JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

PLAN & BUDGET ORGANIZATION (PBO)
THE ISLAMIC REPUBLIC OF IRAN

THE COLLABORATIVE STUDY ON THE COMPREHENSIVE ENERGY DEVELOPMENT PLAN IN THE ISLAMIC REPUBLIC OF IRAN

FINAL REPORT

Vol. I Executive Summary

MARCH 1994

INSTITUTE FOR RESEARCH IN PLANNING AND DEVELOPMENT (IRPD)
THE INSTITUTE OF ENERGY ECONOMICS, JAPAN (IEEJ)

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(IEEJ)

March 1994

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Yanagiya,

Letter of Transmittal

We are pleased to submit you the report on "The Collaborative Study on the Comprehensive Energy Development Plan in the Islamic Republic of Iran". The report contains the advice and suggestions of the authorities concerned of the Government of Japan and your Agency. Also included are comments made by the Plan and Budget Organization and other authorities concerned of the Islamic Republic of Iran during discussions on the draft report which were held in Tehran.

This report presents that promoting energy conservation is one of the most important policies in the Islamic Republic of Iran and that concrete policies to encourage energy conservation in the social and economic sectors are essential. Consequently, more detailed studies to promote energy conservation are necessary to formulate future energy policy in the Islamic Republic of Iran.

We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs, and the Ministry of International Trade and Industry. We also wish to express our deep gratitude to the Plan and Budget Organization and other authorities concerned of the Islamic Republic of Iran for the close cooperation and assistance extended to us during our investigations and study.

Very truly yours,

Mitsuru Miyata

Project Manager

The Collaborative Study on
the Comprehensive
Energy Development Plan in
the Islamic Republic of Iran

PREFACE

In response to a request from the Government of the Islamic Republic of Iran, the Government of Japan decided to conduct the collaborative study on the comprehensive energy development plan in the Islamic Republic of Iran and entrusted the study to the Japan International Cooperation Agency(JICA).

JICA sent to the Islamic Republic of Iran a study team headed by Mr. Mitsuru Miyata of the Institute of Energy Economics, Japan, seven time during the period from February 1992 to March 1994.

The team held discussions on the plan with officials and experts concerned of the Government of the Islamic Republic of Iran and conducted field surveys at the study area.

I hope that this report will contribute to the promotion of the plan and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials and experts concerned of the Government of the Islamic Republic of Iran for their close cooperation extended to the team.

March 1994

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

Foreword

The present report is the Final Report which has been prepared in the framework of technical cooperation between the Plan & Budget Organization (PBO) , the Islamic Republic of Iran and the Japan International Cooperation Agency (JICA) on the energy studies. The work on the energy studies is carried out by the Iranian and Japanese expert teams and the results of this collaborative work are hoped to provide reliable information for preparation of the "Comprehensive Energy Development Plan", which is undertaken by the Institute for Research in Planning and Development (IRPD) and Sharif University of Technology(SUT).

In the first and second stages of the present collaborative study, analysis of energy conservation and energy-environment interactions in selected energy intensive industries was envisaged. For this purpose, visits of the Iranian and Japanese experts to about thirty plants and factories were arranged. During this visit, members of our working groups have enjoyed a very kind cooperation and understanding of the General Managers and technical staff of the plants and factories. Discussions with the experts and exchange of information with them have greatly contributed to our understanding of the issues and problems of energy conservation and environmental protection, which we consider as a valuable asset to the present study.

The assistance and kind cooperation of managers, technical staff and experts in those industries is deeply appreciated, and we would like to acknowledge their kind cooperation.

The members of the Iranian and Japanese expert teams and the staff of the comprehensive energy studies have worked intensively in preparing this report. Their enthusiasm and active participation in the project is deeply acknowledged.

March, 1994

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Project Manager	Project Manager
Comprehensive Energy Studies	JICA Study Team

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Note:		
	CEP:	Comprehensive Energy Plan
	NIOC:	National Iranian Oil Company
	NIGC:	National Iranian Gas Company
	PBO:	Plan and Budget Organization
	MOE:	Ministry of Energy
	ORC:	Oil Research Center of Iran
	SCI:	Statistical Center of Iran
	SUT:	Sharif University of Technology

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Mr. Toru Kimura (IEEJ)

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* Mr. Kihachiro Urushibata (PCI)

Note: IEEJ :	The Institute of Energy Economics, Japan
Martech:	Martech Inc.
U-Tech:	U-Tech Consulting Co., Ltd.
TGEC:	Tokyo Gas Engineering Co., Ltd.
EPDCI:	EPDC International Ltd.
ECCJ:	The Energy Conservation Center, Japan
PCI:	Pacific Consultants International

Abbreviations

a	annum
bl	barrel
BOE	Barrel Oil Equivalent
BPSD	Barrel Per Stream Day
DB	Dry Boiler type kiln
g	gram
Gcal	Giga-calorie
GDP	Gross Domestic Products
GJ	Giga Joule
GWh	Giga-watt hour
h	hour
HFO	Heavy Fuel Oil
hr	hour
KBOE	Kilo Joule
Kcal	kilo-calorie
KJ	Kilo Joule
km	kilo-meter
kt	kilo-ton (thousand ton)
Ktoe	Kilo ton oil equivalent
KW (kw)	Kilo-watt
L	Lepol type kiln
M (m)	Meter (meter)
M(m)Wh	Mega-watt hour
MBOE	Million Barrel Oil Equivalent
Mcal	Mega-calorie
mg	milligram
mio.	Million
Mrd.	Milliard (Billion)
Mt	Million ton
MW	Mega-watt

n.a.	not available
Nm^3	Normal cubic meter
NSP	New Suspension Preheater type kiln
PJ	Peta Joule
pop	population
ppm	parts per million
Rls	Rials
Rs	Rials
SP	Suspension Preheater type kiln
UNEP	United Nations Environmental Program
W	Wet type kiln (without Filter)
WFB	Wet Filter Boiler type kiln
WHO	World Health Organization
y	year

Year: The year of the Islamic Republic of Iran begins on March 21 of the Gregorian calendar year and ends on the following March 20. To arrive at the corresponding Gregorian years, 621 years should be added to the Iranian years.

THE COLLABORATIVE STUDY
ON THE COMPREHENSIVE ENERGY DEVELOPMENT
IN THE ISLAMIC REPUBLIC OF IRAN

FINAL REPORT

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Vol. 2 Main Report

1. Introduction

2. Economic Development

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1. Introduction

Development of a consistent and comprehensive energy policy for improving the energy efficiency of the economy is considered as the most important energy issue in the Islamic Republic of Iran. The main objective of such a policy is to provide a means of establishing an efficient, economical and reliable energy supply system which will be compatible with social development and environment. To achieve this objective, the Plan & Budget Organization (PBO) in the Islamic Republic of Iran has organized a study of "Comprehensive Energy Development Plan". The ultimate goal of this study is to prepare information and a rational and scientific basis for development of long - term energy strategies.

The Institute for Research in Planning and Development (IRPD) in the Islamic Republic of Iran has been assigned by the Plan & Budget Organization to carry out the project on preparing the "Comprehensive Energy Development Plan". This study has been organized at the IRPD in collaboration with Sharif University of Technology (SUT) in the Islamic Republic of Iran since November 1992.

Comprehensive energy studies include five major working groups, which are being organized under the management of the project. Outline of the organization of the study on " Comprehensive Energy Development Plan " is shown in Figure 1.1. The major areas of study are:

a) Development of Energy Data-Base
b) Analysis of Economic Development
c) Analysis of Energy Demand
d) Analysis of Energy Supply System
e) Review of Energy Market

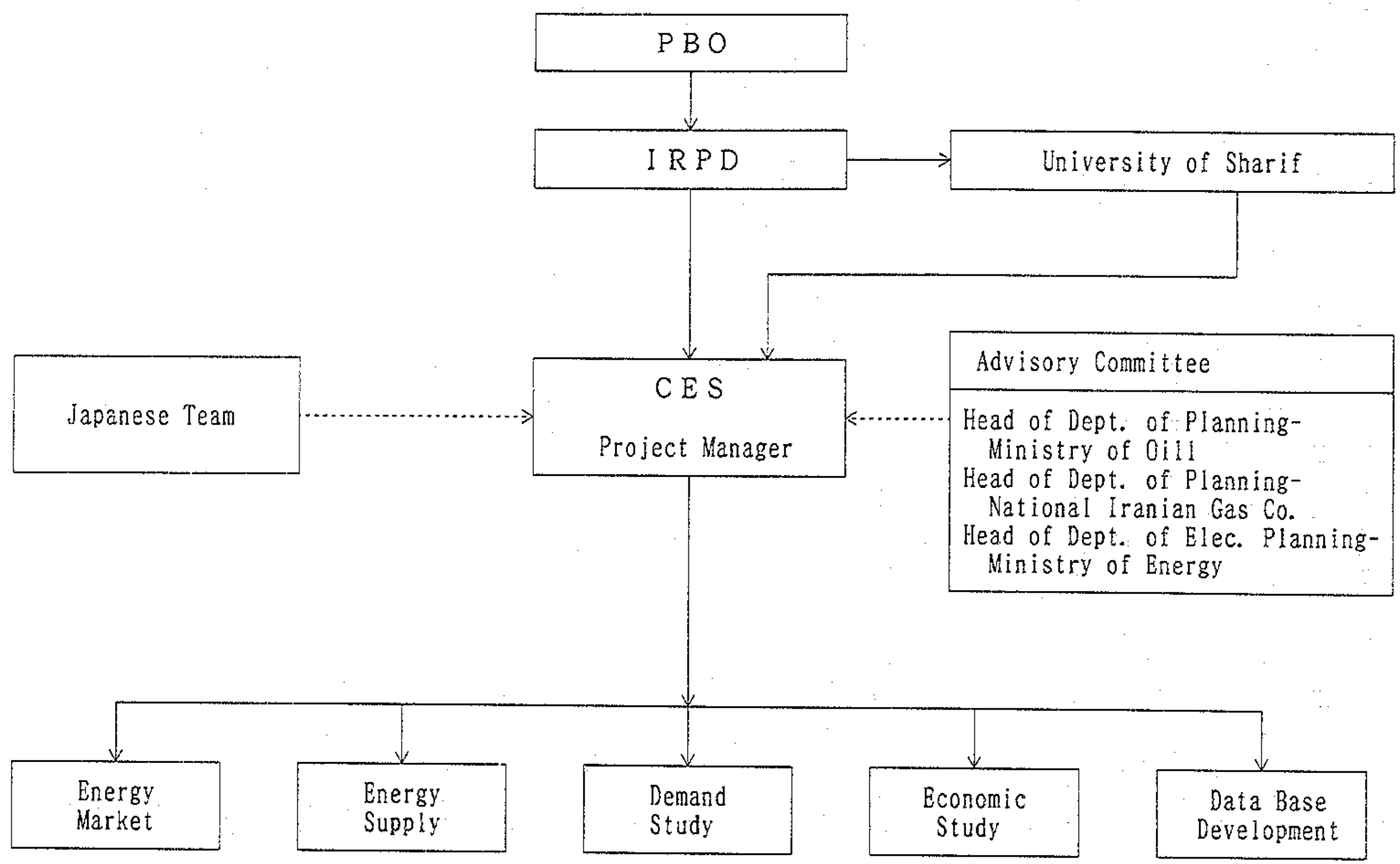


Fig. 1.1 Structure of the Organization of Comprehensive Energy Studies (CES)

1.1 Technical Cooperation

In order to support the efforts of expert working groups in the process of preparing the "Comprehensive Energy Development Plan", technical and scientific cooperation in the field of energy studies were sought by the Plan & Budget Organization (PBO) . In response to the request of the Government of the Islamic Republic of Iran, the Government of Japan agreed to cooperate in energy studies. According to this agreement, the study has been undertaken jointly by the Plan & Budget Organization (PBO) of the Islamic Republic of Iran and Japan International Cooperation Agency (JICA) ,based on the division of undertakings of each side.

JICA entrusted the undertaking of the Japanese side of the study to the Institute of Energy Economics, Japan (IEEJ) in February 1992. Thus, IEEJ has been acting as counterpart to IRPD.

1.2 Division of Undertakings

The collaborative study of the " Comprehensive Energy Development Plan" has been organized according to the division of undertakings (see Fig.1.2). According to this division of work, the Iranian expert team is mainly responsible for the following activities:

a) Development of Energy Data-Base
b) Analysis of Economic Development
c) Analysis of Energy Demand
d) Analysis of Energy Supply System
e) Review of Energy Market

The Japanese expert team is responsible for conducting energy studies in the following areas:

f) Energy Conservation
g) Energy-Environment Interaction
h) Training Iranian experts in the area of energy conservation and environmental analysis

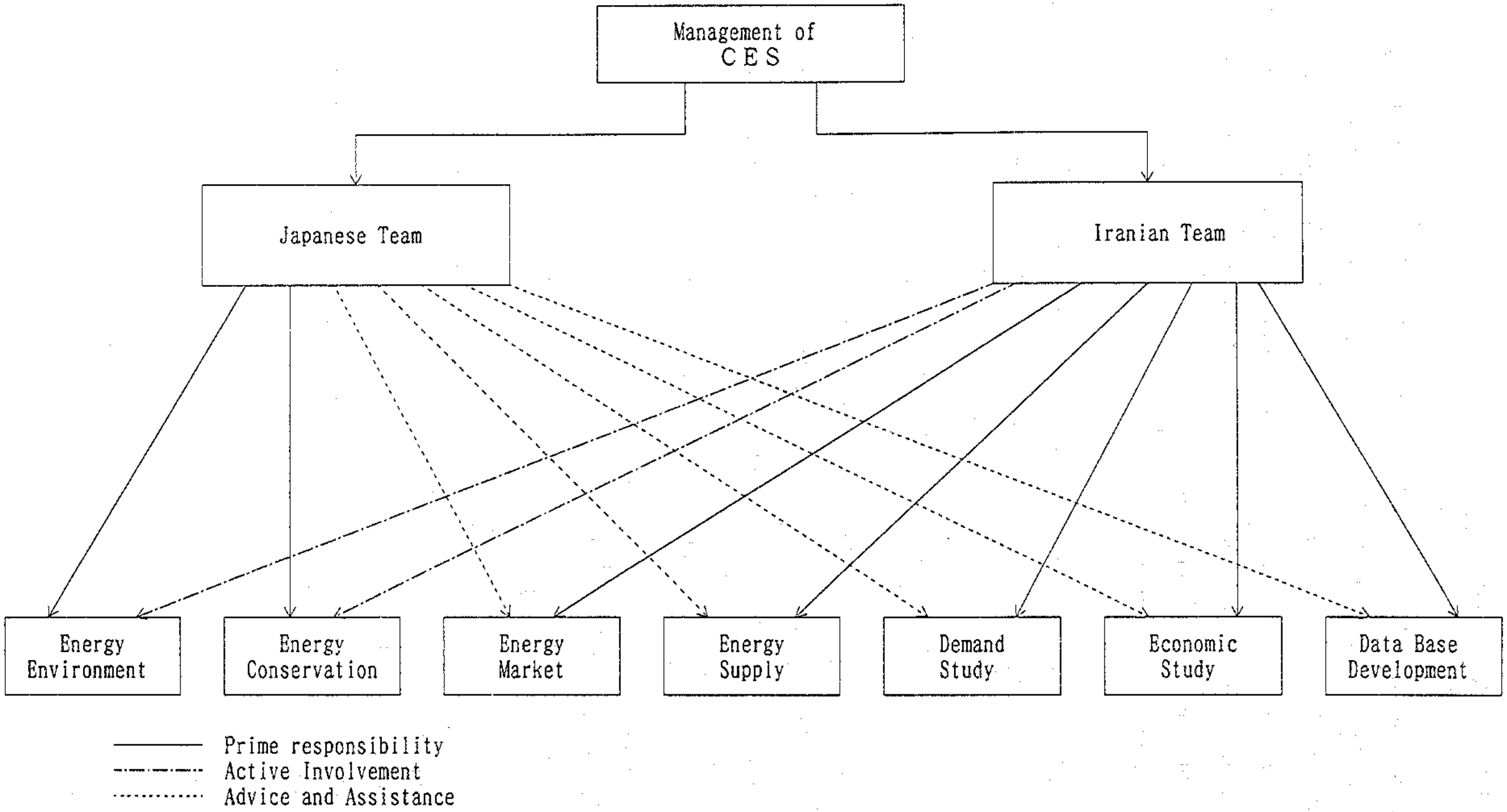


Fig. 1.2 Division of Work between Iranian and Japanese teams

1.3 Reports of the Collaborative Study

Both Iranian and Japanese expert teams were expected to carry out the study and to prepare the reports jointly. The following six reports have been prepared in the process of the present technical cooperation.

a) Inception Report (IR)

Inception report provides an outline of the framework of cooperation and the basic approach that should be taken. This report was prepared in March, 1992.

b) Progress Report (PR/1)

Progress report 1 describes the outcomes of the activities in the first stage of the study. Progress report 1 was prepared in March, 1993.

c) Progress Report 2 (PR/2)

Progress of activities in the second phase of the collaborative study is reported in Progress Report 2. PR/2 was prepared in August, 1993.

d) Interim Report

Interim Report follows the Progress Report 2 and it includes the preliminary conclusions and recommendations of the study.

e) Draft Final Report

The findings and conclusions of the collaborative study are summarized in the Draft Final Report.

f) Final Report

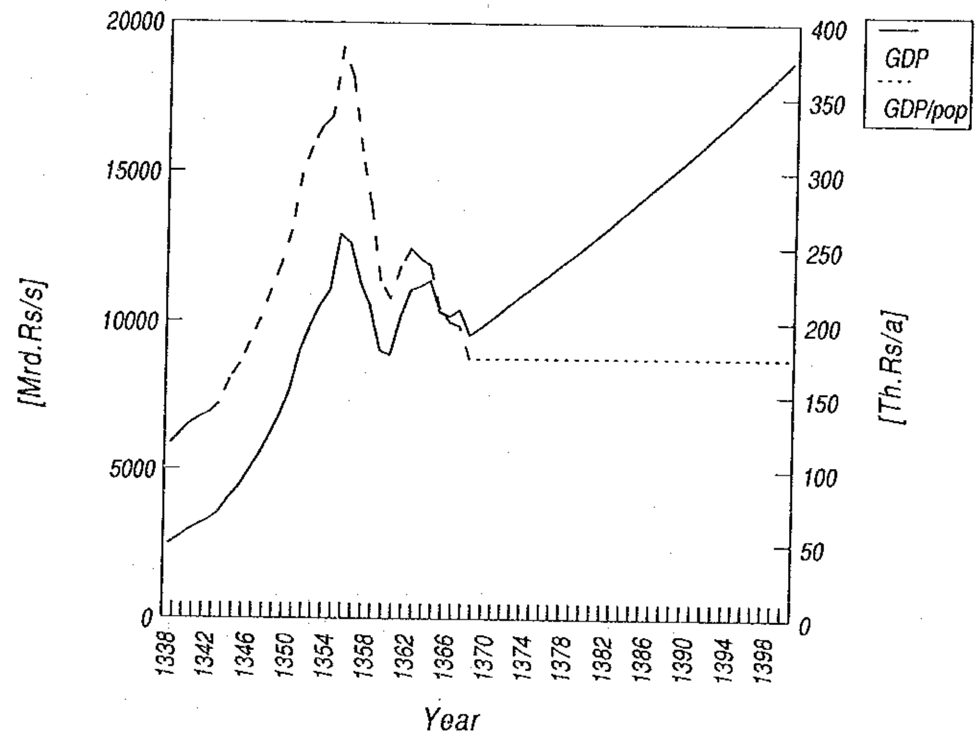
Final Report is the conclusion of the collaborative study.

