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. 2 Main Report

MARCH 1994

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

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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

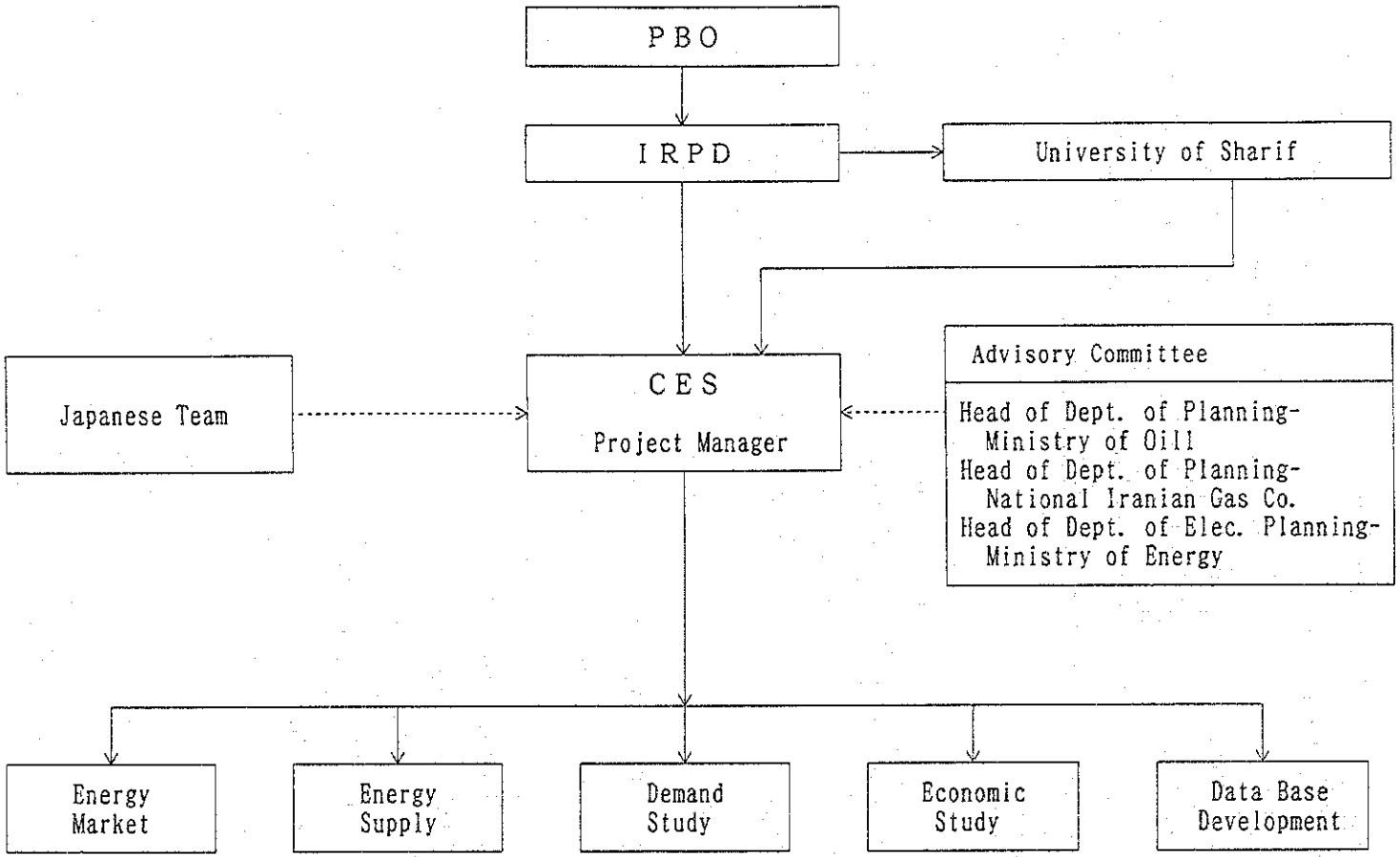


Fig. 1.1 Structure of the Organization of Comprehensive Energy Studies (CES)

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

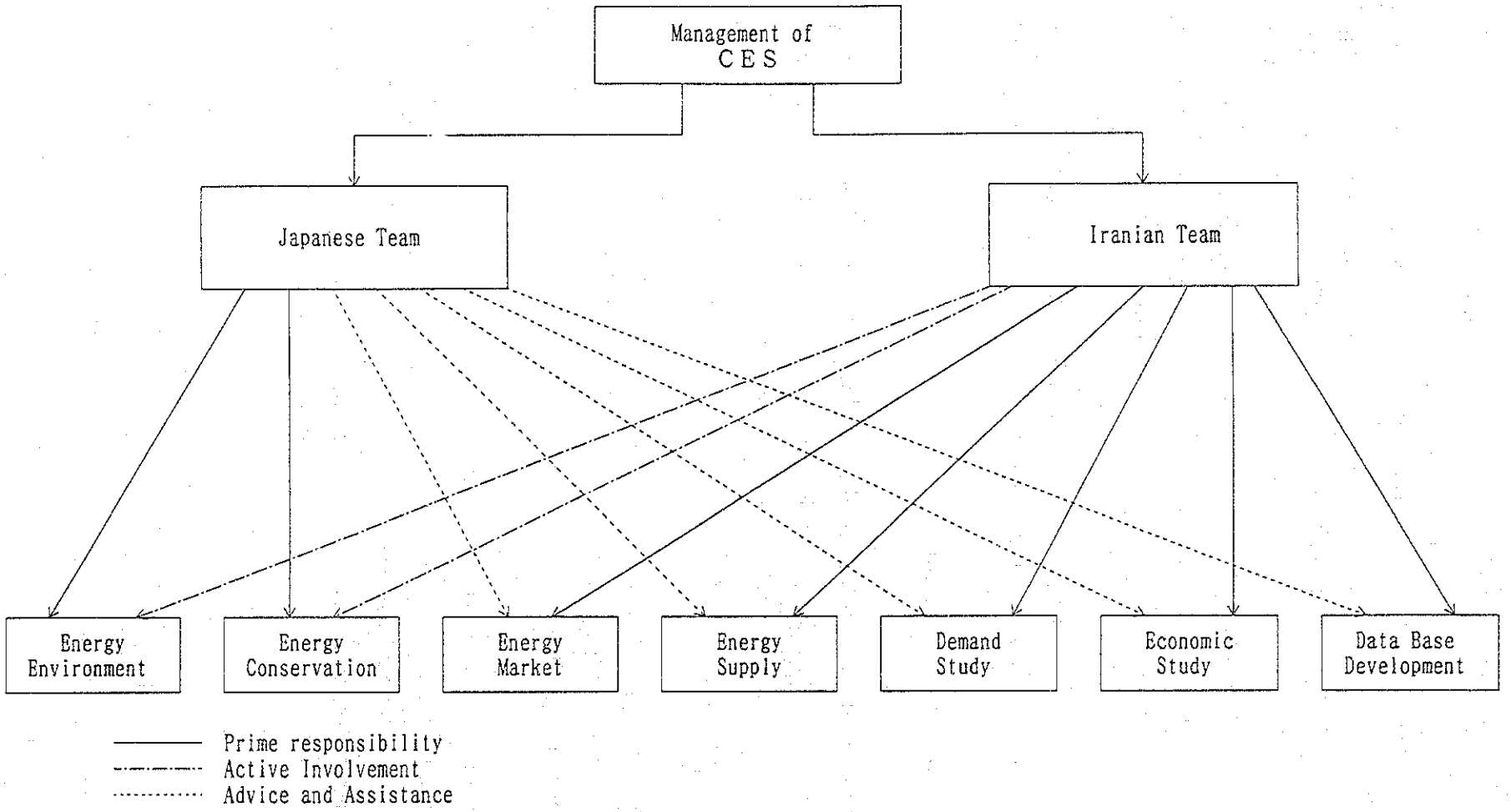


Fig. 1.2 Division of Work between Iranian and Japanese teams

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 Introduction

Economic development in the Islamic Republic of Iran is dependent on the energy export and the changes in the world energy market. Export of energy is an important source of foreign exchange revenue and oil revenue contributes greatly to the government expenditure.

Economic development is associated with the changes in the production processes, production technologies and living standard of the population. Structural changes in the social and economic system leads to the mechanization of production processes, which is followed by increased labor productivity. As a consequence of these changes, energy intensity in the economic and social sectors rises.

Interaction between energy sector and economic growth has been developed extensively in the last three decades, and as a result of that, sustainable development of the economy is conditioned by solving major energy-economy issues. The most important energy-economy issues of the Islamic Republic of Iran may be Summarized as follows:

(1) Impact of changes in world energy market

Changes in the world energy demand results either in an increased or decreased export of energy carriers. Reduction in the oil price leads, on the other hand, to decreased marginal energy revenue. Variation of energy export or energy price influence the foreign exchange revenue of the country, and it has tremendous impact on the import of consumer and capital goods. A fall in import of capital and intermediate goods reduces the activity level in the economic sectors. Production of goods in the domestic market is then disturbed.

(2) Dependence of the economic growth on oil revenue

Dependency of the foreign exchange revenue and the government budget on the development of the oil export and exhaustibility of fossil energy resources is an important issue of the energy

sector. With the development of economy and improvement of the living standard of the population, domestic consumption of energy increases, and allocation of a large share of oil reserves to domestic use becomes necessary. Dependency of the economic growth on the oil revenue requires that the export of oil develops in such a way that the demand for foreign currency is met. Other aspect of this situation is the exhaustibility of oil reserves. Competition between domestic energy consumption and export of the fossil energy carrie's, as a source of foreign exchange earnings, is intensified by the depletion of oil reserves. Hence, shadow prices of oil in underground increases. Optimal allocation of exhaustible energy resources in the process of economic development and estimation of the shadow prices of depletable energy carriers are considered as important energy issue of the country.

(3) Impact of social and economical development on the energy sector

An important aspect of energy-economy interaction is the development of energy demand in socio-economic sectors. Growth of production, changes in the structure of the economic system and improvement of the living condition of the households are major determinants of energy demand. A thorough and detailed analysis of energy demand in social and economical sectors requires that data on the development of production level and share of economic sectors at the aggregated level is available. Such information can reliably be obtained through the analysis of the allocation of natural exhaustible resources in the process of the development of the economy. Importance of optimal allocation of exhaustible energy resources to the domestic consumption and energy export necessitates that utilization of energy sources is studied in the framework of economic development. The aim of such study is to provide information on the energy export required for a sustainable development, economic growth, changes in the structure of the economy, and the shadow prices of exhaustible energy resources. To achieve the aforementioned objectives, a model of "Optimal utilization of Exhaustible Energy Resources" has been developed in the course of comprehensive energy development studies. This model is included in the set of energy models that are used for comprehensive energy studies.

Inclusion of a macro- economic model on the "optimal utilization of exhaustible energy resources" in the set of energy models provides a means of achieving the following tasks:

a) Evaluation of the optimal allocation of fossil energy resources between domestic consumption

and export is made possible.

b) Macro-economic model enables the estimation of the trend of economic growth and changes in the structure of the economic system.

c) The developed macro-economic model provides a means of evaluating the development of the shadow prices of exhaustible energy resources. The macro-economic model for the evaluation of the optimal allocation of energy resources has been applied in studying the economic development.

Application of this model and the most important results that have obtained are being reported. In the present report, the economic development and export of energy is reviewed. In this section the development of production and expenditure of gross domestic product (GDP) is summarized. This part of the report is them followed by a brief description of the basic structure of the model. The last section is then devoted to the presentation of the major results of the analysis of the macro-economic development.

2.2 Economic Development and Export of Energy

2.2.1 Trend of Production, Consumption, and Investment

Development of economy has experienced a gradual rise of production level in the period 1959-78 and total gross domestic product (GDP) in constant prices of 1982 increased from 2,000 Mrd.Rs/a in 1959 to 11,000 Mrd.Rs/a in the last year before the Islamic Revolution (See Figure 2.1). In this period, the foreign trade balance had remained positive and it has contributed to the growth of GDP. Positive foreign trade balance was largely due to the increase in oil revenue, which was originated from rise of oil price and its export level.

After the Islamic Revolution in 1979, the trend of GDP has changed and ups-and-downs are observed frequently. Apart from political upheavals and the impact of Iraq war, the decrease in gross domestic product (GDP) per capita was caused by the lower level of oil export and decline of oil price in the international energy market. The policy of the government after the Islamic Revolution has been to reduce the energy export and to respect the agreements in the OPEC, with regard to the production quotas.

Private consumption has constituted a major part of the gross domestic product. The total private consumption increased from 1,900 Mrd.Rs/a in 1959 to 7,500 Mrd.Rs/a in 1977, in constant prices of 1982. In the last decade, the private consumption has followed the trend of gross domestic product.

The share of investment in GDP (in constant prices) was at a low level of 5% to 10% in the period 1959-1973. After this period the investment level increased and its share in the GDP has been changing in the range of 15% to 30%. This observation shows that
increase in oil revenue has contributed to the investment level.

2.2.2 Production Sectors

Contribution of economic sectors to the gross domestic product (GDP) has been changing in the last three decades (See Figure 2.2). the share of industry in GDP has increased from a% in 1959

Fig. 2.1: Trend of Private Consumption, Total Investment, Balance of foreign Trade & GDP (at Constant Prices of 1361)

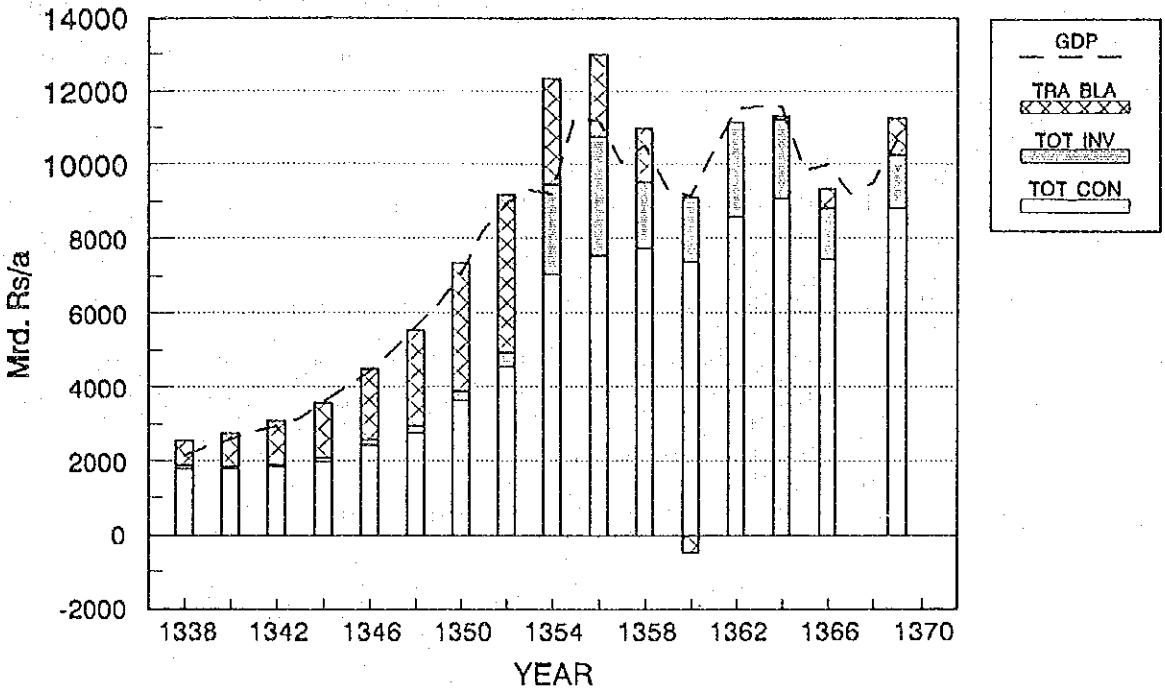
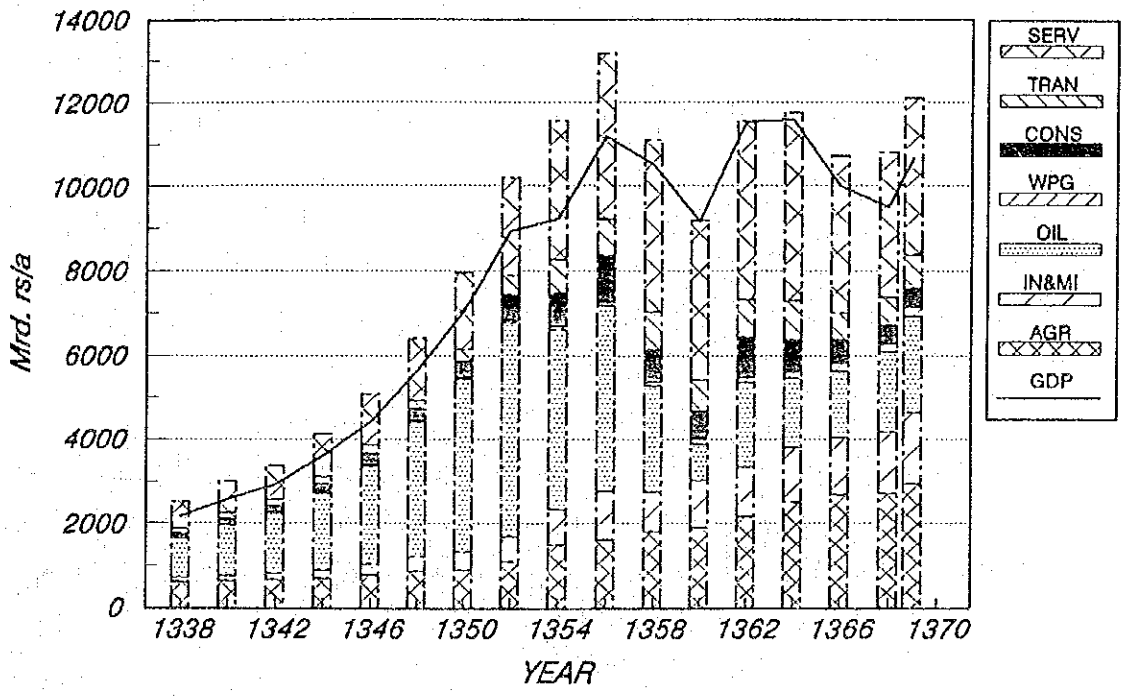


Fig. 2.2: GDP & Value Added of 8 Sectors (at Constant Prices of 1361)



to b% in 1977 and has remained in the range of c-d% since them. A major feature of the economic system is the high share of oil sector in GDP. The share of oil in GDP was a% in 1959 which increased to b% in 1977. Rapid rise of share of oil in GDP was due to higher oil prices in the world energy market. After the Islamic Revolution in 1979 the share of oil in GDP declined to c% in 1981 and d% in 1990.

The characteristics of economic development in the last decade is that share of agriculture in GDP has increased from a% in 1981 to b% in 1990. In this periods production in agriculture has largely contributed to the development of GDP. Historical observations depicted in Fig 2.2 show that the changing trend of GDP in the period 1977-1990 was dominated by the variation in the activity level of oil sector. Lower value-added of oil sector in 1981 caused a decline of GDP and its improvement in 1983 and 1984 was due to the increased oil revenue in that period. Stagnation of GDP in the period of 1985-89 was caused by the intensification of Iraqi›s war.

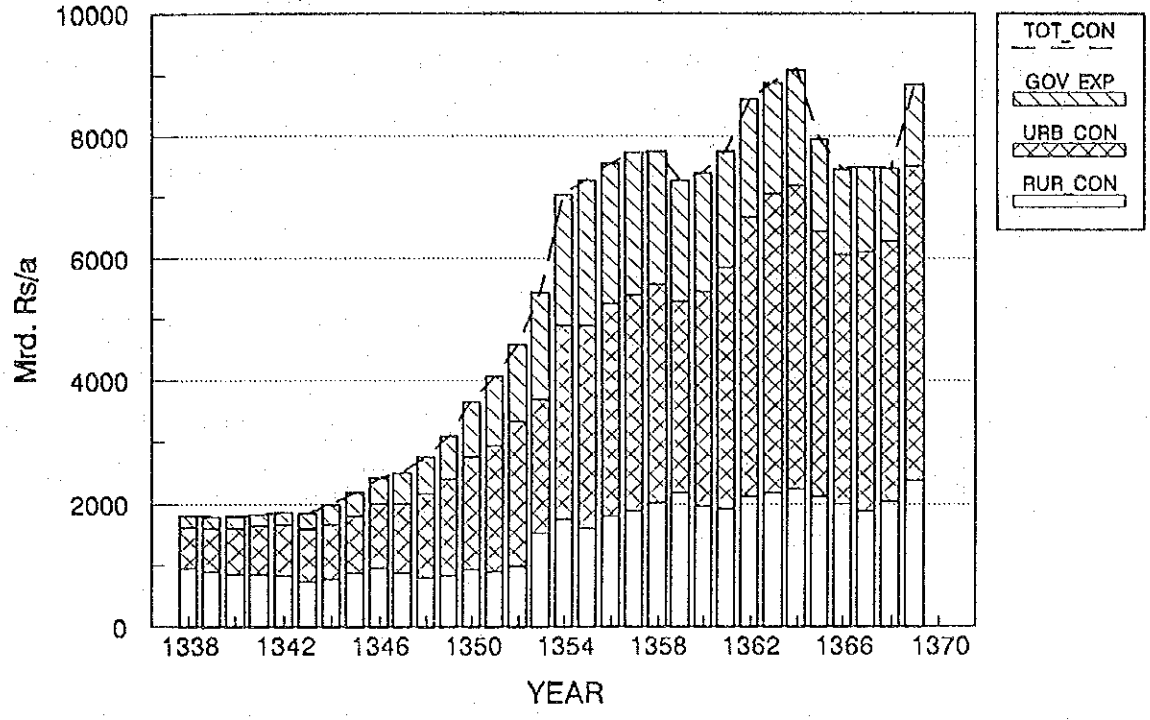
2.2.3 Production and Consumption

Private consumption in urban areas has increased from 677.2 Mrd. Rs/a in 1959 to 3449.5 Mrd.Rs/a in 1977 (See Figure 2.3). The increasing trend of private consumption in urban areas continued in the last decade and reached to 5128.9 Mrd.Rs/a in 1990. Private consumption in rural areas has been changing very slowly. In the period 1959-73, it remained almost constant and then started to increase gradually and reached to 2252.4 Mrd.Rs//a in 1985. Rural households with a share of 40% in total population in 1990, had used only 30% of total private consumption.

Government expenditure has risen from 173.5 Mrd.Rs/a in 1959 to 2379.4 Mrd.Rs/a in 1976. In the period 1973-85, when the oil revenue was at a higher level, the government expenditure constituted a considerable share of total expenditure. With decrease of oil revenue, government expenditure stagnated.

Comparison of total expenditure and gross domestic product indicates that the share of private consumption in GDP has been considerable. This feature of the economy has serious consequences in the process of economic development. The difference between GDP and value-added of oil sector represents the gross domestic product which has its origin in the production sectors of the economy

Fig. 2.3: Trend of Consumption in Rural & Urban Areas, Government Expenditure & Total Final Consumption (at Constant Prices of 1361)



that produce goods for domestic consumption and exporting them. If the total value-added of non-oil sector is represented by GRP (Gross Regional product), it will be observed that the total expenditure, i.e, sum of private and public expenditure, is approximately equal to GRP (See Figure 2.4). It states that the net production of the economic sector has been consumed and they had seldom contributed to the expansion of the production processes. In other words, the investment and capital accumulation in the last three decades has had its bases in the oil revenue. In total, the economic sectors were not able to support their expansion.

A sustainable development of the economy requires that the productive capabilities in different sectors is expanded and part of production is allocated to capital formation. If the achievement of such an objective is pursued together with maintaining the present level of living standard, an improvement of the effectiveness of production factors, enhancement of production efficiency, and optimization of consumption pattern will be required.

2.2.4 Investment

Share of investment in gross domestic product (GDP) reached to the highest level of around 30% in 1976, when the export of oil was at the maximum level in the last three decades (See Figure 2.5). It has then declined to less than 15% in 1990. In the course of last one and half decades, it reached to a local maximum of about 22% in 1983, when the oil revenue was increased due to a rise in the energy prices in the world market. The trend of the share of total investment in GDP shows that the energy export has contributed to the capital accumulation and has been the major source of the development.

Decomposition of total investment into its elements indicates that investment in construction and building has constituted a considerable share of total investment (See Figure 2.6). The share of investment in building has been a% in 1976 and it has remained at higher level since then.

