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POLISH COUNTRY STUDY TO ADDRESS CLIMATE CHANGE

STRATEGIES OF THE GHG'S EMISSION REDUCTION AND ADAPTATION OF THE POLISH ECONOMY TO THE CHANGED CLIMATE

Cooperative Agreement between
the Government of the United States of America
and the Government of Poland

FINAL REPORT

Warsaw, January 1996

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Annex 1
Annex 2

1. Introduction

The Polish Country Study Project was initiated in 1992 as a result of the US Country Study Initiative whose objective was to grant to the countries - signatories of the United Nations' Framework Convention on Climate Change -assistance that will allow them to fulfill their obligations in terms of greenhouse gases (GHG's) inventory, preparation of strategies for the reduction of their emission, and adapting their economies to the changed climatic conditions.

From the US Government side, the entire project was supervised and managed by the inter-sectoral Country Studies Management Team (CSMT) which comprised representatives of the Department of State, Department of Energy, Environmental Protection Agency, Department of Agriculture, and other.

In February 1993, in reply to the offer from the United States Government, the Polish Government expressed interest in participation in this program. The Study proposal, prepared by the Ministry of Environmental Protection, Natural Resources and Forestry was presented to the US partner.

The program proposal assumed implementation of sixteen elements of the Study, encompassing elaboration of scenarios for the strategy of emission reduction in energy sector (including electricity and heat generation as well as renewable energy sources), industry, municipal management, road transport, forestry, and agriculture, as well as adaptations to be introduced in agriculture, forestry, water management, and coastal management. The entire concept was incorporated in macroeconomic strategy scenarios. A complementary element was the elaboration of a proposal for economic and legal instruments to implement the proposed strategies. An additional element was proposed, namely the preparation of a scenario of adapting the society to the expected climate changes.

The program was subject to a scrupulous assessment of American experts and of the CSMT mission, which, in the summer of 1993, carried through detailed discussions with the implementation unit and representatives of the Ministry of Environmental Protection, Natural Resources and Forestry.

As a result of the above mentioned analysis the CSMT has approved 14 elements. In the cases of agriculture, forestry, transport and legal and economic instruments only further work on elaboration of new programs were accepted. The element concerning social adaptations was rejected.

The Study proposal, modified accordingly, formed a basis of the cooperative agreement on the implementation of the Study, signed in November 1993 between the US Department of Energy and the Ministry of Environmental Protection, Natural Resources and Forestry of Poland.

The signed agreement foreseen that the implementation of the Study would take place between October 1993 and September 1995. The total cost of the Study was defined as 850,800 USD. The American party committed itself to cover the cost of 584,800 USD, while the Polish party 266,000 USD.

On the US Government side, funding was provided by the Department of Energy, on the Polish side - by Scientific Research Committee, National Fund for Environmental Protection and Water Management, and Polish Academy of Sciences as well as sectoral scientific institutes from its statutory funds,.

In the third quarter of 1994 implementation of the project was interrupted due to legal and organizational difficulties that arose on the Polish side. After removal of the obstacles, implementation was resumed in the forth quarter 1994. The delay thus originated caused a necessity to change the deadlines of the Study completion and to sign a new agreement. The new documents foreseen the completion of the Study to be postponed for December 1995, with no cost revisions.

In accordance with the Study proposal, in the first quarter of 1994 the new programs of four Study elements were elaborated, i.e. for forestry, agriculture, transport and legal and economic instruments. Those programs received an approval of the CSMT, however due to the above mentioned difficulties and delays, negotiations over their implementation were not possible. Finally, the elements concerning transport sector, legal and economic instruments and, partially, agriculture were initiated without additional costs. It failed however, to gather funding for preparation of scenarios of strategies for forestry and for complete elaboration of the strategy (emission reduction and adaptations) in agriculture. For the needs of macroeconomic scenario, under the first Study element, partial analysis concerning agriculture, necessary for this work, were commissioned.

The study focused on analyzing the economic situation until the year 2030. This is a very long term horizon, from the perspective of the available knowledge on technology, economic management, social preferences, etc. At the same time however, it is necessary to consider such a long-term planning horizon in order to elaborate an effective policy that would protect against possible adverse effects of the raise in GHG's concentration in the atmosphere.