2. Economic Development

2.1 Summary of the Result of the Reference Scenario

Development of the gross domestic production (GDP) and GDP per capita (in constant prices of 1982) are depicted in Figure 2.1. GDP increases from 10 Mrd. Rs/a in 1989 to 24 Mrd.Rs/a in 2021. GDP per capita rises initially, but decreases in the last decade.

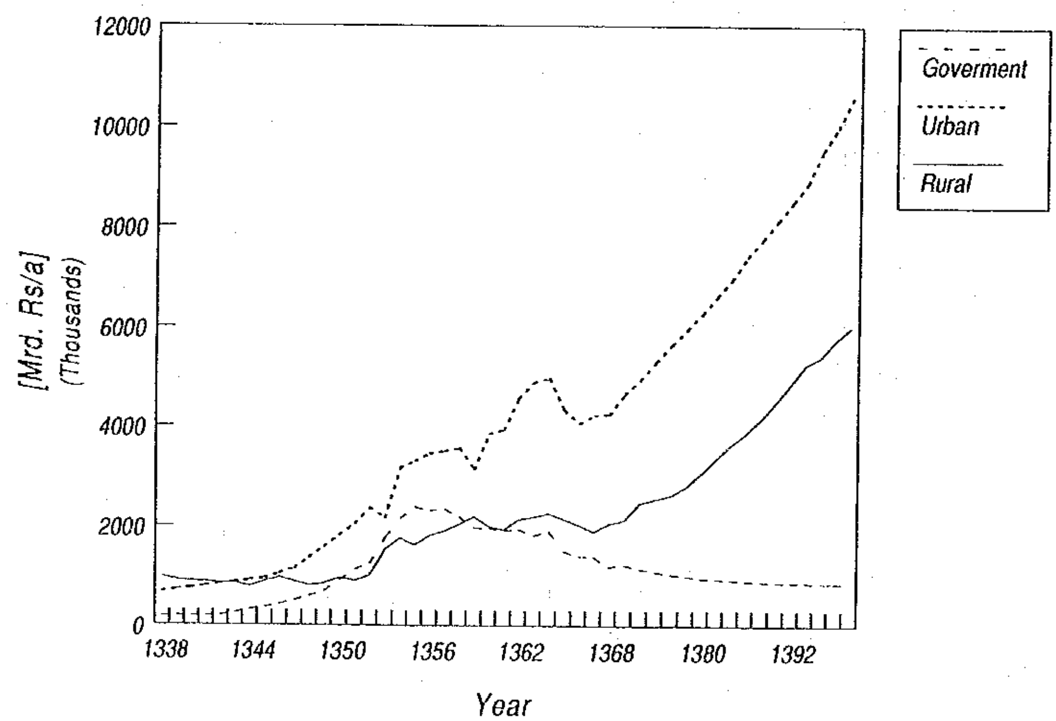
Fig.2.1 : Development of GDP and GDP per Capita



Changes in the structure of the economy is also observed. The share of mining and industry in GDP increases from 13.6% in 1989 to 19.2% in 2021. The share of agriculture and services in GDP remain almost constant.

Private consumption in urban and rural areas rises from 4,246 and 2,052 Mrd.Rs/a in 1989 to 10,572 and 5,998 Mrd. Rs/a in 2021. But the government expenditure remains at the present level of 1,300 Mrd.Rs/a (See Figure 2.2).

Fig. 2.2 : Consumption of Urban, Rural, and Government Expenditure



Capital formation rises very rapidly in the next three decades. Total capital stock accumulates from 19,000 Mrd.Rs in 1989 to 50,000 Mrd.Rs in 2021. It can be observed in Figure 2.3 that the trend of capital formation is supported by rapid rise of investment during the planning period and the level of investment goes up by almost four times and it reaches the level of almost 3,500 Mrd.Rs/a in 2021.

Development of foreign trade indicates that the import of consumer goods is to be limited and considerable changes is not observed (see Figure 2.4). Import of capital goods rises rapidly in the initial periods, and its level does not show any changes after 2010. But import of intermediate goods continues rapid increases and it constitutes a considerable share of total import.

Export of non-oil goods goes up very rapidly and it rises by two and half times in the period 1990-2021 (See Figure 2.5). Export of oil increases gradually and it remains at the level of about 2,000 Mrd.Rs/a after year 2000.

Figure 2.6 shows the development of the shadow prices of crude oil and foreign currency. Shadow price of oil rises from $16.7/bl in 1991 and it reaches a level of $30/bl in 2021. The rate of increase of shadow prices of oil is 7%/a which is equal to the real rate of return of capital, that is considered as exogenous variable in the model. The trend of shadow price of oil shows that energy resources are valuable scarce commodities and the scarcity of this resource will have considerable impact on the economic development of the country.

Shadow prices of the foreign exchange rises from 250 Rs/$ in 1989 to just about 550 Rs/$ in 2021. Increase in the import of intermediate and capital goods stimulates higher demand for foreign currency and the rapid depletion of energy resources and limitation on the export of energy reduces the potential of foreign exchange earnings. As a consequence of that, excess demand for foreign currency comes to effect and the shadow price of foreign currency rises.

Fig. 2.3 : Development of Capital Stock and Investment

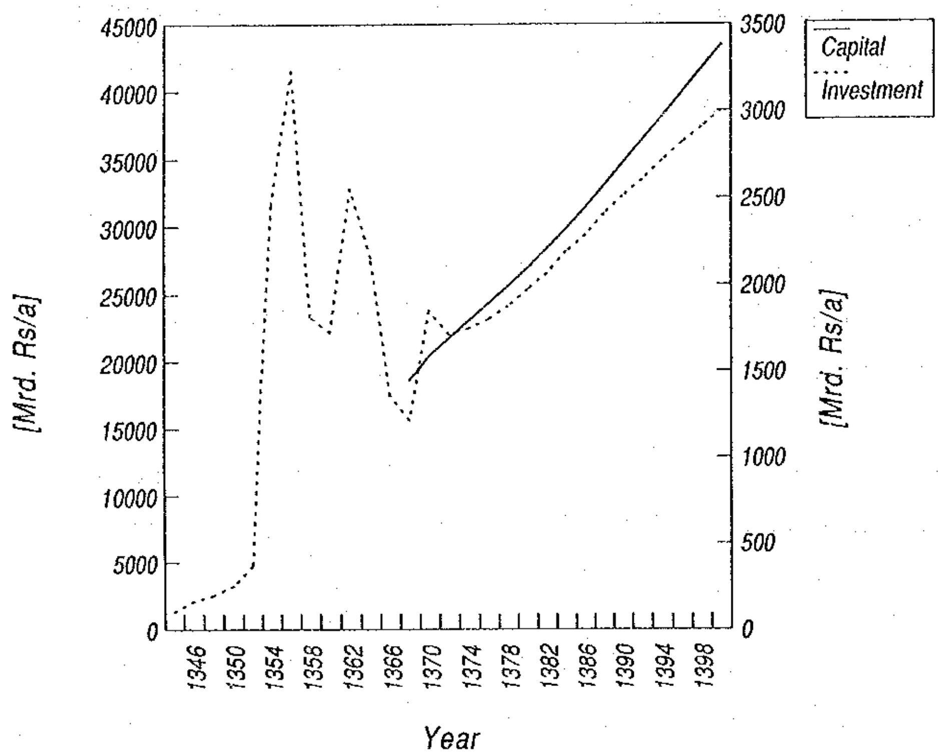


Fig. 2.4 : Import of Consumer, Intermediate and Capital Goods

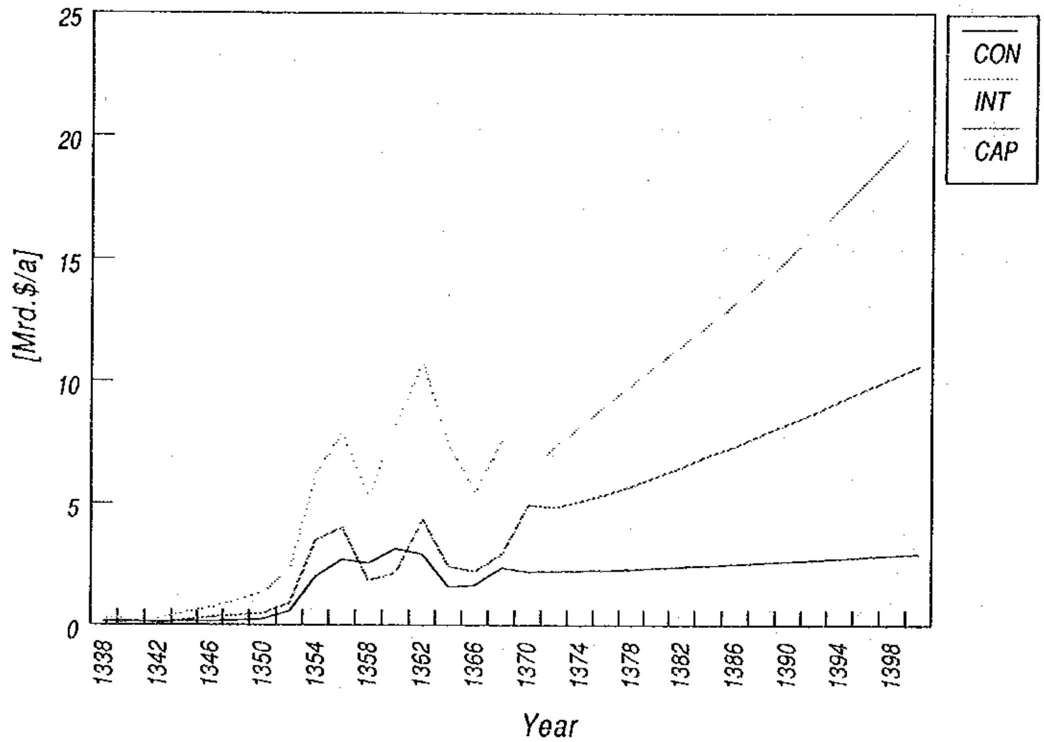


Fig. 2.5 : Export of Non-Oil Goods

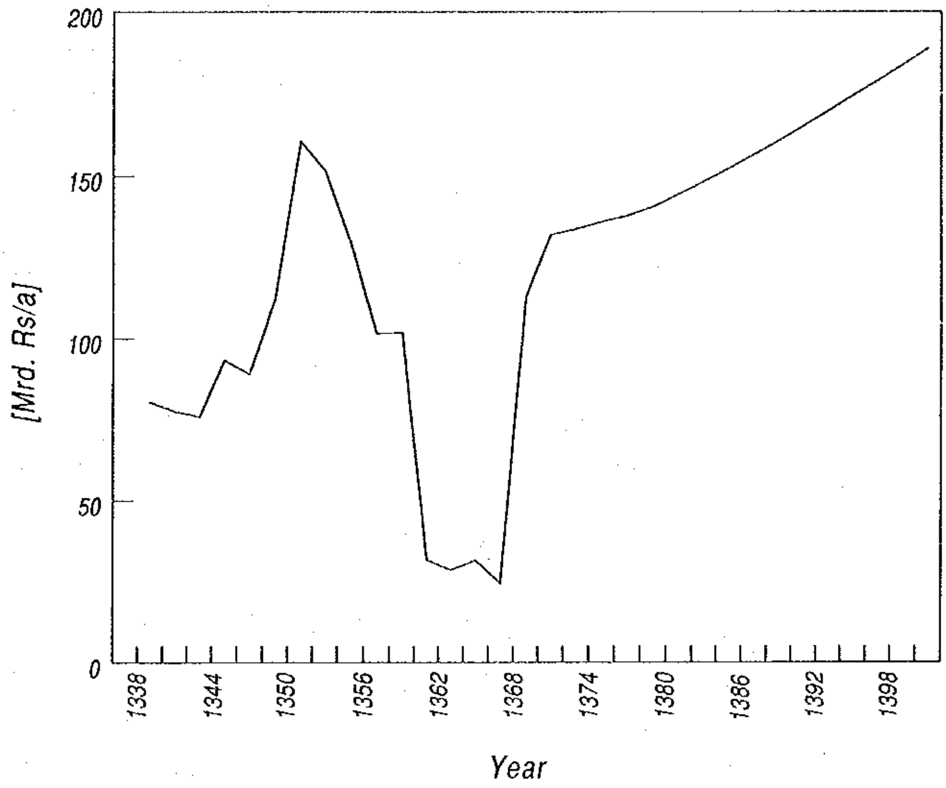
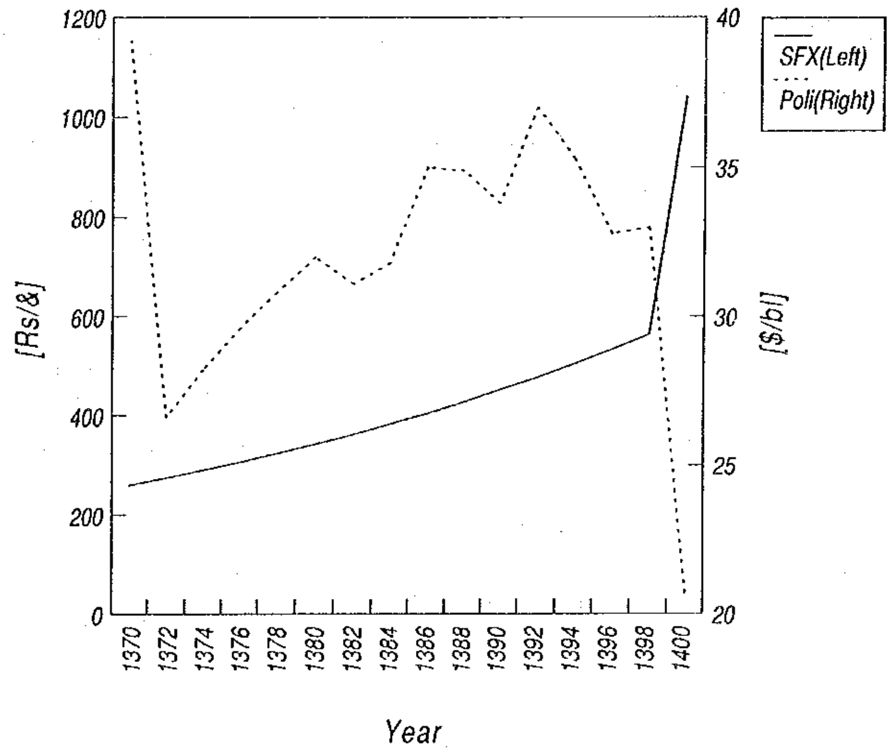


Fig. 2.6 : Shadow Price of Foreign Exchange Reserves and Oil



2.2 Impact of Domestic Energy Consumption

To study the impact of domestic energy consumption on the economic development, two further scenarios of the rate of growth of domestic energy consumption are considered (See Figure 2.7).

Scenario DOIL-1 represents a case, where moderate energy conservation policy is pursued and as a result of that the rate of growth of the energy consumption is reduced to the 50% of its present value in the year 2010. In the second scenario, it is assumed that an acceleration of energy conservation in different social and economic sectors is pursued. As a consequence of promotion of rapid energy conservation, the rate of growth of domestic energy consumption in the year 2000 will be the 50% of its value in 1990.

Analysis of the impact of the promotion of rapid energy conservation indicates that in the case of scenario DOIL-2, the gross domestic product (GDP) rises with an average annual rate of 8%/a in the period 1994-2021. Comparison of scenarios DOIL-1 and DOIL-2 with the reference scenario reveals the fact that the promotion of energy conservation in the domestic market provides an impressive potential for the economic development of the country.

With the promotion of rapid energy conservation, the constraints on the fossil energy resources and foreign exchange reserves are relaxed, and as a consequence of that the shadow prices of oil and foreign exchange reserve are reduced. This point can be observed in the Figures 2.8 and 2.9. In Figure 2.8, the trend of shadow price of oil in the case of scenario DOIL-2 remains at the lowest level. In Figure 2.9 it is seen that the shadow price of foreign exchange reserves follows a lower trend in case of DOIL-2 than in other scenarios.

Fig. 2.7: Scenarios of Domestic Oil Consumption

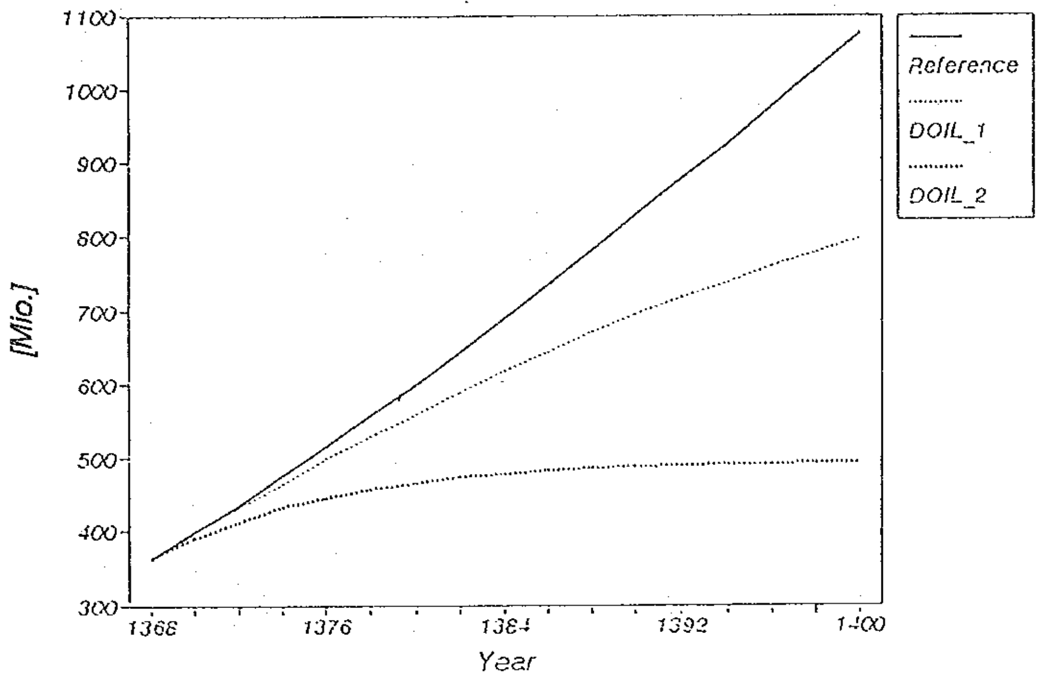


Fig. 2.8: Shadow Prices of Crude Oil for Diff. Scenar. of Domestic Oil Con.