2.2.5 Foreign Trade

Balance of trade in the last three decades has been positive in general (See Figure 2.7). This situation has been the outcome of rapidly increased oil revenue, which was due to rising energy

Fig. 2.4: GDP, GRP, Government Expenditure, Urban & Rural Consumption (at Constant Price of 1361)

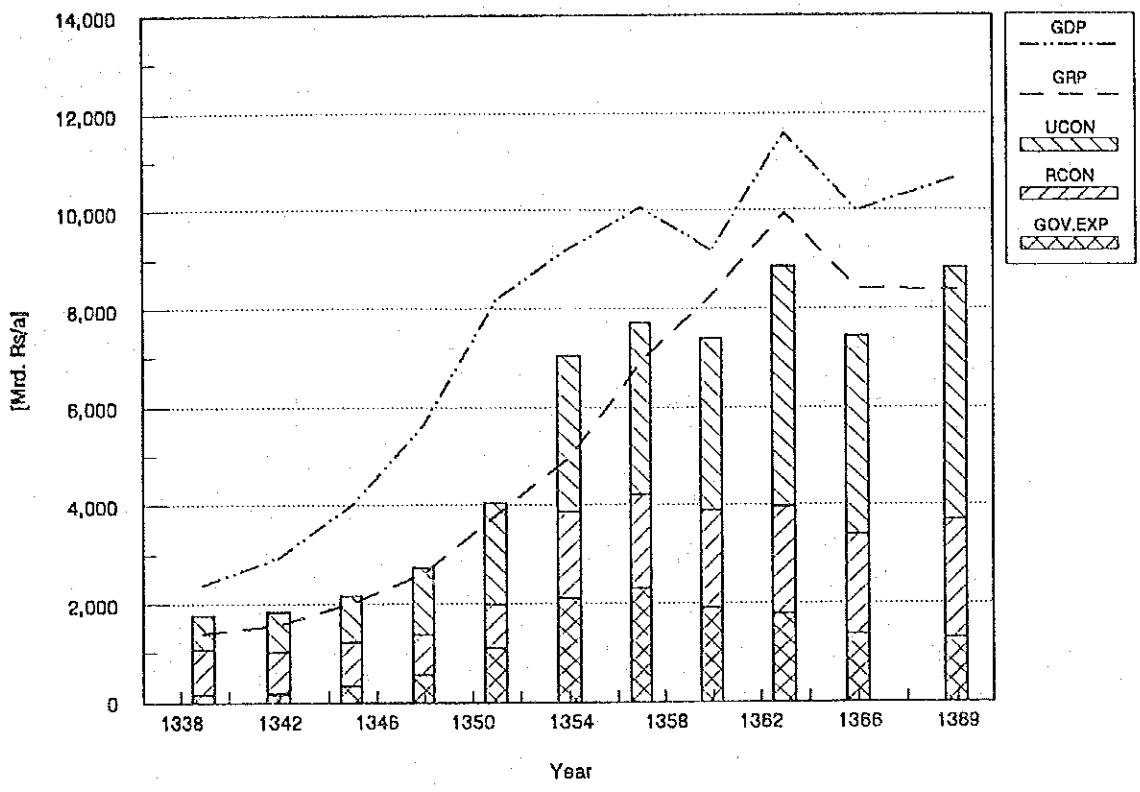


Fig. 2.5: Ratio of Oil Revenue to GDP (at Constant Prices of 1361)

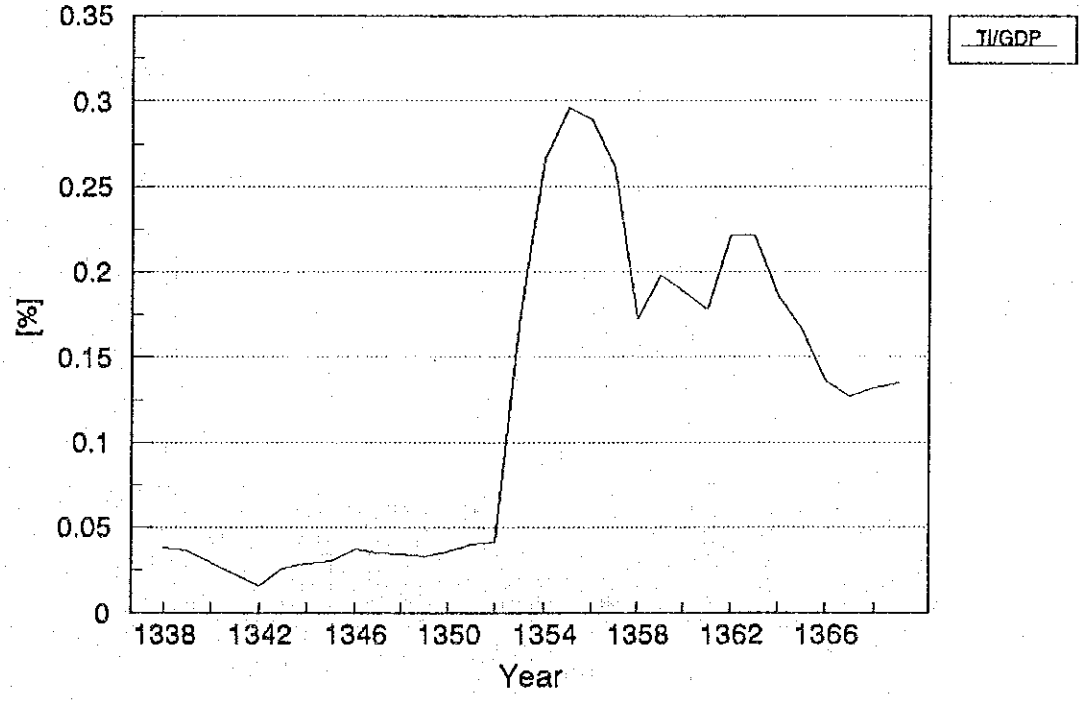


Fig. 2.6: *Trend of Investment in Construction & Machinery and Total Investment (at Constant Prices of 1361)*

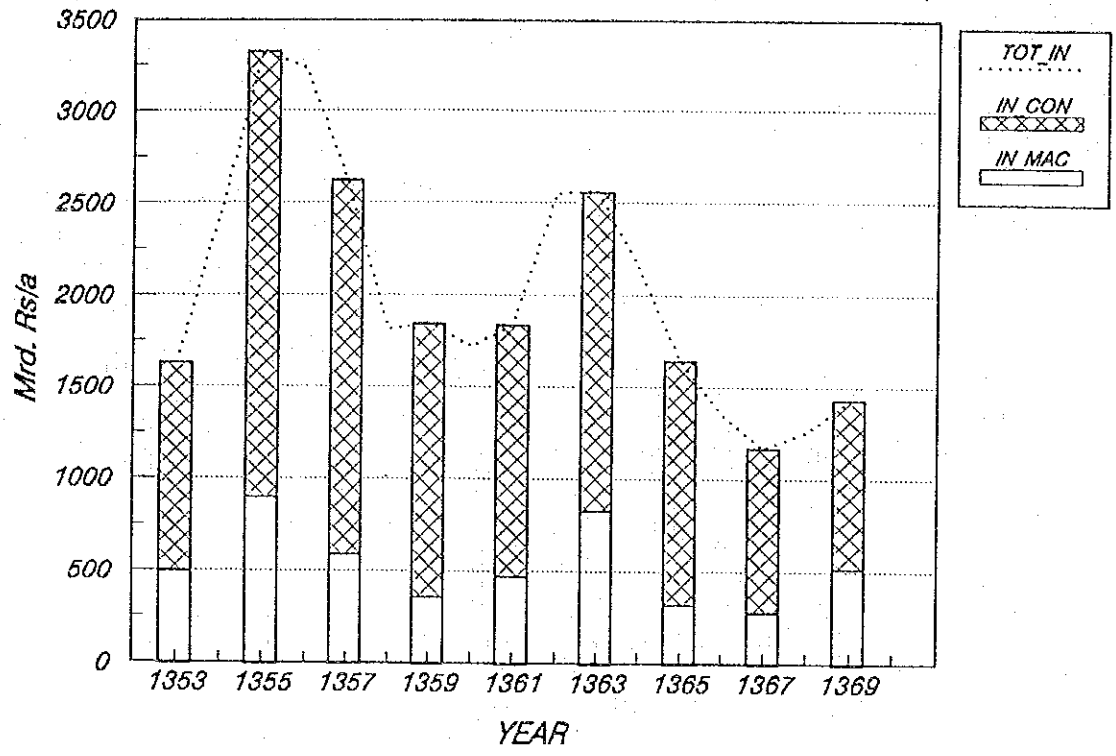
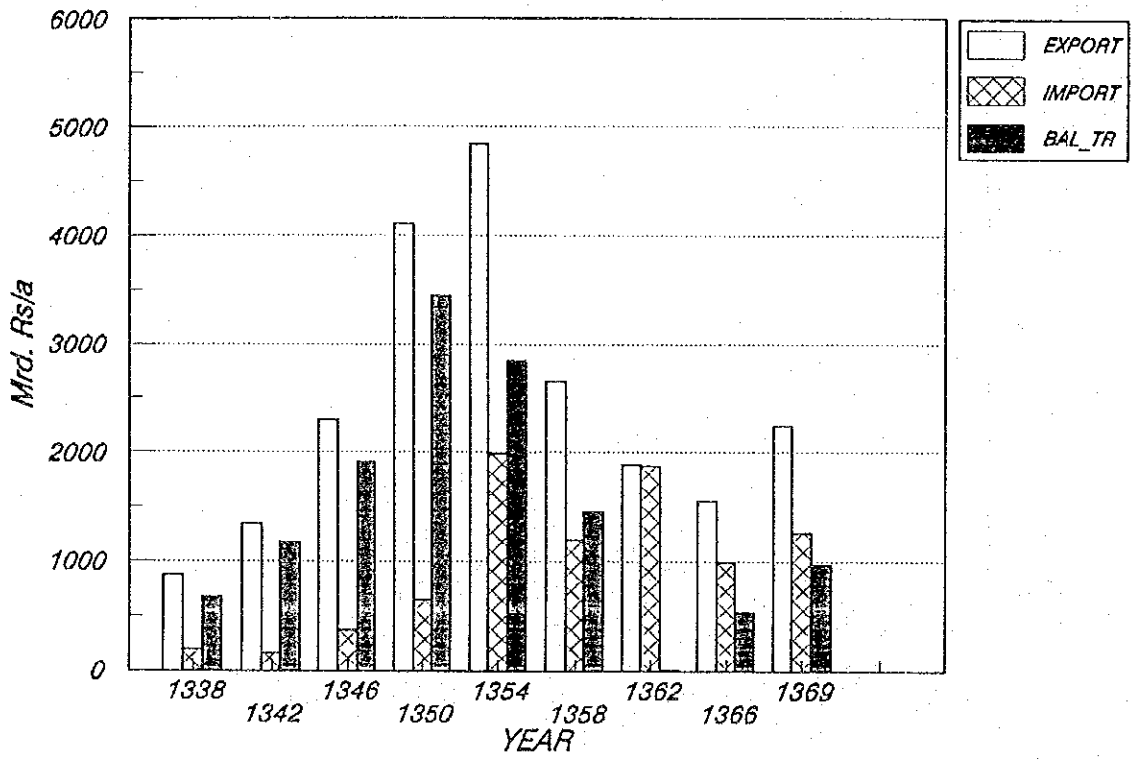


Fig. 2.7: *Export, Import & Balance Foreign Trade (at Constant Price of 1361)*

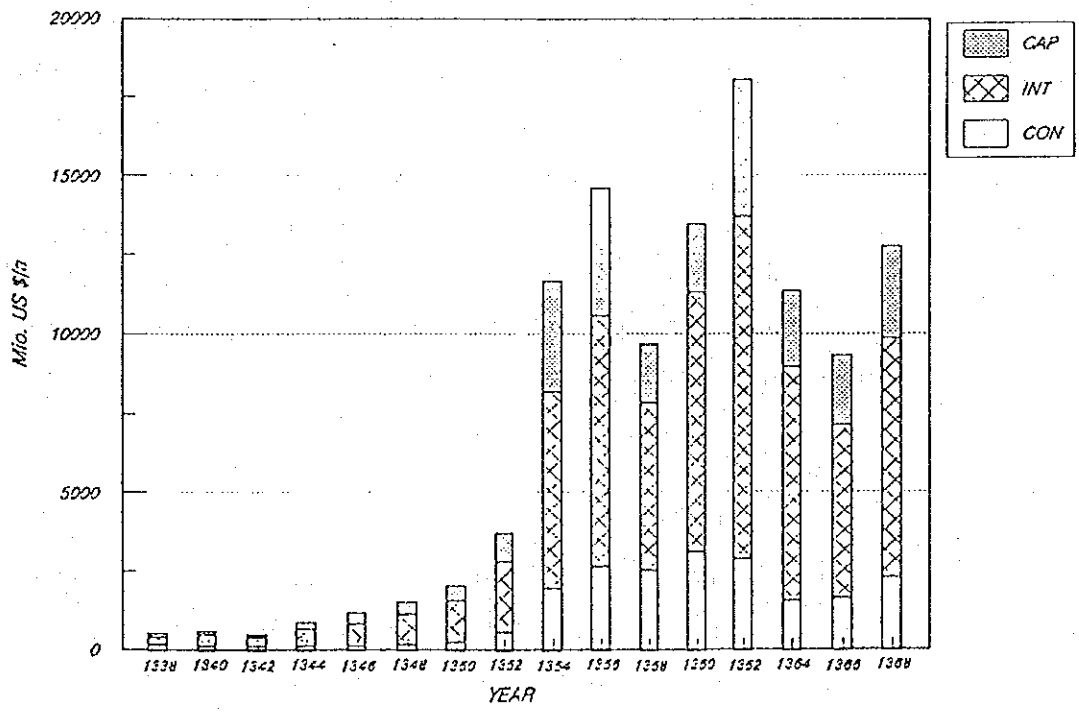


prices in the international energy market. With the fall of oil revenue, the positive foreign trade balance has been declined in the last decade.

Increased foreign exchange reserve has motivated a rapidly rising demand for imported goods in the period 1975 - 89 (See Figure 2.8). Composition of the imported goods indicated that import of intermediate goods has constituted a major element of foreign trade.

This situation shows, on the other hand, that the productive sectors of the economy are highly dependent on the international markets and changes in the world economy do have tremendous impact on the economic growth.

Fig. 2.8: Import of Consumer, Intermediate and Capital Goods



2.3 Model for Analysis of the Economic Development

2.3.1 Economic Issues

A review of economic development in the last section reveals that the economic growth is highly dependent on the oil revenue. Continuation of production process is conditioned by the availability of the intermediate goods, which is mainly imported. Expansion of production capacities has been supported by the income from the energy export in the last three decades. Any structural and technological changes in the production processes can be achieved in the present situation, when a source of income outside the economic sectors is available. Therefore, export of energy provides an important source of economic development. Utilization of oil revenues for maintaining a sustainable development and reducing the dependency of the economy on the export of oil is an important issue of the economic development.

Oil is a source of energy, which contributes to the domestic energy consumption, and its export is required for sustaining the development of the economy. Increasing energy consumption together with export of oil leads to rapid depletion of energy reserves. As a consequence of this situation, the shadow price of exhaustible energy resources increases. Shadow price of energy indicates the scarcity of the resources and signals out the importance of the optimal utilization of oil and gas in the process of economic development. Shadow price of energy sources provides information on appropriate allocation of oil and gas for domestic consumption and export. Therefore, evaluation of the shadow price of energy sources is vital task of energy planning.

2.3.2 Outline of the Model

To study the optimal utilization of energy resources, a macro economic model has been developed. The macro-economic model is based on the optimal control methods and it helps to identify the optimal path of the development of the main economic indicators.

Development of population and its distribution in rural and urban areas are exogenous parameters of the model. Based on the growth of population, the labor supply is estimated. The private consumption in rural and urban areas are distinguished from each other and its maximization

during the planning horizon is considered. Maximization of private consumption generates final demand for goods.

Final demand for goods is met partly through domestic production, and partly via importation of required commodities. Development of demand for final goods necessitates the expansion of production sectors and stimulates demand for investment goods. Similarly, the demand for investment goods is met through domestic production and import.

Goods produced in the economic sectors are used for supplying the consumers with final consumption, intermediate and capital goods. Part of the produced commodities in the domestic market are also exported. Export of goods consists of export of oil and gas and non-oil commodities. Export of non-oil commodities is considered as a function of production in different economic sectors. The balance between import and export of goods is taken as the balance of foreign trade. Foreign exchange reserve is then related to the balance of trade through a dynamic inventory equation.

Fossil energy resources are used both for domestic consumption and export. The trend of domestic energy consumption is considered as exogenous variable in the model and export is taken as indigenous variable. The fossil energy reserves in each period are evaluated through a dynamic equation and it is related to the export, consumption level in each period and reserves in the previous period.

The sum of total private and public consumption together with investment and balance of foreign trade is then taken as equal to the total gross domestic product in each period.

The interrelationships between consumption, production, investment, population, import and export in each period define a set of feasible options of economic development during the planning horizon. In order to select the most appropriate feasible option, an objective function has been defined as a criterion. The objective function is taken as total private consumption plus the total capital stock and value of energy reserves at the end of planning horizon. The goal of this study was to maximize the sum of discounted value of the objective function over the planning horizon.

2.4 Economic Development

Economic development has been studied with the help of the macro-economic model. The objective of this study was to obtain information on the general trend of macro-economic indicators and to identify the impact of various exogenous parameters of the model on the economic development. To achieve this objective, a reference scenario has been defined. The reference scenario does not mean that the development paths in this case will be highly probable, but rather it presents a scale for comparing trend of economic growth in different condition. Comparison of the results of the model in different cases will provide information on the extent of the impact of various energy policies on the economic development.

In the next part of this section, the framework of the reference scenario is defined and trend of major exogenous variables is presented. Description of scenario is then followed by the presentation of the basic results of the reference scenario. Then, the impact of changes in exogenous parameters on the economic development is discussed.

2.4.1 Reference Scenario

The most important exogenous parameters of the models are population, price of oil in the world energy market, and domestic consumption of oil, gas and electricity. Figure 2.9 shows the trend of total and urban population growth. Total population rises from a mio person in 1990 to b mio.persons in 2021. The reference scenario for the price of oil in the world market and domestic consumption of oil are depicted in Figure 2.10. Price of oil gradually increases from $16.7/bl in 1991 to $25/bl in 2021 in constant prices of 1991. Domestic consumption of oil goes up.

Figures 2.11 and 2.12 show the assumed future trend of domestic consumption of electricity and natural gas and their rate of growth respectively. Consumption of electricity increases from 50 GWh/a in 1989 to 400 GWh/a in 2021 and demand for natural gas rises from 50 Mrd.m^3/a in 1989 to 1300 Mrd.m^3/a in year 2021.

Fig. 2.9: Total & Urban population

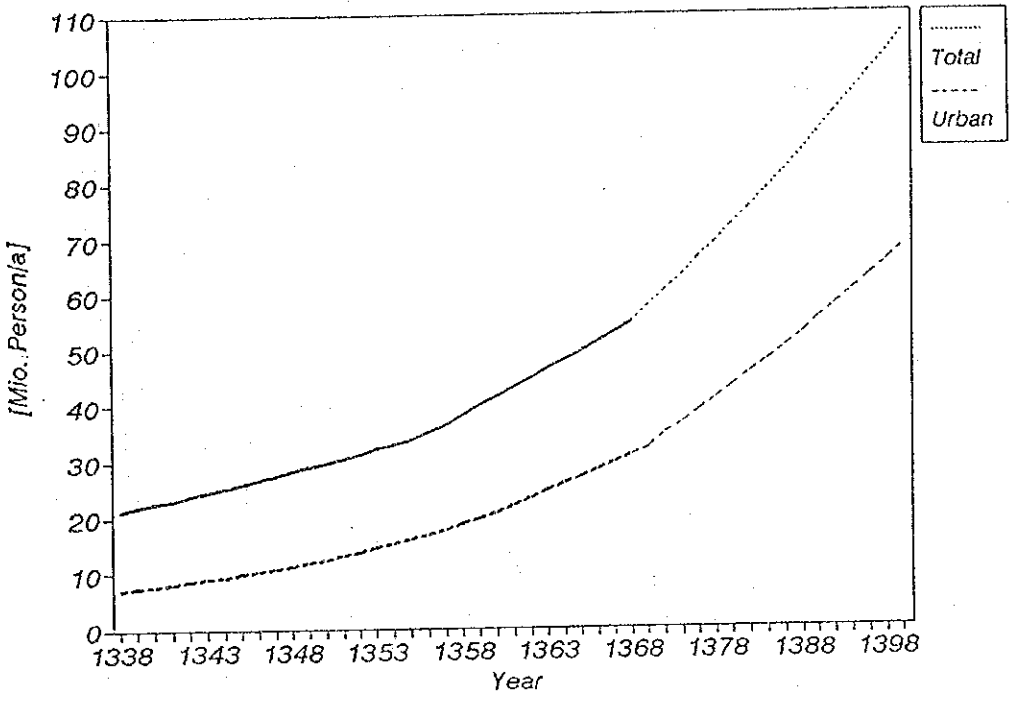


Fig.2.10 :Crude Oil Price in the World Market & Domestic cons. of Oil

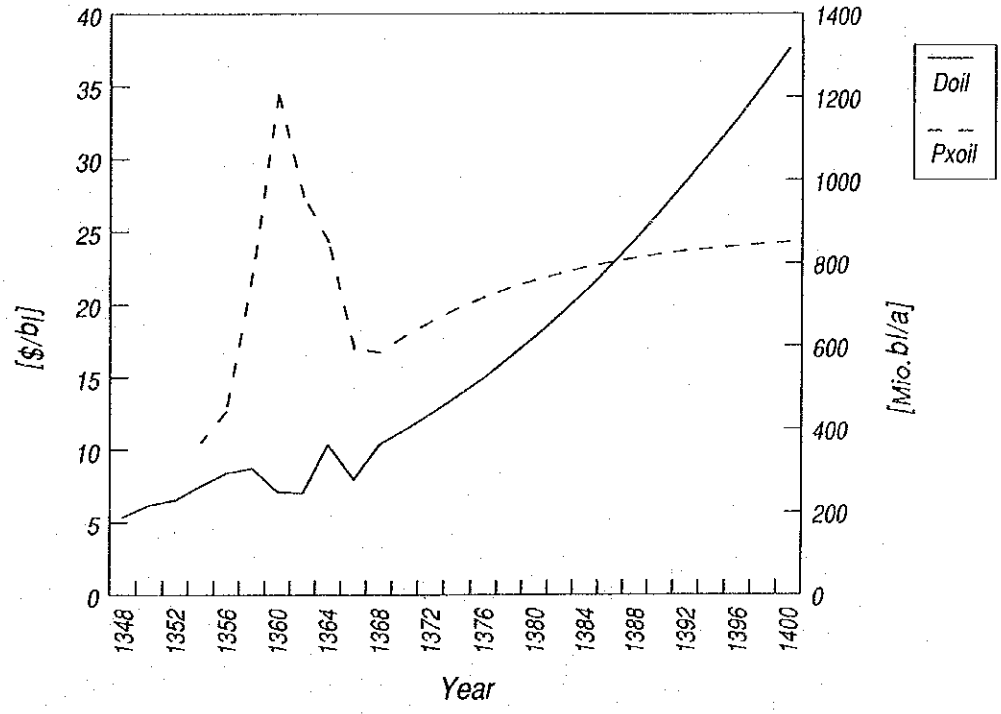


Fig. 2.11 Consumption of Electricity and Natural Gas Consumption

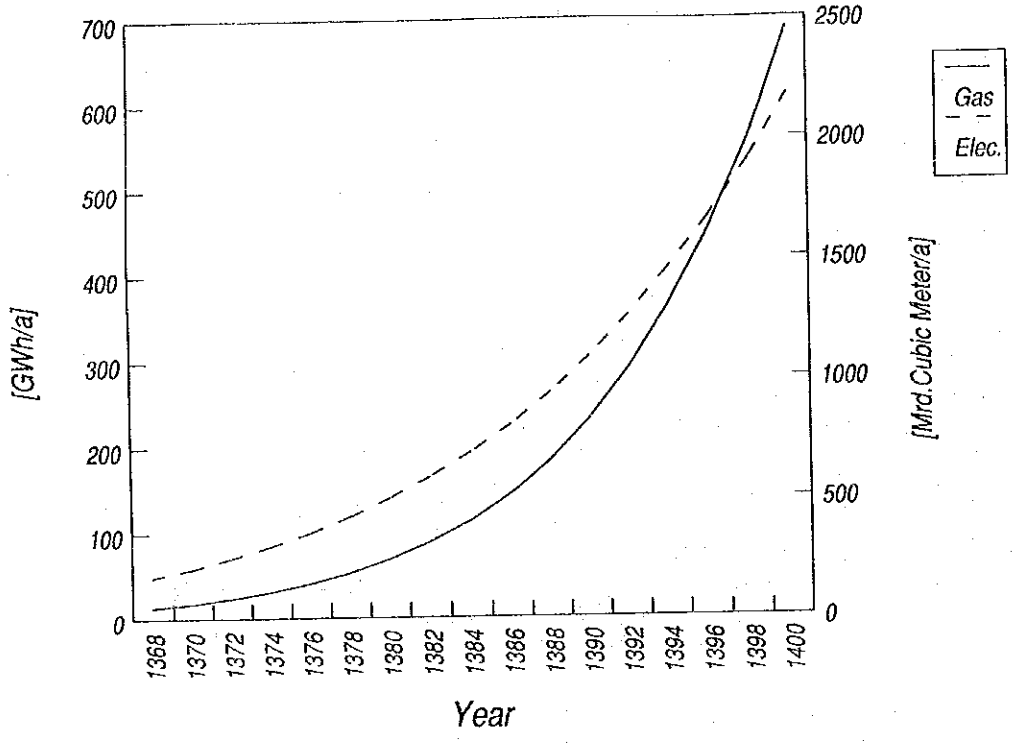
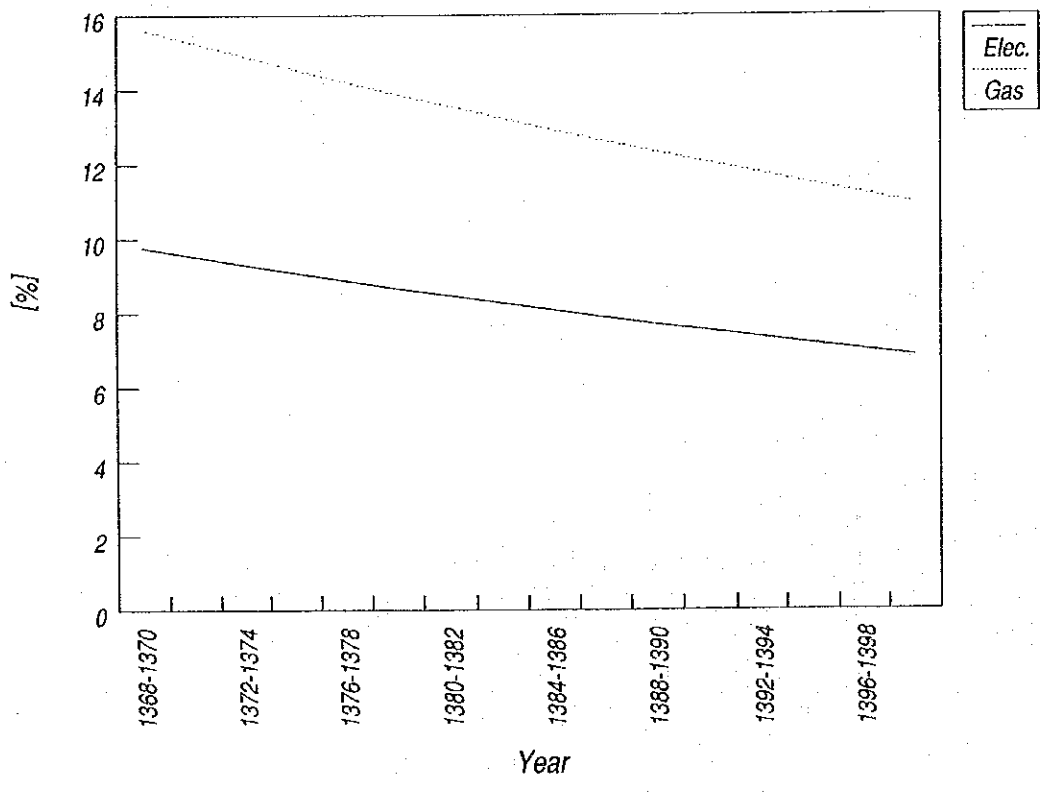


Fig. 2.12 Rate of Increase of Electricity & Gas Consumption



2.4.2 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 2.13. 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.

