Prices as low as $ 500 per installed kilowatt capacity are expected within the foreseeable future and will thus make wind power a viable option.

A major problem inherent in wind power is the fact that air currents are far from uniform and production therefore tends to fluctuate. However, working in tandem with other renewable energy systems could overcome this problem; in fact solar energy systems might be a good compliment, since wind velocities often stand in inverse proportion to insulation rates.

The study of wind power generation in Israel is at its initial stages, yet the program calls for/the ~~first~~ 200 KW Demonstration Wind powered generator to be installed next year.

CHAPTER 15

GEOTHERMAL ENERGY

Preliminary studies, based largely on data obtained from oil well records, suggest that it may be practical to utilize geothermal energy in Israel.

Data obtained from oil exploration drillings in the Ashdod area indicate that large amounts of hot brine can be pumped from the Upper Jurassic formation there. At a depth of about 8,000 feet, brine was found at temperatures of about 110 degrees C. - It seems that at about 11,700 feet below the surface, temperatures not less than 140 degrees C can be reasonably expected.

In Ashdod, one potential customer is the Joint U.S.-Israel Desalination Project, which has indicated its interest in a continuous supply of at least 85 million kilo calories per hour, at a maximum cost of $7.5 per million kilo calories. Estimates suggest actual production cost will be significantly lower.

The next step will have to be an engineering appraisal, based on precise data, regarding each well's production capacity, the water's stable temperature and its chemical composition. Two abandoned dry wells in the Ashdod area can be used for this purpose, one for pumping tests and the other for observation. In addition, the hot brine can be used to heat homes during the winter and boost agricultural production in nearby hot houses.

It is also believed that similar reserves of hot brine can be found in other parts of Israel, including many likely coastal plain locations.

CONCLUSION

Despite all her efforts of diversification and use of alternative sources of energy, Israel will still be 30-40% dependent on oil in the year 2000. As far as electricity is concerned, the share of oil-fired plants will be 10% or less, coal will provide 50-60%, nuclear power 30-40% and hydro and solar power the rest, provided that electricity does not exceed 45% of all energy resources. Figures 10 and 11 provide a graphical representation of the total primary energy resources distribution and the input distribution for electricity.

Only a higher rate of electrification involving the introduction of new technologies (electric car), perfection of existing technologies (coal gasification for small industries) and heavy investments in infrastructure to change current structural patterns (electric mass transportation) will further reduce oil dependency, but they require determination, technological progress and additional financial resources.