This report is a synthesis of the Study. It comprise sectoral scenarios and strategies, and macroeconomic scenarios and strategies.

Detailed documentation, databases, methodology descriptions, studies done for specific Study Elements (SE) are deposited with the Heads of SEs.

2. Justification for the Study

Being a signatory of the Framework Convention (and since 1994 the Party), Poland is obliged to work out and implement a strategy for reduction of the GHG's emission and adapting those sectors of the economy which are most dependent on climatic conditions to the expected climate changes.

For Poland, where globally significant amounts of carbon dioxide (about 1.5%, mainly as a result of coal combustion) are emitted into the atmosphere, the issue of reduction of the emission of this gas is economically important. On the other hand, the period of transition does not favor the preparation of long-term economic strategies because of uncertainty of transformation processes. Also because of high priority of current social and economic problems, e.g. unemployment, privatization, creation of banking system, etc., long-term economic goals are not a subject of interest of decision-makers to a degree allowing for elaboration of the scenarios.

For this reason the US Country Study Initiative created a chance to trigger off a process which would further lead to elaboration, updating and implementation of a long-term social and economic policy of the country, that would take into account all activities aimed at reduction of GHG's emission, first of all through a rise of the country economy efficiency, including decrease of the energy and mater consumption level.

3. Study Objective

The objective of the Study was to elaborate a strategy for the reduction of GHG's emission in the Polish economy by the year 2030 as well as to assess possibilities for adapting selected social and economic sectors to the changed climatic conditions. The main goal of the strategy for the GHG's emission reduction is to stimulate modernization of the economy and to direct the economy into sustainable development principles. Specific objectives of the strategy included reduction of the GHG's emission through a decrease of mater and energy consumption in industrial production, better utilization of ecosystems (managed and unmanaged), and rationalization of energy and matter consumption in households.

The idea of sustainable development is becoming to gain a status of an indicator of social and economic changes, that already take place in the developed countries and will also be taking place in the Polish economy. Implementation of this idea is a complex of coordinated activities of strategic nature, beginning with changes in social and political system and ending with stimulating specific projects, such as implementation of recycling, improvement of environmental management, etc. One of the key elements of the Study was the elaboration of guidelines for political and economic decision-makers in Poland, to be taken into account during formulation of a national strategy for the country's economic development.

Formulation of the scenarios of emission reduction required their comparison with scenarios of social and economic development, which do not consider this issue. However, because of economic transitions of Poland, there is no long-term macroeconomic strategy for the country. This also had to be elaborated for the purpose of this Study.

Additional products of the Study are the following: databases, detailed sectoral studies containing *inter alia* scenarios of the emission reduction and strategies for adaptations prepared in Polish, proposed changes of technology, cost analyses, publications and papers given by the Study authors.

Major objectives of the research carried out within the framework of the Country Study included:

- elaboration of methodologies (utilizing formal tools) for the creation of scenarios of GHG's emission in the economy as a whole and its sectors encompassed by the Study;
- assessment of possibilities to use technological options and mechanisms of their stimulation in the relevant sectors of the country economy based on the elaborated method of cost and benefit analysis;
- elaboration of sectoral scenarios for the emission reduction and increase sinks of GHG's and their integration in the form of national strategies that have as their background the adopted options of economic development;
- formulation of partial strategies of adapting to the climate changes in water and coastal management;
- proposing methodologies (utilizing formal tools) for the construction of national policy concerning reduction of GHG's emission in the relevant sectors of the economy; and
- recommendation for development directions of relevant sectors of the national policy.

4. Organization of the Study

The Minister of Environmental Protection, Natural Resources and Forestry has nominated Prof. Maciej Sadowski, Head of Climate Protection Center of the Institute of Environmental Protection, as a Project Manager. The Polish Foundation for Energy Efficiency was granted a function of the administrative body. On behalf of the Ministry supervision was carried out by the Department of Protection of Air and Earth Surface as well as the Department of International Cooperation.