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 2.14).

Capital formation rises very rapidly in the next three decades. Total capital stock accumulates from 19000 Mrd.Rs in 1989 to 50000 Mrd.Rs in 2021. It can be observed in Figure 2.15 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 3500 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 2.16). 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 2.17). Export of oil increases gradually and it remains at the level of about 2000 Mrd.Rs/a after year 2000.

Figure 2.18 shows the development of the shadows prices of crude oil and foreign currency. Shadow price of oil rises from $S/bl in 1991 and it reaches a level of $40/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

Fig.2.13: Development of GDP and GDP per Capita

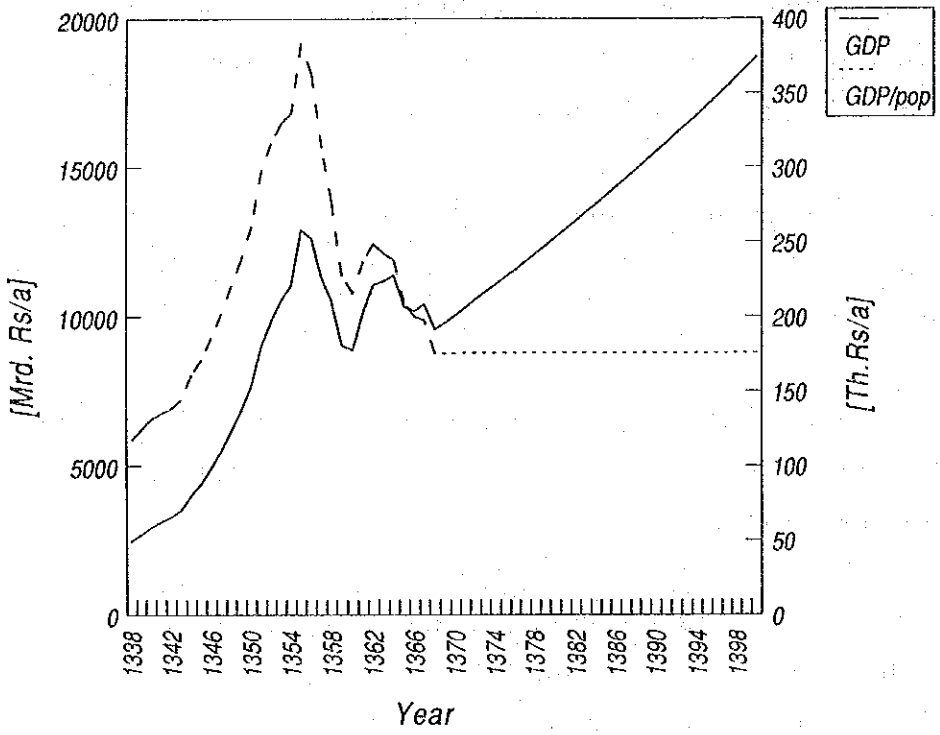


Fig. 2.14: Consumption of Urban, Rural, and Government Expenditure

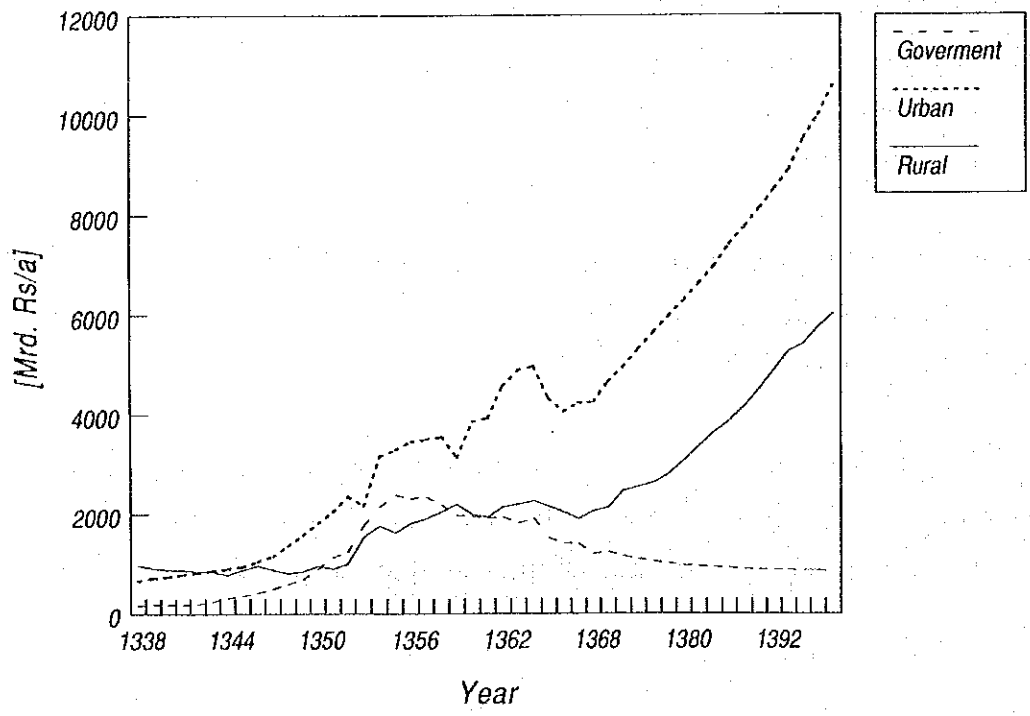


Fig.2.15:Development of Capital Stock and Investment

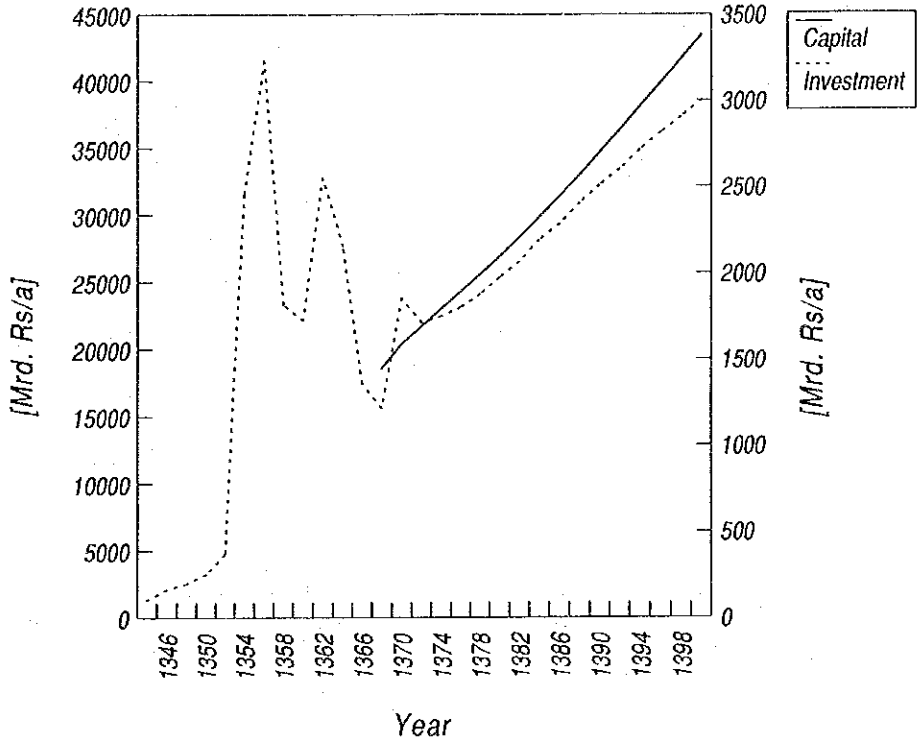


Fig.2.16 :Import of Consumer, Intermediate & Capital Goods

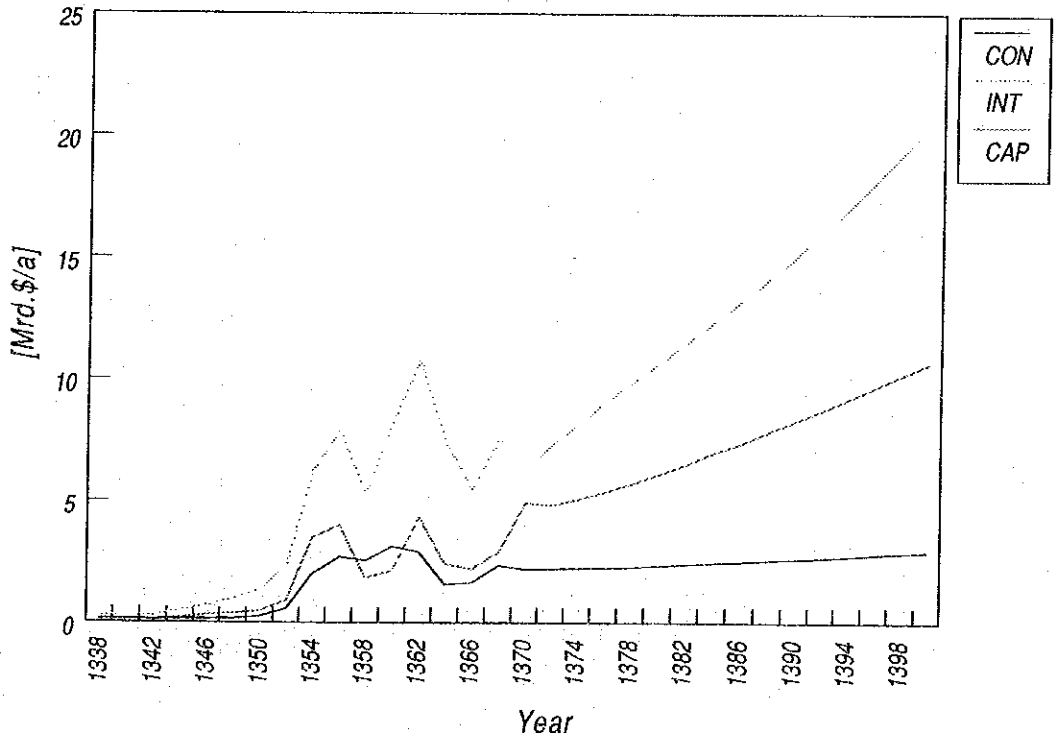


Fig.2.17 :Export of Non__Oil Goods

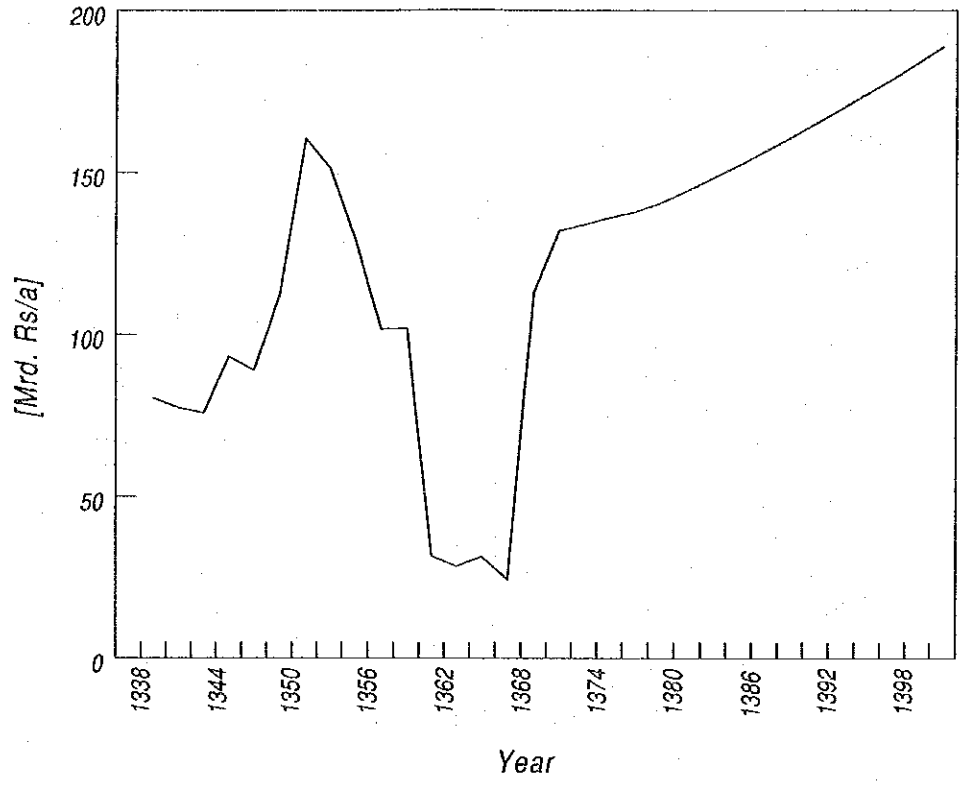
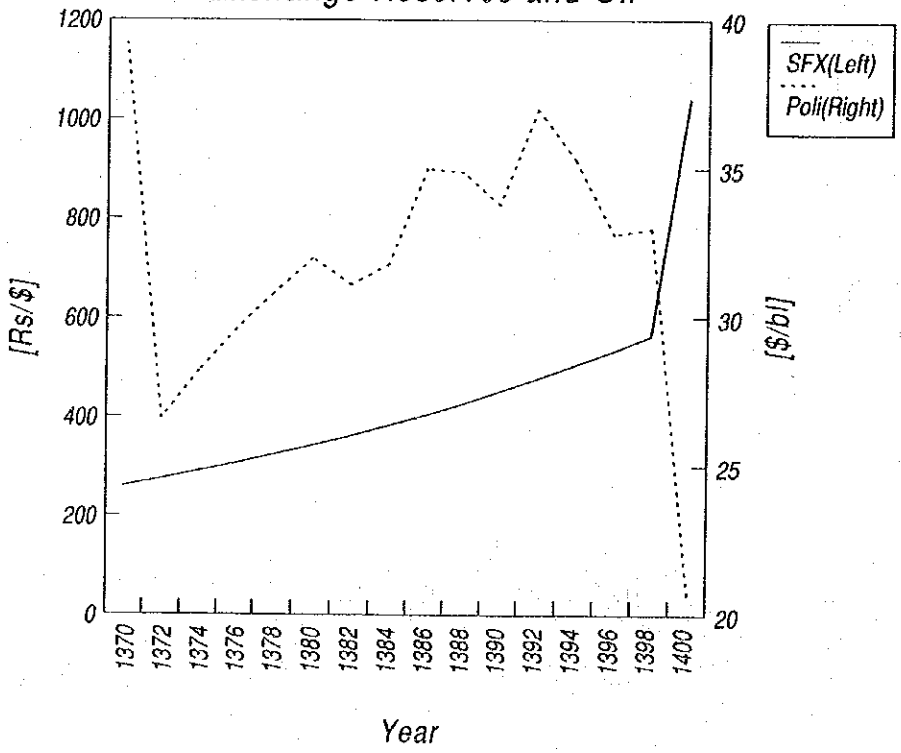


Fig.2.18:Shadow Price of foreign Exchange Reserves and Oil



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.

2.4.3 Impact of Oil Prices on Economic Development

In order to study the impact of the development of oil prices on the development of economy, different scenarios of oil prices in the world market is considered. The basic scenarios are shown in Figure 2.19. Scenario POIL-3 depicts a situation, where oil prices rises rapidly and reaches a level of $35/bl in the year 2000.

Scenarios POIL-1 and POIL-2 shows lower growth rate of oil prices during the planning horizon. In the case of scenario POIL-4 the price of oil in the world market is assumed to rise to $20/bl in the year 2021.

Figure 2.20 shows the development of GDP in various cases of oil prices. Higher energy prices in the world market increases the potential of economic development. As the energy prices go up, the possibility of accelerating the process of economic development widens to a large extend.

2.4.4 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 2.21).

Scenario DOIL-1 represents a case, where moderate energy conservation policy is pursued and

Fig. 2.19: Crude Oil Price in the World Market

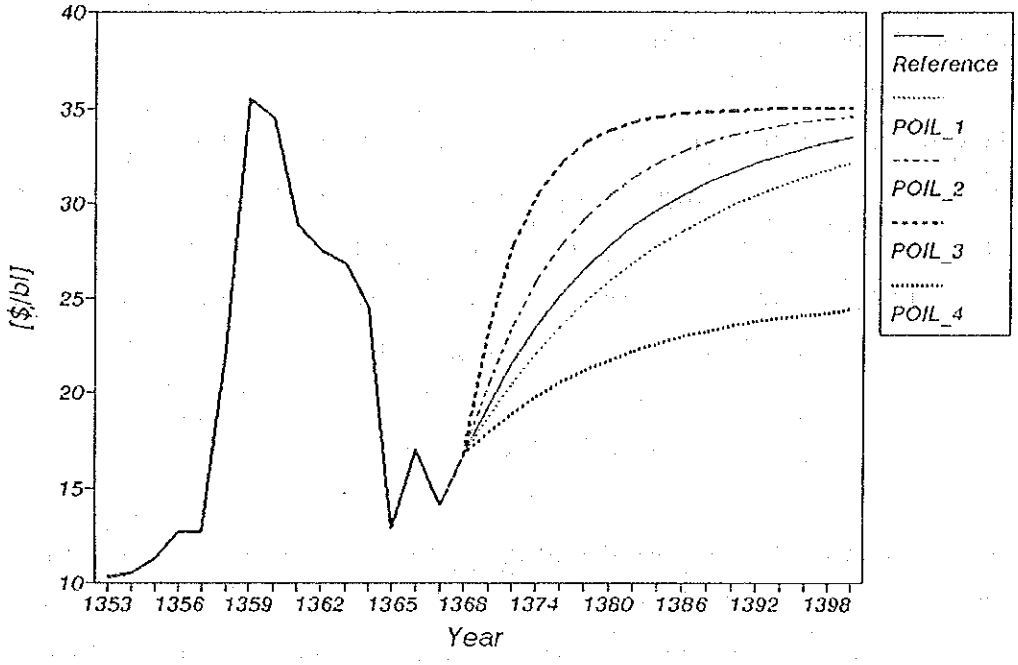


Fig. 2.20: Development of GDP for Diff. Scenarios of Oil Prices

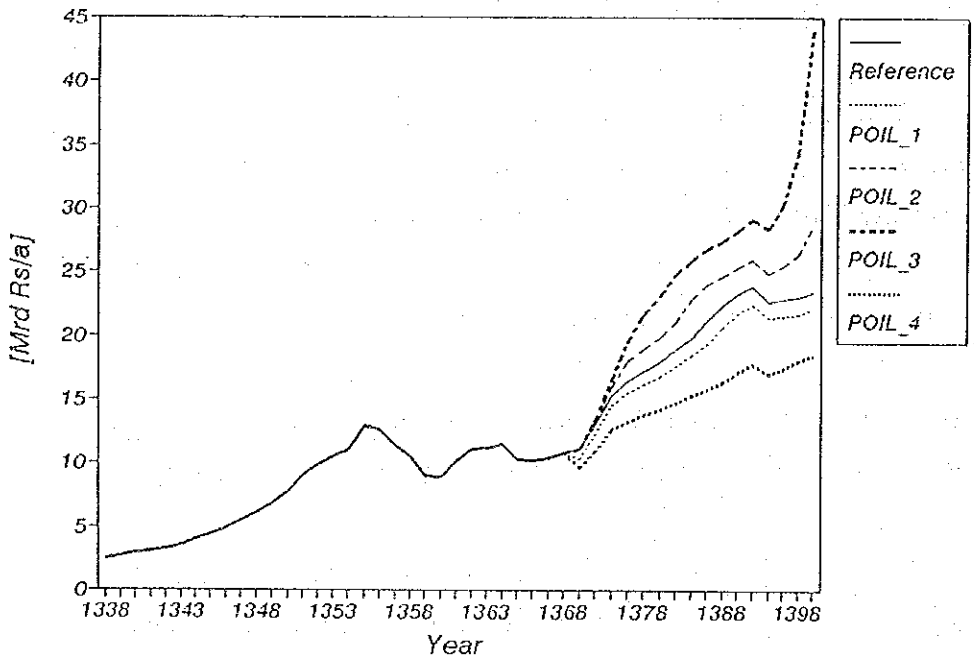
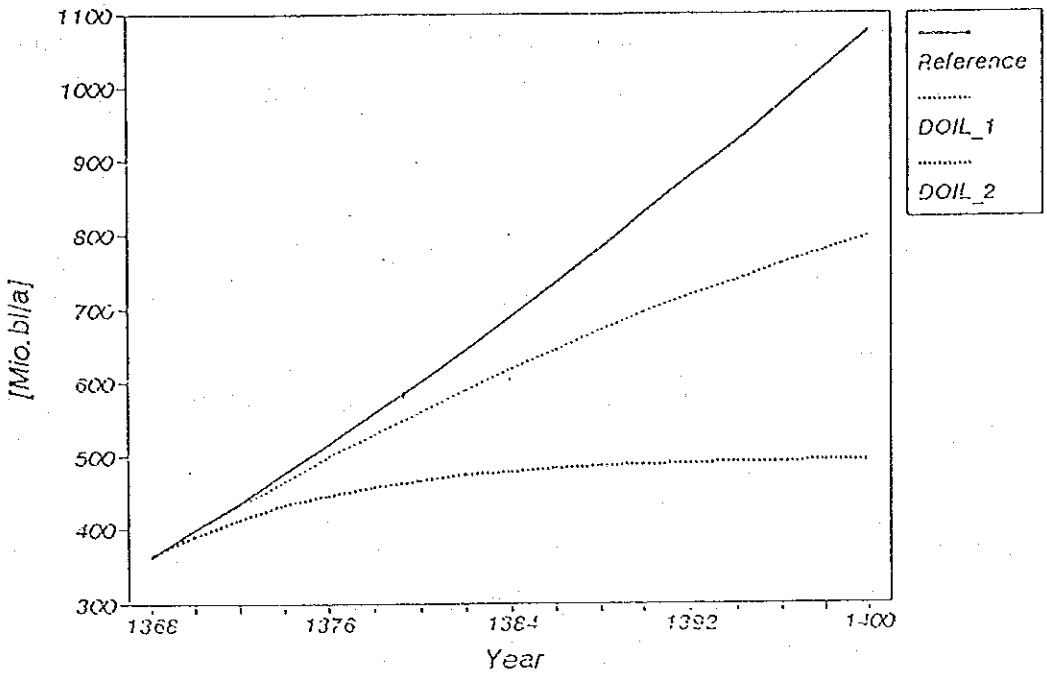


Fig. 2.21: Scenarios of Domestic Oil Consumption



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 2.22 and 2.23. In Figure 2.22, the trend of shadow price of oil in the case of scenario DOIL-2 remains at the lowest level. In Figure 2.23 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. 2.22: Shadow Prices of Crude Oil for Diff. Scenar. of Domestic Oil Con.