Figure 10

PRIMARY ENERGY INPUT DISTRIBUTION FOR ELECTRICITY

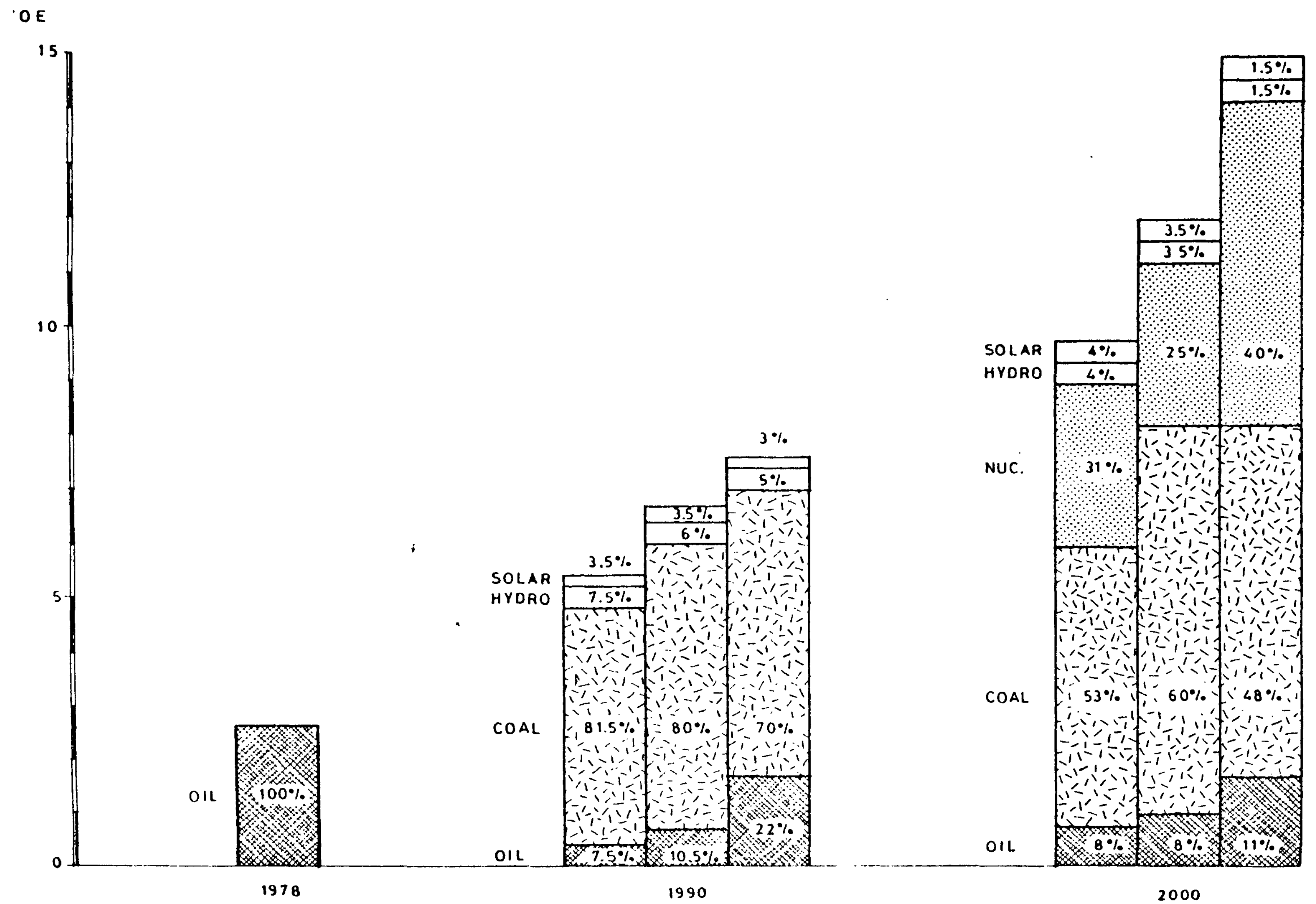
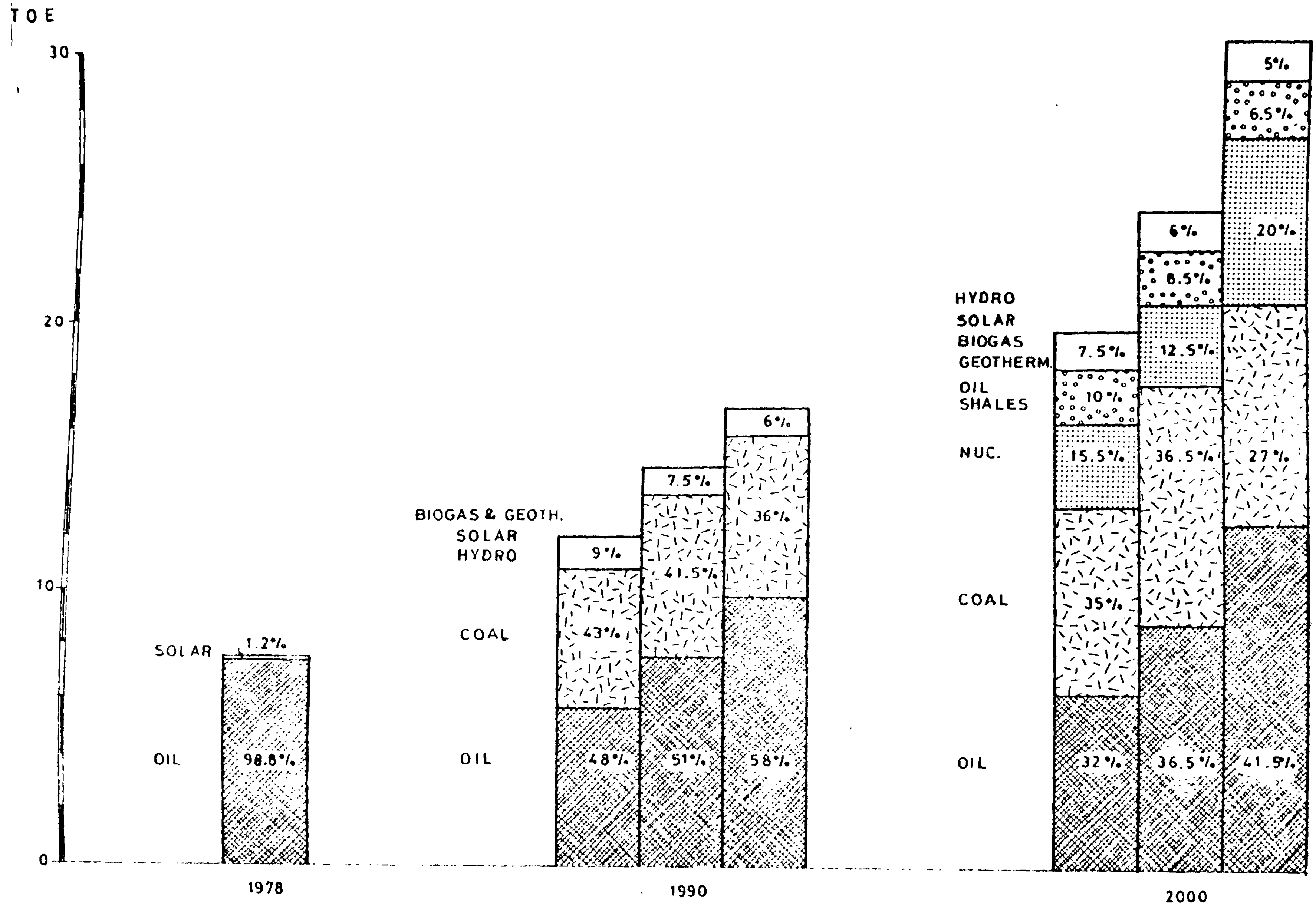


Figure 11

TOTAL PRIMARY ENERGY RESOURCES DISTRIBUTION



APPENDIX

INTERNATIONAL COMPARISONS OF ENERGY CONSUMPTION PATTERNS

In order to provide a reference to the energy consumption patterns of Israel, as well as to point out her unique energy characteristics as compared with other countries, a set of graphical comparisons is presented.