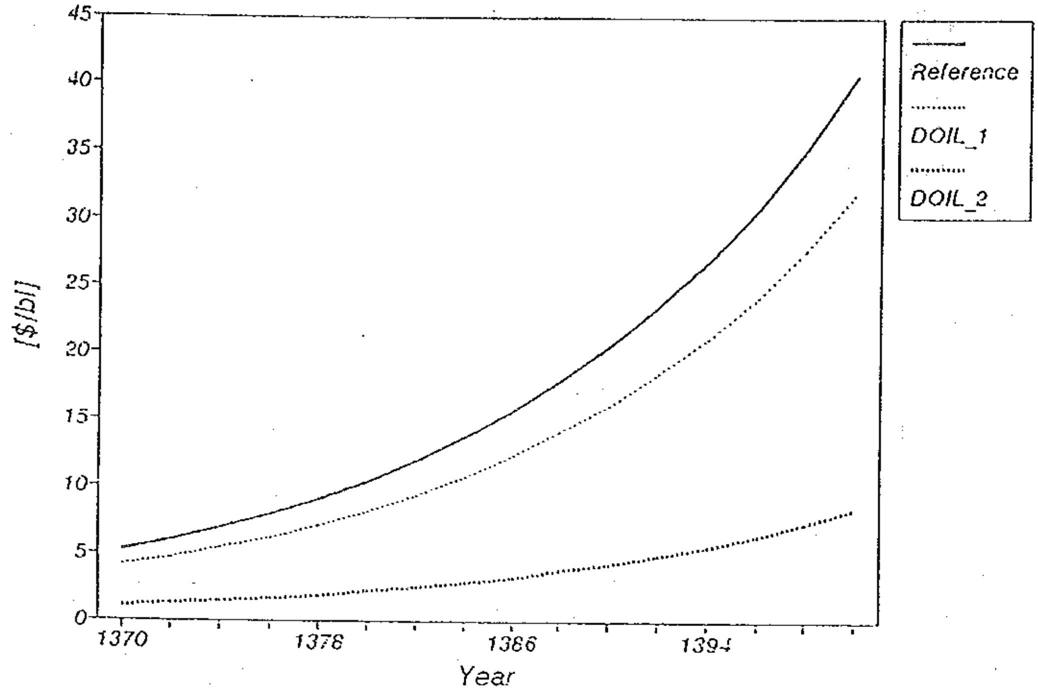
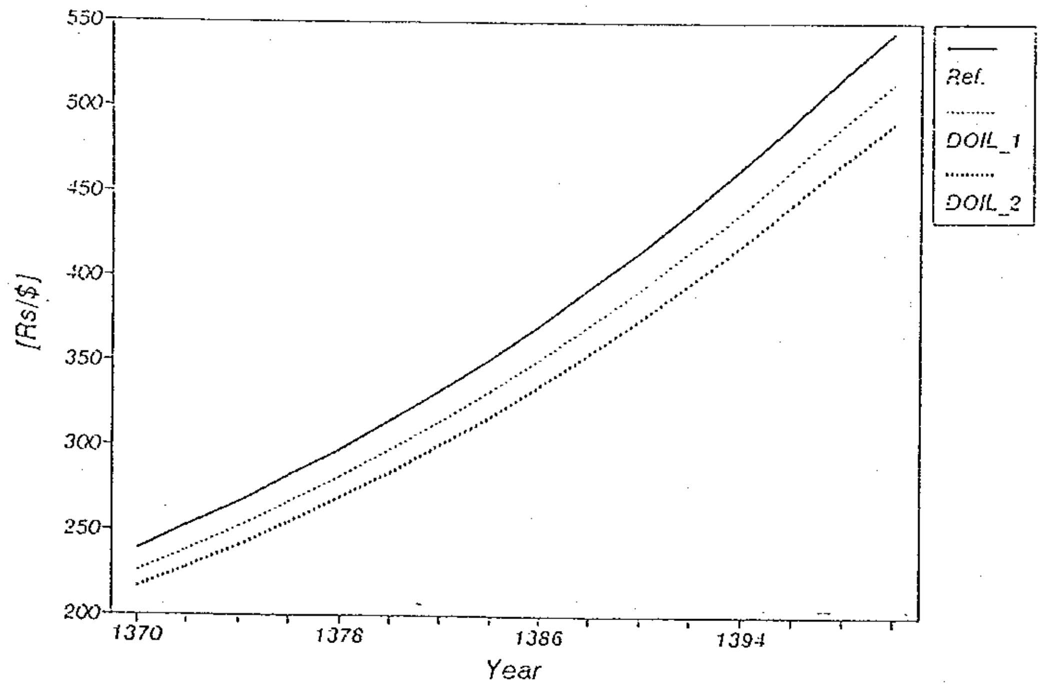


Fig. 2.9: Shadow Prices of Foreign Exch. Res. for Diff. Scen. of Domes. Oil Con.



2.3 Summary of the Results

A review of the results of the model in the reference case and its comparison with the scenarios on the oil prices and rate of growth of domestic energy consumption indicates that export of energy resources is an unavoidable task of the economy, and as a consequence of that the economic development is influenced by the changes in the foreign exchange revenue from the energy export.

Increase in energy prices provides a potential for accelerated economic development. Stagnation of energy prices in the world market results in many difficulties in the process of economic development. Relaxation of the limitation on the energy export can be conceived of as an important source of economic growth.

Relaxation of the constraints on the energy export requires that energy saving in the domestic market is promoted. Promotion of energy conservation in the domestic market has two important outcomes. Reduced growth rate of domestic energy consumption leads, on the one hand, to lower investment requirement for the expansion of the energy supply system and less import of capital and intermediate goods in the energy sector. On the other hand, declining growth rate of domestic energy consumption results in relaxation of the constraint on the export of energy resources and to lower shadow price of oil and foreign exchange reserve. In this case, the potential of the economic growth increases. Therefore, promotion of energy conservation in the domestic market provides a reliable and promising option for economical development of the country.

3. Development of Energy Requirement

Energy planning is conceived of as a process of preparing information on the development of energy demand and supply balance and it is to facilitate the economic growth and improvment of the living condition of the population. Such a task necessitates that energy requirement in each social and economical sector is estimated; and then the means of supplying the energy needs is studied with the help of the models of energy supply system. For this reason, the analysis of energy demand in the present study was focused on the evaluation of the energy needs in the economic sectors and households. Therefore, projection of useful energy demand, as a representation of the energy needs, has been the subject of this study. Projection of the useful energy demand is then used in the energy supply model, in order to evaluate different energy supply strategies. Hence, in the following sections, the projection of useful energy demand in the social and economic sectors will be outlined briefly.

3.1 Useful Energy Demand of Households

To study the useful energy demand, the distribution of population in different expenditure groups is projected. Figures 3.1 and 3.2 show the estimated share of each expenditure group in urban and rural areas in population respectively. The main assumption of the present sceneries is that achievement of objective of improving the living condition of the poor households is pursued in the process of social and economical development. As a consequence of the implementation of such a policy, household in low expenditure groups will move to higher expenditure groups and their consumption pattern shall be similar to the consumption of families that are presently in the higher expenditure groups. In this case, total private consumption in urban areas will increase from 170,000 Rs/capita in 1989 to 340,000 Rs/capita in 2021 (See Figure 3.3). Private consumption in rural areas shall undergo little changes. This is partly due to the fact that part of the rural population shall migrate into urban areas. On the basis of the above scenario, useful energy requirement in rural and urban areas shall rise from 37 PJ/a and 100 PJ/a in 1989 to 60 PJ/a and 320 PJ/a in 2021 respectively (See Figure 3.4 and 3.5). Structure of useful energy requirement indicates that thermal energy needed for cooking and heating shall be the main form of energy that is required in the household sector.

Fig. 3.1 : Development of Share of Exp. Groups in Urban Pop.

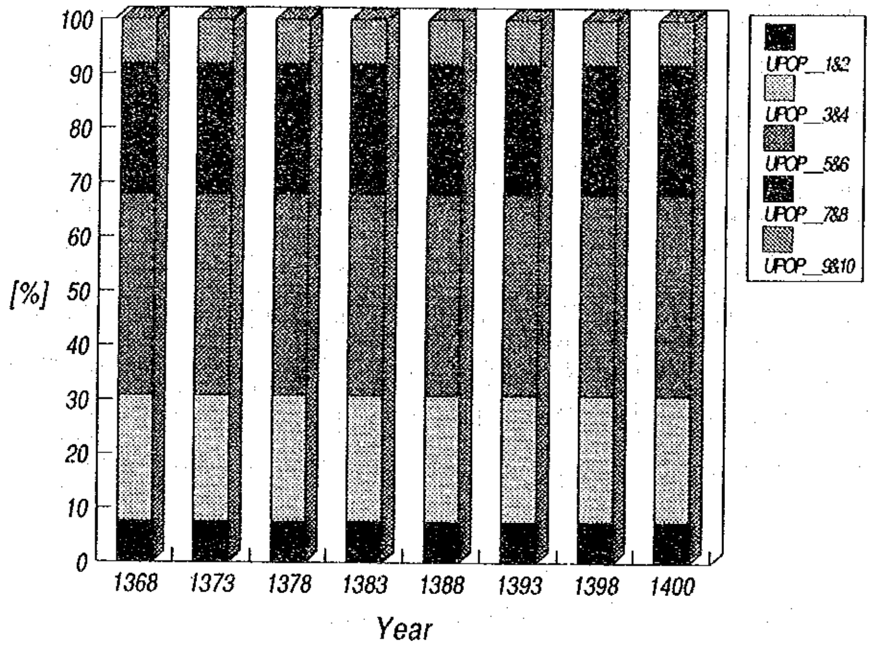


Fig. 3.2 : Development of Share of Exp. Groups in Rural Pop.

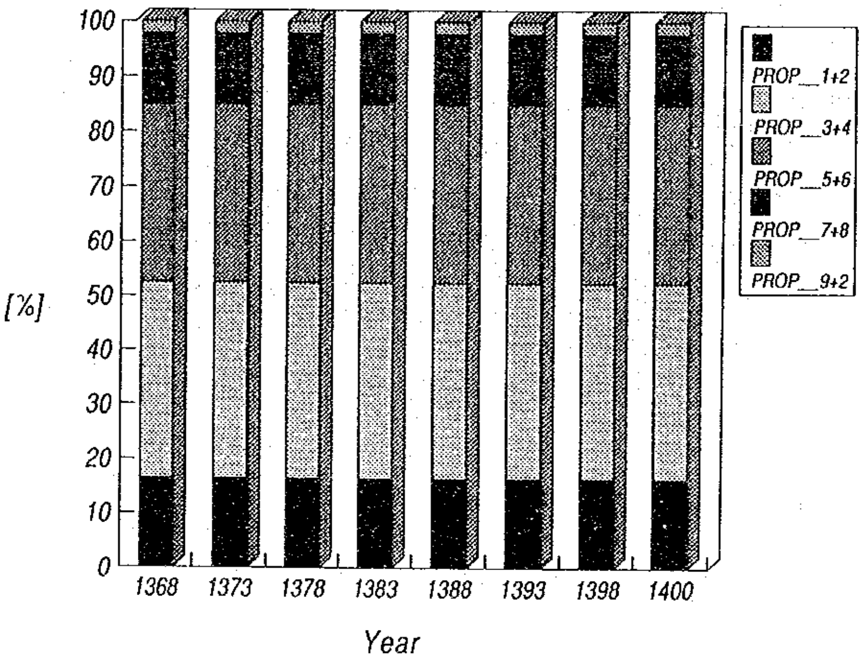


Fig. 3.3 : Development of Real Exp. of Urban & Rural Households

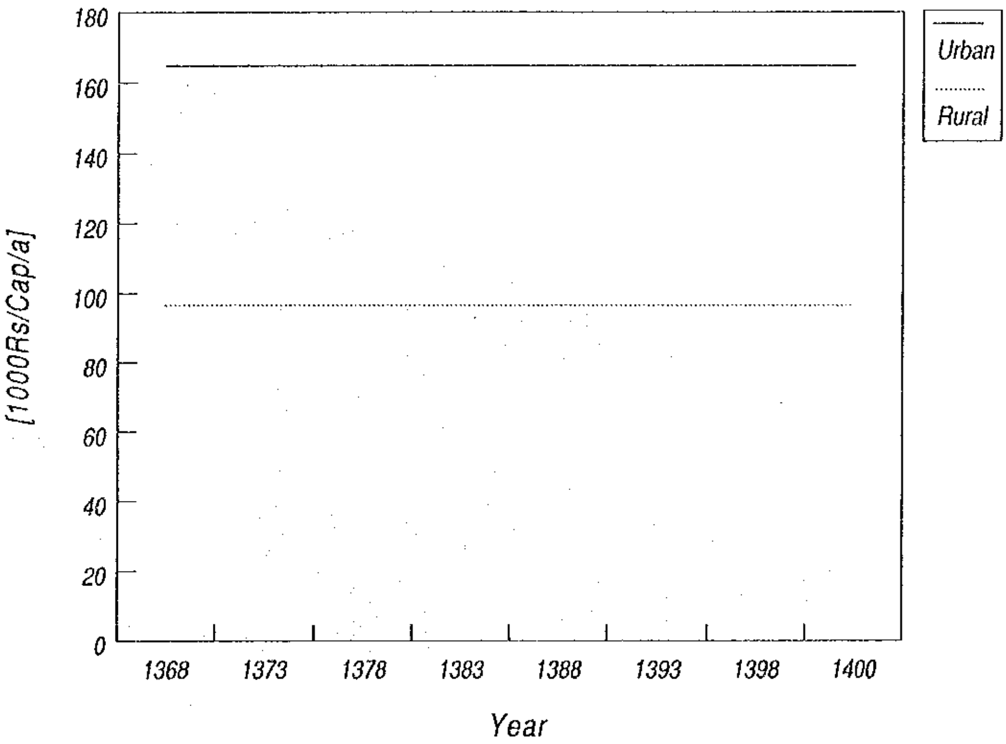


Fig. 3.4 : Development of Demand for Useful Energy in Rural House.

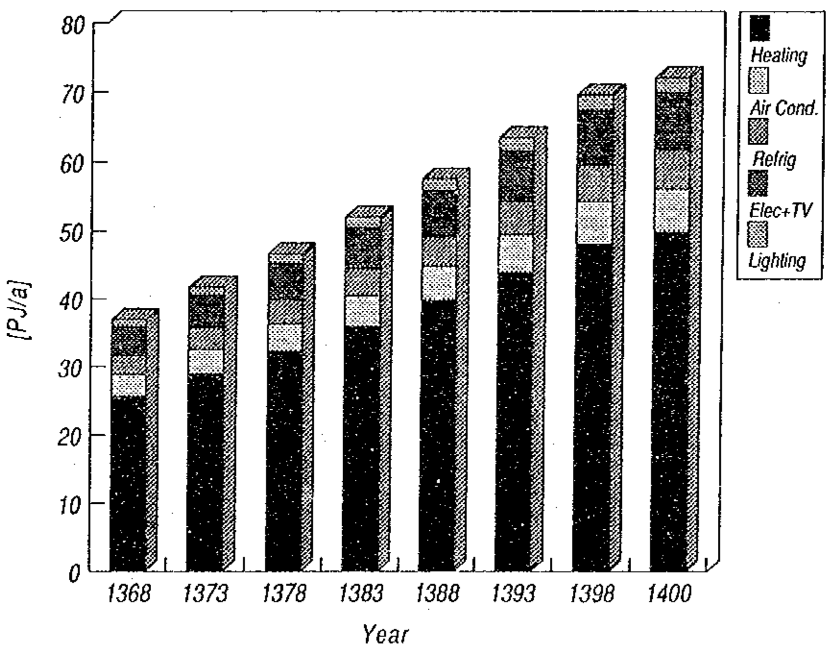
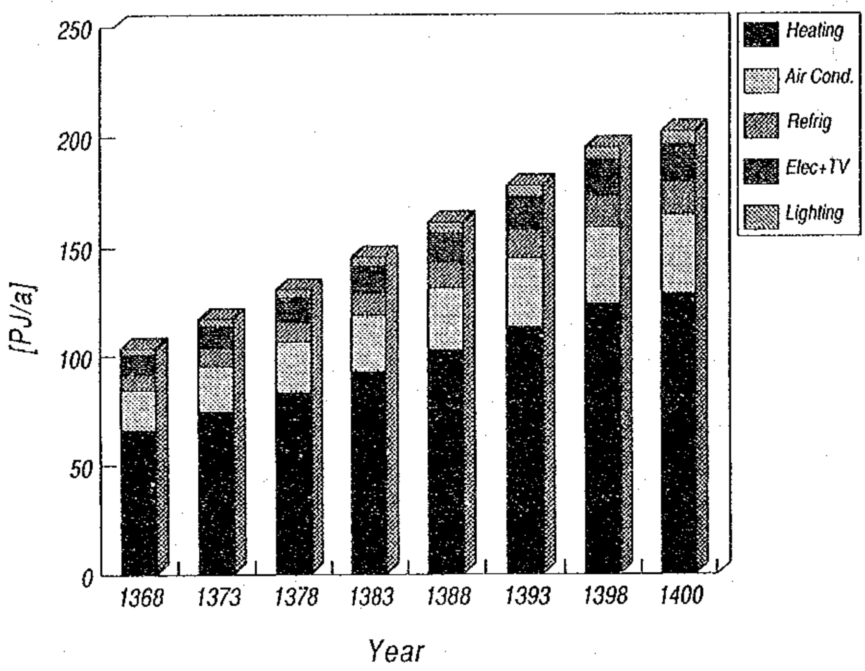


Fig. 3.5 : Development of Demand for Useful Energy in Urban House.



3.2 Useful Energy Demand in Industry

Main forms of useful energy that are used in industry are process heat, motive power and useful energy generated by electrical equipments. Due to ambiguity of the output of electrical appliances and lack of reliable data on such output, electricity required to supply the output of electrical appliances is termed as non-substitutable electricity. Figure 3.6 shows the useful energy requirement in industrial sector. Useful energy demand increases from 600 PJ/a in 1989 to 2,000 PJ/a in 2021. Process heat needed in industry has the highest share in the useful energy requirement of industry. The second largest share of useful energy belongs to motive power, which is generated as mechanical energy in various processes. Non-substitutable electricity has, on the other hand, a share of less than 10% in total useful energy requirement in industry.

3.3 Useful Energy Demand in Transport

Useful energy requirement in transport sector has been studied in three main sub-sectors of transportation, namely urban passenger, intercity passenger transport, and freight. In these sub-sectors different modules of transportation is considered explicitly. In this way, it has been possible to study the impact of structural changes in the transport sector on the useful energy demand. Figure 3.7, 3.8 and 3.9 show the development of useful energy demand in different sub-sectors of the urban, intencity passenger transport and freight. It is observed that in urban passenger transport, private cars have a share of more than 70%. In the case of intercity passenger transport large and small buses play a dominant role and their share in useful energy demand of this sub-sector increases from 60% in 1989 to just 70% in the year 2021. Freight transportation is based on road transportation, and trucks are the main means of transportation.

Fig. 3.6 : Development of Demand for Useful Energy in Industry

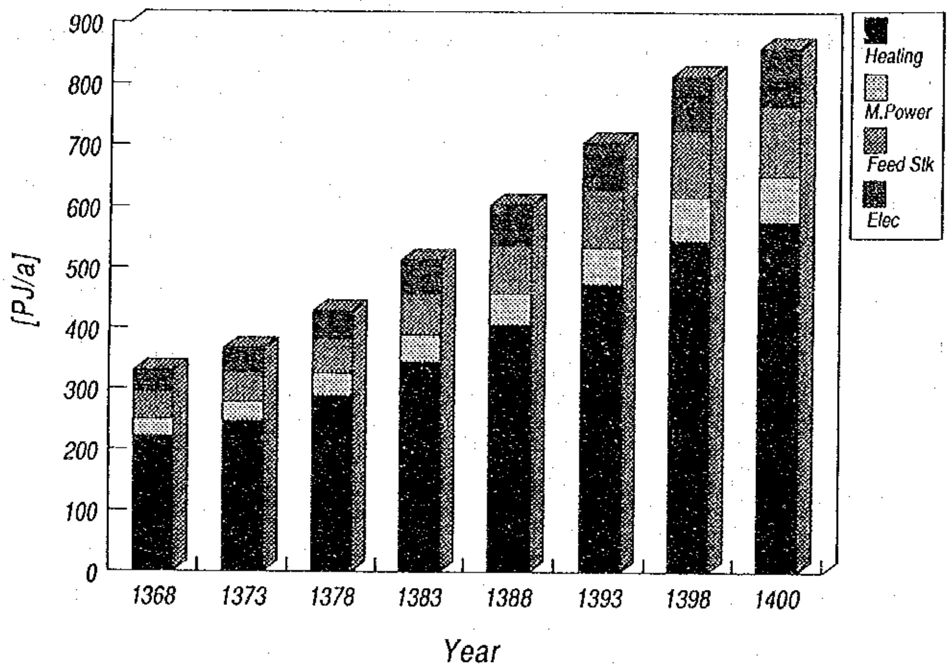


Fig. 3.7 : Development of Demand for Useful Energy of UP_Trans.