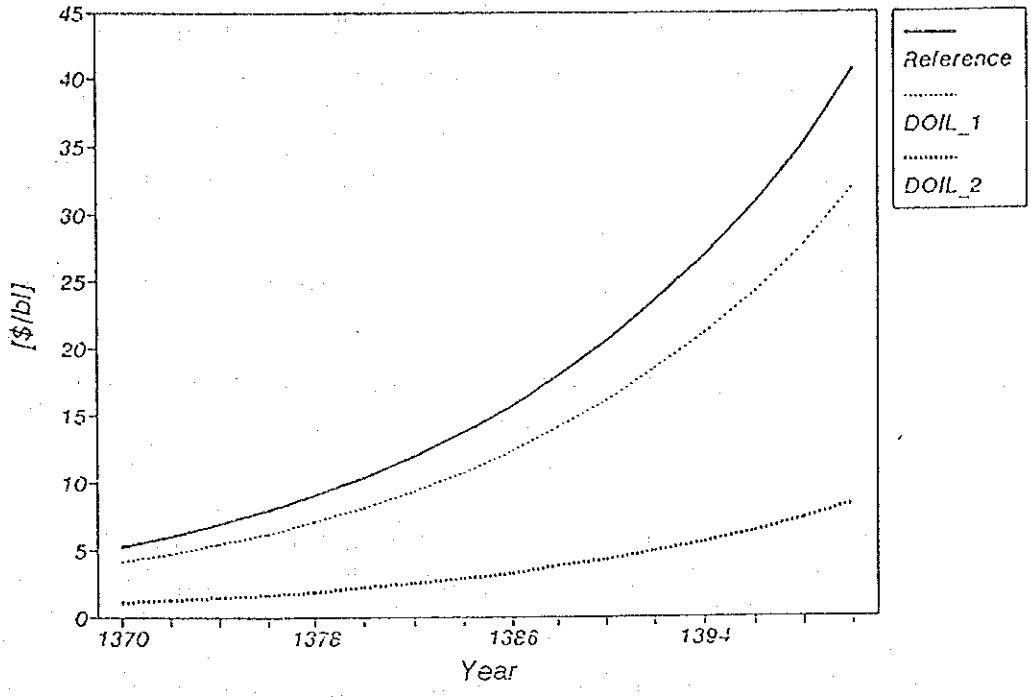
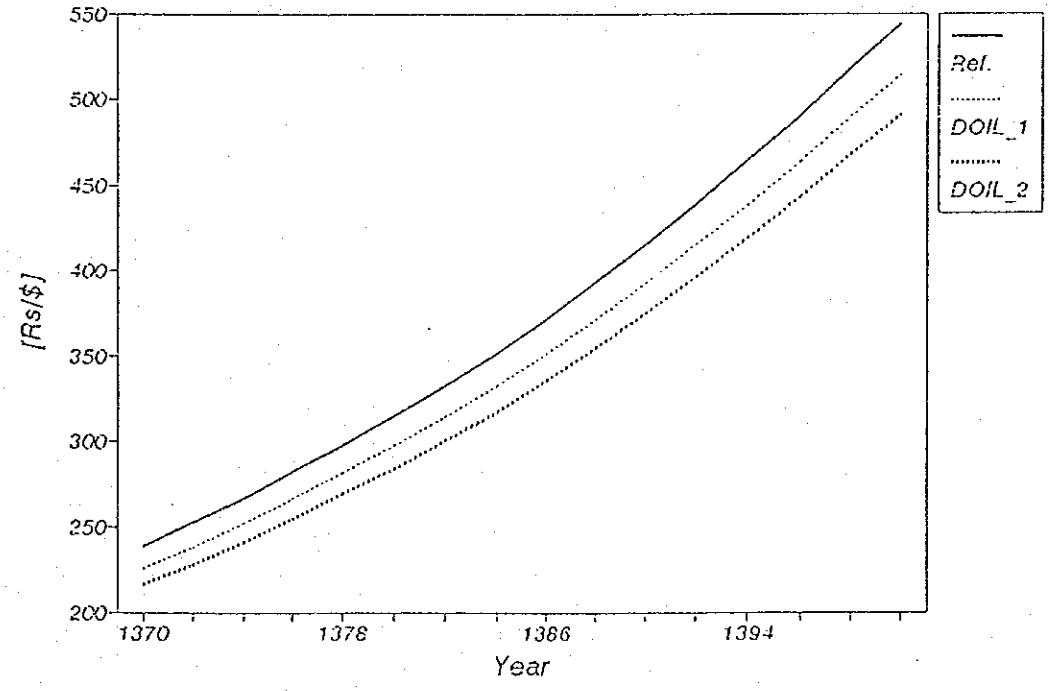


Fig. 2.23: Shadow Prices of Foreign Exch. Res. for Diff. Scen. of Domes. Oil Co.



2.5 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

3.1 Introduction

Development of domestic consumption of energy plays important role in the process of economic growth. Increase in domestic energy consumption, on the one hand, leads in rapid depletion of energy reserves and it limits the potentials of energy export and foreign exchange earning. On the other hand, rising energy demand would require higher investment in the energy sector, which limits the availability of foreign exchange in other sectors of the economy. Hence, shortage of foreign currency results in bottle-necks in the process of the development of other sectors of the economy.

Analysis of the impact of energy demand on the potentials of energy export and investment in the energy sector is an important task of comprehensive energy planning. Energy demand in different social and economical sectors has been studied in detail. The main objective of this study has been to identify the trend of development of energy demand and to obtain information on the impact of social, economical, and technical changes on the consumption of energy carriers.

To achieve the objectives of the analysis of energy demand, distinction has been made between useful energy and final energy demand. In the present study, useful energy demand is first studied, in order to project energy requirement in the process of development. Then, to meet the useful energy requirement, optimization if the energy supply system has been considered, in order to identify optimal strategies.

In this case, it has been possible to study the development of fuel mix, substitution of energy and productions factors, and alternative technological options that are available in the energy sector.

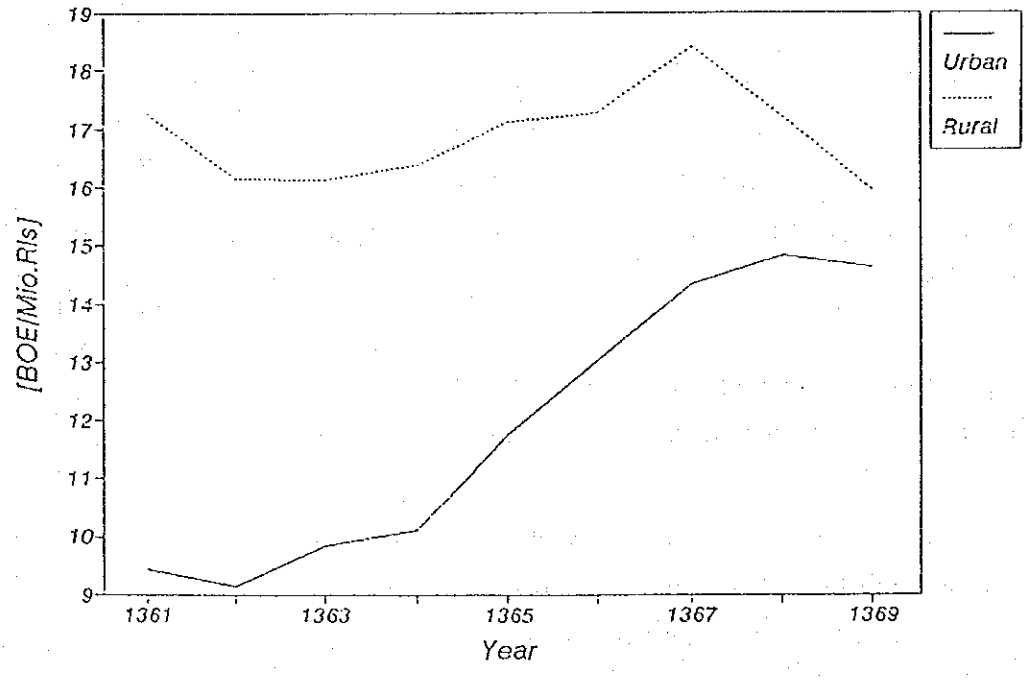
In this chapter of the present report, detailed analysis of energy demand will be described. First, energy consumption in households, industries, and transport sectors will be outlined. Then, after a brief description of the approach adopted in studying the energy demand, the main results of the analysis will be summarized.

3.2 Energy Consumption in Social and Economical Sectors

3.2.1 Households

Final energy uses per unit of private consumption in urban areas has increased from 5 BOE per million Rials of private household consumption (in prices of 1982) to 15 BOE per million Rials in 19 90, which corresponds to an average annual growth rate of a%/a. Energy uses per unit of private consumption has remained almost constant during last decade (See Figure 3.1).

Fig. 3.1: Final energy uses per unit real exp. in rural and urban hous.



Distribution of final energy consumption in rural and urban areas indicate that in 1982 more than 50% of final energy carriers was consumed in urban areas, and then this share increased to about 60% in 1990(See Figure 3.2).

Fuel mixes of final energy consumption indicates that the share of traditional fuels in final energy consumption of households has undergone a declining trend in the last decade and it has decreased from a% in 1982 to b% in 1990 (See Figure 3.3). Structures of final energy consumption in urban and rural areas in the Figure 3.4 and 3.5 show that traditional fuels have contributed to more than 50% of energy consumption of rural households. But, the share of traditional fuels in final energy consumption of urban households was a% in 1982, which has fallen to household b% in 1990.

Differences in the structure of final energy consumption of rural and urban can also be observed between households in various income groups in urban and rural areas. Figures 3.6 to 3.13 show the consumption of final energy carriers in different expenditure groups in urban areas.

These figures reveals three major developments. First, the total energy consumption of households in the higher income groups has had an increasing trend. Second, share of natural gas in final energy consumption of households has been rising. Third, households in higher expenditure groups consume much more energy than households in the lower expenditure groups, which stems from the fact that households in higher expenditure groups enjoy a better living standard than the population in lower groups.

Comparison of final energy consumption in different expenditure groups in rural areas shows that the increase in final energy consumption of households in higher expenditures groups has been lower than in lower expenditure groups of urban areas. In rural areas, traditional fuels are important element of final energy consumption. Consumption of natural gas in rural households has been increasing, but its share is still much less than the contribution of petroleum products to the final energy consumption.

Fig. 3.2: Share of final energy consumption in rural and urban areas

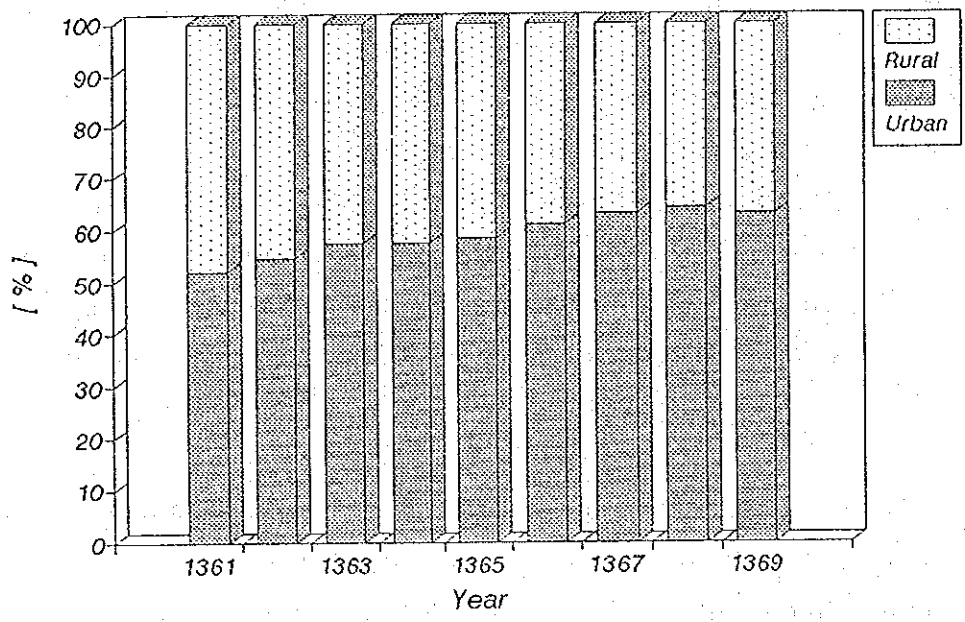


Fig. 3.3: Development of final energy consumption in household

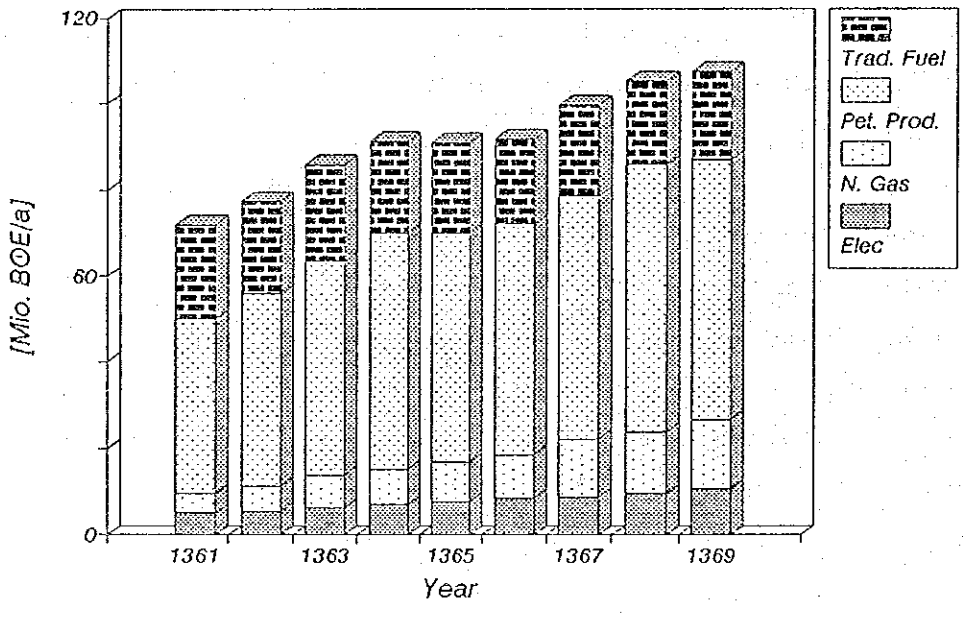


Fig. 3.4: Development of final energy consumption in urban household

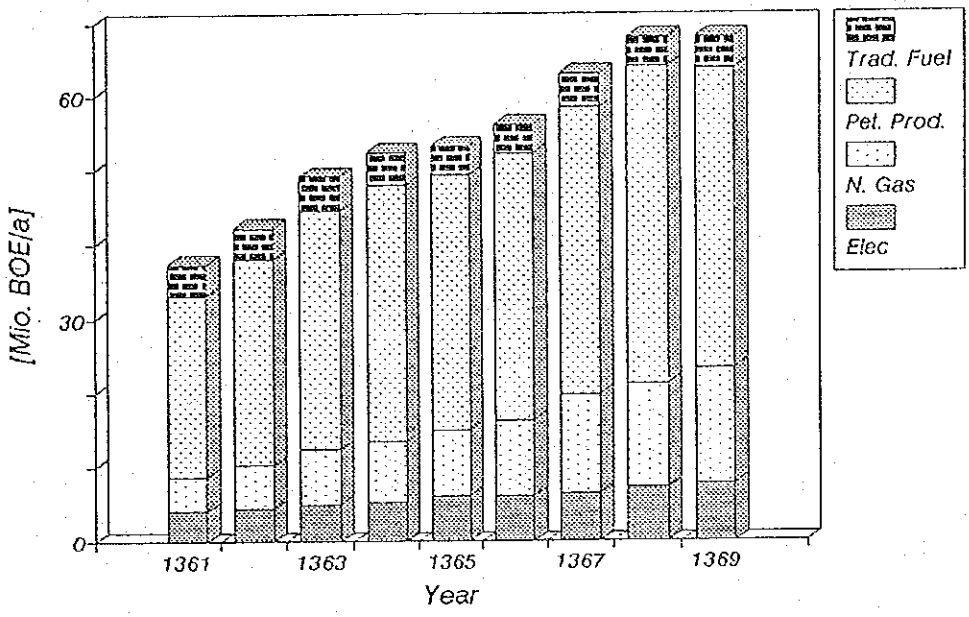


Fig. 3.5: Development of final energy consump. per cap. in urban hous.

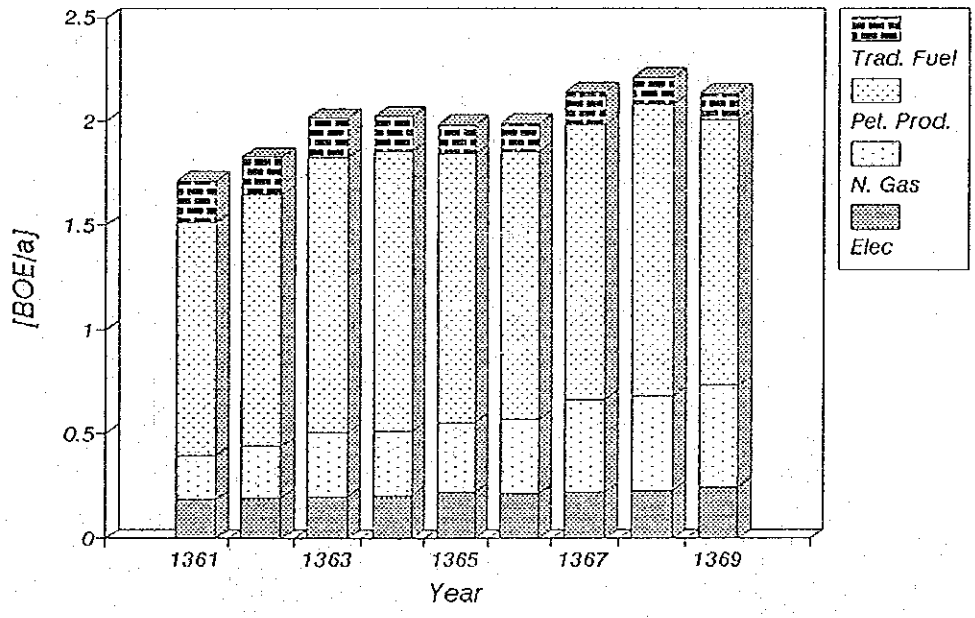


Fig. 3.6: Developement of energy con. of a family in urban areas (1361)

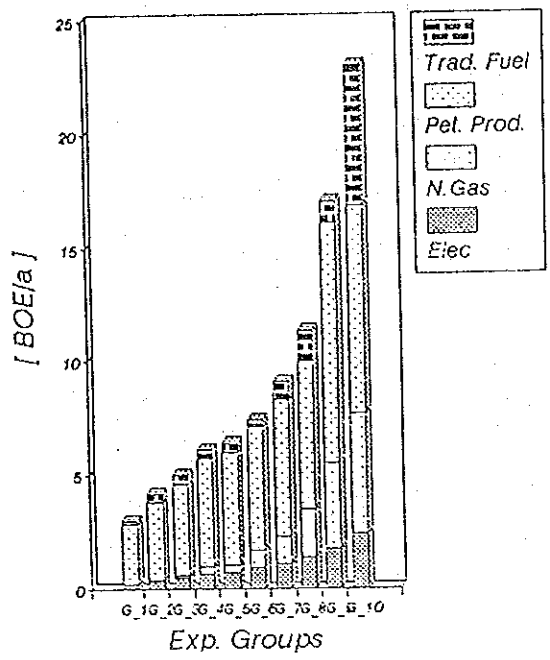


Fig. 3.7: Developement of energy con. of a family in urban areas (1363)

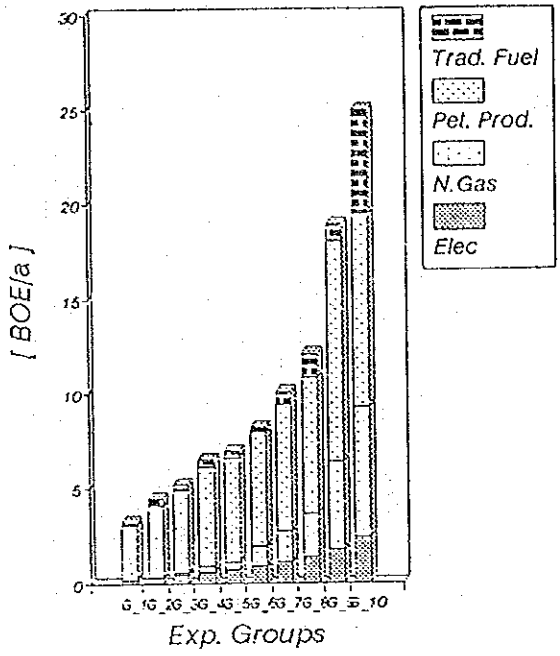


Fig. 3.8: Developement of energy con. of a family in urban areas (1366)

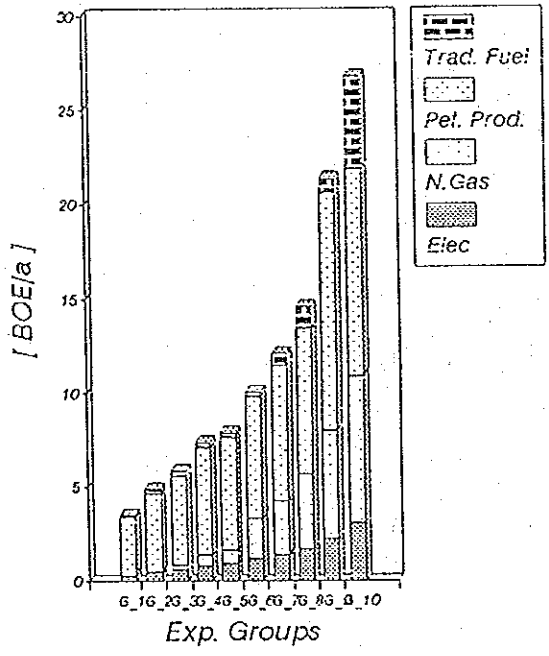


Fig. 3.9: Developement of energy con. of a family in urban areas (1361)

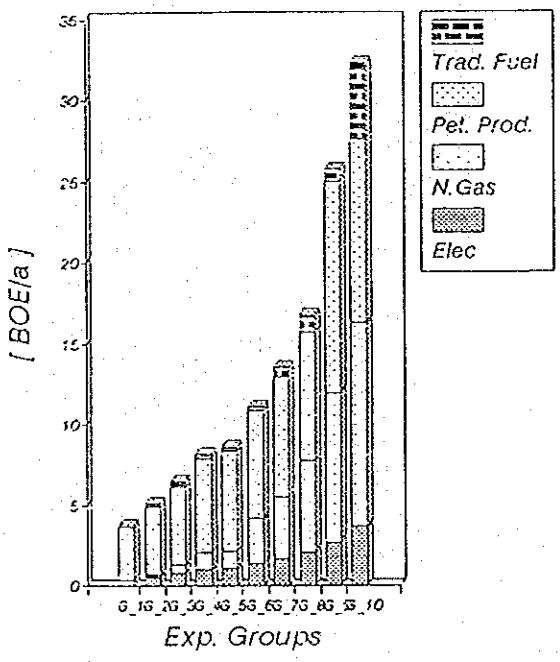


Fig. 3.10: Developement of energy con. of a family in rural areas (1361)

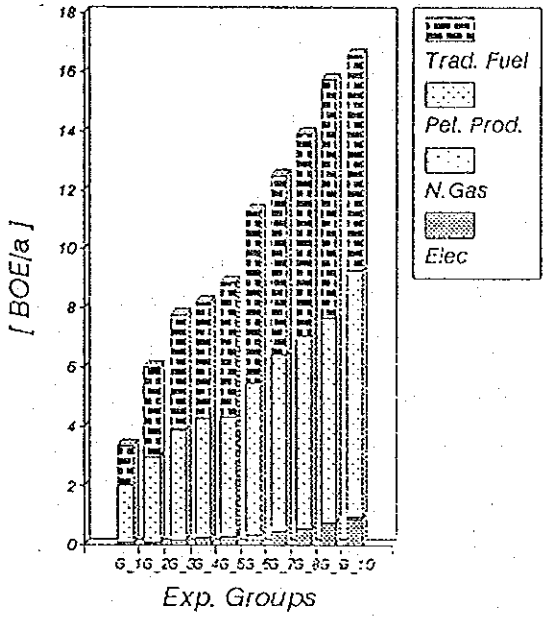


Fig. 3.11: Developement of energy con. of a family in rural areas (1363)

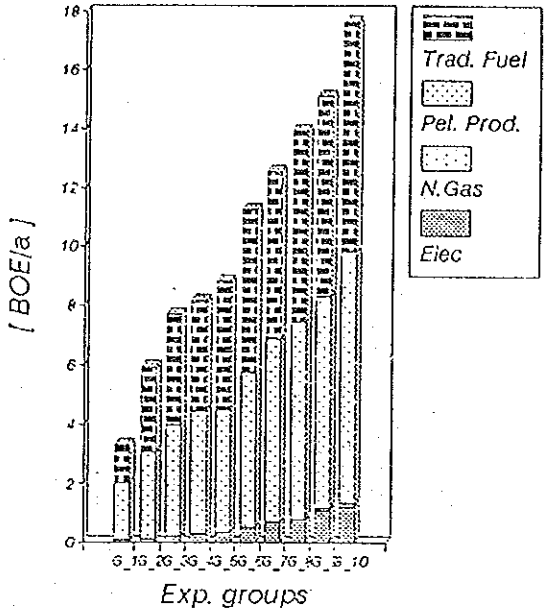


Fig. 3.12: Developement of energy con. of a family in rural areas (1366)

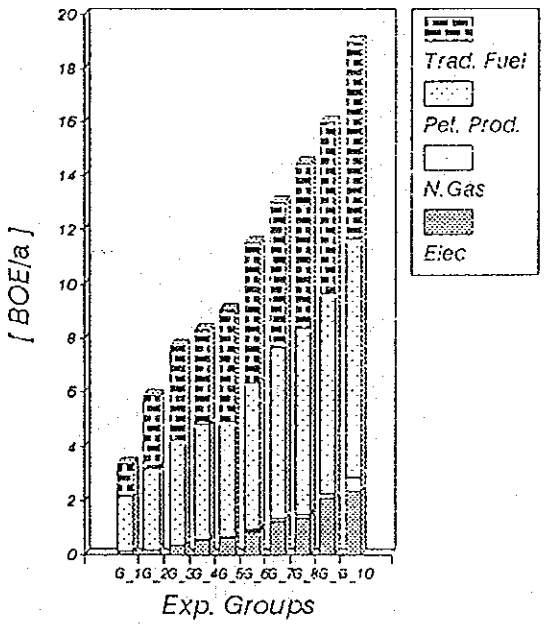
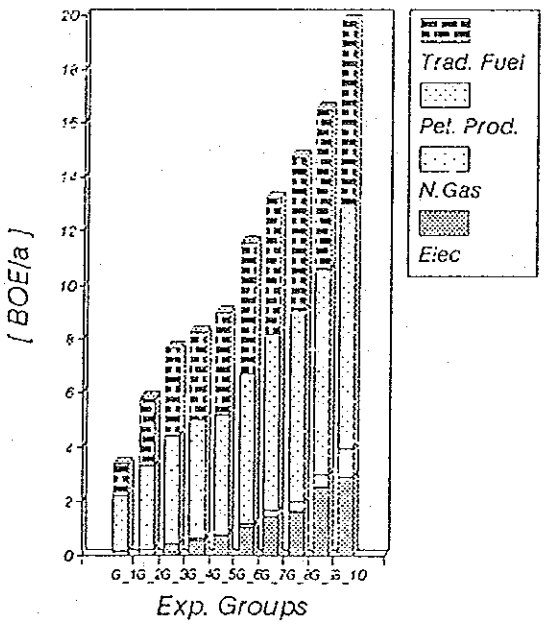


Fig. 3.13: Developement of energy con. of a family in rural areas(1369)



Difference in energy consumption of households in expenditure groups in rural and urban areas is much higher, when the useful energy requirement of households is compared. Figures 3.14 to 3.2 1 reveal the fact that availability of energy in households of expenditure groups in rural and urban areas can be distinguished. Population in higher expenditure groups enjoy a better living standard, and hence require more useful energy to sustain their living condition.