These comparisons relate to the energy characteristics of 21 industrialized nations and 16 developing countries in 1977 (the last year for which world-wide comparative data is available.

Figures 12, 12A presents per capita energy consumption vs. per capita gross domestic product for 1977.

Figures 13, 13A presents the corresponding data with respect to per capita electricity generation.

The last two figures (figures 14, 14A, 15 present the relevant data on the share of electricity in their countries domestic energy consumption and the degree of dependence on oil imports.

While these figures are self-explanatory, it is worthwhile noting the following points:

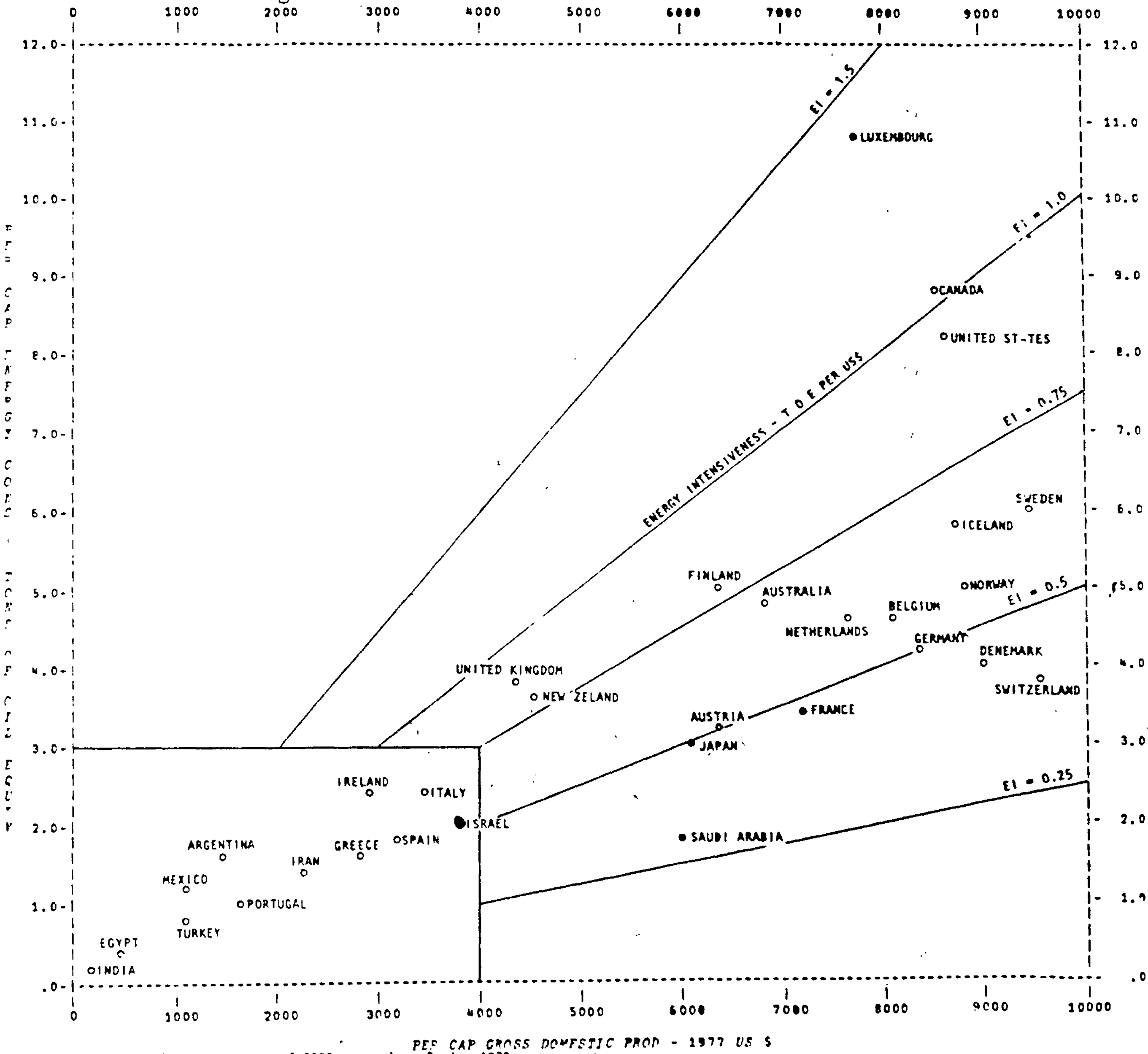
a. The bulk of the industrialized countries exhibit an energy intensiveness, i.e., energy consumption per GDP, of 0.5-0.75 kg/$. A small group of countries show higher energy intensiveness and some industrialized countries lower intensiveness, with most of the developing countries above the 0.5 kg/$ mark line.