On the American side a Regional Project Coordinator - Chris Bordeaux (CSP) and the Project Officer were nominated. The latter position was held by Dr. J. Elkind, Dr. J. Krider, and Dr. M. Safley successively. Terms of Reference of the Project Officer and Project Manager were defined in the General Terms of Agreement. Dr. R. Dixon was nominated as a Country Study Program Director.

Establishment of an inter-sectoral commission to supervise preparation of the Study was originally planned, however the Minister of Environmental Protection, Natural Resources and Forestry decided finally to grant this function to the Commission for Sustainable Development. The Commission has inter alia review the reference scenario prepared under the Study.

4.1. Cooperation with the Country Studies Management Team (CSMT)

The CSMT mission to Poland took place in July 1993 with an aim to discuss the Study proposal and clarify outstanding uncertainties. The visit resulted in the approval of the project for implementation.

In June 1995 the Project Officer of CSMT conducted a detailed audit of the project progress, carrying out discussions with the heads of all Study Elements as well as with representatives of the Ministry of Environmental Protection, Natural Resources and Forestry. According to the Project Officer opinion, the project progress was satisfactory and no serious shortcomings or deviations were found.

In June 1995 the CSP Management and a group of the US experts attended a Symposium organised in Warsaw by OECD/CSP/USEPA for EIT countries. This was a convenient opportunity for the Polish experts to carry out consultations and detailed discussions.

The Project Manager has twice had an opportunity to present the progress of work in Washington. In December 1993 the program assumptions and in December 1994 the progress of technical work were presented by him and a team of authors. On the latter occasion the Polish team was granted the diploma for the "creative cooperation" with CSMT.

In accordance with the Agreement, quarterly interim reports on the work progress were prepared (six in total), and submitted to the Project Officer on a regular basis.
The following members of the project implementation team visited the United States and other countries to conduct consultations, participate in seminars and present in detail progress of work:

H. Gaj, Ph.D. - Lawrence Berkeley Lab. 1995
E. Hille, M.Sc. - CSMT Washington 1993
E. Hille, M.Sc. - Mandelieu, France, 1995, ECEEE Summer Study
B. Jankowski, M.Sc. - Argonne, NL and Brookhaven, NL, 1995
Z. Kaczmarek, Prof. - VA Assessment Training Workshop, Washington, 1994, ENCAR, GFDL, 1995
E. Kowalska, M.Sc. - CSMT Washington, 1993
T. Lis, Ph.D. - Argonne, NL and Brookhaven, NL, 1995
J. Napiórkowski, Ph.D. - US Army Corps of Engineers, 1995
A. Olecka, M.Sc. - VA Assessment Training Workshop Washington, 1994
E. Radwański, Ph.D. - CSMT Washington, 1993
E. Radwański, Ph.D. - Copenhagen, Denmark 1994, International Conference on national Action to Mitigate Global Climate Change
M. Sadowski, Prof. - CSMT Washington, 1993, 1994
R. Zeidler, Prof. - Kobe, Japan, 1994, 24 International Conference on Coastal Engineering; GeoDan, Haga, NL, 1995

Moreover, prof. W. Suchorzewski meet the Project Officer and the experts from the transport sector during his visit to the United States.

The Study comprises 13 following elements (SE):

1.	SE1	Macroeconomic approach applied to strategies for the reduction of GHG's emission
2.	SE2	Strategies for the CO2 emission reduction by the year 2010 in the economy sectors dependant on the energy production
3.	SE3	Elaboration of a GHG's emission reduction mathematical model for electricity and heat energy subsectors
4.	SE4	A strategy of structural industry changes and technology development to enable GHG's emission reduction
5.	SE5	Options of Polish agriculture development under forthcoming greenhouse effect and possibility of adaptation to climate change - developed as a subtopic under SE1
6.	SE6	Regional scenarios of climate changes
7.	SE7	Elaboration of a strategy and technology of utilisation of the renewable energy sources
8.	SE9	Elaboration of a program for the GHG's emission reduction in the transport sector
9.	SE10	Elaboration of a program for the GHG's emission reduction in the municipal sector
10.	SE11	Legal and economic aspects of the GHG's emission reduction strategies in the Polish economy
11.	SE12	Strategies for the water management in face of climate change
12.	SE13	Coastal zone management and protection for Poland's coastal segments most vulnerable to climate change in the scales of decades and centuries
13.	SE14	Management and coordination of the project and preparation of the final report