3.2.2 Energy Consumption in Industry

Industry is a growing sector of the economy and its share in GDP (in constant prices) has increased from 5% in 1959 to more than 15% in 1990. Expansion of industrial activity has been more rapid in the last decade especially. Figure 3.22 indicate the development of GDP and value-added of industry in the period 1959-1990. Changes in the share of industry in GDP is depicted in Figure 3.2 3. This figure also shows the trend of the share of industry in GRP (Gross Regional Product), and it represents the fact that the contribution of industrial activities to the gross regional product, i.e. gross domestic product minus the value-added of oil sector, has increased more rapidly in the recent years.

Fig. 3.14: Dev. of useful energy cons. of a family in urban areas (1361)

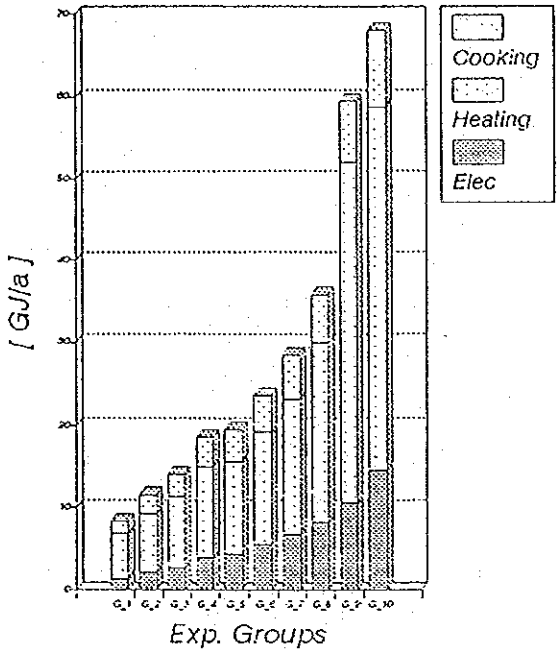


Fig. 3.15: Dev. of useful energy cons. of a family in urban areas (1363)

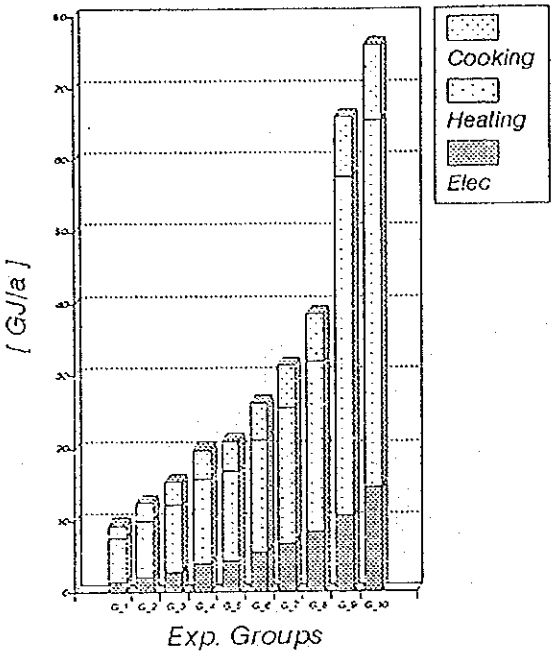


Fig. 3.16: Dev. of useful energy cons. of a family in urban areas (1366)

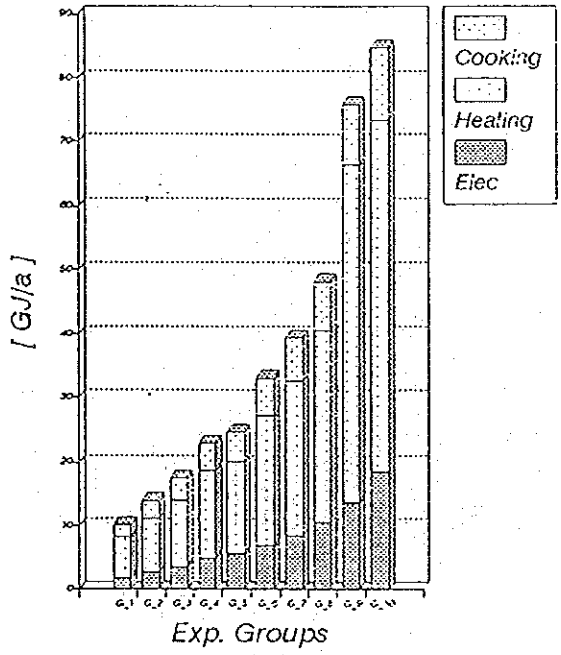


Fig. 3.17: Dev. of useful energy cons. of a family in urban areas (1369)

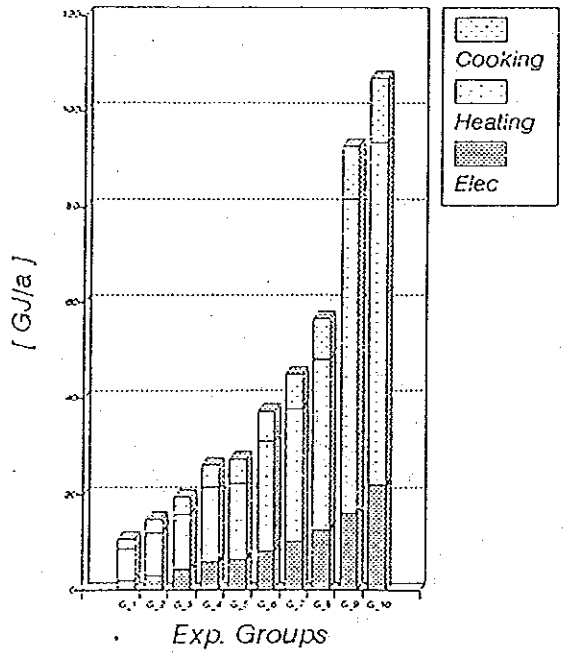


Fig. 3.18: Dev. of useful energy cons. of a family in rural areas (1361)

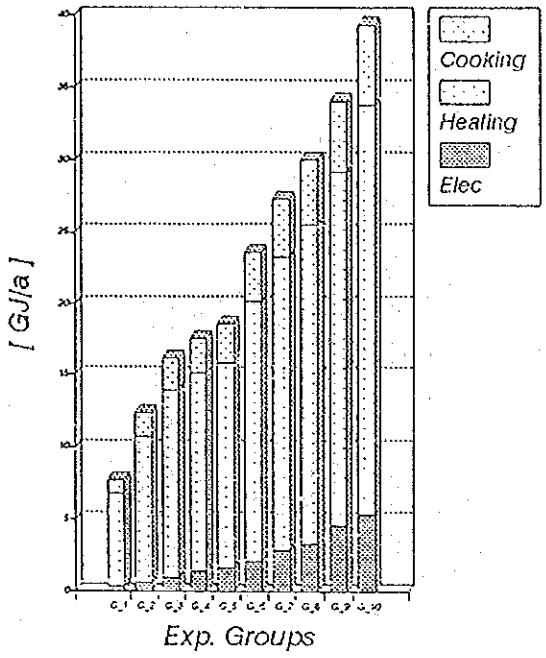


Fig. 3.19: Dev. of useful energy cons. of a family in rural areas (1363)

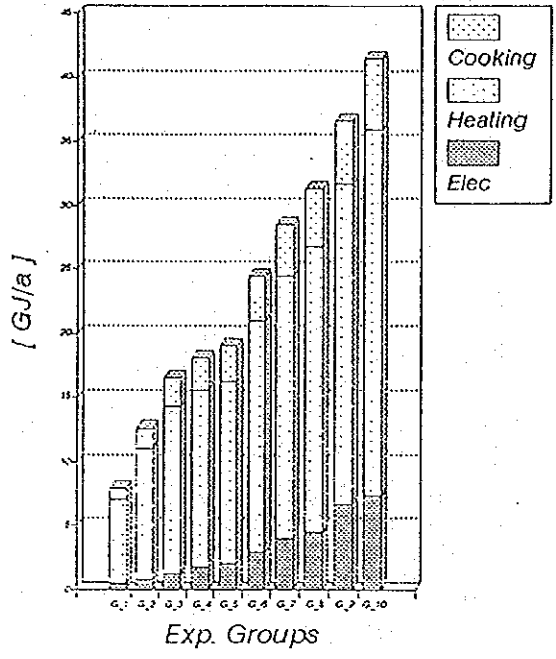


Fig. 3.20: Dev. of useful energy cons. of a family in rural areas (1366)

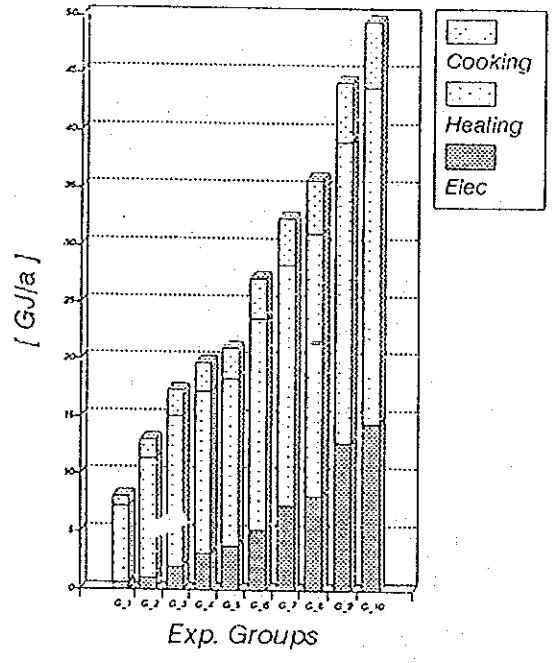


Fig. 3.21: Dev. of useful energy cons. of a family in rural areas (1369)

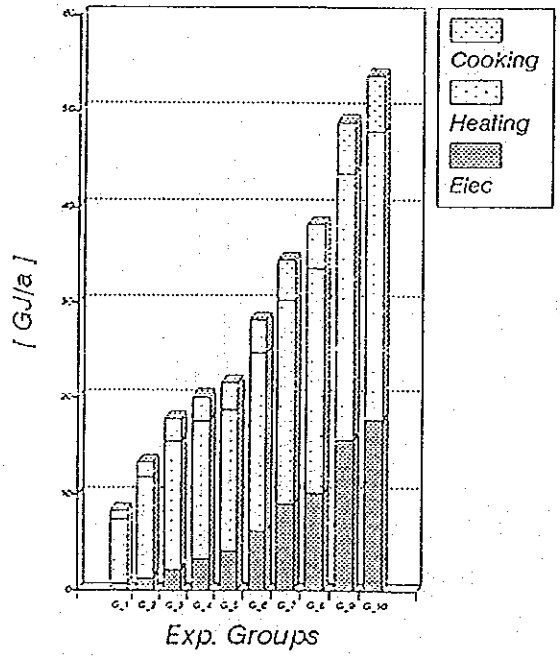


Fig. 3.22: Value-added of industry and GDP in constant prices of 1361

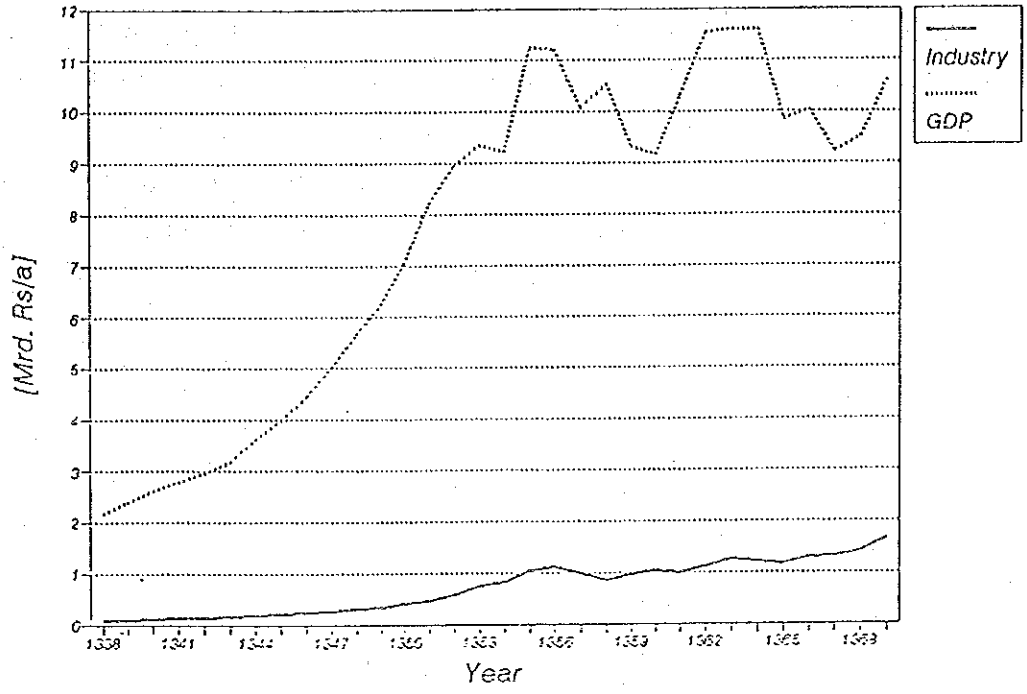
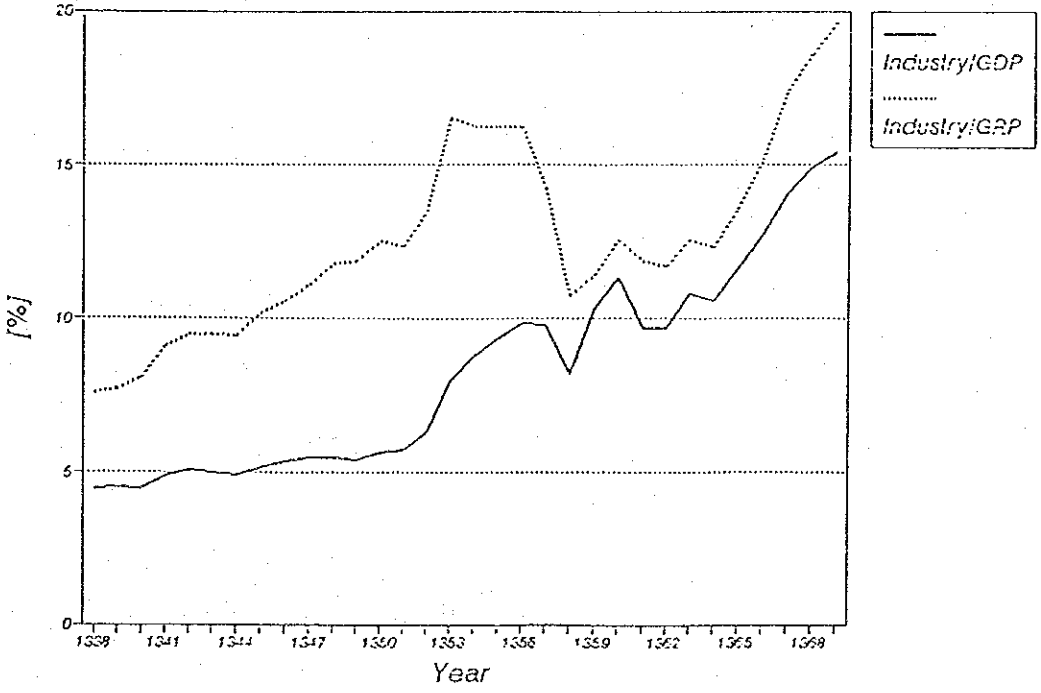


Fig. 3.23: Share of ind. value-added in GDP and GRP at constant prices(1361)



With increased contribution of industry to the economic growth, the energy consumption in this sector has risen. Figure 3.24 shows the trend of total energy consumption in large industries and the development of the share of industry in final energy consumption can be observed in Figure 3.25. Fuel mix of consumed energy in large industries is presented in Figure 3.26. It is noticed that petroleum products are the major constituents of final energy consumption. The share of natural gas has been increasing, and it reached just a bout 40% in 1990. Contribution of natural gas to the energy consumption in industry is conditioned by the availability of natural gas and supply constraint is a major determinant of the share of natural gas in energy consumption.

Fig. 3.24: Energy consumption in total of Large industry

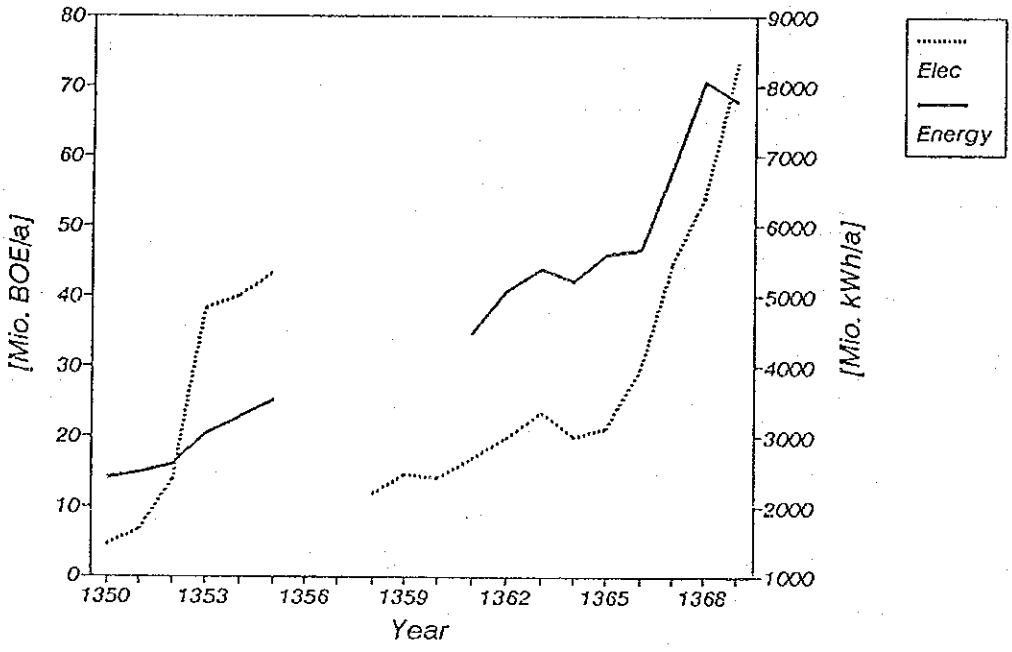


Fig. 3.25: Share of industry in energy consumption

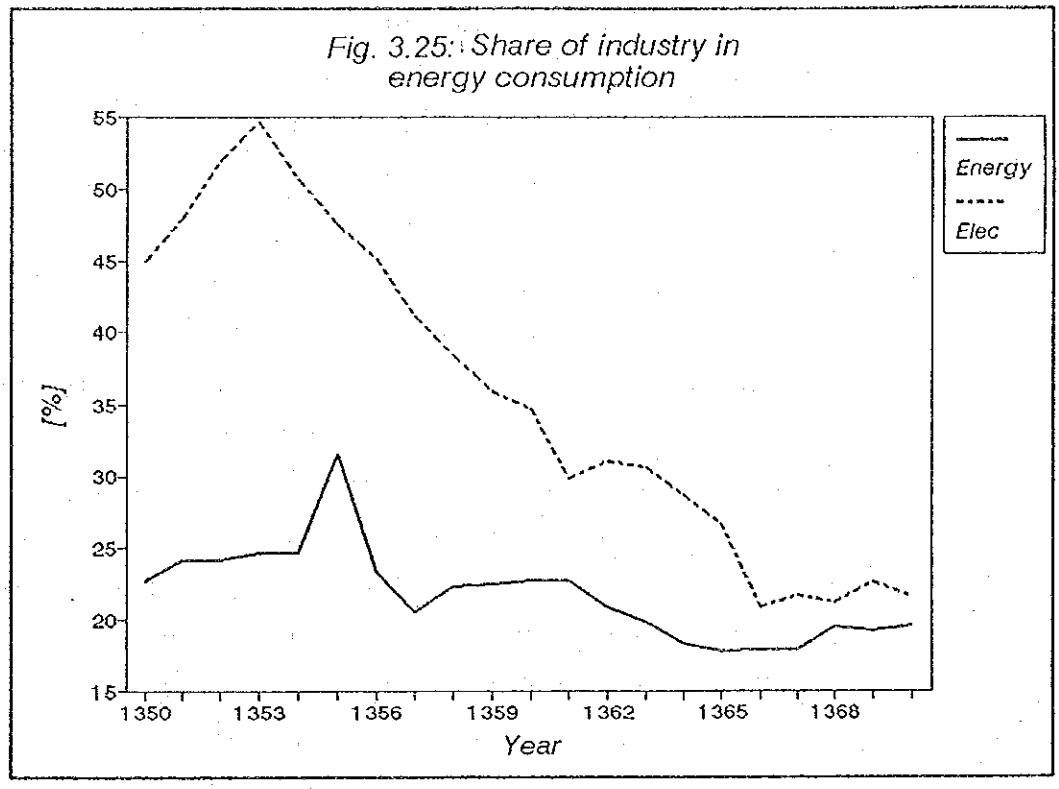
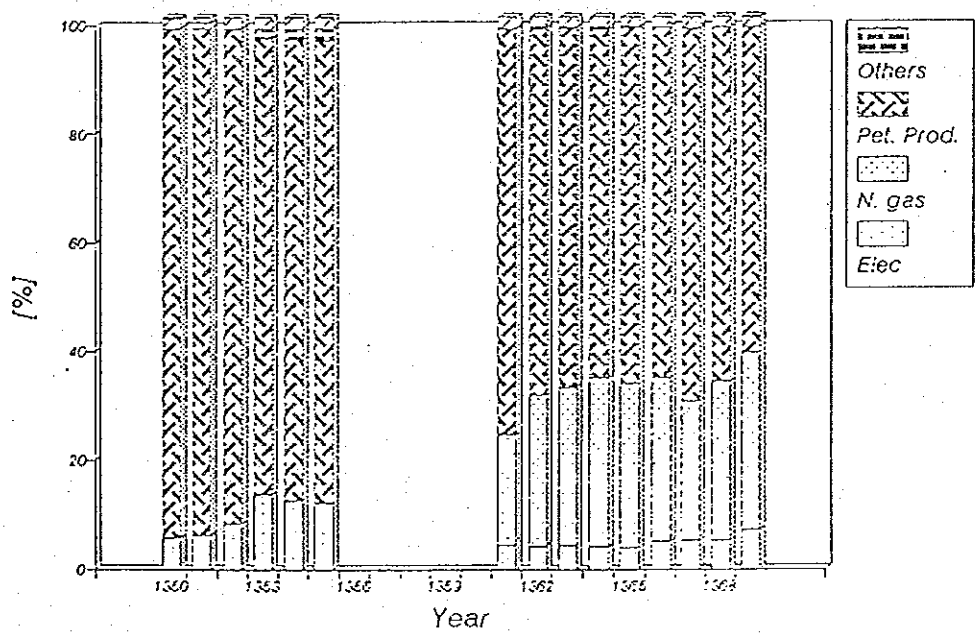


Fig. 3.26: Share of energy carriers in energy consumption of industry



Distinction between sub-sectors of industry indicate that non-metal mining industry is the largest industrial energy consumer in the country . More than 30% of final energy consumption in large industries was attributed to non-metal mining industries in 1971 and increased to more than 40% in 1990 (See Figure 3.27). The other largest industrial energy consumers are basic metal and food and drinks industries respectively. More than 70% of industrial energy consumption takes place in the aforementioned sub-sectors of industry. Production in the industrial sector has gone under changes in the last two decades. Variation in the value-added of industry has been caused by the social and political changes after the Islamic Revolution in 1979 and the war. Trend of energy consumption and value-added indicate that total energy consumption has increased in the recent years, although the activity level has declined in some years. This is mainly due to the fact that production capacities were under utilized. This point many be explained by the trend of an indicator of under utilization of existing production capacities. To this end, the ratio of value-added to capital stock of industry (in constant prices) has been estimated and it is used as an indication of under utilization of production capacities. It can be observed in the Figure 3.28 that the ratio of value-added to capital stock has fallen. This situation results in increased energy intensity in industry.