Israel with a GDP/capita of about $4,000 and per capita energy consumption of almost 2 tons of oil equivalent lies on the 0.5 boundary of intensiveness.

b. Electricity intensiveness does not always follow the pattern of energy intensiveness due to the high share of hydro-electric power in various countries on the one hand and the specific industrial structure on the other. The lack of indigenous primary resources as alternatives to electricity may provide another reason for a higher electricity intensiveness. Israel with a share of 36% of electricity of the total domestic energy consumption (small energy consumption for heating) exhibits a somewhat higher electricity intensiveness than should be expected from its energy intensiveness.

c. Israel is 98% dependent on oil imports and leading the list but there are a substantial number of countries which are currently over 50% dependent on oil imports.

Figure 12 PER CAPITA ENERGY CONSUMPTION vs GROSS DOMESTIC PRODUCT - 1977



Sources: Energy balances of OECD countries, Paris, 1979
Workshop on energy data of developing countries, v.2, IEA, Paris, 1979
International financial statistics, IMF, Washington D.C., 1979

Figure 12A PER CAPITA ENERGY CONSUMPTION vs GROSS DOMESTIC PRODUCT - 1977

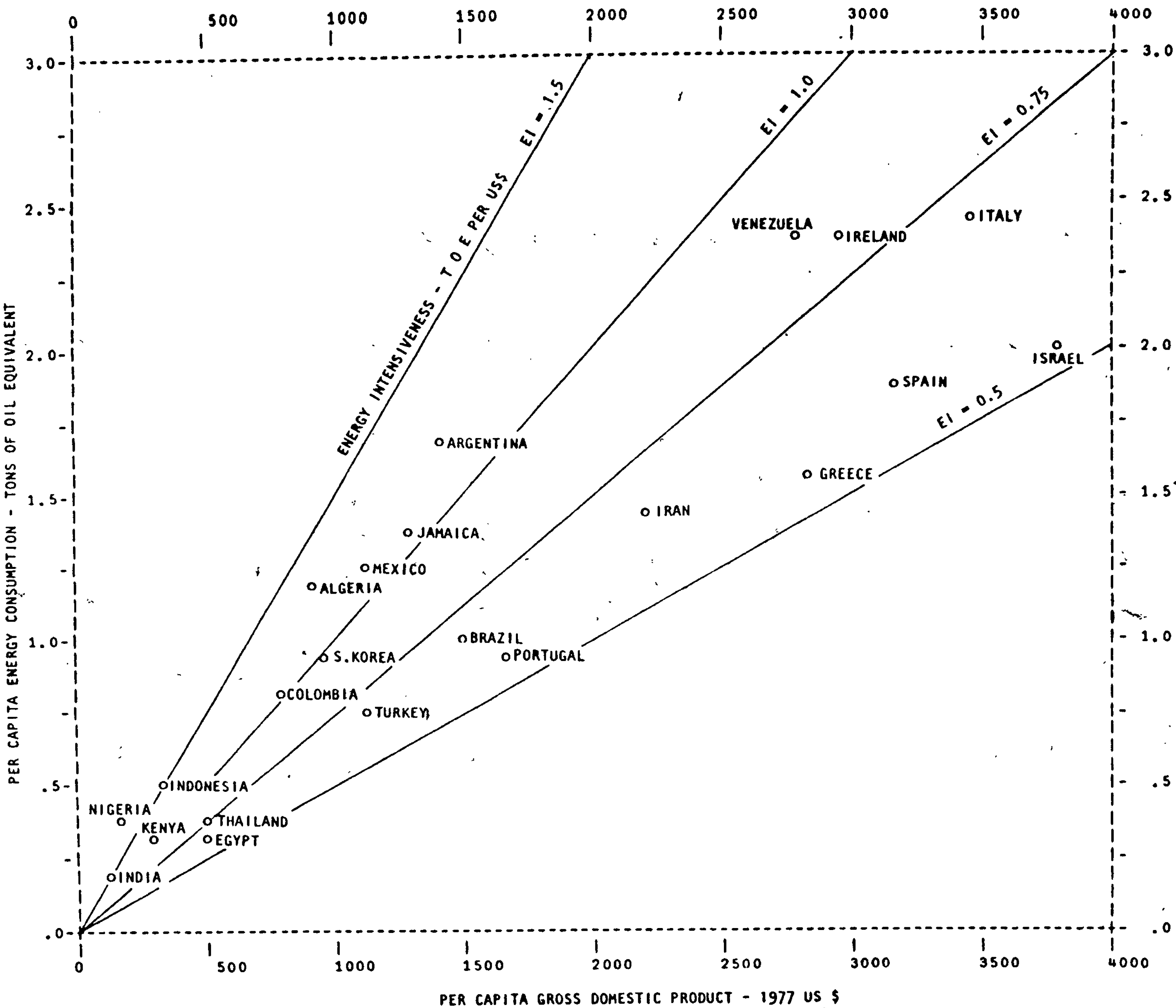
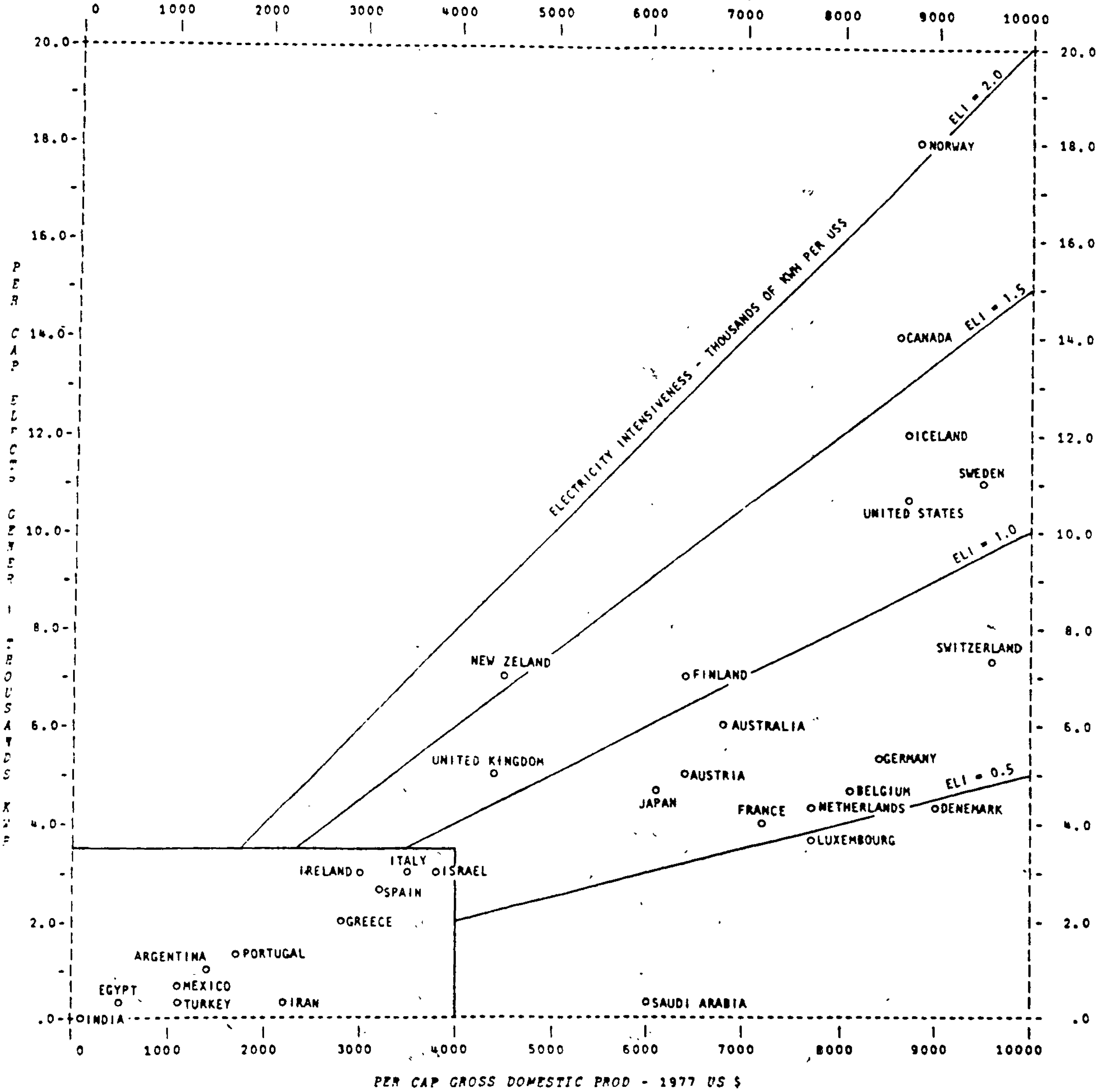