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5. Political and economic background

5.1. Basic information about Poland

Since 1989 the Polish economy has undergone the period of transition from a centrally planned to a free market economy, processes of backing out from budget subventions for businesses and privatization processes. The 1994 *Strategy for Poland* defines main objectives and tools for the implementation of the country social and economic policy until the year 1997. Its main assumptions include: acceleration of economic development of the country, macroeconomic and system stabilization, reduction of social costs of reforms and improvement of the quality of living of the society, increase of Poland's international economic competitiveness, and working towards a fast integration with the European Union. The process of reforms in the Polish economy commenced however as early as just after the "Round Table" and now, after 5 years of reforms, positive changes in most economy sectors can be observed. The most important factor of changes was the process of privatization in the public sector and the development of small private enterprises. Financial instruments gained more and more importance in the steering of the economy. The main objective of financial policy was to stop the inflation processes. The major activities that have been undertaken after 1990 in order to reach this objective included: release of prices, change of fiscal policy, introduction of free market operations, obligatory requirements from the bank to maintain a relatively high level of reserves in the Polish National Bank, limitation of bank loans, revaluation of wages in the public sector lower than planned in the budget, and other. As a result, the inflation ratio has fallen significantly since 1990 still however maintaining a relatively high level (Fig. 5.1.1).

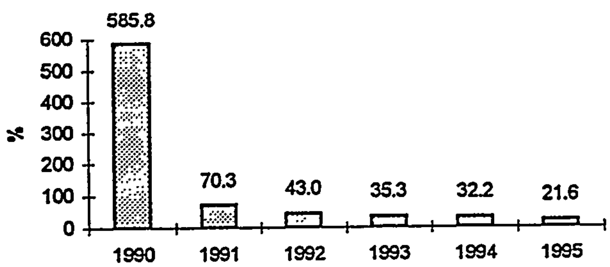

Fig. 5.1.1. Inflation rate in period 1990-1995
(average growth in the year)

In 1991 the Polish Parliament adopted the National Environmental Policy, which set out a number of priority objectives. The main goal of the implementation program to the environmental policy is to ensure a noticeable improvement of environmental quality and to create conditions for a sustainable social and economic development, in particular: to reduce atmospheric emission of gases and dusts as well as discharge of effluents into surface fresh water bodies and sea, to reduce clean water deficit, to intensify protection of raw resources, to reduce volume of generated and stored industrial and municipal waste, to accelerate actions towards safe disposal of toxic and hazardous waste, to stop the increase of an adverse environmental impact from transport, energy lines and telecommunication means (fumes, noise, radiation), to diminish threat to people and environment posed by industrial and transport accidents (including transboundary threats), to improve the health status of forests and to extend the area protected for a high natural value. Economic reforms and decline in economic activity after 1989 have significantly reduced the environmental pressure. Reduction of this pressure was higher that the drop in GDP which shows the effectiveness of environmental measures. In 1992 the outlays for the environmental protection reached 1.3 per cent of GDP which is a substantial share.

One of the economy sectors generating the most adverse environmental impact is the energy and fuel sector. This results mainly from the fact that coal is still a dominating source of primary energy in the Polish economy. However, between 1990 and 1994 the share of this fuel dropped from 76.5 per cent to 74 per cent, which is a result of the tendency to switch to other energy carriers such as oil and natural gas. Coal however will long remain being the major energy carrier in Poland. Successful activities have also been undertaken towards abatement of the emission from energy sector through the reduction of the use of low quality coal as well as a construction of coal desulphurization installations and improvement of flue gas cleaning efficiency. The energy policy elaborated in 1992 comprise mainly an analysis of industry restructuring, possibilities of energy efficiency increase and environmental policy related solutions. The energy policy adopted the assumptions of the national environmental policy. This resulted in a significant progress in incorporating environmental issues into a national energy policy and related programs, at least within the electricity subsector. However, the energy consumption indicators in Poland remain at a very high level (energy-intensity: 2.5 toe per capita; energy consumption per GDP unit ratio: 1.7 toe/1000 USD).