Fig. 3.27: Share of major sub-sectors in the energy consumption of industry

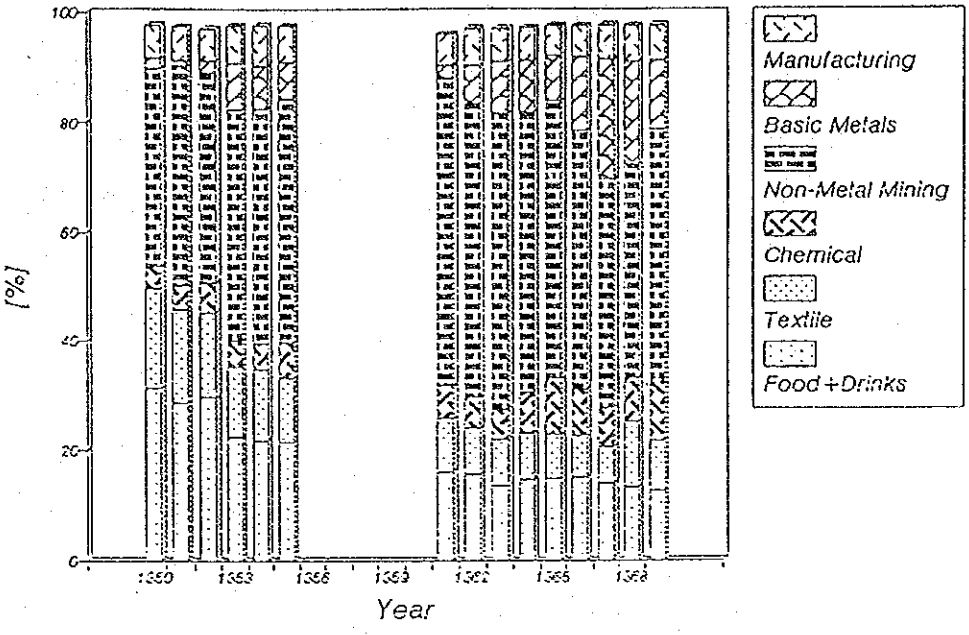
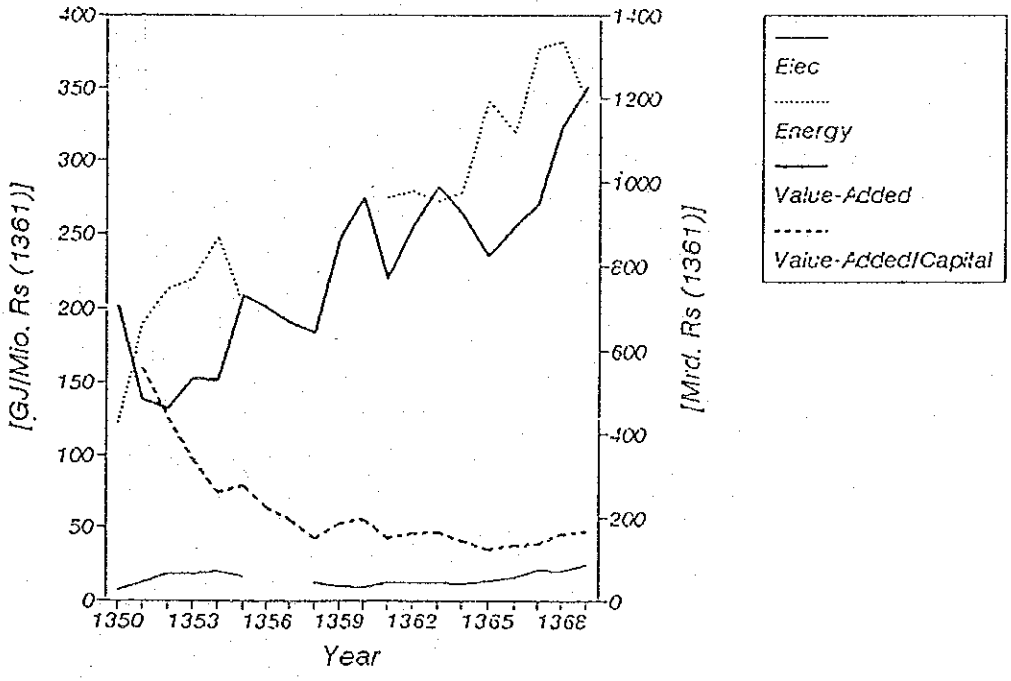


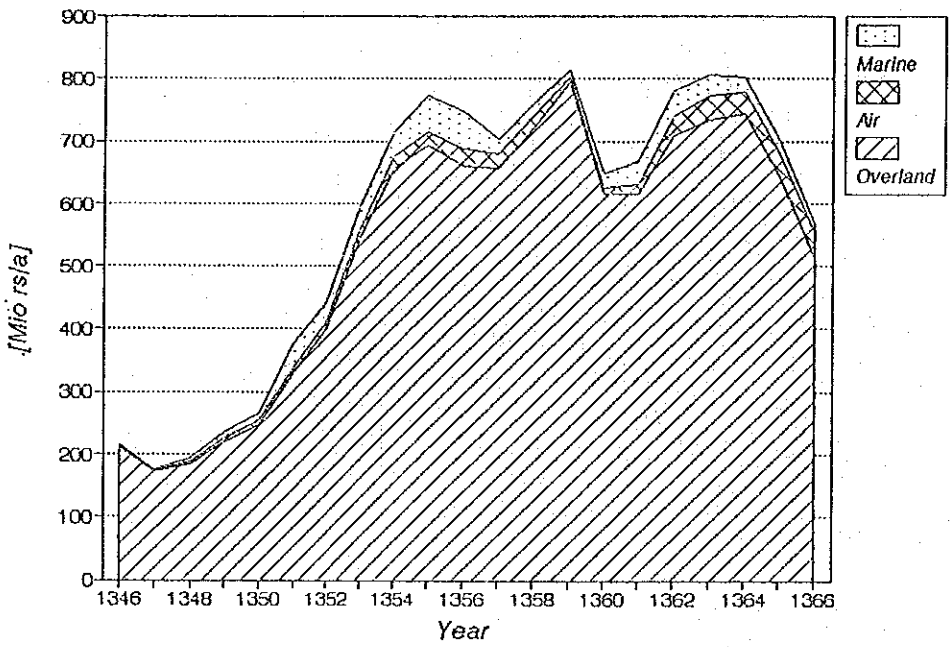
Fig. 3.28: Energy intensity, VA, and capacity factor in total industry



3.2.3 Energy Consumption in Transport

Transport sector is an important element of the economic system and technical infrastructure of the country. The share of transportation in GDP was just above 3% in 1970, but it increased rapidly in the 1970. It was more than 6% in 1990. Figure 3.29 shows the trend of value-added in transport sector in the last two and half decades. In this diagram, it may be observed that the overland transportation (i,e. road and rail transportation) has the largest share in the activity level of the transport sector, which was more than 90% in 1987.

Fig. 3.29: Value added of transport sectors fixed prices of 1361



Passenger transportation and freight are the major sub-sectors of the transport sector. The activity level of passenger transportation increased by more than four in the period 1970-90. Total activity of passenger transportation was 170 billion passenger-kilometer in 1990 (See Figure 3.30). Road transportation had the largest share, which is attributed to private cars, mini-bus, and bus mainly.

The activity level of freight also shows a rapidly increasing trend, and it has risen from 19 billion t-km/a in 1970 to more than 100 billion t-km/a in 1990 (See Figure 3.31). Trucks are the dominant means of transportation. Fuel consumption in transport sector has increased from 12 Mio. BOE/a in 1970 to 70 Mio. BOE/a in 1990. More than 50% of final energy consumption in the transport sector is allocated to truck. The second largest consumer of final energy in the transport sector is private car (See Fiure 3.32). About 70% of transport energy consumption is attributed to trucks and private cars.

Fig. 3.30: Activity level of passenger transport modes

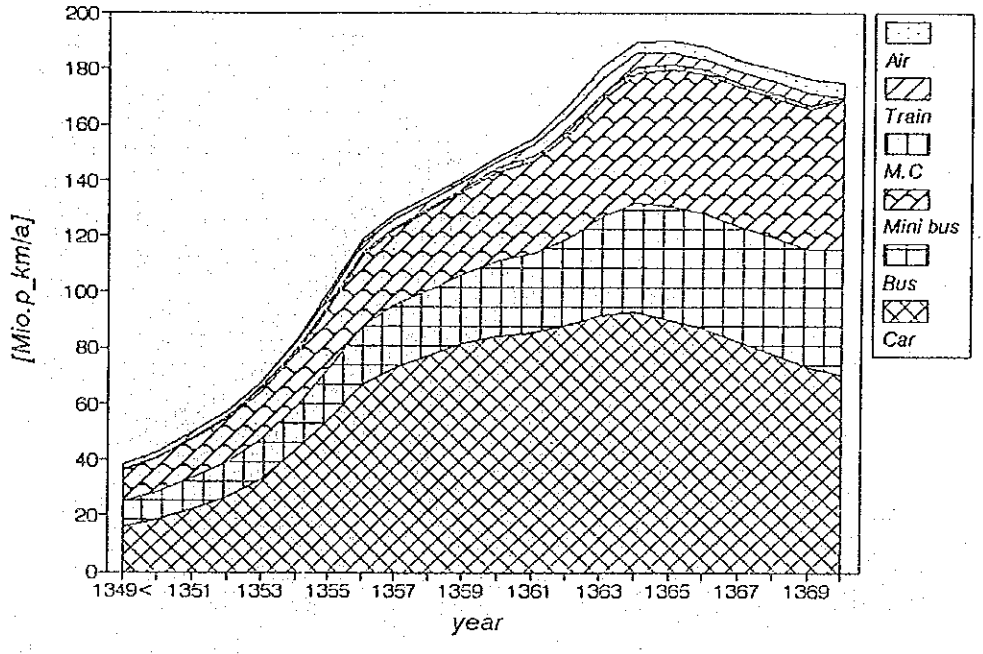


Fig. 3.31: activity of modes in Freight transportation

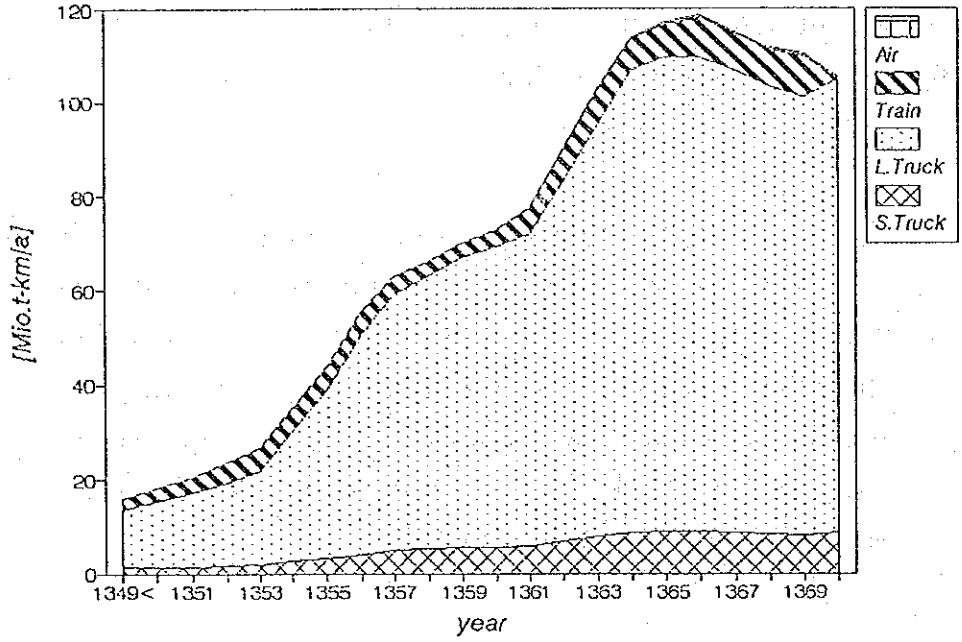
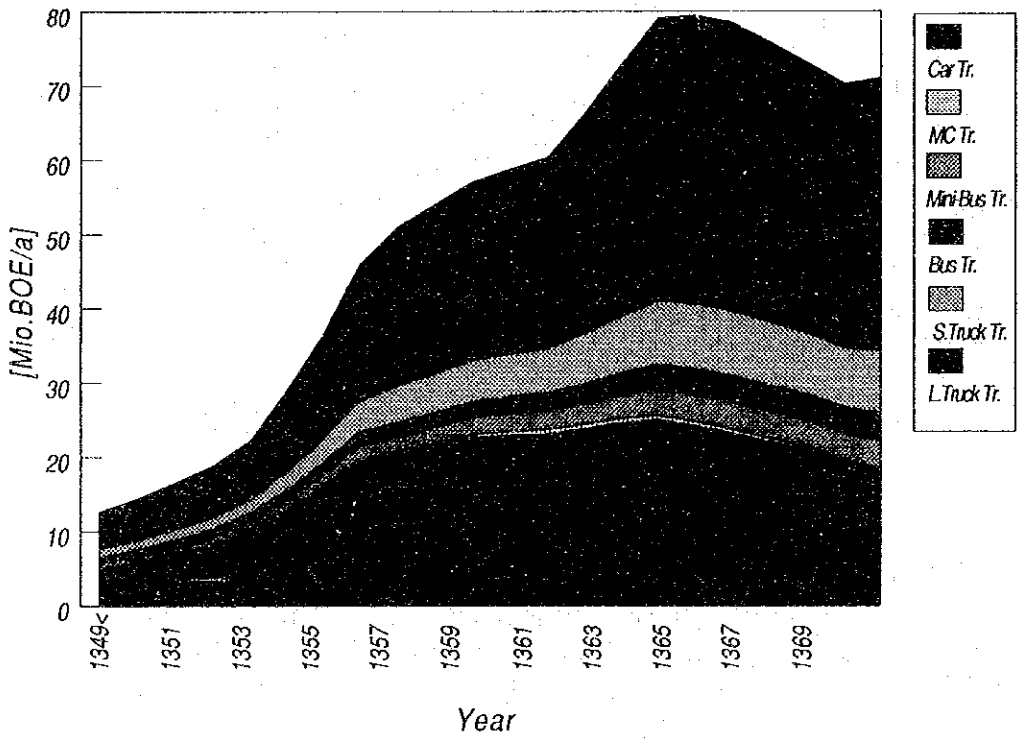


Fig.3.32: Fuel consumption in rail and road transportation



3.3 Model for analysis of energy demand

3.3.1 Issues of energy demand

A review of final energy consumption in various sectors of the social and economic system reveal that increasing trend has been the most important feature of energy consumption in the last two decades. Increase in population, economic growth and improved living condition of the population were determinants of rising energy demand.

A closer look at the energy consumption pattern shows that households in urban areas have a larger share in energy consumption than population in rural areas. Energy consumption in different expenditure groups can be distinguished clearly. Households in higher expenditure groups consume more final energy than families in lower expenditure groups.

Energy consumption in industry conditioned by the changes in the structure of the industry, and more than 70% of final industrial energy consumption is used in sub-sectors of basic metals, non-metallic mining, food and drinks industries. Undercapacity utilization in the production processes has had a considerable impact on the energy intensity; and as a consequence of that energy productivity has declined.

In the transport sector, the road transportation has the largest share in the energy consumption. Mass transportation by railways has little contribution to the activity level of transport sector. In addition, lack of modernization of the production lines of car manufacturing has resulted in unchanged trend of final energy intensity in the transport sectors.

Development of energy intensity in transport sector indicates that there has been little changes in the specific energy consumption of means of transport; Figures 3.33 and 3.34 show the final energy consumption services. In both cases, decline in energy industry has been very small. Since private cars and truck are the main transport facilities, and a large share of stock of cars and trucks have been manufactured in the domestic market, but the production lines have not been modernized. Therefore, the efficiency of means of transportation has remained almost unchanged.

Fig. 3.33: Final energy intensity in passenger transportation modes

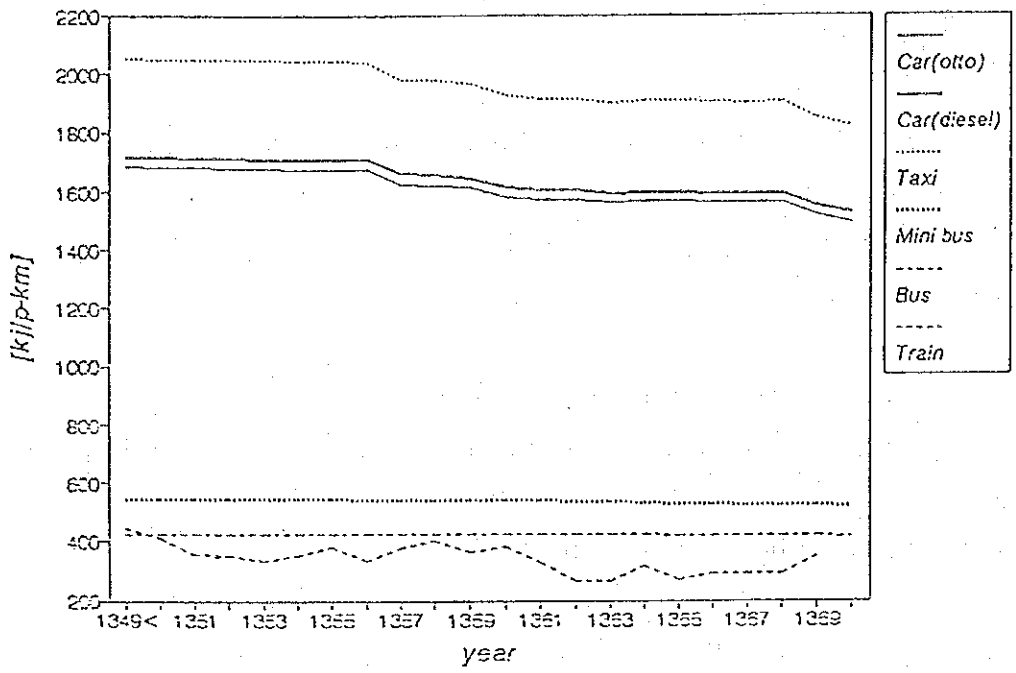
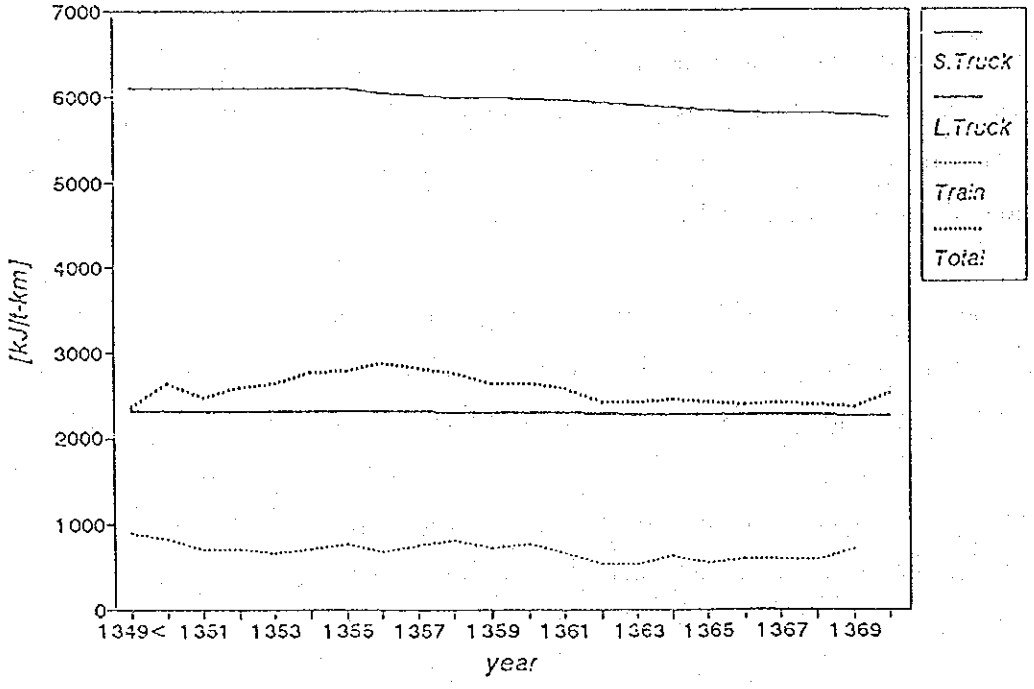


Fig. 3.34: Final energy intensity in transportation sectors



A detailed study of energy consumption in different sectors of the economy leads to the conclusion that improvement of energy consumption pattern in social and economical sectors and energy demand management is the most important issue in the consumer sectors. Therefore, evaluation of the energy demand management in various sectors and estimation of the potentials of energy conservation may be considered as essential tasks of energy planning in this country.

3.3.2 Outline of the Model

Energy demand model is an analytical tool that is to be used for detailed analysis of the development of energy demand. Such a study is to help a better understanding of the impact of technological and economical factors on the energy demand, on the basis of which rational decision making may be founded. Realization of this objective requires that the analytical tools should provide a means of studying the energy issues.

Based on the review of energy consumption and gools of economic development,an appropriate demand model has been developed for studying energy demand. This model is MODE-II (Model for Analysis of Demand for Energy).

Structure of the model MADE-II is shown in Figure 3.35. Model MADE-II is a simulation model based on the engineering process technique. Energy demand in each sector is considered as a function of activity level and energy intensity of each economic sectors. Activity level on economic sector is determined on the basis of the economic growth and structural changes in the economy. This information is obtained with the help of macro economy model that has been described in the first part of the report.

Energy intensity in each sector of the social and economical system is taken as exogenous variable. Development of energy intensity is analysed through detailed study of energy consumption in different branches of industry and transport sectors. Such a study helps to identify major issues of energy management in production and service sectors and to obtain information on the possibility of improving energy consumption pattern through different technical and economical measures.

Analysis of household energy demand is based on the population growth and income

distribution. Population growth is considered as an exogenous variable. Income distribution is assumed to be a policy oriented issue. If the objective in the process of economical and social development is to improve the living condition of poor households, this shall lead to movement of population from low income groups to high income groups. Outcome of this process will be such that with improved living condition of the poor population, consumption pattern of the population shall change; and as a result of that, energy requirement of households shall develop further.

The impact of income distribution on the energy requirement of households is represented with the help of household section in the model MADE-II. This model provides an analytical tool for detailed study of the development of the energy requirement of households, when the objective of improving the living condition of the poor is pursued in the process of economical and social development.

The main features of the model MADE-II, that are being described, represent the energy issues which are considered as important aspects of the energy sector in the Islamic Republic of Iran. Application of such a model will provide a means of obtaining information on the impact of technical and economical changes on the energy demand.