Figure 13 PER CAPITA ELECTRICITY GENERATION vs GROSS DOMESTIC PRODUCT - 1977



Sources: Energy balances of OECD countries, Paris, 1979.
Workshop on energy data of developing countries, v.2, IEA, Paris, 1979.
International financial statistics, IMF, Washington, D.C., 1979.

Figure 13A PER CAPITA ELECTRICITY GENERATION vs GROSS DOMESTIC PRODUCT - 1977

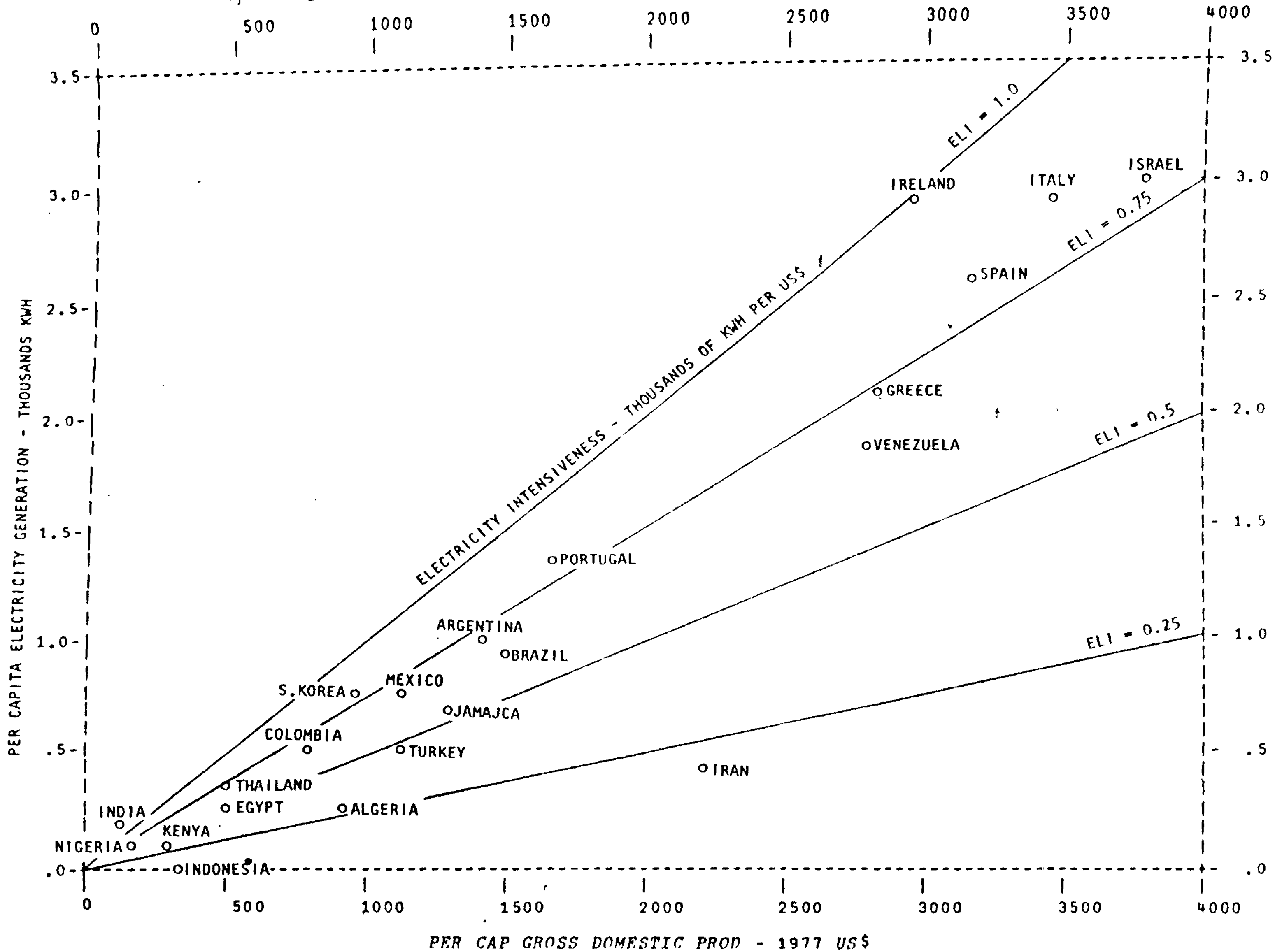
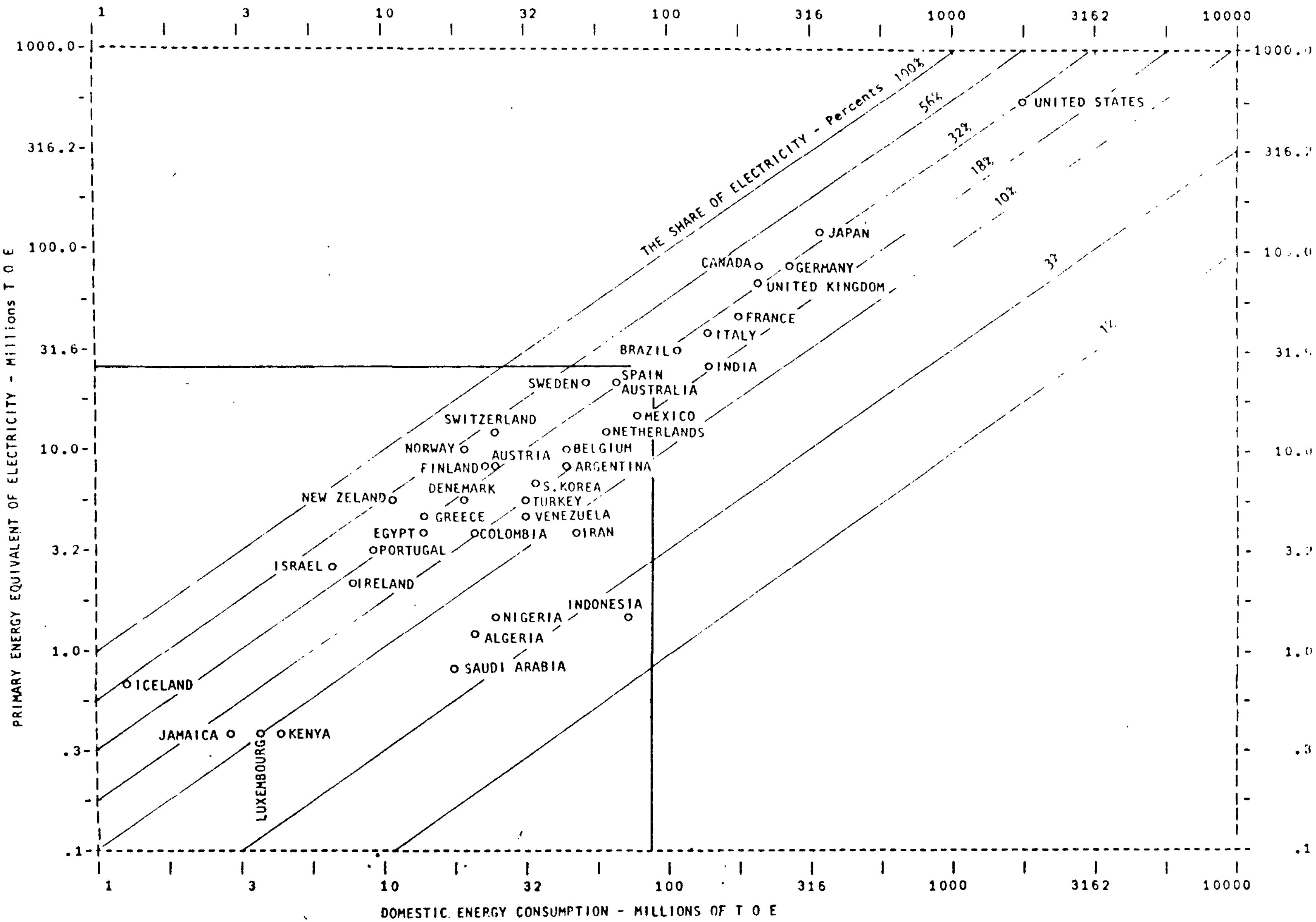