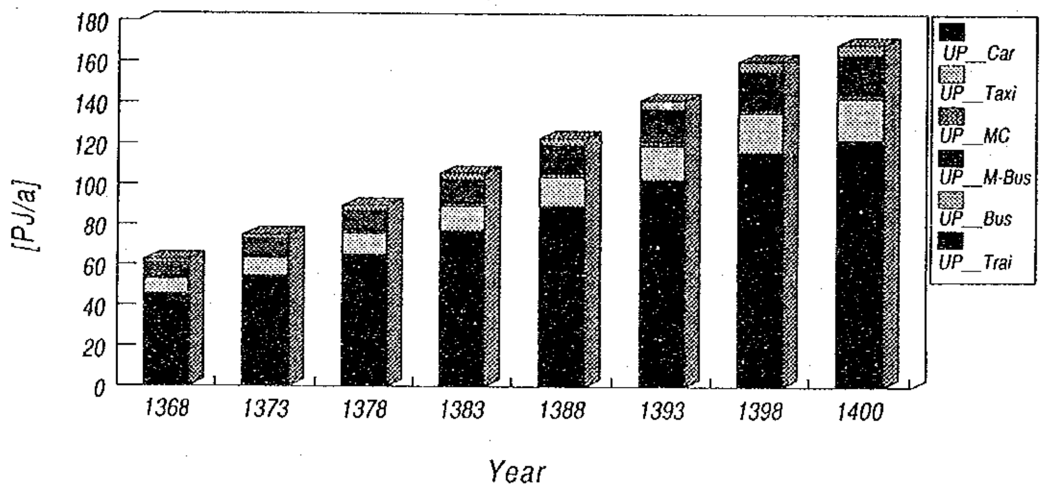


Fig. 3.8 : Development of Demand for Useful Energy of IP_Trans.

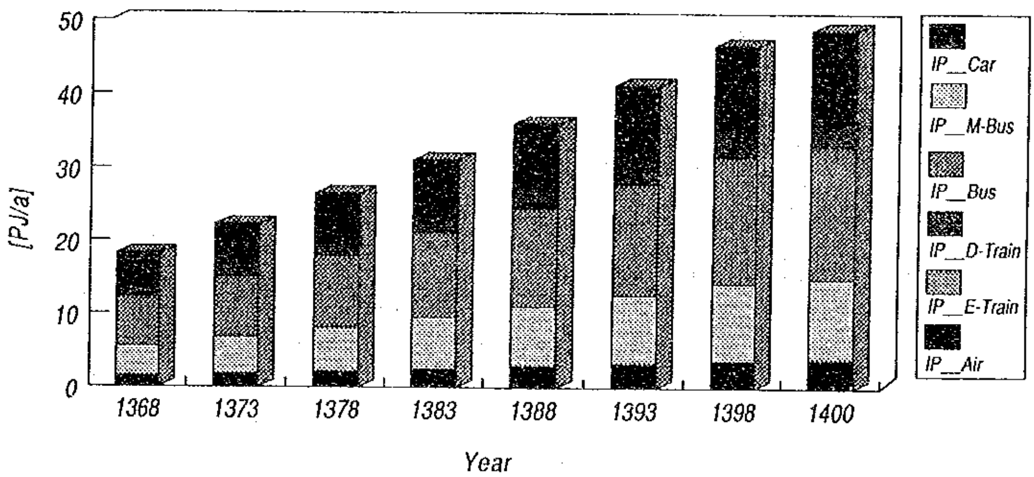
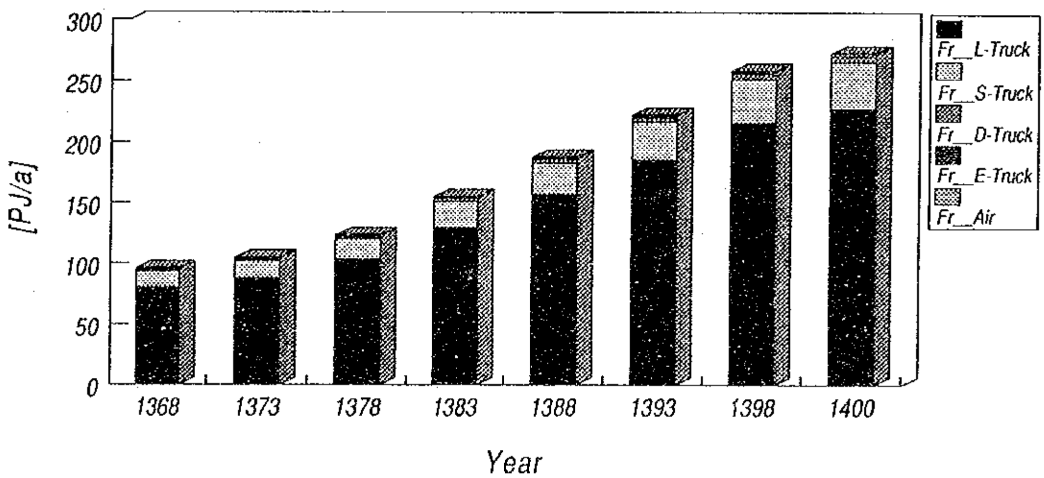


Fig. 3.9 : Development of Demand for Useful Freight Trans.



4. Development of Energy Supply System

4.1 Reference Scenario

In the reference case the production of primary energy increases from 1,806.5 MBOE/a in 1994 to 2,064.4 MBOE/a in 1999 and 2,003.3 MBOE/a in 2021. Production of primary energy includes crude oil, natural gas, coal and hydro power. The share of oil in total primary energy production is 70% in 1994, which increases to 70.8% in 1999 and then decreases to 67.1% in 2021. Export of crude oil is an important aspect of its use. After 2010 the level of domestic consumption of oil approaches the level of crude oil export.

Second to crude oil is natural gas as the main source of primary energy. Share of natural gas in production of primary energy decreases from 28.0% in 1994 to 25.7% in 2010 and then rises to 26.5% in 2021.

Hydro power constitutes 0.7% of total primary energy requirement in 1994 and reaches 4.7% in 2021.

4.2 Production of Secondary Energy

Secondary energy carriers are produced in refineries, power plants and processing systems. Production of petroleum products increases from 344.0 MBOE/a in 1994 to 445.7 MBOE/a in 1999 and 880.4 MBOE/a in 2021, which corresponds to an average annual growth rate of 5.31%/a and 3.14%/a in the periods 1994-1999 and 1999-2021 respectively. Share of middle distillates in production of petroleum products rises (See Figure 4.1). Share of gas oil increases due to enhanced consumption of this product in transportation and natural gas is substituted by kerosene in the household sector.

Production of natural gas increases from 332.3 MBOE/a in 1994 to 374.9 MBOE/a in 1999 and then decreases to 329.4 MBOE/a in 2004. Production of lean gas reaches to the level of 354.6 MBOE/a in 2021.

As it can be seen in Figure 4.2, the fuel consumption of thermal power plants rises from 142.3 MBOE/a in 1994 to 166.2 MBOE/a in 1999 (with an average annual growth rate of 3.2%/a) and 204.8 MBOE/a in 2021 (with an average annual growth rate of 1.72%/a). Consumption of fuel oil in power plants decrease with an annual rate of 2.4%/a in the next five years and then increases with a rate 4.4%/a. Share of fuel oil in fuel consumption of power plants changes from 41.4% in 1994 to 31.4% in 1999. After year 2000, contribution of fuel oil to fuel consumption of power plants rises to 66.2% in 2021. Share of natural gas in fuel consumption of thermal power plants reaches to 63.7% in 1999 and then declines to 9.7% in 2021.

Generation of electricity increases from 78.9 GWh/a in 1994 to 95.5 GWh/a in 1999. The rising trend of production of electricity continues until 2021 and it reaches to 166.8 GWh/a in 2021. Average annual growth rates of electricity generation in the periods 1994-99 and 1999-2021 correspond to 3.8%/a and 2.6%/a respectively. Share of hydro power plant in electricity generation reaches to 7.9% in 1999 and increases to 33.7% in 2014; and then it is reduced to 31.4% in 2021.

Fig. 4.1 Production of Petroleum Products

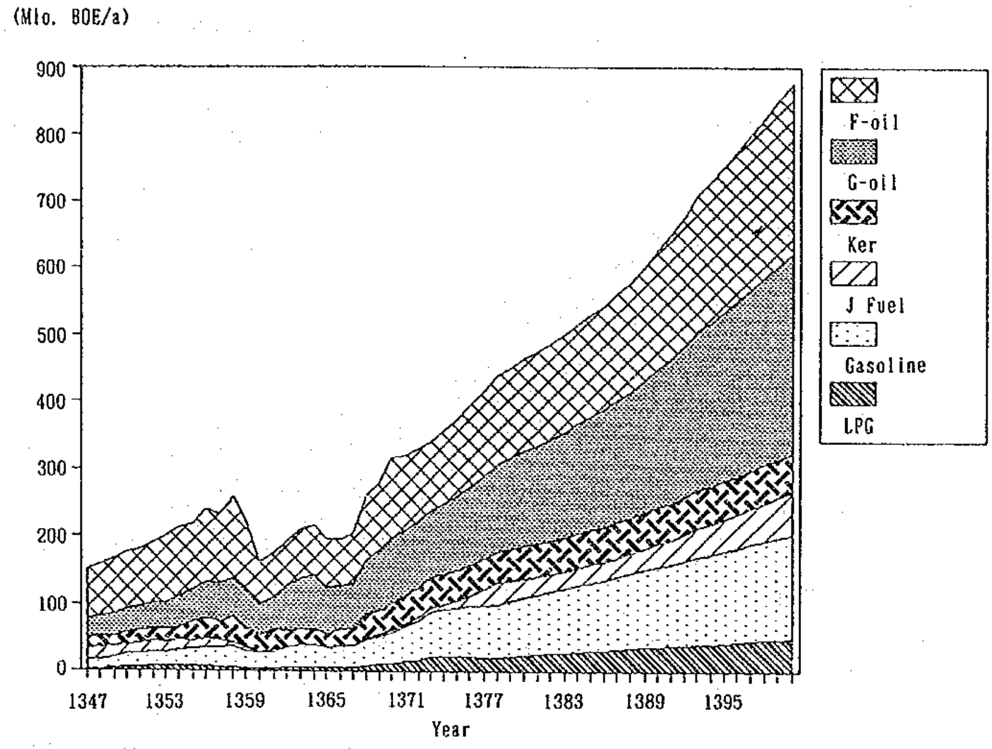
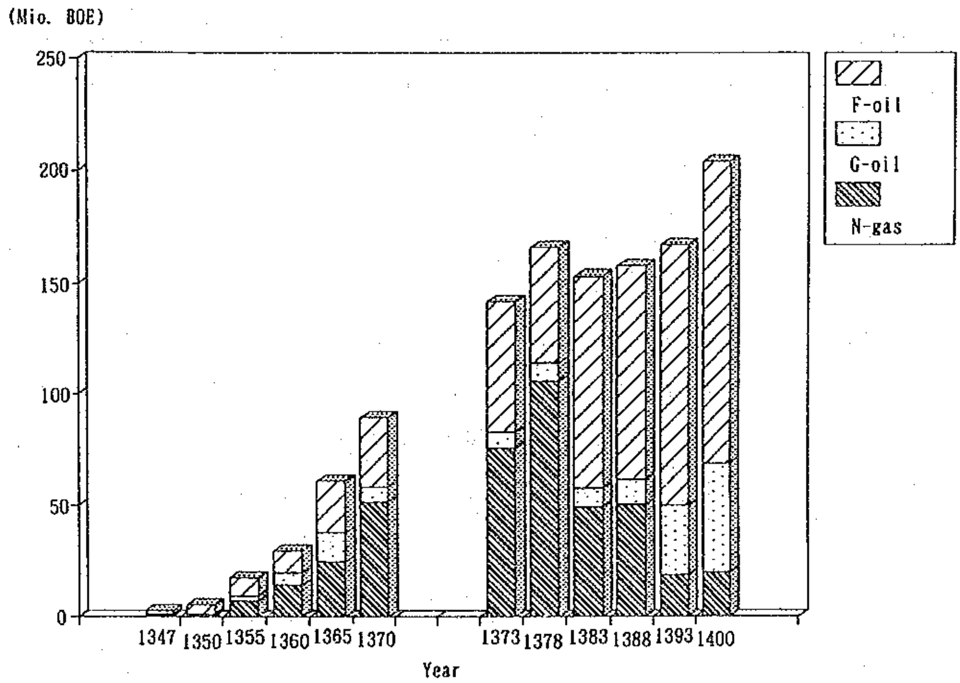


Fig. 4.2 Fuel Consumption of Thermal Power Plants



4.3 Capacities of Processing Systems

Expansion of refineries indicates that the capacity of atmospheric distillation increases from 389 mio.bl/a in 1994 to 1,000 mio.bl/a in 2021 and its rate of growth corresponds to 8.0%/a and 2.6%/a in the periods 1994-1999 and 1999-2021 respectively, capacities of conversion units decrease. The main reason for this situation is that the extraction cost of crude oil remains low and in the absence of considering the opportunity cost of oil underground, rapid extraction of oil is preferred.

Capacities of power plants rise with an average annual rate of 3.8%/a in the next five years and 1.3%/a in the period 1999-2021. Total capacity of electricity generation reaches to 39,934 MW in the year 2021. Technological mix of power plants changes in the next 3 decades and capacities of steam power plant and gas turbine decline and they are replaced by combined cycle power stations. Capacity of combined cycle power plants rise from 1,039 MW in 1999 to 11,542 MW in 2021, which corresponds to an average annual growth rate of 11.6% /a in the period 1999-2021.

Self generation of electricity in industry complements national electric system and its capacity increases from 2,377 MW in 1994 to 3,134 MW in 2009 and then decreases to 869 MW in 2021 due to expansion of national grid. Capacity of hydro power plants rises to 3,936 MW in 1999 and its increasing trend continues until 2021, until it reaches 13,076 MW in that year.

Reserve margin of the electric system is considered 30%, 10% of which is taken as spin reserve. Capacity utilization of power plants is 3,140 h/a in 1994, which rises to 3,147 h/a in 1999 and 4,177 h/a in the year 2021.

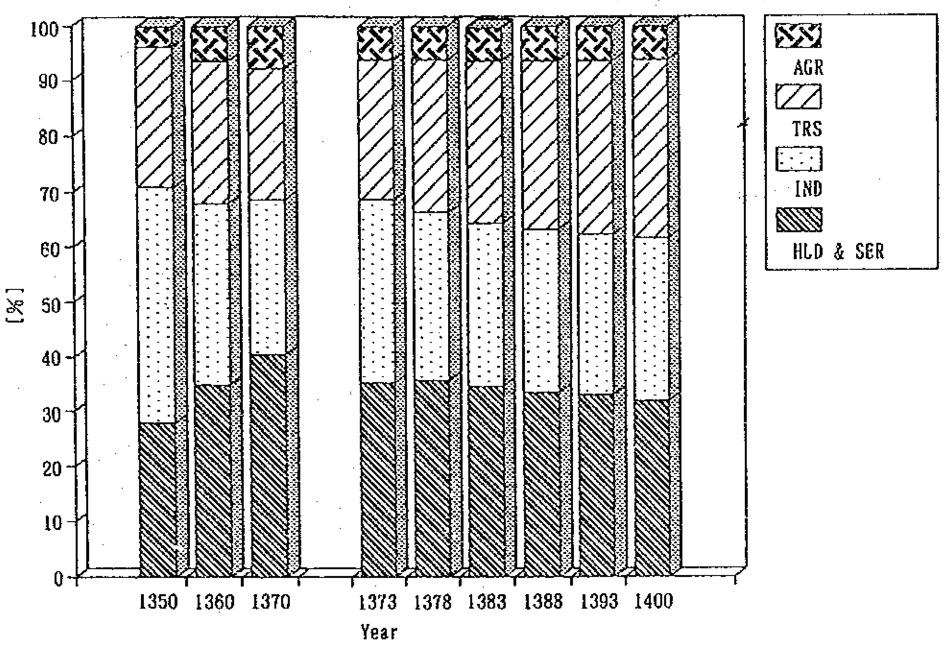
Energy Export

Energy export is 898.2 MBOE/a in 1994 and rises to 1,017.1 MBOE/a in 1999. After year 2000 a declining trend of crude oil export is observed and it decreases to 447.4 mio.bl/a in 2021. Export of petroleum products increases with an annual growth rate of 4.1%/a in the period 1999-2021 and it reaches to 65.6 MBOE/a in 2021.

4.4 Consumption of Final Energy

In Fig. 4.3 share of sectors in final energy consumption is presented. Annual growth rate of final energy consumption in transport sector is the highest which is influenced by population growth and economic development. Final energy consumption in commercial and household expands more slowly than in other sectors. As a consequence of this situation, the share of industry and transport increases in the final energy consumption.

Fig. 4.3 Share of Sectors in Final Energy Consumption

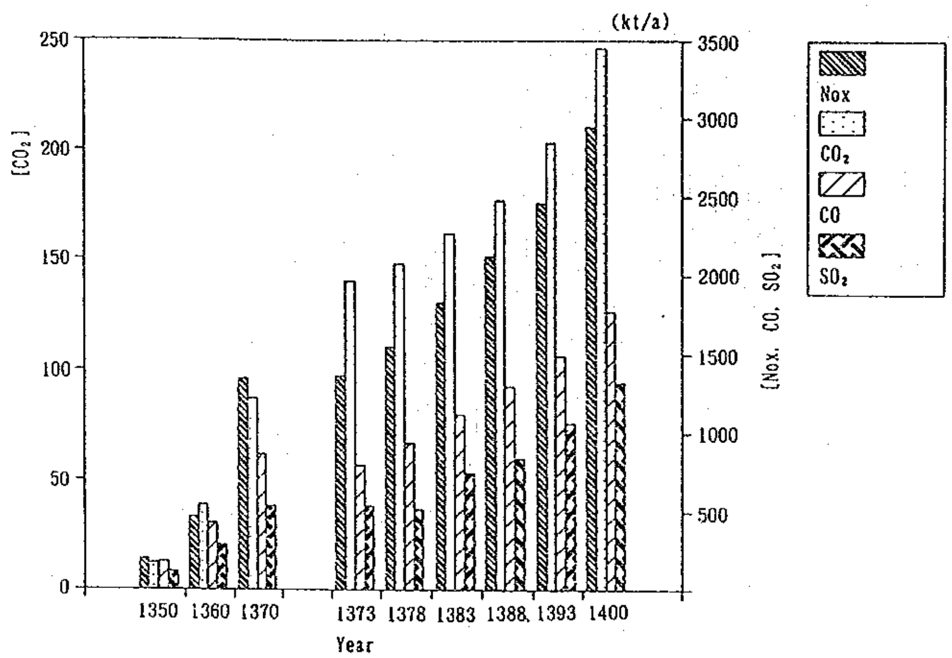


4.5 Emission of Pollutants

The main pollutants of the environment that have been considered are CO, CO_2, SO_2 and NO_x. Emission of CO takes place mainly in the transport sector and it rises from 793 kt/a in 1994 to 936 kt/a in 1999 and 1,777 kt/a in 2021. Average growth rate of the emission of CO is 3.4%/a and 3.0%/a in the periods 1994-99 and 1999-2021 respectively (See Figure 4.4). Emission of CO_2 shows also a rising trend and it expands from 140.0 mio.t/a in 1994 to 246.0 mio.t/a in 2021.

Emission of NO_x and SO_2 increases in a similar manner. Amount of NO_x emitted rises from 1,354 kt/a in 1994 to 2,946 kt/a in 2021 and emission of SO_2 in 2021 reaches to 2.44 times of its level in 1994, which is 541 kt/a. Rapid increases of the emission of SO_2 and NO_x is due to the higher share of petroleum products in production and consumption energy.