5.1.1. Domestic economy aspects

Since 1992 the GDP has shown a tendency of growth after the significant drop in the previous years. In 1994 the growth reached 5 per cent against the previous year while after first five months of 1995 the growth of 6 per cent is forecast (Fig. 5.1.2). The share of industry in the GAP generating has declined, while this of other sectors, including services, has increased. Export and investment share have grown, while consumption has increased only by 3 per cent. Industry has been the main source of GAP having a 40 per cent share in its generation in last year. Therefore this sector has a key influence on the pace of the economic development of Poland. Industrial production has been still growing, however this year its rate is foreseen to be slower than last year (Fig. 5.1.3).

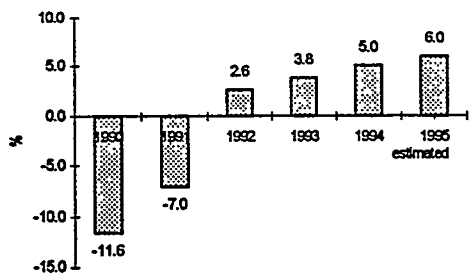

Fig.5.1.2. Dynamics of Gross Domestic Product in period 1990-1995 (previous year = 100)

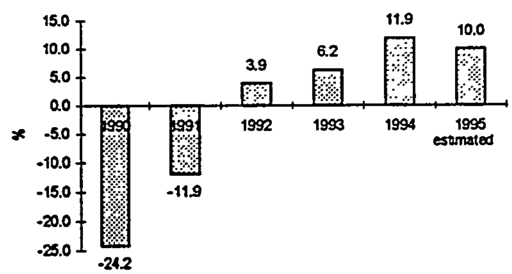

Fig.5.1.3. Changes in industrial production in period 1990-1995 (previous year = 100)

After a very long period, the year 1994 was the first when the growth of investment ratio was higher than GDP growth. Investment outlays growth indicator in 1994 increased by 7.1 per cent against the preceding year and the prognosis for 1995 speak about the rise of about 10 per cent (Fig. 5.1.4).

The housing sector, after initial development tendencies recorded a period of stagnation and in 1994 grew only by 0.2 per cent against 1993. In 1994 the number of finished and inhabited apartments was half of the number in 1989 and was roughly similar to the figures achieved in the 50-ties. The chief reason for such situation is a very high construction cost in relation to income per household.

The most adverse phenomenon resulting from the social and economic changes is the unemployment. In 1994 the number of unemployed reached 16 per cent of all capable of work citizens. The highest increase of unemployment was recorded between 1991 and 1992, reaching the level of 1.1 million people/year. Thanks to the improvement of economic situation which stimulated creation of new work places this number began to decline last year (Fig. 5.1.5).

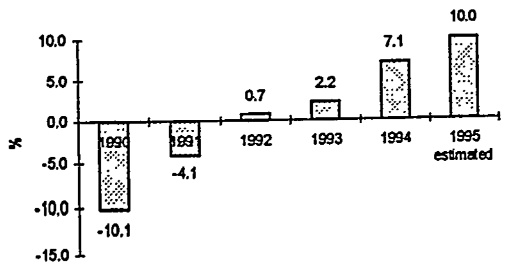

Fig.5.1.4. Rate of investment inputs in period 1990-1995 (previous year = 100)

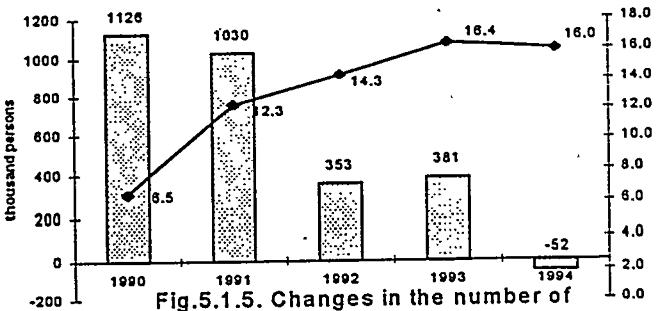

Fig.5.1.5. Changes in the number of unemployed [thousand persons] relatively to previous year and unemployment rate [%] in period 1990-1994