Figure 14 PRIMARY ENERGY EQUIVALENT OF ELECTRICITY vs DOMESTIC ENERGY CONSUMPTION - 1977



NOTE: Domestic energy consumption includes use of non-commercial fuels

SOURCES: Energy balances of OECD countries, Paris 1979
Workshop on energy data of developing countries, v.2, IEA, Paris, 1979

Figure 14A PRIMARY ENERGY EQUIVALENT OF ELECTRICITY vs DOMESTIC ENERGY CONSUMPTION - 1977

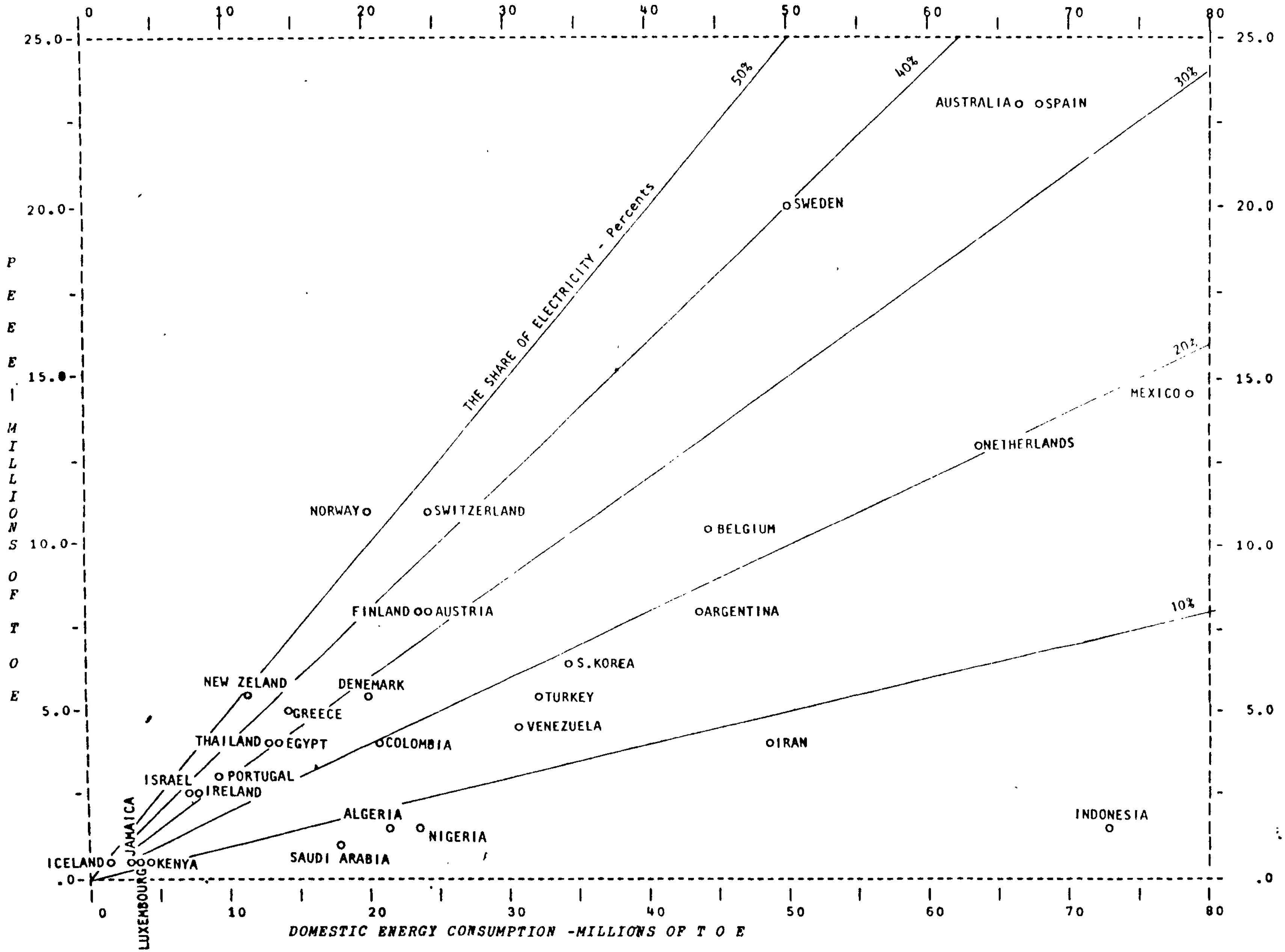
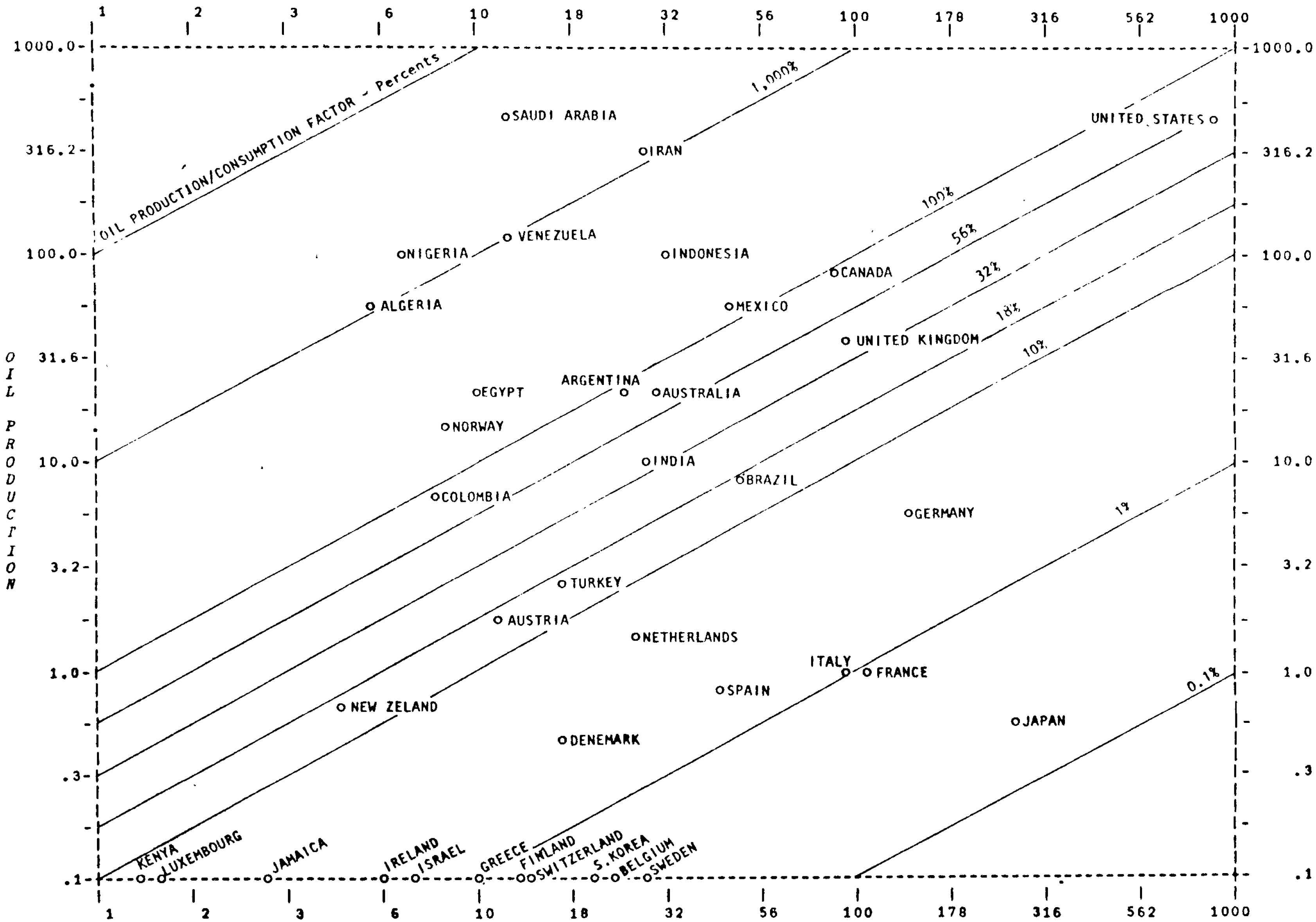


Figure 15 INDIGENEOUS OIL PRODUCTION vs DOMESTIC OIL CONSUMPTION



SOURCES: Energy balances of OECD countries, Paris 1979
Workshop on energy data of developing countries, v.2, IEA, Paris, 1979