Fig. 4.4 Emission of Pollutants in I.R. Iran



4.6 Impact of Subsidization of Energy

Commercial energy carriers are supplied to the final consumers with prices that are much lower than the marginal cost of energy carriers. But analysis of energy carriers in the previous section was based on the fact that all energy carriers are delivered to the final consumer with a price equivalent to their long-run marginal cost. Now, the basic question is what will be the effect of further subsidization of energy carriers on the development of the energy system? This issue was studied in the framework of a scenario with the help of the energy supply model.

In the case of continued subsidization of energy, the primary energy requirement rises from 96 8.7 MBOE/a in 1994 to 1,669.5 MBOE/a in 1999 and 2,238.1 MBOE/a in 2021, and its average annual growth rate is 11.5%/a and 3.8%/a in the periods 1994-99 and 1999-2021 respectively. Subsidization of energy carriers leads to a situation where primary energy consumption is 97% and 5 8.8% more than primary energy requirement in the Reference case in the years 1994 and 2021 respectively.

4.7 Opportunity Cost of Crude Oil

In the Reference scenario it was considered that the opportunity cost of crude oil underground would be zero. In another case it is assumed that the value of oil underground would be 70% of oil prices in the international market. In this case production of crude oil rises from 1,195.4 mio.bl/a 1994 (1,264.8 mio.bl/a in reference case) to 1,329.3 mio.bl/a in 1999 (1,462.4 mio.bl/a in reference scenario). Then, it decreases to 999.1 mio.bl/a in 2021 (1,344.7 mio.bl/a in reference case). When the opportunity cost of crude oil is taken into account, domestic consumption of oil is reduced by 14.2% and 19.5% in the periods 1999 and 2021 respectively. But, the consumption of natural gas rises by 16.3% and 52.1% in the years 1999 and 2021 respectively, when compared with the amounts in the Reference case.

4.8 Potentials of Rational Use of Energy

With the help of the energy supply model, the rational use of energy, and specially energy conservation, is estimated and its results are outlined very briefly.

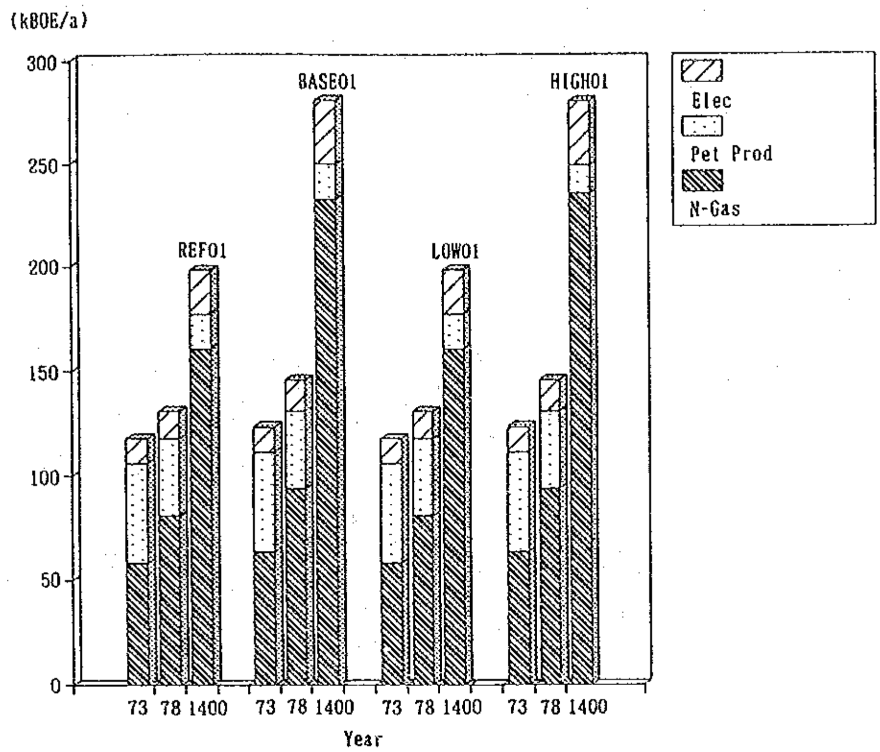
Household Sector

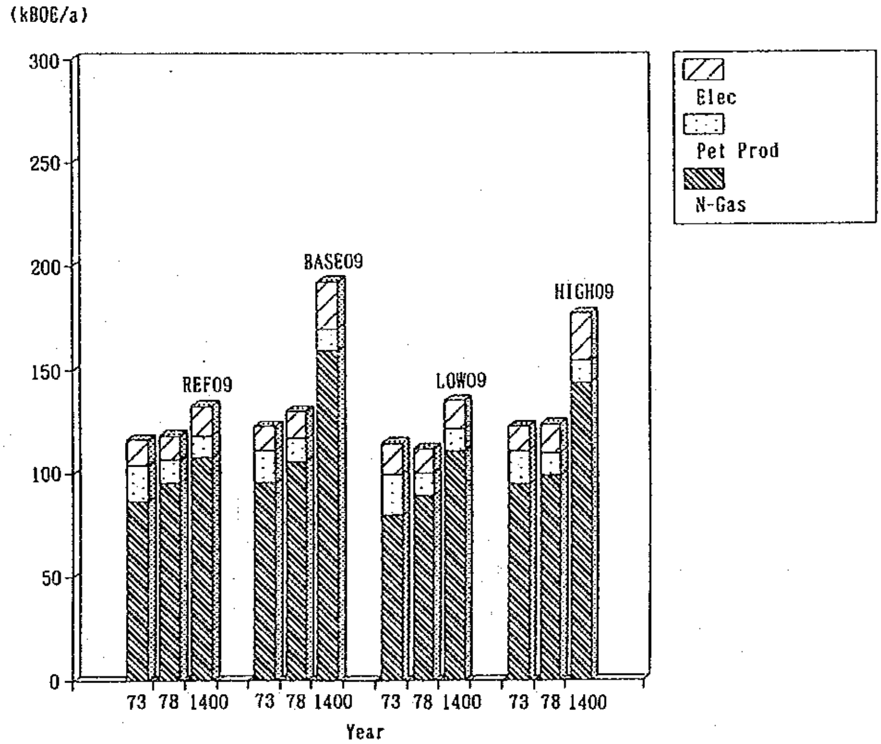
Improvement of the efficiency of the household appliances causes a decrease in the energy consumption in general, and electricity consumption in particular. As it can be seen in the Figure 4.5, with the help of energy management, the final energy consumption in household decreases by 33.2% in 2021, compared with the Reference case.

Commercial and Service Sector

Comparison of the trend of the development of final energy consumption in commercial and service sector for the cases Reference and Energy Management indicates that final energy consumption in this sector may be reduced by 19.3% and 44.05% in the years 1999 and 2021 respectively.

Fig. 4.5 Consumption of Energy Carriers in Household of I.R. Iran





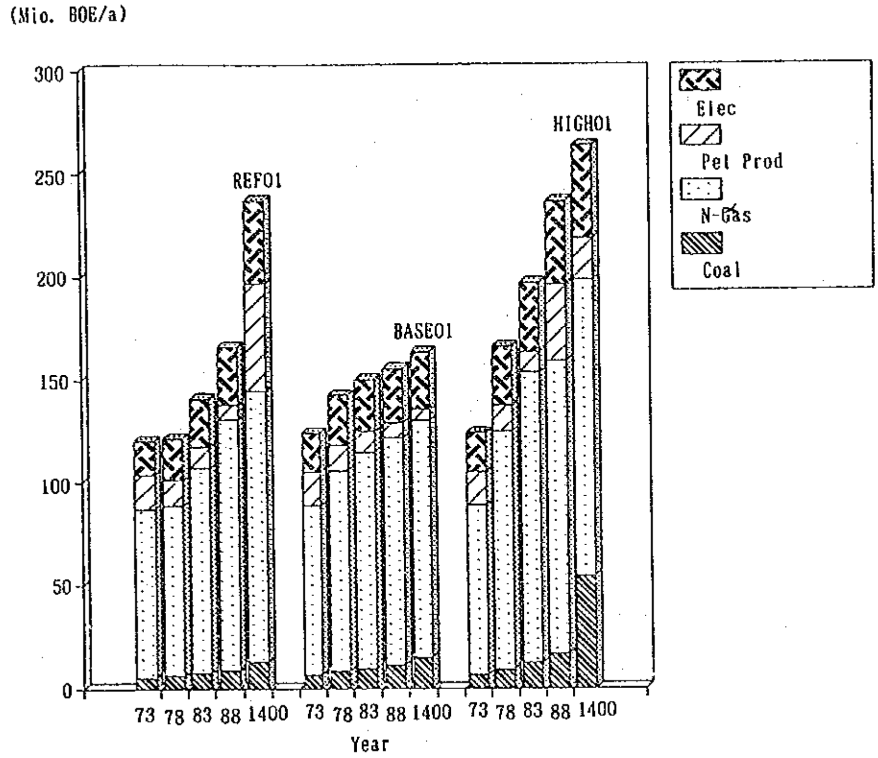
Industry

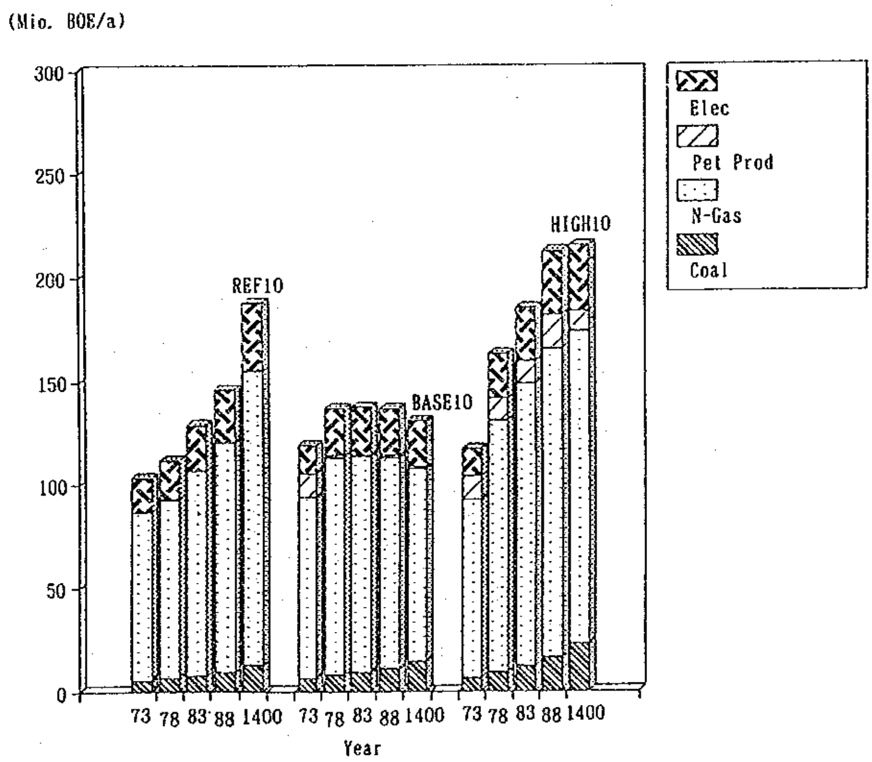
When the final energy consumption of industry in the base cases of the scenarios Reference, Base and High growth rate are compared with the results in the case of energy management (See Figure 4.6), one observes that there is considerable potential of energy conservation. It is estimated that the potential of energy conservation is more than 4% and 21% in the years 1999 and 2021 respectively.

Transport Sector

Analysis of the potential of rational use of energy in the transport sector shows that with better maintenance of transport systems, structural changes towards increased share of mass transportation and with reduction of the energy intensity of vehicles through improved engine efficiency there is a large potential of energy conservation that may be realized. The long-term potential of energy conservation in transoport sector is more than 30%.

Fig. 4.6 Consumption of Energy Carriers in Industry of I.R. Iran





5. Energy Conservation

5.1 Introduction

5.1.1 Importance of Energy Conservation

Promoting energy conservation will help solve some of the major energy issues in the Islamic Republic of Iran (I. R. Iran) including rational use of energy, expansion of oil exports, and preservation of the environment. In the first five-year plan of I. R. Iran, the following policies are cited with regard to energy consumption in the country.

- Optimum utilization of the energy
- Implementation of energy saving in equipment and appliances
- Changing the pricing policy to accelerate energy conservation

5.1.2 The Viewpoint, Focus, and Objectives of the Study

Estimating the economic potential of energy conservation is the focus of this study. The policy direction of promoting energy conservation has been decided by the government as mentioned above, and the decision is endorsed by the analyses in Chapter 2, 3 and 4 in this report. In other words, at this stage the government places importance on finding right answers to the following questions:

(i) How can energy consumers including individuals, companies, and others be urged to conserve energy?

(ii) How much energy can be conserved by feasible measures in the coming years ?

In general, the answer to the first question includes such policies as: guidance, advice and education; compulsory measures; instruction; and inducements (increase in the price of and taxation on energy carriers) and incentives (tax credits, special depreciation allowances, or favorable financing on energy conservation devices). Comparing the prices of energy carriers with the costs of energy conservation measures is necessary for the government to propose and implement concrete policies for energy conservation. If only pricing policy is implemented (which means that the other policies above are not introduced), a consumer will determine to adopt a measure for energy conservation in the case that the costs required for the measure are smaller than the benefits borne from them (which means the amount of energy conservation). Energy conserved by measures which individual consumers view to be economically justifiable is defined as the "economic potential" of energy conservation in this study.

The objectives of the study are, thus, to estimate the economic potential of energy conservation in I.R.Iran so that policy issues on energy conservation can be clarified from the economic criteria in the meaning mentioned above. In order to achieve the objectives, the past and current status of energy consumption is first evaluated and analyzed, then the measures for energy conservation, including technologies and devices available now and in the future, are investigated and examined. Third, costs are assessed and compared with the amount of energy conserved. Finally, based upon the assessment and comparison, tentative scenarios for promoting energy conservation are presented.

5.1.3 Selection of Targets

The industriy sector, the energy conversion sector, and the transport sector were selected as targets to be analyzed for promoting energy conservation in our collaborative study for following reasons:

a) The industry sector and the transport sector are two of the main energy users, accounting for around one-fourth of the total final energy consumption in I.R.Iran. Data necessary for analyzing energy conservation are available in I.R.Iran and Japan for some industries and sub-sectors in these sectors.
b) Data in the household sector is insufficient for analysis although it accounts for more than one-fourth of the final energy consumption in Iran.
c) Efficient use of energy in the conversion sector, which includes power generation, petroleum refining, and gas processing, is critical for one country to improve efficiency of the total energy flow. Data necessary for the analysis are available in I. R. Iran and Japan on thermal power generation and petroleum refining.

5.2 Estimate of the Technical and Economic Potential of Energy Conservation

5.2.1 The Industry Sector and the Energy Conversion Sector

5.2.1.1 Introduction

(i) Selection of Target Industries

Four industries - cement, sheet glass, sugar, and iron and steel - are selected as targets to be analyzed in the industry for the following reasons:

a) They are consuming a large amount of energy and are very energy intensive. Therefore, measures for energy conservation can result in energy saving in these industries.
b) The study team was able to visit some factories in the industries and get data and information necessary for analyzing the present status of energy consumption in them.
c) Data and information necessary for estimating the potential and the investment costs of energy conservation are available in Japan.

(ii) Basic ways for energy conservation in the industry sector

Considering measures for energy conservation and estimating its potential in industries, our attention is turned to following basic ways for energy conservation:

a) Improvement of fuel combustion
b) Improvement of heating and cooling
c) Prevention of heat loss
d) Recovery of waste heat
e) Improvement of conversion from heat to power
f) Prevention of electric resistance loss
g) Improvement of conversion from electricity to power

(iii) Three categories of measures for energy conservation

Measures for energy conservation are divided into three categories, defined as follows:

Category 1... Measures which can be implemented by proper management of operation and maintenance and do not require significant investment.

Category 2... Measures which can be implemented by converting or adding to existing facilities and which require a certain amount of investment.

Category 3... Measures which can be implemented by the replacement or modernization of existing facilities and which require significant investment.

(iv) Characteristics to be taken into account in I. R. Iran

(ii) and (iii) mentioned above are common in every country, but the following items should also be taken into account when studying measures for energy conservation and estimating its potential in the Islamic Republic of Iran:

a) Many years have passed since plants or equipment were installed.

b) Plants or equipment have not necessarily been well maintained or rehabilitated because of the war or the lack of foreign currency.

c) Many plants operate at lower rates.

d) The scale of plants or equipment are generally small because of a) and b) above and the national scale of demand itself.

Among these items, a), b), and c) imply that future measures for energy conservation will result in a large volume of energy saving while item d) will not.

(v) How to estimate the technical and economic potential of energy conservation

a) Technical Potential

The technical potential of energy conservation achieved in exciting plants in an industry by a certain year in future can be defined as follows:

$$PTE = \frac{a \cdot a' + b \cdot b' + c \cdot c' + d \cdot d' \ldots}{t}$$

where PTE: Technical potential in existing plants,

a,b,c: Effect of energy conservation achieved by measures A, B, C......,

a', b', c': Production in plants in which measures A, B, C...... have been implemented,

t : Total production in all existing plants.

And the technical potential of energy conservation achieved in existing and new plants in an industry by a certain year in future is shown in the following equation:

$$PT = PTE \bullet \frac{E}{T} + PTN \bullet \frac{N}{T}$$

where PT: The technical potential in an industry as a whole,

PTN: The technical potential in new plants,

E: Production in existing plants,

N: Production in new plants,

T: Total production in the industry.

b) Economic potential

The economic potential of energy conservation achieved in existing plants in an industry by a certain year in future is equivalent to the part of the technical potential which is economically justifiable in the meaning mentioned above. For instance, if measures A and D are justified and B and C not , the economic potential in existing plants (PEE) is shown in the following equation:

$$PEE = \frac{a \cdot a' + d \cdot d' \ldots\ldots}{t}$$

As discussed later, if we consider the potential for a short period of around five years to come, measures which are economically justifiable in I.R.Iran are mainly those belonging to category 1.

The economic potential is defined in the same way as the technical one as follows:

$$PE = PEE \bullet \frac{E}{T} + PEN \bullet \frac{N}{T}$$

where PE: The economic potential in an industry as a whole,

PEN: The economic potential in new plants.

5.2.1.2 Estimate of the Technical Potential

(i) Cement

According to experiences in the cement industry in Japan after the first oil crisis, the effects of energy conservation achieved by measures in category 1 are estimated to be 30 - 50 Mcal (3.2-5.3 liters of fuel oil equivalent) / t - clinker. They are equivalent to 2.5~4.2 percent of the current specific energy consumption (s. e. c.) in the cement industry in I.R.Iran, which is 1,200 Mcal (126.3 l) / t-cl.

It is estimated that measures in category 2 and 3 can achieve the energy conservation of 196 Mcal (20.7 l) / t-cl.

If all of these measures in category 1, 2, and 3 are implemented, their effects will total 23.9~26.0 l, equivalent to 18.9~20.6 percent of the current s. e. c in the cement industry in I.R.Iran (Table 5.1).

Table 5.1 Estimates of the Technical Potential of Energy Conservation in Exisiting Plants(*)

	Category 1(**)	Category 2(and 3)(**)
Cement	2.5-4.2%	16.4%
Sheet glass	5.0%	10.0%
Sugar(***)	5.0%	n.a.
Iron and steel	(1) 3.4% (2) 10-15%	(1) 5.4% (2) n.a.
Thermal power	3-5%	more than 5%
Petroleum refining	17%	8.0%

(*) Only data and information for the cement industry are available on newly - built plants.
(**) Figures in per cent show that of the current specific energy (or fuel) consumption in industries in I.R. Iran.
(***) In the case of manufacturing beet sugar.

Note i) (1) and (2) in iron and steel are on "blast furnace process" and "direct reduction process" respectively.
ii) n.a. ----- not available.

In addition, if the s. e. c in new plants is 900 Mcal / t - cl in 1999, the s.e.c. in the cement industry as a whole is estimated to be 928~938 Mcal / t - cl in 1999. Accordingly, the s.e.c. in the cement industry in I.R.Iran can be improved technically by 22~23 per cent for the next five years.