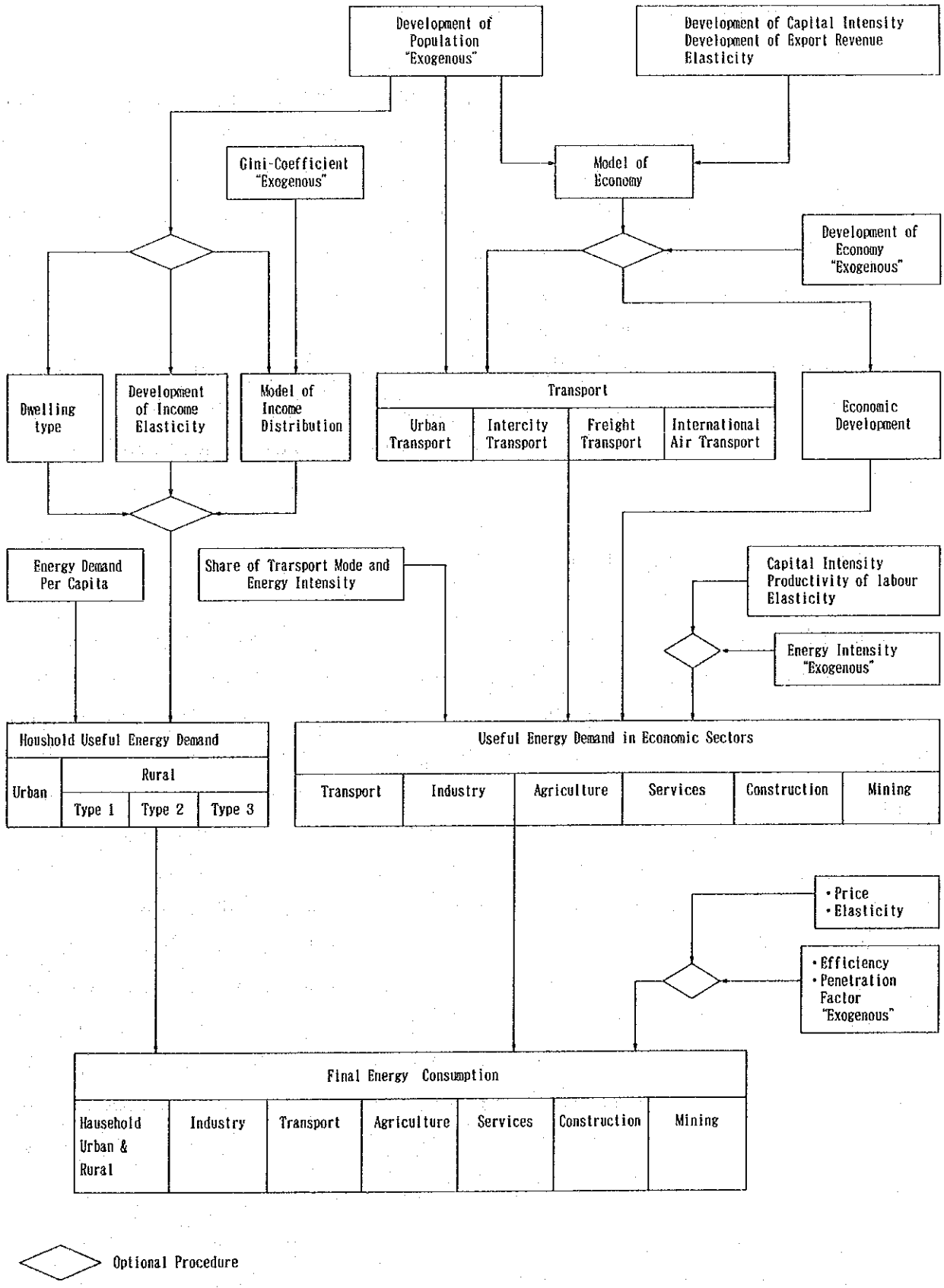


Fig. 3.35 Structure of Model MADE-II

3.4 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 economical sectors will be outlined briefly.

3.4.1 Useful Energy Demand of Households

To study the useful energy demand, the distribution of population in different expenditure groups is projected. Figures 3.36 and 3.37 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 170000 Rs/capita in 1989 to 340.000 Rs/capita in 2021 (See Figure 3.38). Private consumption in rural areas shall under go little changes. This is partly due to the fact that part of the rural population shall migerate 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 3.39 and 3.40). 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.3.36: Development of Share of Exp. Groups in Urban Pop.

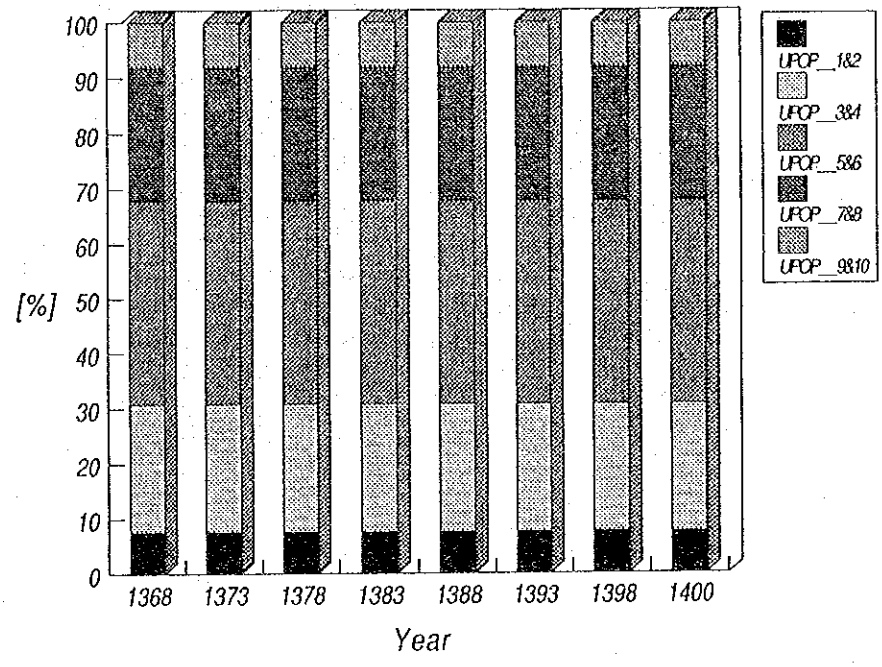


Fig.3.37 :Development of Share of Exp. Groups in Rural Pop.

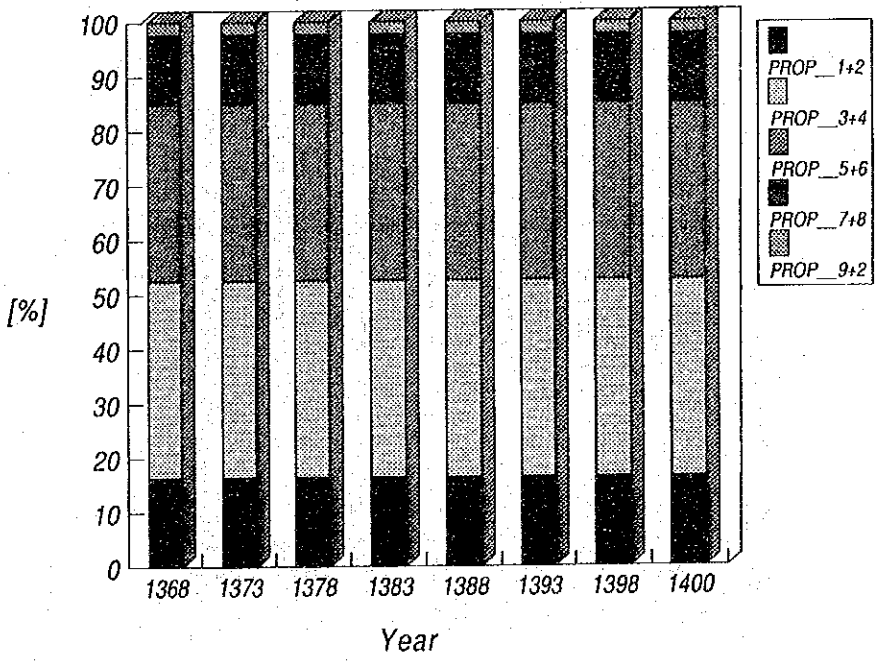


Fig.3.38 :Development of Real Exp. of Urban & Rural Households

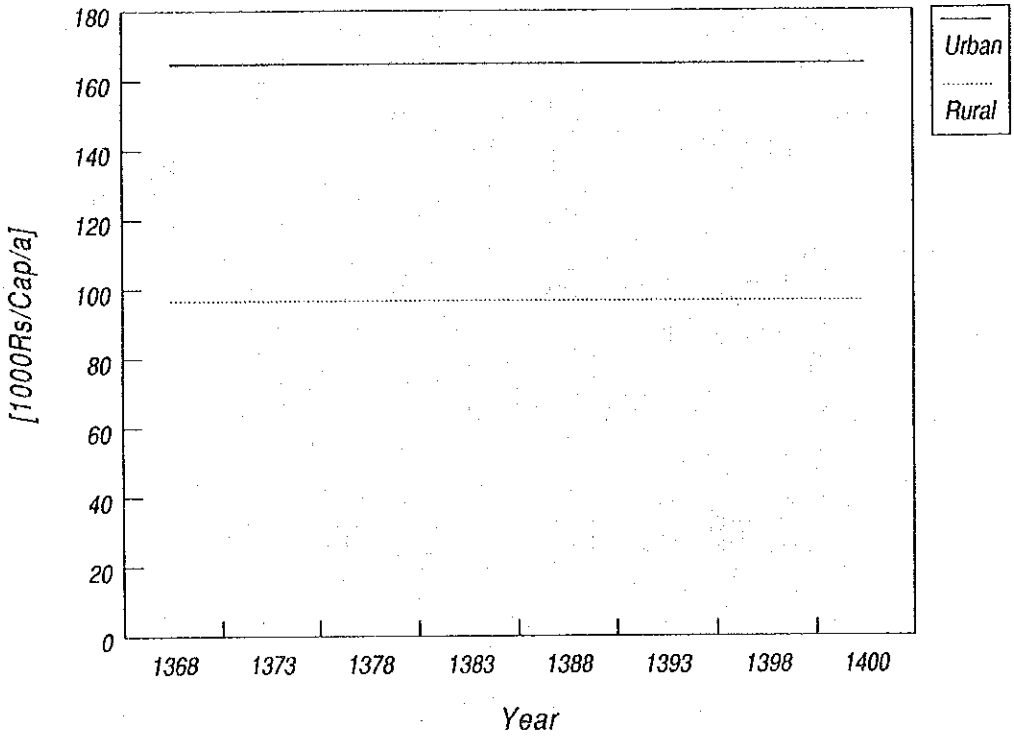


Fig.3.39 :Development of Demand for Useful Energy in Rural House

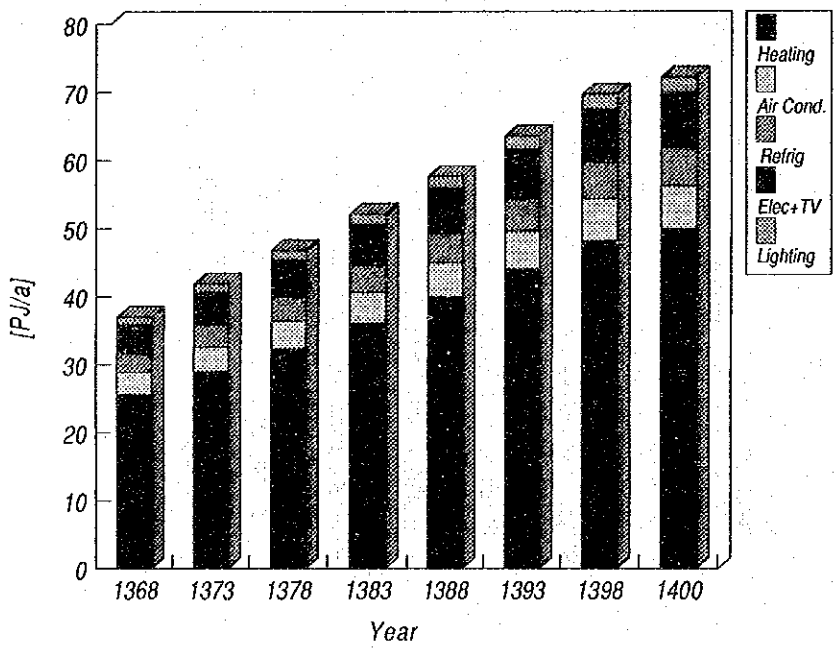
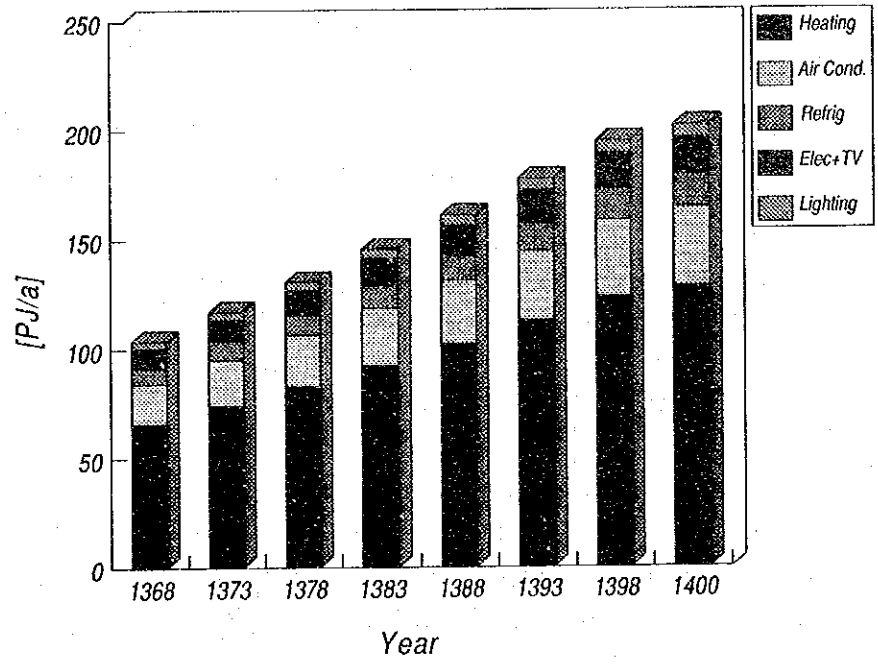


Fig.3.40 Development of Demand for Useful Energy in Urban House.



3.4.2 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-subititutable electricity. Figure 3.41 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.

3.4.3 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 3.42, 3.43 and 3.44 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.3.41 :Development of Demand for Useful Energy in Industry

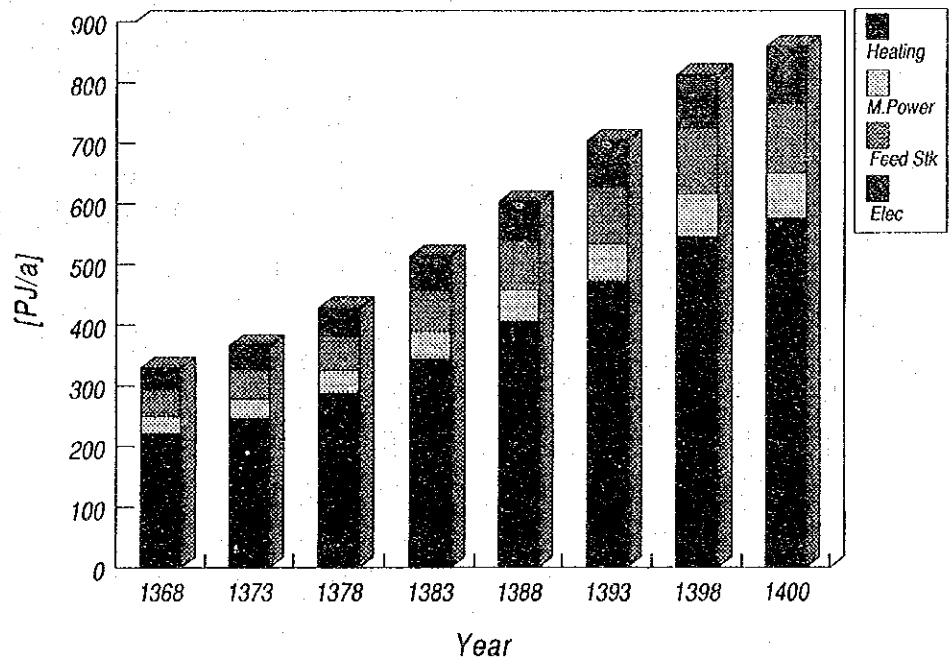


Fig.3.42 Development of Demand for Useful Energy of UP__Trans.

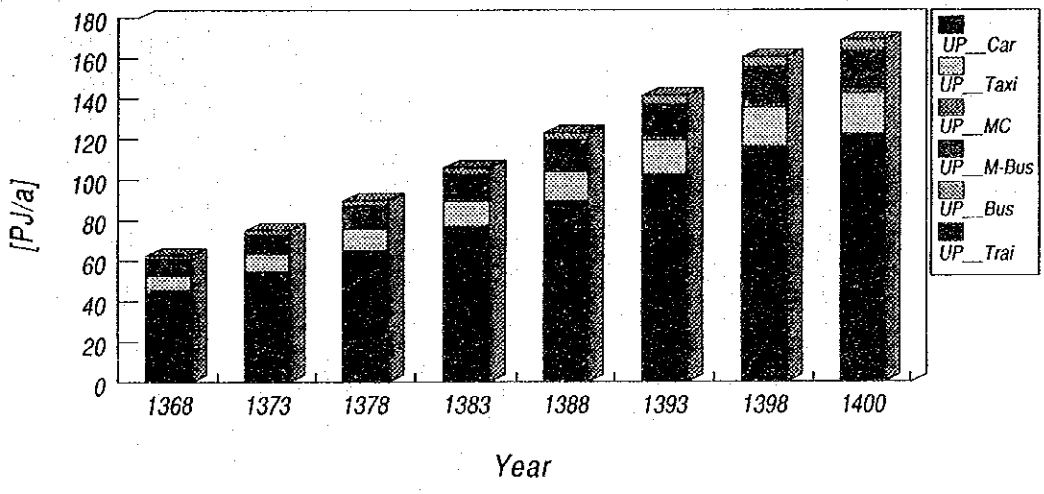


Fig.3.43 Development of Demand for Useful Energy of IP__Trans.

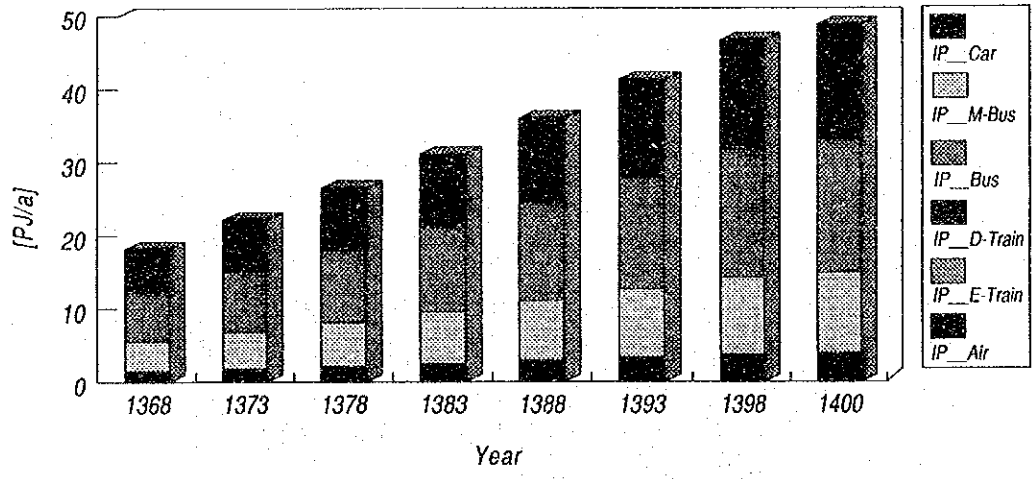
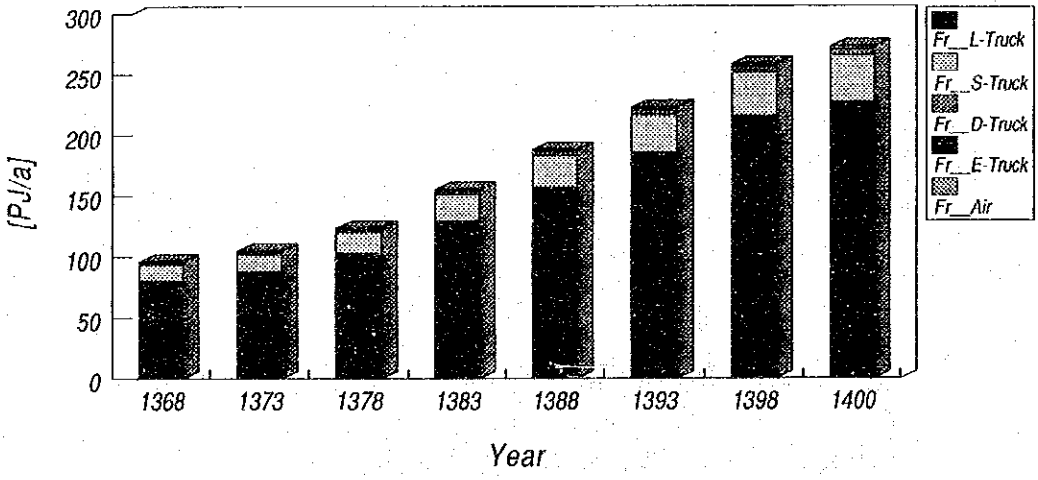


Fig.3.44 Development of Demand for Useful Freight Trans.



4. Development of Energy Supply System

4.1 Introduction

Following the analysis of economic development and a review of the trend of useful energy demand in different social and economic sectors, the major question that had to be attended was organization of the energy supply system, in order to meet the estimated useful energy demand. To this end, the analysis of the development of energy supply system is outlined in the present chapter. First the energy supply model and the outline of the analytical approach will be described. Thereafter, the framework of the study and structure of the main scenarios are presented. In the last section of the chapter, the main findings of the analysis will be discussed.

4.2 Models and Methodologies

4.2.1 Basic Approach

The objective of energy supply analysis is to obtain information on the long-term development of the structure of the energy supply system and to evaluate the appropriate technologies for processing, conversion, transportation and transmission of energy carriers. In the course of this study, it is intended to analyze the interactions between sub-sectors of energy system and to investigate the development of optimal economical energy supply system, which will also be compatible with the environment.

Energy supply analysis will be based on the evaluation of the flow of energy through different stages of processing and conversion, and it will be founded on the Reference Energy System (RES). Reference Energy System is in the form of a network which represents the flow of different energy carriers through various stages of energy processing and conversion.

4.2.2 Energy Supply Model

Optimal development of the energy supply system will be studied with the help of model MESSAGE-III (Model for Energy Supply Strategies and their General Environmental Impact). This

model represents the integrated regional energy supply system; and it is a dynamic system based on Linear and Non-Linear programming. With the help of this model, it is possible to identify the optimal mix of energy processing, conversion, transportation and transmission technologies. It also provides a means of estimating the impact of alternative energy supply strategies and to evaluate the compatibility of the energy supply system with the environment.

Figure 4.1 shows different levels of energy supply system that are represented in the model MESSAGE-III.

The information required for the application of the model MESSAGE-III in the framework of C.E.P. study may be summarized as follows:

a) General information
(The main information include reference year, number of time period, length of each period, number of regions, definition of energy levels, definition of energy carriers at each level)

b) Information on energy demand
(The main required information are definition of energy demand level, definition of load regions for each energy carriers, energy demand in each region)

c) Objective function
(The objective function may be defined as minimization of total costs, minimization of the pollution of the enviornment, or combination of these criteria)

d) User defined relations
(Specific relations may be defined by the user of the model)

e) Information on technologies
(Input & output energies of technologies, efficiency of the technologies, plant life, plant factor, fixed and variable costs of the technologies, emission of the pollutants and restrictions on the application of the technologies)

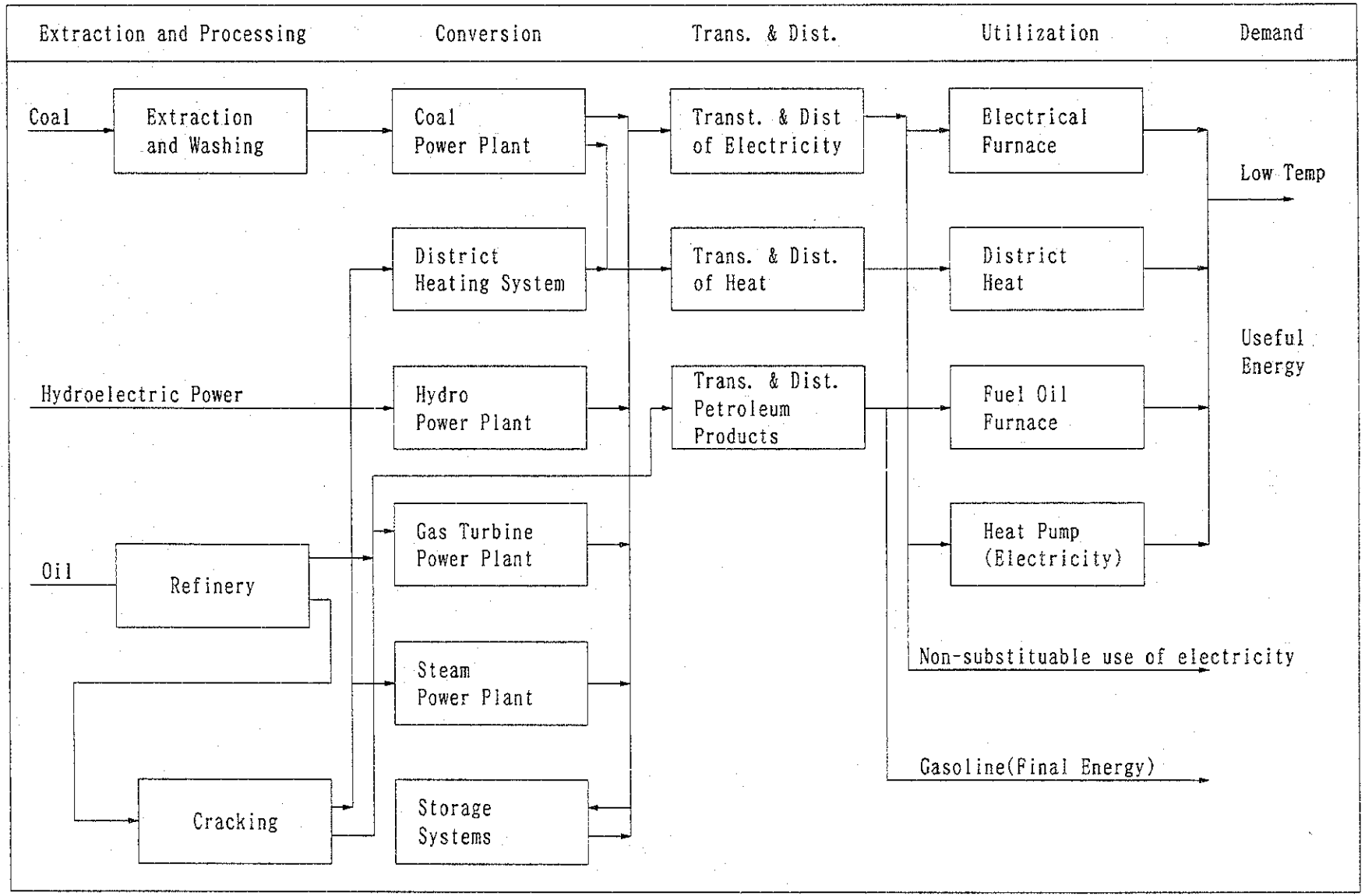


Fig. 4.1 Representation of Energy Supply System in Model MESSAGE-II

f) Information on storage technologies

(Input & output energies, efficiency of system, period in which energy is stored, period in which energy can be extracted, plant life, plant factor, fixed and variable costs, restrictions)

g) Information on energy resources

(Reserve of primary energy carriers, world energy prices, fixed and variable costs of extraction technologies of different grades of energy carriers)

4.3 Scenario Structure

Main determining factors of the development of energy supply system are trend of useful energy demand, price of energy in the international market, energy export renew requirement of the whole economy, load management, improvement of energy efficiency, emission control of pollutants. Combinations of different assumption on the above factors are developed to build up a set of scenarios. With the help of the scenarios it is intended to evaluate the impact of changes in the economy and energy market on the energy balance of the country.