(ii) Sheet Glass

According to experiences in the sheet glass industry in Japan after the first oil crisis and those of a Japanese sheet glass company in one of the south eastern Asian countries, the technical potential of energy conservation by measures in category 1 are assumed to be at least 5 percent of the current specific fuel consumption in this industry in I.R.Iran .

And the experiences in Japan show that at least 10 percent of energy conservation can be achieved by measures in category 2 and 3.

Accordingly, if all of the measures in category 1, 2, and 3 are implemented, at least 15 percent of energy conservation will be achieved in the sheet glass industry in I.R.Iran.

Since data on new plants is insufficient, the technical potential of energy conservation in the sheet glass industry as a whole is not estimated.

(iii) Sugar

Estimates have not been made on the potential of energy conservation achieved by measures in category 1 in manufacturing sugar. The potential of energy conservation by the measures is, therefore, assumed roughly around 5 percent by taking into account experiences in other industries including petroleum refining and thermal power generation in Japan which are dealt with in this study.

However, data and information on measures in category 2 and 3 and on new plants is insufficient to estimate the technical potential of energy conservation in this industry as a whole.

(iv) Iron and steel

Experiences in the iron and steel industry in Japan show that the effects of energy conservation made by measures in category 1 is at least 300~350 Mcal (31.6~36.8 l) / t-crude steel and that those by measures in category 2 and 3 is at least 621 Mcal (59.0l) / t-crude steel in the blast furnace process. The amounts are equivalent to 3.4 percent and 5.4 percent of the current s.e.c. in the iron and steel industry (the blast furnace process) in I.R.Iran respectively.

It is also estimated that 10~15 percent of energy conservation can be achieved by measures in category 1 in the direct reduction process. Data is insufficient to estimate the effect of measures in category 2 and 3 in this process.

Unfortunately, sufficient data and information have not been available for estimating the s.e.c. in this industry as a whole (both on the blast furnace process and the direct reduction process).

(v) Thermal Power Generation

Experiences in Japan show that energy conserved by measures in category 1 will total 3~5 percent of the current gross fuel rate in the thermal power generation in I.R.Iran. Energy conserved by measures in category 2 is estimated to be at least 5 percent. In addition, measures in category 3 can achieve substantial results.

However, data is insufficient for estimating the technical potential of energy conserved in thermal power generation as a whole including those on new plants.

(vi) Petroleum Refining

According to data collected by the petroleum refining industry in Japan, the technical potential of energy conservation achieved by measures in category 1 and 2 can be estimated to be more than 15 percent and around 8 percent of the current s.e.c. in the petroleum refining in I.R. Iran respectively.

Consequently, if all of the measures are implemented, more than 25 percent of energy conservation can be technically accomplished in I.R.Iran.

5.2.1.3 Estimate of the Economic Potential

(i) On Measures in Category 1

Being based entirely upon available data, it has been estimated that around 3 - 5 percent of energy conservation can be accomplished by measures in category 1 in many industries targeted in this study while iron and steel making in the direct reduction process and petroleum refining are exceptional in achieving much more energy conservation as shown in Table 5.2.

Table 5.2 Estimates of the Economic Potential of Energy Conservation in Exisiting Plants(*)

	Category 1(**)	Category 2(and 3)(**)
Cement	4.2%	2.8% <--->
Sheet glass	5.0%	---(***) <--->
Sugar	5.0%	---(***) <--->
Iron and steel	(1) 3.4% (2) 10-15%	(1)---(***) <---> (2)---(***) <--->
Thermal power	3-5%	---(***) <more than 2%>
Petroleum refining	17%	---(***) <more than 3%>

(*) Only data and information for the cement industry are available on newly - built plants.
(**) Figures in < > show the potential in the case of energy prices being increased by around five times.
(***) ----- means "negligible." However, it is assumed that at least a few per cent of energy conservation can be achieved.

Additionally, if we take into consideration the following facts, we can presume that the economic potential of energy conservation is much larger in these industries.

First, more than 15 percent of energy conservation was accomplished by low-cost measures in category 1 in petroleum refining in Japan. We can presume that there may be more room for energy conservation than the 3 - 5 percent mentioned above in other industries.

Second, only measures in category 1 can create greater energy conservation than the 3 - 5 percent of the current s.e.c. in I.R.Iran, mainly because no measures for energy conservation have been implemented in this country.

Third, many surveys on energy conservation in developing countries by the Energy Conservation Center, Japan (ECCJ) show that 10 - 15 percent of energy conservation can be achieved only by measures in category 1.

(ii) On Measures in Categories 2 and 3

It has been estimated that the economic potential of energy conservation achieved by measures in these categories would be very small if energy prices remain at current levels in this country. However, if the price of energy (fuel oil) for industry is increased fivefold, the economic potential of energy conserved will be 2 - 3 percent of the current s.e.c. in thermal power generation and petroleum refining.

We have not made estimates of the economic potential of energy conservation in the cement, sheet glass, sugar, and iron and steel industries which are based entirely upon available data. However, if the following is taken into consideration, it is reasonable for us to consider that these industries can accomplish 1-2 percent of energy conservation at least when the price of energy at factories is increased around five times.

Generally, there must be cheaper measures in category 2 also in these industries as have been found in thermal power generation and petroleum refining in Japan. More concretely, to strengthen insulation in cement manufacturing and to promote waste heat recovery in iron and steel manufacturing are some examples of such measures which are less expensive than those that show the economic potential of around 2-3 percent.

(iii) For an industry as a whole

Only data on the cement industry is available for estimating the future s.e.c. in an industry. It is estimated that the s.e.c. will be reduced by 16 percent by 1999 and by 25 percent by 2009 in the cement industry in I.R.Iran.

Since the technical potential is estimated to be 22-23 percent by 1999 as mentioned above, the economic potential by the same year is equivalent to 70 percent of it. The main reason why the amount of the economic potential is so large is that existing kilns will be converted to or replaced with SP or NSP kilns as one of measures in category 2 and 3.

No estimates have been made on the economic potential for other industries.

5.2.2 The Road Transport Sector

There are also three categories of measures for energy conservation in the road transport sector, implemented by drivers, manufacturers, and governments.

Among the measures, proper driving and proper maintenance of vehicles are implemented by drivers, improvement of fuel efficiency by manufacturers, and improvement of road traffic systems and modal shift by central and local governments.

5.2.2.1 The Estimate of the Technical Potential

(i) Maintenance and Driving of Automobiles

Educational programs on routine vehicle maintenance and methods of driving is a potential measure for energy conservation that can be carried out at present time. It is also necessary to teach drivers to observe traffic rules and driving manners. For example, drivers should know that illegal parking decreases the road capacity remarkably and causes congestion.

Due to lack of parts and mechanics, vehicle maintenance in Tehran is insufficient. However, a campaign to teach proper driving methods with fuel efficiency is one of the most effective and practical means to conserve energy.

(ii) Automotive Technologies by Manufacturers

a) Measures by Improvement of Gasoline Cars and Diesel Cars

Technological advancement has contributed to better energy conservation for automobiles and diesel-fuel vehicles in industrialized countries. Therefore, introducing modern gasoline cars and diesel cars will affect energy conservation in the short term (by 1999) as well as in the long term (2000-2021).

It is estimated that 20 percent of cars in Tehran are less than 10 years old, 50 percent between 10 and 20 years old, and 30 percent between 20 and 30 years old. Modern cars probably have at least 30-percent better fuel efficiency than the cars in Tehran.

b) Use of Alternative Fuels

It will be possible to introduce natural gas vehicles in the near future in the area where natural gas is produced. Since I.R.Iran produces natural gas and has a large quantity of reserves, employment of natural gas vehicles is possible in the short term.

It will take a long time to urge vehicles to use alternative fuels other than natural gas.

(iii) Automobile Traffic Systems

Preventing congestion and increasing average speeds of automobiles to proper speeds are effective measures for energy conservation. It is observed that the average speed of cars in Tehran is 20~30 km/h. If the speed is increased by 10 km/h, 30 percent more energy will be conserved. Since the improvement of automobile traffic systems requires construction of infrastructure, this is not a short-term measure. Traffic signal control systems and frequent broadcasting of traffic information by radio will be necessary in the future.

However, adding right and left turn lanes at intersections and increasing the number of lanes where congestion tends to occur can be done soon. Improved traffic patterns and driver education will help alleviate traffic problems.

Driving cars in shopping areas and bazaars where many citizens come together should be prohibited in some instances. In these cases park and ride systems, where shuttle buses travel between the shopping areas and parking lots in the neighborhood will be employed.

(iv) Intelligent Vehicle-Highway Systems

A part of Intelligent Vehicle-Highway Systems are put in practical use in industrialized countries. Since many of the systems are still in the research phase even in these countries, it will take long time to put them in practical use.

5.2.2.2 Estimating Economic Potential

Economic potentials for energy conservation resulting from each measure mentioned above have not been estimated. Economic potenials for measures in category 1 can be estimated, however.

Fuel consumption per one thousand passenger cars decreased by more than 10 percent for a few years after the first oil crisis in Japan. It is not unreasonable for us to assume that measures in category 1 contributed to a major part of the decrease during the period in which the fuel efficiency of passenger cars was declining, although reduction in driving distance of cars should be taken into account.

5.3 Scenarios for Promoting Energy Conservation

5.3.1 Policies for Energy Conservation

Basic ways for promoting energy conservation as policy measures are classified as follows:

(1) Guidance, advice, and education
(2) Compulsory measures
(3) Instruction
(4) Inducement
(5) Incentives
(6) Detailed studies

The following are examples of guidance, advice, and education:

(1) To establish an Energy Conservation Day and/or Energy Conservation Month
(2) To begin campaign for energy conservation
(3) To set up an Energy Conservation Center which is in charge of the following items:
- Guidance, advice, and education
- Survey and study
- Energy auditing
- Training

The following are examples of compulsory measures:

(1) Closing petrol stations on Fridays
(2) Prohibiting cars from entering a certain areas in large cities

The following are examples of instruction:

(1) To establish standards for evaluating energy efficiency of factories or plants, appliances, and vehicles
(2) To implement energy audit
(3) To provide people, companies, and others with information necessary for energy conservation

The following are examples of inducements:

(1) Pricing policy on energy carriers
(2) Taxation on energy carriers

The following are examples of incentives:

(1) To give tax credits and depreciation allowances to those who invest in energy conservation devices

(2) Make long-term, low-interest loans to those who invest in energy conservation devices

In addition to the ways mentioned above, detailed studies of each sector should be done for implementing concrete policy measures, including the following items:

(1) Collecting and organizing data into a database

(2) Analysis of energy uses at the micro level

(3) Study of detailed measures for promoting energy conservation

(4) Estimate of technical and economic potentials of energy conservation

5.3.2 Scenarios for Energy Conservation

Considering the policy measures shown above as well as economic potentials mentioned in 5.2.1.3 and 5.2.2.2, the following scenarios can be described as realistic ones for promoting energy conservation in the Islamic Republic of Iran.

5.3.2.1 Scenario for Short Period (1994-1999)

First, among individual measures in existing factories and plants in 5.2 above, some of those in category 1 are considered realistic to be implemented in the industry sector and the energy conversion sector. In the road transport sector, improving driving ways and proper maintenance of cars, both of which should be implemented by drivers with the governments' support, and efficient use of existing roads are considered to be realistic measures in this period.

Second, the adoption of efficient plants and equipment is recommendable in constructing new ones or expanding existing ones as far as their financing is possible. Governments should encourage production of energy-efficient cars (It is reported that the average consumption of gasoline per each car in Tehran is 15 liters per 100 km, which is around twice that in Japan).

The following are policies to encourage individual measures:

(1) Guidance, advice, and education

(2) Compulsory measures, particularly in the road transport sector

(3) Increase in energy prices in the real term

As already mentioned, even a fivefold increase in energy prices may not have a big effect on energy savings made by a major part of measures which need investment costs in the industry sector and the energy conversion sector. However, a much greater increase in price in a short period is too drastic, particularly considering its impact on people's lives.

Measures in category 1 are reasonable ways for industry, energy conversion and road transport sectors to conserve energy.

Finally, detailed studies on energy conservation in each sector should be commended during this period so that their results can be utilized over time.

5.3.2.2 Scenario for Longer Period (2000-2021)

First, future detailed studies can identify concrete policy measures and estimate more reliable figures on the economic potentials of energy conservation including those achieved by measures in the household, commercial, and agricultural sectors, which are not dealt with in this study, as well as those achieved by measures mainly in category 2 and 3 in the industry, energy conversion, and road transport sector, which could not be estimated sufficiently in this study.

Second, we can expect that measures requiring investment will be implemented in existing factories and plants based upon the studies mentioned above.

In the road transport sector, many of measures in categories 2 and 3 also can be considered and implemented along with introducing more efficient cars.

Third, stronger policy measures and financial aid can be considered to support and encourage energy conservation measures and the adoption of more efficient plants, equipment and vehicles.

6. Energy and Environment

6.1 Introduction

6.1.1 Energy and Environment

Energy is indispensable for our modern life and economic activities. Energy systems, however, consume energy resources, impose loads on the environment in different stages of each fuel cycle and create waste. Above all, oil, coal, natural gas and other fossil fuels are closely tied to environmental issues. In combustion, storage and other phases, sulphur oxides, nitrogen oxides, soot and dust, hydrocarbons and other air pollutants are discharged, causing regional air pollution and acid rain.

Fossil fuels also emit carbon dioxide and other greenhouse gases which cause global warming. Methane is emitted in the mining process and leaked in the shipping process. Energy consumption in urban areas sometimes causes heat islands.

As for offshore oil fields, once a major accident occurs, the ocean is seriously polluted like the accident at the North Sea Oil Field. Crude oil spilled in the accidents of huge tankers and ballast water in their cargo holds are also causes for marine pollution.

If we focus on air pollution, environmental pollution associated with energy consumption is classified into following three groups:

(1) Local Air Pollution

Potentially, the combustion of fossil fuels may result in the emission of traditional air pollutants such as soot and dust, sulfur oxides (SOx), nitrogen oxides (NOx), carbon monoxide (CO), hydrocarbons (HC) and other chemicals.

Soot and dust which are less than 10 microns in particle diameter are suspended in the atmosphere over long periods of time and are likely to be deposited in the respiratory track or pulmonary alveoli, impacting the lungs, so that environmental quality standards are determined as those for Suspended Particulate Matter (SPM). SOx negatively affects human health, the aquatic ecosystem, crops and forests, and buildings. NOx mainly stem from the burning of fossil fuels at high pressure. NO_X generates photochemical oxidants, smog and acid precipitation together with sulphur oxides. Ambient levels of SOx and NOx are represented by measured concentration in the air, and their emissions are given as the quantities of sulphur dioxide (SO_2) and nitrogen dioxide (NO_2).

CO interferes with the absorption of oxygen by red blood cells. Volatile organic compounds (VOC) are considered to be the main precursors of photochemical air pollution together with nitrogen oxides. After all, photochemical oxidants are generated by CO, NO_X and HC, which are generated by incomplete combustion of fuels, and poses problems on regional air pollution in conjunction with energy consumption.

(2) Acid Rain (Regional Air Pollution)

The generation of acid rain results from the melting of SO_X and NO_X produced in the combustion of fossil fuels. Acid rain sometimes falls and inflicts serious damage on areas thousands of kilometers away from the source, becoming an international political issue.

(3) Global Warming

Emissions of greenhouse gases (GHGs) such as carbon dioxide(CO_2), methane and chlorofluoracarbons (CFCs) and the other factors including deforestation are cited as factors causing global warming. According to *Policy Options for Stabilizing Global Climate, Feb. 1989, US-EPA,* about 57 percent of all anthropogenic contribution to global warming is due to energy production and consumption, followed by 17 percent by CFCs, 14 percent by agricultural work and 9 percent by changes in land use. CO_2 related to energy consumption is essential in countermeasures to prevent global warming because CO_2 contributes the largest share to the greenhouse effect which potentially effects the climate, sea level and world agriculture.

6.1.2 The Focus and Objectives of the Study

The final goal of this kind of study on energy and environment is to identify individual measures for environmental improvement and to formulate concrete policies, which can support and encourage the measures, in order to reach the targets of environmental preservation. To formulate and propose concrete policies, the following steps are needed.

First, as far as local and regional pollution is concerned, the concentration of environmental pollution as well as the emission of pollutants are surveyed (or monitored) to accurately grasp the current status of environmental pollution by area.

Second, if the current status is deemed undesirable to inhabitants in and around the area, an acceptable or desirable level of environmental pollution is considered to establish a standard, which will be used to regulate the emission of pollutants in and around the area.

Third, in conjunction with setting standards, environmental conservation methods, such as the installation of technical devices, are considered along with the economic feasibility of such methods.

In this study, some data and information on the concentration of air pollution, which have been surveyed mainly by international organizations, have been collected and analyzed, while past and present emissions is estimated.

The acceptable or desirable level of environmental pollution in I.R. Iran has not been studied partly because the Iranian Government is now studying the standard, while the current control system of environment in I.R.Iran has been reviewed.

Measures for environmental preservation on both stationary and mobile sources are studied in order to suggest basic ideas on policies. In addition, the costs or capital requirements of the measures are reviewed to provide policy makers with some data and information for formulating concrete policies.

Finally, based upon studies mentioned above, some considerations on policy measures are made for more concrete ones to be identified for the future.

6.2 Potentials of Reduction in Pollutants and Considerations on Measures for Environmental Improvement

6.2.1 Main Findings of the Study

6.2.1.1 Current Status of Air Pollution in I.R. Iran

(1) In large cities

The historical trend of air pollution in Tehran shows that the concentrations of main pollutants including lead were higher than the WHO guidelines for cities. For instance, the concentration of SOx considerably exceeded the WHO guideline of 0.04 - 0.06 mg per cubic meter.

International comparisons also show that Tehran was highly ranked in terms of the concentration of air pollution. In 1992, Tehran was ranked at the top in the number of days per year in which levels of SPM and smoke exceeded critical values, and at the second that of SO_2.

According to reports in newspapers published in Iran, Mashhad, Isfahan, Shiraz, Tabriz, and Arak are the most polluted cities following Tehran.

A report prepared in February, 1993 indicates that 65 percent of total air pollution in Tehran is caused by nearly two million vehicles moving in the city. Around one - fourth of the pollution is reported to be from industries, and one - tenth from the households.

(2) In the country as a whole

Main emission sources in energy consuming sectors are generally listed as follows:

- Oil field; flaring, or burning some 10 to 15 percent of production
- Petroleum refineries with some 5 to 10 percent loss of geed
- Oil-burning power boilers of more than 100 t/h rating
- Gas turbine generators burning low grade (high sulfur) fuels
- Small and medium-scale industries burning low grade fuel oil
- Large scale iron and steel mills
- Big cities with a population of more than one million
- Motor vehicles

The total emissions of SOx from energy consumption increased about 6 times during the period from 1970 to 1990, according to our calculation. Emissions generated by the industrial sector and the energy conversion sector grew significantly, and accounted for 60 percent of total emissions from energy consumption in 1990. In addition, the volume of SOx emissions from the flaring associated gas is estimated to be almost the same as that from the total energy consumption in I. R. Iran in 1990.

The total emissions of NOx from energy consumption increased about 5 times during the same period. The most significant increase in NOx emissions was recorded in the transport sector, which accounted for about 60 percent of the total NOx emission from energy consumption in 1990. It is estimated that the emissions of NOx from flared gas is very little compared with that from other sources.

The total emissions of CO_2 increased in every energy consuming sector in accordance with the increase in fuel consumption. The CO_2 emission from flared gas is estimated to be equivalent to about 10 percent of the emission from other sources in 1990.

6.2.1.2 Forecasting Emission Volumes

Estimates have never been made on the future concentration of air pollution in major cities or areas for the future, which will be one of the most important tasks in the next step of environmental studies in Iran.

Our estimates show that SOx emissions are likely to increase markedly, especially in the transportation sector. SOx emissions are not likely to increase much in the industrial sector and the energy conversion sector because gas consumption will grow rapidly in the sectors.

Emissions of NOx will grow significantly in the transportation sector while the emissions will remain steady or increase only slightly in the industrial and energy conversion sector.

The transportation sector will lead other sectors in an increase in CO_2 emissions.

Emissions of SOx, NOx, and CO_2 from flared gas has not been estimated mainly because the flaring will be relinquished when the planned gas facilities to remove H_2S from sour associated gas are completed and operation begins.

6.2.2 Technical Potential of Reduction in Pollutants

6.2.2.1 Factors contributing to air pollution

In analyzing factors contributing to air pollution, we find that a contributing factor has a different effect on reducing each type of pollution.

The fuel switching factor (fuel improvement and fuel conversion) is the greatest contributor to SOx reduction. The second biggest contributor is the energy intensity improvement factor.

The fuel switching factor and the energy intensity improvement factor are the major contributors with regard to NOx emission.

The energy intensity improvement is the greatest factor in reduction of CO_2. The second biggest contributor is the fuel switching factor.

Two kinds of trial calculations are made below. One is on a macro basis and the other micro.

6.2.2.2 Estimate of the Technical Potential

(1) Assumption for the Estimation

1) Fuel Improvement

The effect of fuel improvement is evaluated based on the assumption that three major kinds of liquid fuel -- fuel oil, gas oil and gasoline -- are improved in sulfur content as shown in Table 6.1 below.

Table 6.1 Assumed improvement of Fuel in Sulphur Content

(%)

	Before Improvement	After Improvement
Gasoline	0.1	0.004
Gas Oil	0.9	0.2
Fuel Oi	13.3	1.0

The assumed sulphur contents for 'After Improvement' case are based on the present Japanese values. The contents for 'Before Improvement' are estimated present status in Iran.

2) Fuel Conversion

It is assumed that all the fuel oil which is currently consumed in I.R. Iran is substituted by natural gas.

3) Energy Intensity

Improving energy intensity greatly contributes to the reduction of NO_x and CO_2. It is the only practical way to achieve CO_2 reduction.

Figure 6.1 (a) and Figure 6.1 (b) show the historical trends of energy intensity in I.R.Iran and Japan. These figures indicate that the primary energy requirement per GDP in I.R.Iran has been increasing continuously since 1971. The figures also indicate that in Japan the energy intensity has decreased 18.59 Kcal/Yen (4,722 Kcal/US$) in 1974 to 11.67 Kcal/Yen (2,964 Kcal/US$) in 1991. That constant price based on 1985 and the exchange rate of 254 Yen/$ have been used. The ratio of the reduction is 37%.

The energy intensity in I.R. Iran in 1985 is estimated to be 3,557 Kcal/US$. This figure is derived from the parameters as follows.

Exchange rate:	89.5	Rls/US$
Primary Energy Requirement	412.2	MMBOE
GDP	15.168x10^12	Rials
GDP per Capita	3,655	US$/capita

Fig. 6.1(a) Trend of Energy Intensity; I.R. Iran

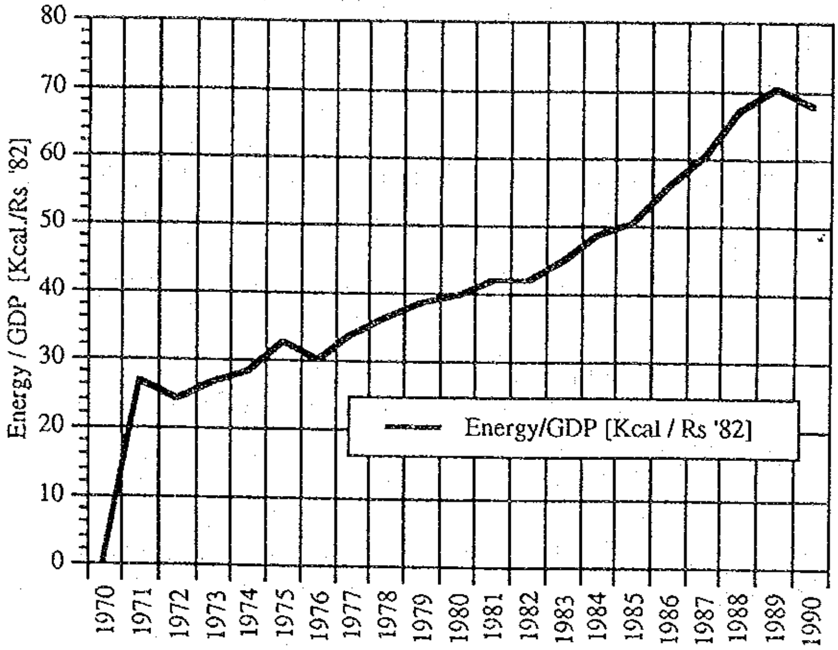


Fig. 6.1(b) Trend of Energy Intensity; Japan

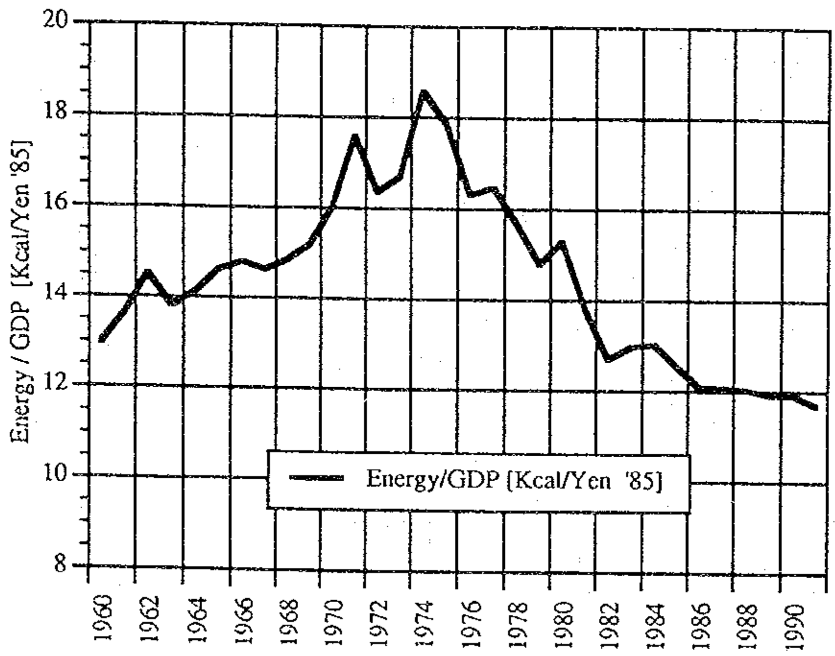


Table 6.2 summarizes the energy intensity values in 1985 and 1990 for these two countries.

Table 6.2 Comparison of Energy Intensity

			1985	1990
I.R. Iran	Value @'85 Price	Kcal/$	3,577	4,792
	Value @Current Price	Kcal/$	3,577	5,476
	Exchange Rate	Rial/$	90	262
	GNP Deflator	1985=100	100	229
Japan	Value @'85 Price	Kcal/$	3,187	3,032
	Value @Current Price	Kcal/$	3,187	1,781
	Exchange Rate	Yen/$	254	150
	GNP Deflator	1985=100	100	107

Source: APPENDIX - * Parameter Table
EDMC, "Energy Economics Statistic Table", 1993

The value of energy requirement/GDP based on U.S.$ depends on the exchange rate which is difficult to evaluate. According to the table, the energy intensity values in I.R.Iran and Japan in 1990 are 3,032 Kcal/$ and 4,792 Kcal/$ respectively at '85 constant price.

Supposing that it is possible to improve the energy intensity in I.R.Iran to the level of Japan in 1990, the ratio of reduction, or improvement, will be 36.7%. On the basis of this review, the potential improvement of energy intensity in I.R. Iran is assumed to be 35%.

(2) Technical Potential of Reducing Pollutants

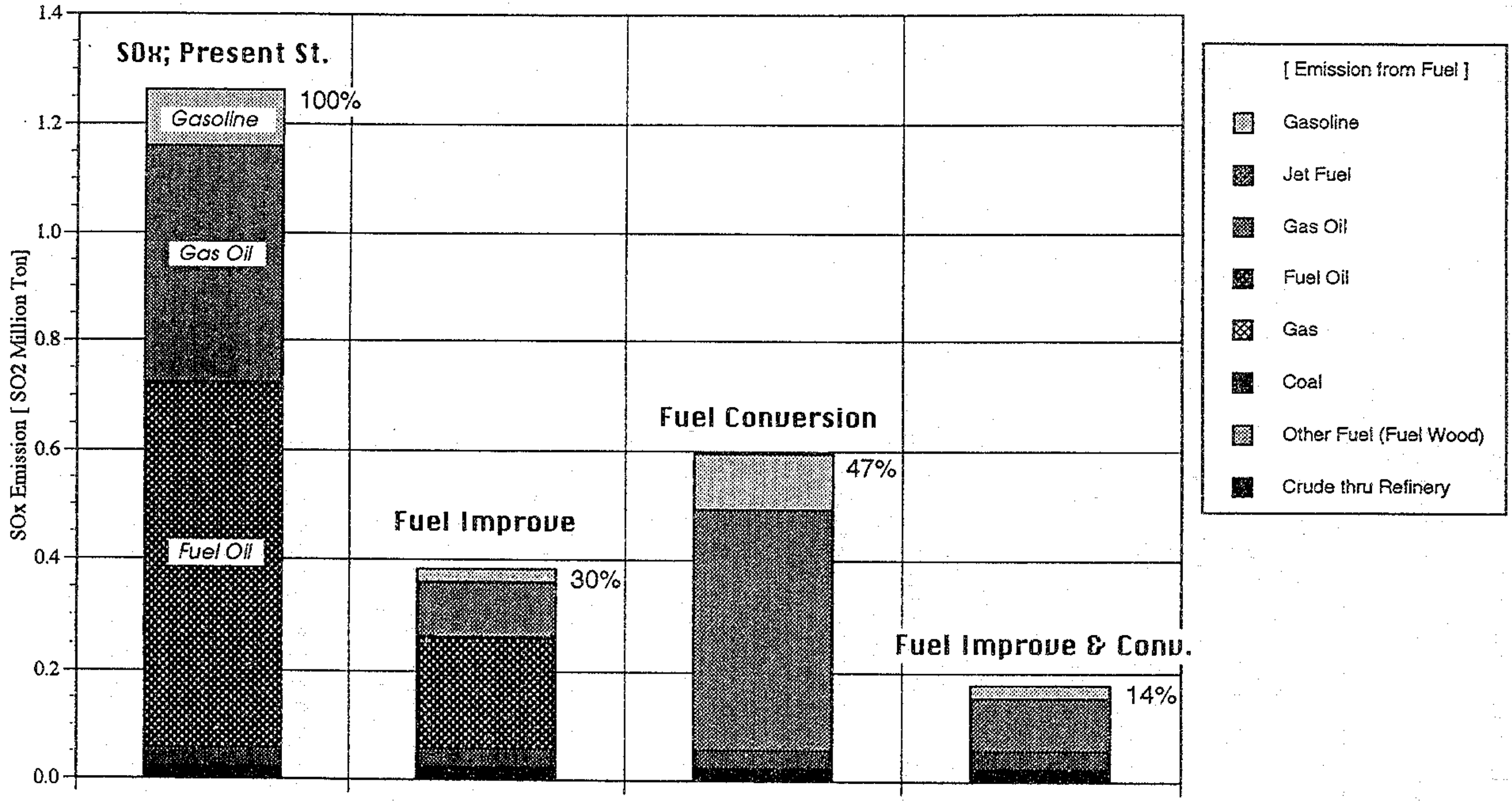
1) SO_x

a) Fuel Improvement and Fuel Conversion

Figure 6.2 shows the result of the calculation which estimates the potential SO_x reduction by fuel improvement and fuel conversion in 1990. The effect of fuel improvement based on the assumption above is displayed as the fuel improvement case in the figure. The fuel improved and conversion case in the figure displays the result of summation of former two cases.

According to the figure, improving fuel, the fuel conversion and the sum of these two measures is expected to reduce SOx emissions by 70 percent, 53 percent and 86 percent, respectively. These drastic figures show that there is quite a big potential of SO_x reduction in the country.

Fig. 6.2 Potential in Reduction of SOx Emission ; I.R. Iran 1990



In Japan, Japanese Industrial Standards (JIS) specifies sulfur content in kerosene for home use to be within 0.015 percent, but actually it is reduced to 10 ppm (0.01 percent) in commercial market. For industrial use, the maximum content in kerosene and gas oil has been 0.2 percent sulfur since 1992. All the refineries in Japan have been ready to produce such petroleum products commercially. Further reduction of sulfur content in general use kerosene and gas oil to 0.05 percent is set for 1997. As for heavy fuel oil, there are four grades of sulfur content by use, ie. 0.5, 2.0, 3.0 and 3.5 percent max.

b) Improving Energy Intensity

The improvement of energy intensity can result in the additional reduction of SO_x emission. This factor with the other two factors -- fuel improvement and fuel conversion -- will improve the overall SO_x reduction ratio from 86 to 91 percent.

2) NO_x

a) Fuel Conversion

Figures 6.3 shows the effect of fuel conversion on NO_x emission. Improvement in burning efficiency is not considered in this study. Supposing that all the requirements of fuel oil are respected with natural gas, the effect on NO_x reduction is estimated to be 9%. The result agrees with the Japanese experience which indicates that combustion modification and the exhaust gas control contribute to lower NOx emissions.

b) Energy Intensity

Improving energy intensity dramatically reduces NO_x and SOx emissions. The potential improvement of energy intensity, which is estimated to be 35%, can reduce NO_x by 41 percent.

3) CO_2

a) Fuel Conversion

Figure 6.4 shows the effect of fuel conversion on CO_2 emission. Supposing that all the requirement of fuel oil is replaced with natural gas, the effect on CO_2 reduction is estimated to be 6 percent.

b) Energy Intensity

Improving energy efficiency directly contributes to lower CO_2 emissions. The potential improvement of energy intensity can reduce CO_2 by 39 percent. Potential reduction rates of emitted pollutants and CO_2 are summarized as follows.

Table 6.3 The Potential Reduction of Pollutants and CO_2 (%)

	Fuel Improvement and Fuel Conversion			Energy Intensity Improvement	Overall Reduction
	Improvement	Conversion	Total Effect		
SO_x	70	86	86	35	91
NO_x	-	-	9	35	41
CO_2	-	-	6	35	39

6.2.2.3 Effects of Fuel Conversion to Natural Gas in Power Plants

(1) Assumption of the Estimation

Following assumptions are made for the estimation:

1) All steam turbine plants using fuel oil and gas oil are to be converted into using natural gas.
2) All gas turbine plants using gas oil are to be converted into using natural gas.
3) All gas turbine plants using natural gas are to be innovated into gas combined cycle plants.

Actual operation data of power plants in I.R. Iran as of 1992 are shown in Table 6.4.

Fig. 6.3 Potential in Reduction of NOx Emission;I.R. Iran 1990

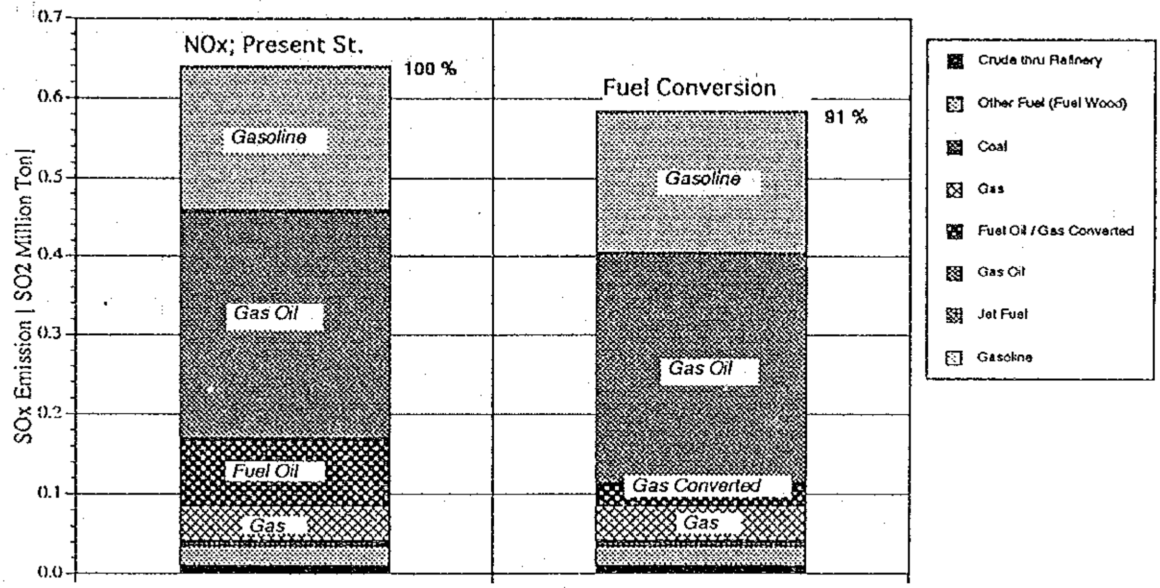


Fig. 6.4 Potential in Reduction of CO_2 Emission;I.R. Iran 1990

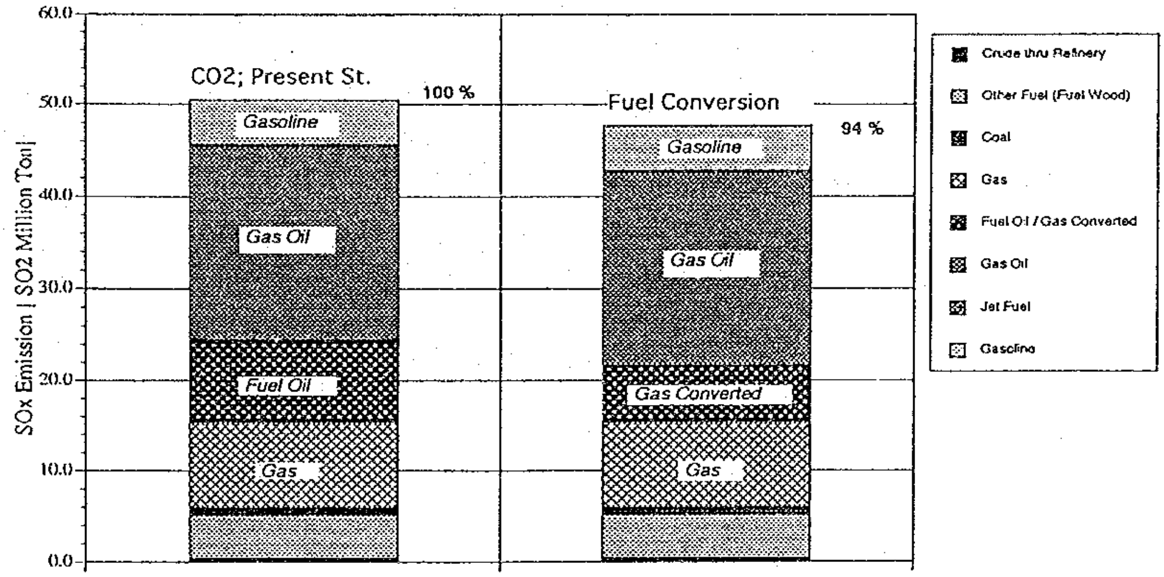


Table 6.4 Actual Operation Data of Power Plants in Iran (1992)

<Steam Turbine>

	Total	Fuel Oil	Gas Oil	Natural Gas
Capacity (MW)*	5,373 MW*			
Fuel Consumption (PJ/y)	418 PJ/y	187 PJ/y	1 PJ/y	230 PJ/y
Production (GWH)	42,362 GWH			
Therm Efficiency	34.2 %			
SO_x Emission (million ton/y)	291 Mt/y	290.5*	0.5*	0.005*
NO_x Emission (million ton/y)	69.4 Mt/y	45.6*	0.7*	23*

<Gas Turbine>

	Total	Fuel Oil	Gas Oil	Natural Gas
Capacity (MW)	1,378 MW*			
Fuel Consumption (PJ/y)	157 PJ/y	0 PJ/y	26 PJ/y	131 PJ/y
Production (GWH)	10,866 GWH			
Therm Efficiency	22.9 %			
SO_x Emission (million ton/y)	12 Mt/y	0*	11*	1*
NO_x Emission (million ton/y)	31 Mt/y	0*	17*	14*

*= calculated value (Capacity's value includes 10% reserves)

(2) Effects of Fuel Conversion on Emission of SOx and NOx

As can be been in Table 6.5, 298 million tons of SOx can be reduced annually by the conversions mentioned above, and 53 million tons of NOx by the conversions and through technological innovation. The latter includes 9 million tons which can be reduced through energy (natural gas) saving accomplished by the innovation to combined cycle system.