Structure of the energy supply scenarios is presented on Figure 4.2. The four main scenarios considered are Reference (REF), Base, Low and High. These scenarios represent combination of the main cases of economic growth and useful energy demand with different assumptions on the energy management, export of energy, and environmental pollution. The results of analysis of the energy supply system in these scenarios are discussed briefly in the following sections.

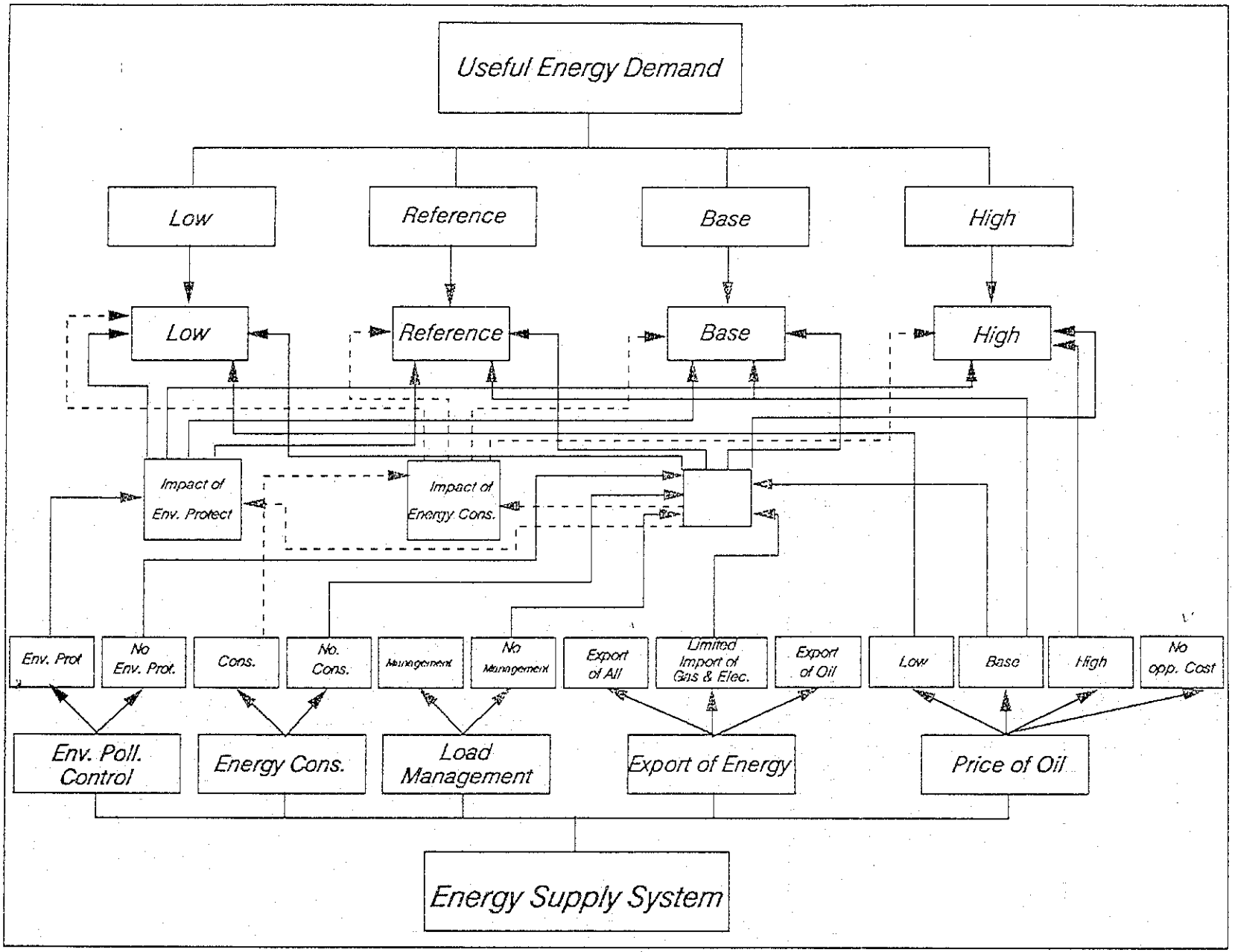


Figure 4.2 Structure of Scenarios of Energy Supply

4.4 Energy Flow in 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 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

.(1) 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 4.3). Share of gas oil increases due to enhanced consumption of this product in transportation and natural gas in 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 may be seen in Figure 4.4, 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. 4.3 Production of Petroleum Products

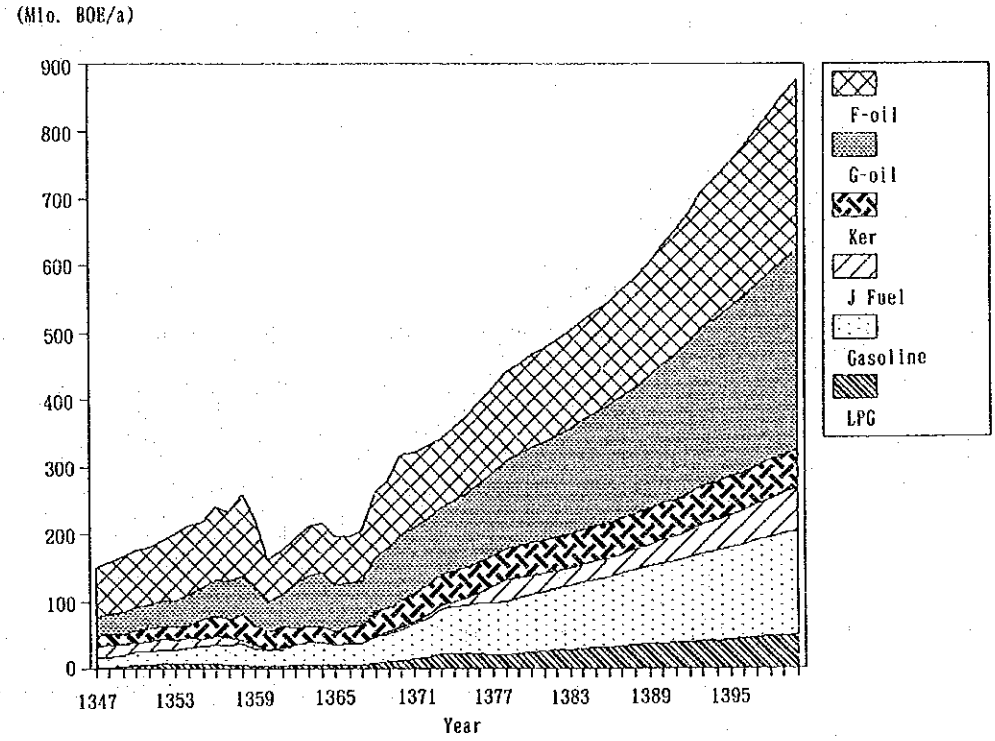
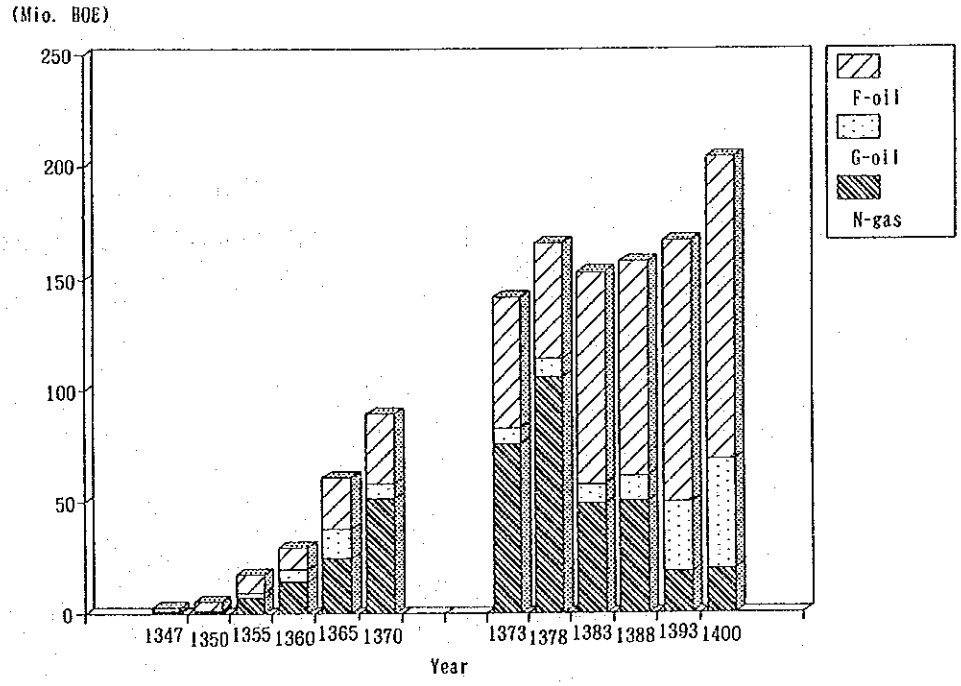


Fig. 4.4 Fuel Consumption of Thermal Power Plants



(2) Capacities of Processing Systems

Expansion of refineries indicate 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.

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.

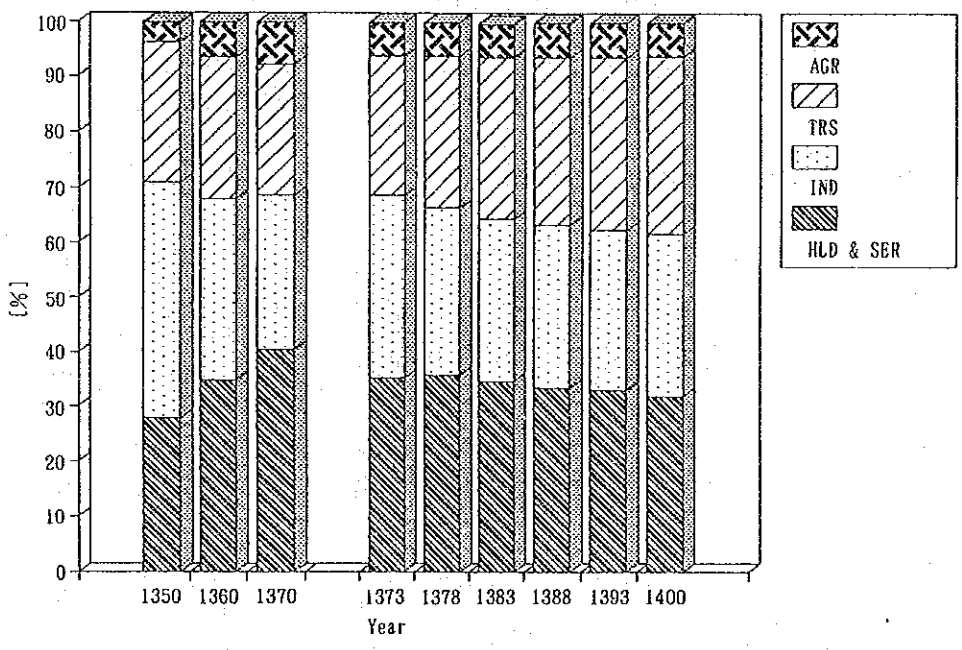
(3) Energy Export

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) Consumption of Final Energy

In Figure 4.5 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. 4.5 Share of Sectors in Final Energy Consumption

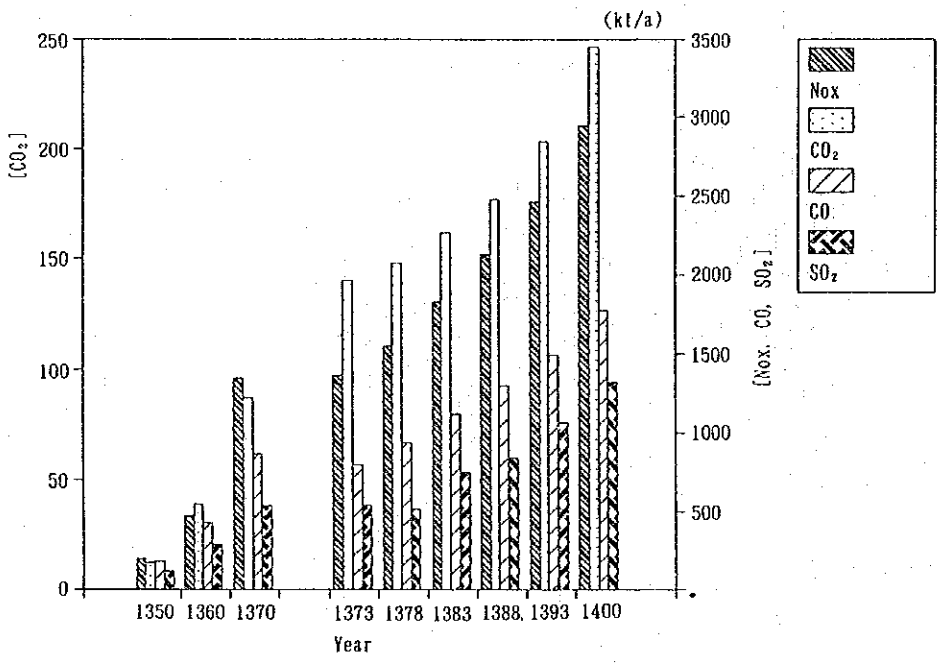


(5) Emission of Pollutants

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 4.6). 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. 4.6 Emission of Pollutants in I.R. Iran



(6) Impact of Subsidization of Energy

Commercial energy carriers are supplied to the final consumers with prices, that are much lower that the marginal cost of energy carriers. But analysis of energy carries 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 968.7 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 carries leads to a situation where primary energy consumption is 97% and 58.8% more than primary energy requirement in the reference case in the years 1994 and 2021 respectively.

4.5 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.

4.5.1 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.

(1) 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 4.7, with the help of energy management, the final energy consumption in household decreases by 33.2% in 2021, compared with the reference case.

(2) 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.

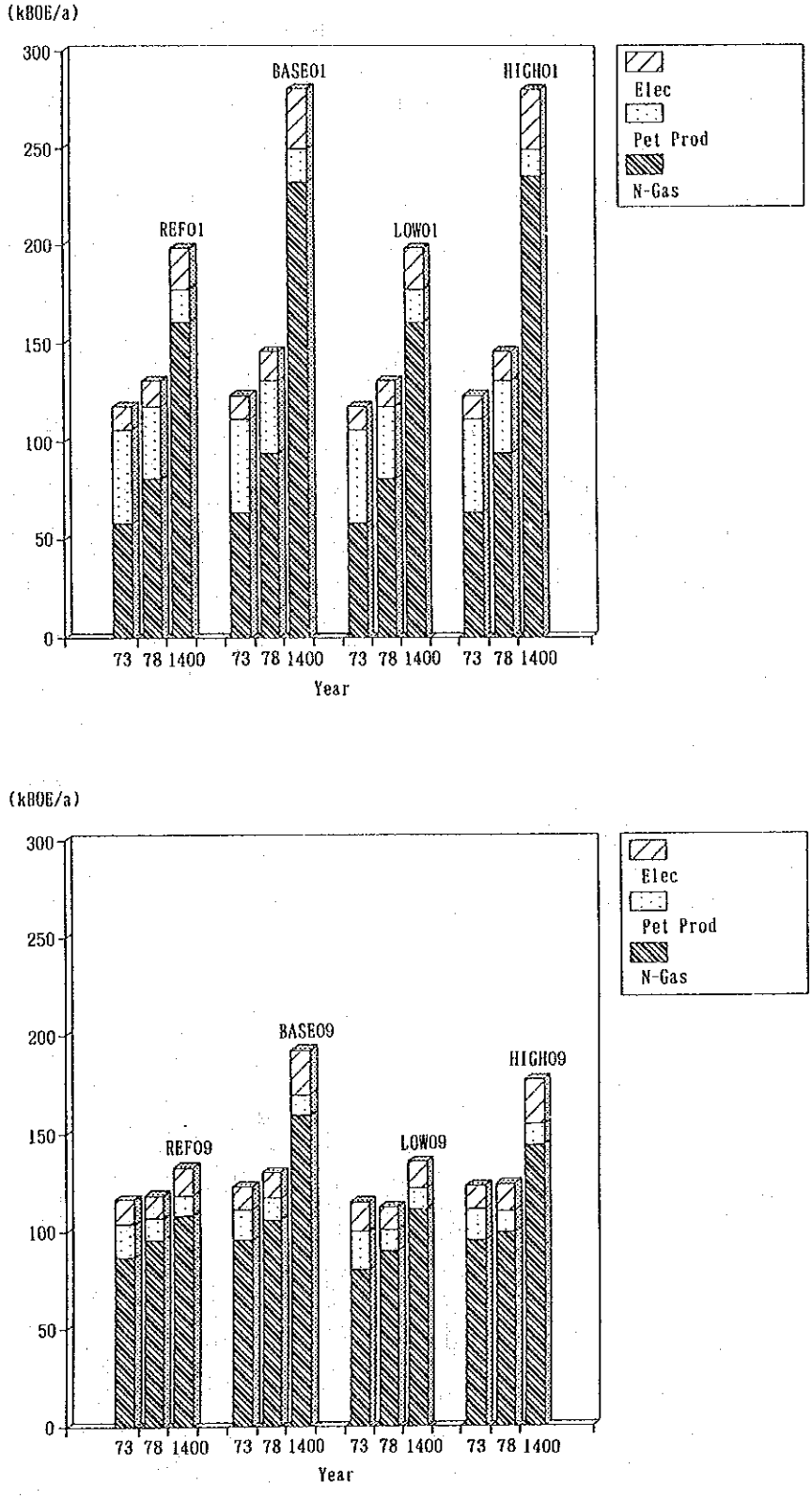


Fig. 4.7 Consumption of Energy Carriers in Household of I.R. Iran

(3) Industry

When the final energy consumption of in 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 4.8), 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.

(4) 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%.

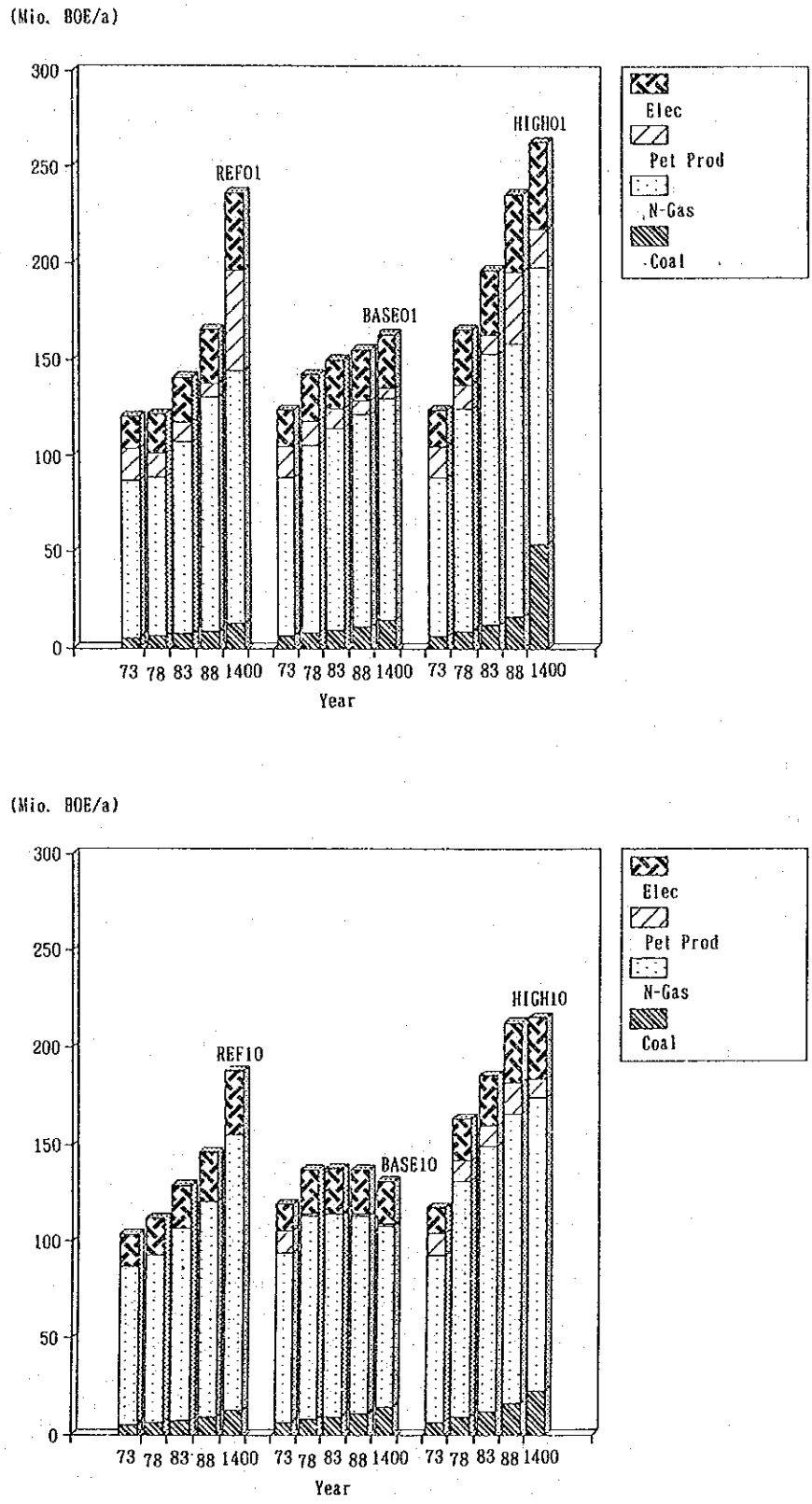


Fig. 4.8 Consumption of Energy Carriers in Industry of I.R. Iran

4.6 Prospects of the development of energy sector

Primary and final energy consumption per capita has been increasing continiously in the last two decades and it rose from 3 BOE/a capita in 1968 to 9.87 BOE/a/capita in 1991. Average annual growth rate of per capita primary energy consumption has been relatively high in the recent years and it reached to 8.3%/a in the period 1989-91. Projection of the development of per capita primary energy consumption indicates that in the high growth scenario it increases to 17.2 BOE/a/capita in 2014 and there after decreases to some extent. In all other scenarios, the per capita primary energy consumption remains at its present level or changes very little.

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(*) (**).

(*) Not only the amount of energy conservation but also such factors as increase in labor productivity and product quality enhancement are generally taken into account as benefits when some measures are justified economically from the viewpoint of individual consumers.

(**) It is needless to say that the viewpoint of the nation or society is important for estimating the "economic" potential in addition to that of individuals. For instance, a study report complied by the Office of Technology Assessment, the U.S. Congress states: "From a societal viewpoint, there is a wider range of relevant costs and benefits. All monetary, health, and ecological costs and benefits accrued to society are pertinent ("Industrial Energy Efficiency," August 1993).

In comparison to this approach which can be said to consider even indirect costs and benefits, there is another approach in which only direct costs and benefits are considered. For example, M. Munasighe makes the cost / benefit analysis by using the concepts of market price and "economic value" (opportunity cost or shadow price) for each of energy carriers and energy using equipment (See Mohan Munasinghe, "Third World Energy Policies -- Demand Management and Conservation," World Bank Reprint Series: No. 255).

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.