SOx and NOx emissions decrease 98 percent and 51 percent respectively.

Table 6.5 Effects of Fuel Conversion on Pollutant Emission

	SOx Reduction	NOx Reduction	Energy Saving
<Steam Turbine> Fuels Conversion	287Mt/y (△98%)	29Mt/y (△41%)	
<Gas Turbine> Fuels Conversion	11Mt/y (△92%)	15Mt/y (△48%)	
<Gas Turbine> Renovation Combined Cycle			76PJ/y (△48%)
Effects by Energy Saving above		9Mt/y	
Total	298Mt/y (△98%)	53Mt/y (△53%)	

6.2.3 Considerations on Measures for Environmental Protection

Based upon the findings of this study, the following items are concepts to be considered by the Government of I.R.Iran to improve the environment.

6.2.3.1 A Monitoring System

A monitoring system is indispensable to hammering out realistic and concrete polices for environmental protection although it has been gradually developed especially in Tehran.

Recent technical cooperation with Japan on environmental studies is expected to contribute to a monitoring system.

6.2.3.2 Acceleration of Energy Conservation

As mentioned in 6.2.2, energy conservation will have a significant effect on reducing the emission of pollutants including CO_2. The measures for energy conservation which are mentioned in the Chapter 5 will contribute also to improving the environment.

One of the most important measures for energy conservation is the proper maintenance and operation of factories or plants and vehicles.

Since the transportation sector will account for a larger share of pollution, particularly in the emissions of SOx and NOx, accelerating energy conservation in the sector is highly important.

6.2.3.3 Conversion of Petroleum to Gas

As mentioned in 6.2.2, converting fuel from petroleum to gas will contribute to reducing many pollutants in all sectors including road transport. CNG and LPG are already being utilized as fuels for vehicles in I.R.Iran although on a small scale.

On the other hand, the cost of conversion will not be so little that it might be necessary for planners to provide some strategies for proceeding the conversion. From this point of view, the priority should be put on power plants and large factories which consume a large amount of fuels.

6.2.3.4 Improvement of Refinery Configuration

In the existing refineries in I.R. Iran, there are no hydro - desulfurization units for removing sulfur from gas oil and fuel oil except for some isomax units. These products are distributed to users without further removal of sulfur. Considering this, it is envisaged that the modernization of refinery configuration should be subject to discussion in light of upgrading the products with less SOx emission , in addition to controlling their product yields for meeting more the market demands.

In reviewing the refinery configuration, each refinery shall be classified into two major categories, fuel upgrading refinery and conversion refinery, in which sulfur contents are removed in the process of converting heavier fractions to ligher ones.

6.2.3.5 Measures for Efficient Driving of Vehicles

Proper maintenance and operation of vehicles can contribute to reducing air pollutants not only indirectly through reducing fuel consumption but also directly through the more efficient combustion of fuels. SPM and smoke are two of typical pollutants which are generated by imperfect combustion of fuels.

Incomplete combustion is said to be the result of shortage of spare parts and due to the height above sea level of Tehran, but the lack of skills and efforts for the proper maintenance of vehicles can be added as important causes for incomplete combustion.

6.2.3.6 Measures for Flared Gas in the Oil Fields

SOx emission from flared gas is estimated to be as much as that from total fuel consumption in I.R. Iran. As mentioned already, the associated gas which has high content of H_2S has to be flared because it cannot be used.

The planned facilities to remove H_2S from sour associated gas and to utilize it are expected to complete as soon as possible.

7. Conclusion

7.1 Summary and Findings of the Study

In the process of comprehensive energy studies, a large amount of data on energy demand in social and economical sectors are collected and analyzed and rational use of energy in various sectors was studied. In this chapter the general conclusion of the study is being outlined.

Conclusion of the results of the comprehensive energy studies is based on the fact that energy policy is considered as a means of maintaining a framework for establishing optimal balance between energy demand and supply based on the competitiveness of consumption and supply of energy carriers, and the economical and social cost of energy use will be kept at minimum level. In this way energy policy and energy economy is to contribute to the establishment of an energy supply system, with the help which the following objection would be realized.

a) Useful energy demand of all social and economical sectors and citizens in all parts of the country will be met.
b) The required useful energy will be supplied with maximum efficiency and effectivity; and the cost of energy supply shall be minimum in the long run.
c) Energy sector will be compatible with the social values and sustainable development of the country.
d) Health damages and environmental pollution will be kept at the lowest level.
e) Meeting the living requirements and improving the living condition of future generations will be considered.

Based on the above criteria, the major conclusions of the study are summarized as follows:

1. Economic development and improvement of the living standard of the poor is associated with rising useful energy demand. Useful energy demand is to increase from 878.7 PJ/a in 1994 to 1,011.5 PJ/a is 1999 and 1,908.5 PJ/a in 2021. According to different scenarios, the range of variation of useful energy demand is found to be 1,011.5 to 1,342.5 PJ/a in 1999 and 1,629.6 - 2,423.8 PJ/a in 2021.
   To meet the useful energy demand, restructuring of the energy supply system will be required. In the case of "business as usual" and continuation of the present situation (i.e. when energy is heavily subsidized), consumption of final energy increases to 628.9 MBOE/a in 1999 and

1009.8 MBOE/a in 2021. On the other hand, when the subsidization of energy prices is avoided and energy carriers are delivered to the final consumers with a price equivalent to their long-run marginal cost, the final energy consumption rises from 506.6 MBOE/a in 1994 to 552.7 MBOE/a in 1999 and 961.2 MBOE/a in 2021. In this scenario, it is also assumed that the opportunity cost of oil underground would be zero.

When the opportunity cost of oil is considered as equal to the export prices of crude oil, final energy consumption reaches to a level of 503.0 MBOE/a in 1994 and increases to 549.8 MBOE/a in 1999 and 959.4 MBOE/a in 2021. When the two cases of with and without considering the export value of crude oil underground are studied, it is realized that when due consideration is given to the value of oil underground, final energy consumption is reduced by 0.52% and 0.18% in 1999 and 2021 respectively and the share of natural gas in primary energy consumption rises more rapidly.

When improvement of the efficiency of energy processing, conversion, transportation, distribution and consumption systems is pursued, final energy consumption decreases to 490.9 MBOE/a in 1999 and reaches 673.8 MBOE/a in 2021. When this case of energy management and rational use of energy is compared with the reference scenario, one observes that the final energy consumption may be reduced by 10.71% and 29.24% in 1999 and 2021 respectively. Energy management leads to a reduction of primary energy consumption by 12.31% and 31.67% in 1999 and 2021.

2. Development of the structure of the energy supply system indicates that utilization of hydro power potentials in various parts of the country is a necessity for lowering the cost of electricity supply and decreasing the environmental pollution.

   In eastern part of the country, consumption of coal in industrial furnaces increases in the period 2009 to 2021 and coal provides an economical alternative for supply process heat. Therefore, a detailed evaluation of coal reserves and utilization of clean coal is an important step in the process of optimal development of the energy supply system.

   In the next two decades, when the economy grows more rapidly (with an average annual growth rate of more than 5%/a) and the prices of crude oil increases to $30/bl in 2021, it is found that non-fossil energy sources provide an optimal option for supply of domestic energy needs of the country. This indicates that R&D activities in the area of non-fossil energy should be organized and efforts should be made to build up power plants using non-fossil energy in the next two or three decades.

3. Evaluation of energy export for the purpose of meeting the foreign exchange requirement of the

country indicate that export of crude oil will continue to have a higher share in energy export; but the share of petroleum products in energy export shows a rising trend. It is also found that export of natural gas through the eastern regions of the country and to Pakistan and India provides an appropriate option. In general, structure of energy export develops in such a way that export of petroleum products and natural gas increases gradually.

4. Economic development is greatly influenced by the energy consumption in different sectors. Saving in energy consumption leads, on the one hand, to reduced investment of the energy supply system; on the other hand, it enhances the potentials of energy export in general and oil export in particular. Optimal consumption and rational use of energy in the domestic market provides a reliable option for increasing of GDP per capita and improving the living condition of the population. Management of exhaustible energy resources indicate that sustainable economic development and reducing the dependency of the economy on the changes in the international energy market can be the outcome of the optimization of production and consumption of energy carriers.

5. Comprehensive analysis of the development of energy system indicates that meeting useful energy requirement in social and economical sectors is feasible in the long run, and its realization is not necessarily associated with rapid increase in final and primary energy consumption. In other words, economic development and improvement of the living standards of the population may be achieved with the present level of per capita final and primary energy consumption. It is observed that only in the case of rapid economic growth a rising trend of per capita primary energy consumption may be expected in the next one and half decades. It is realized that adjustment of energy demand and improving the efficiency of energy supply shall lead to a situation, where increase in per capita final and primary energy consumption will not be a necessity.

Evaluation of the trend of final and primary energy intensity indicates that economic growth does not necessarily lead to a higher energy intensity. In fact, economic development is subject to stabilization of energy intensity and reduction of energy intensity would result in higher economic growth. Therefore, two main important short- and long-term objectives may be identified in the energy sector as follows;

a) To stabilize per capita final and primary energy consumption at a level of 8.17 and 11.87 BOE/a respectively;

b) To increase the energy productivity (or reduce energy intensity), so that the primary energy intensity would decline by an annual rate of 0.48%/a during the second five years development plan.

6. Reduction of primary energy intensity requires that a policy of rationalization of energy use in social and economical sectors and optimization of energy supply system and better management of energy resources is pursued and the useful energy requirement of the society is met with minimum losses. Analysis of energy consumption is service and production sectors and households reveals that there is a considerable potential for rational use of energy and its realization can be a major element of a comprehensive energy policy. Detailed evaluation of the rational use of energy in production and service sectors and formulation of action plans for energy conservation requires that development of energy data-base and preparation of R&D programms in the area of rational use of energy are considered seriously.

7. Implementation of a policy of rational use of energy and reduction of energy intensity through improvement of energy efficiency of the economic system would result in saving capacities, and consequently capital, in the energy supply system. In this case, capacities of power plants would increase from 31932 MW in 1999 to 46460 MW in 2021 and throughput into the refineries would remain constant at the level of 1.4 MBOE/a in the period 1999-2021. Therefor, rational use of energy would lead to a reduction of the capacity of refineries by 9.11% and 43.6% in the years 1999 and 2021 respectively compared to the case of "Business As Usual". Hence, following the rational use of energy, the potentials of the economy will develop, and large resources would be available for the rapid development of non-energy sectors of the economy, that otherwise should have been allocated to the energy supply.

8. Development of energy demand and supply is associated with the emission of pollutants and increased consumption of fossil energy carriers is accompanied by rising emission of pollutants. Emission of CO_2 increases with a rate of 2.6 %/a in the period 1999-2021 and it reaches a level of 245 million ton in 2021. Rising trend is also observed by SO_2 and NO_x. Emission of SO_2 amounts to 1,330 kt/a in 2021. Amount of NO_x emitted in 1994 is 1,354 kt/a, which increases to 2,946 kt/a in 2021.

Controlling the emission of pollutants leads to a structural changes in the energy sector. Energy conservation in the consumer sectors together with rapid utilization of clean energy sources provide the most economical and reliable option for preserving the environment. When the emission of CO_2, SO_2 and NO_x is controlled, so that the per capita emission of the pollutants in the I.R. of Iran in 2021 would not exceed the present level of per capita emission rate in Japan, it is realized that energy saving in the consumer sectors by 5.8% in 1999 and 16.8% in 2021 would be necessary. Such a measures would provide the most economical means of environmental protection. It would be possible to reduce the emissions of CO_2, NO_x and SO_2 in the year 2021 by an amount of 72.4 million ton, 118.1 kt/a and 559.2 kt/a respectively, compared with the emission level in the Reference case of without pollution control.

9. Energy market in the I.R. of Iran has been distorted extensively. Subsidization of energy is a major obstacle of rational use of energy. Energy carriers are supplied with prices that are much below their marginal costs. This situation has led to rapid increase in energy consumption and depletion of exhaustible energy resources is accelerated.

   Energy is mainly subsidized to help the poor, utilize the relative advantages of the economic system and control the inflation. But the analysis of the real situation indicates that delivery of energy with prices lower than the marginal cost of production and supply of energy carriers has hindered the realization of the aforementioned objectives. Economic resources are invisibly allocated to households and economic sectors through energy subsidization and the basic criteria for the distribution of the resources has been the level of energy consumption. Social groups and economic sectors that consume more of high quality energy carrier, benefit the most from the energy subsidization. The fact is that the invisible allocation of resources through energy subsidization can not be considered as a rational policy of more equitable distribution of income, which households with a better living condition and accessibility to modern household appliances have a higher share in receiving invisible income through energy subsidization than poor households; Supply of energy with prices much lower than its marginal cost distorts the competition between production factors (labour and capital) and energy. In this case, appliances and processes with low efficiency and low quality, that have high operation cost but low capital cost, will be preferred. Outcome of this situation would be promotion of high energy consumption and domestic production of equipment and machinery with low quality. As a consequence of this situation, potentials of the competitiveness of domestic products in the international market will be limited. Subsidization of energy results in misallocation of economic resources, reduction in potentials of the competitiveness of the economic system, inappropriate distribution of economic resources among the households and limitation of economic potentials of the country.

10. Establishing optimal balance of energy demand and supply and restructuring the energy management in the country makes it necessary to develop energy policies on the basis of a

better and deep understanding of energy issues of the country and comprehensive evaluation of energy production and consumption patterns. For this purpose, organization of goal oriented energy R&D activities is considered as a necessary and urgent step.

Further development of energy studies in the area of energy information system, energy demand management, optimization of energy supply system, optimal utilization of energy resources, and a better understanding of the mechanisms of energy pricing and its determinants in the world energy market are important elements of energy studies that ought to be considered seriously.

7.2 A Priority Plan
-- For Promoting Rational Use of Energy and Energy Conservation --

The main results of our collaborative studies strongly indicate that promoting the rational use of energy and energy conservation is one of the most important policies in I. R. Iran, as mentioned above. Concrete policies to encaurage energy conservation in the social and economic sectors are essential.

However, data and information relevant for adopting and implementing the policies are insufficient so that reliable and realistic measures can not easily be drawn up at this moment. Consequently, more detailed studies to promote rational use of energy and energy conservation are necessary to formulate future energy policy in I. R. Iran.

Our suggestions on the studies are as follows:

The main subject of the study is to establish a basis for the rational use of energy at micro level in order to provide detailed information for energy management in the process of modernization of the economy in the Islamic Republic of Iran. The following items will be given due consideration in the course of this study.

a) Establishment of Energy Data Base for Studying Rational Use of Energy

The different production and service processes will be analyzed and studied for representing the flow of energy in each process and/or sector, and a measurement of the energy flow in different processes would be carried out, in order to establish a reliable database for micro analysis of energy conservation and the rational use of energy. Then, it should lead to identifying the technical and economic potentials of saving energy, and to study the appropriate measures for optimal utilization of the potentials in the social and economic sector in the Islamic Republic of Iran.

b) Study of Measures for Energy Conservation

- Reduction of Unnecessary Consumption of Energy

  Unnecessary consumption of energy is the amount of consumed energy carriers, which does not affect the production of goods and services. It is intended to examine the usage of energy in different processes and identify the measures that could prevent the unnecessary consumption of energy carriers.

- Improvement of the Effectivity

The energy efficiency of the production and service sectors will be studied, and the effect of maintenance and the state of the technologies on the use of energy shall be examined. On the basis of this analysis, the measures for improving the maintenance of the systems and replacement of the obsolete technologies will be identified.

- Recovery of Energy

  Recovery of heat in different processes and utilization of the recovered energy will be studied. Technical and economical potentials of this alternative will then be evaluated.

- Electric and Gas Load Management

  Electric and gas load management in the economic sectors will be studied in detail and measures contributing to the peak shaving and the more efficient utilization of the capacities of the power plants and gas supply facilities shall be evaluated.

c) Estimates of Energy Conservation Potentials

- Estimates of Technical Potentials

  The energy intensity, i.e. amount of energy used for a unit of production in economic sectors, will be studied, and the results will be compared with the energy intensity of similar processes in Japan and other industrialized countries.

- Estimates of Economic Potentials and Impacts on Labor Productivity

  The investment cost for implementing the measures of energy saving will be examined, and the impact of energy conservation and rational utilization of energy on the labor productivity will be analyzed

- Optimization of Energy Intensity

  Thereafter, conclusion will be drawn on the optimization of the energy intensity with identifying the policy options and instruments for development of the country.

d) Preliminary study of Appropriate Policies

  On the basis of this project, the framework of policies for energy management will be outlined. Thereby, the appropriate measures for energy conservation will be described, and the main features of the programs for encouraging energy conservation, energy pricing scheme, modernization of the technologies and improvement of institutional arrangements will be studied.

7.3 "Action Plan"
-- Basis for Sustainable Implementation of the Plan --

It can be suggested that the "Action Plan" should be considered as the basis for sustainable implementation of the plan for promoting rational use of energy and energy conservation even in advance of making the detailed studies mentioned on 7.2 above. Tentative and preliminary studies show that several aspect including policy, institutional, financial, and human ones should be taken into consideration.

a) Basic policy direction should be considered, formulated, and declared in order to lead people to be willing to promote energy savings. Pricing policy is one of policies indispensable to promoting rational use of energy and energy conservation and taxation is another to be considered seriously. Research, development, and demonstration (R. D. & D.) policy also should be formulated for future technology for promoting energy conservation.

b) Institutional Arrangements

Identification of the measures for energy demand management will be followed by the analysis of the management system in the energy sector. Thereafter, development of institutional infrastructure for implementation of rational use of energy will be examined.

(i) Establishment of Energy Information System

In the process of the development of the project, the necessary data and information for the analysis of energy management data and information system will then provide a scientific basis for promoting rational use of energy and helping to evaluate various policy options of energy management in the Islamic Republic of Iran.

(ii) Development of Educational Infrastructure for Training Energy Managers

Implementation of the measures for energy conservation and rational use of energy is conditioned by the fact that well trained energy managers are employed in different sectors. To this end, it is intended to establish a department within IRPD where trainings of both classroom and practical skills on energy management will be employed.

(c) Financing Arrangements

Financial supports by the government are necessary for promoting energy savings, including providing companies and others with long-term and low interest money. Tax credit as well as depreciation allowance have also the effect of financial aid to those who will try to promote energy savings. A special fund can be one of devices which will finance such financial supports.

(d) Human Development

Human development is also necessary for promoting rational use of energy and energy conservation, including the way mentioned b) - (ii) above. Effective and sustainable implementation of the policy needs such sorts of human resources as researchers in institutes, administrators in the governments, managers and workers in companies or factories who are well trained and motivated for energy conservation.

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