Economic condition of the Polish agriculture comprising approx. 2 mln individual farm holdings is very difficult. Over 70 per cent of holdings are low income farms with no chances for restructuring or modernizing. As a result of liquidation of the State Agricultural Enterprise the area of fallow land is increasing. At the moment those areas comprise about 10 per cent of the total arable land area. In the last five years production in the agricultural sector has been gradually declining and reached in 1994 the level lower by 20 per cent comparing with 1990. Unfavorable agricultural and meteorological conditions during the recent years have counteracted potential results of activities undertaken to improve the condition of Polish agriculture.

5.1.2. Foreign economy aspects

Opening of the Polish economy into external markets, increase of Polish goods competitiveness, entering of Polish business into a world business circles, as well as system changes have caused a growth of foreign trade in the recent years. Export has become an important factor of economic development and in 1994 grew by nearly 3 billion USD as compared with 1993. In the same period import grew from 9.8 billion USD in 1993 to 21.6 billion USD in 1994. Increase of export however, have not reduced the Polish foreign debt and was not sufficient to cover the service of debt. Although last year the London Club decided to reduce the Polish debt by nearly 10 billion USD, the level of debt will continue to grow systematically. The Polish export is based primarily on natural raw resources and to a lower extent on final products. Germany has become the single largest trade partner for Poland, in terms of both export and import. Other important trade partners include other countries of West, East and Central Europe as well as countries of former Soviet Union (Fig. 5.1.6 and 5.1.7)

Capital brought into Poland by foreign companies has high importance in investment activity. During the first three months of this year foreign companies invested in Poland 700 million USD, which is more than half of the sum invested in the whole 1994.

Poland has signed a number of bilateral agreements with OECD countries concerning financial assistance for environmental protection, i.e. with Belgium, Denmark, Finland, the Netherlands, Norway, Germany, Switzerland, Sweden and the United States. Apart from the support given by the European Union (PHARE Program), Poland also received assistance from the World Bank, Japan, and Great Britain. In November 1993 the value of total foreign assistance for environmental protection reached 230 million USD directed into 236 projects.

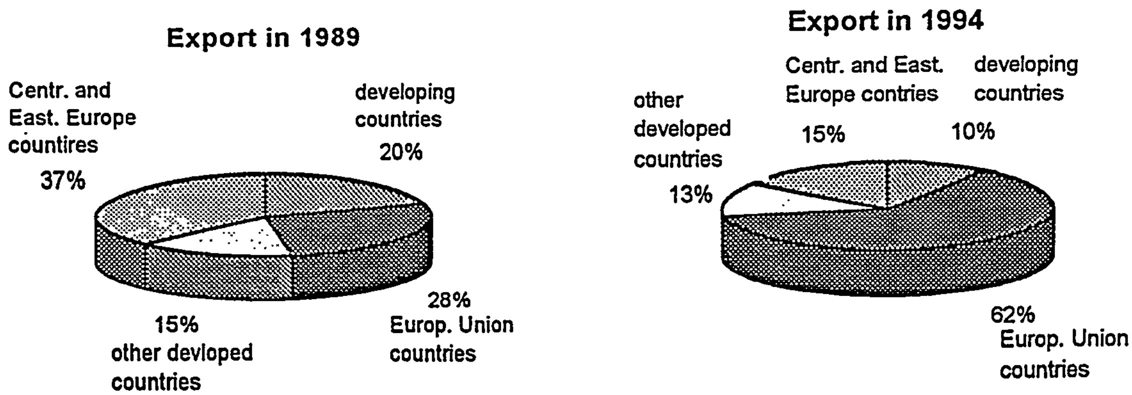

Fig. 5.1.6. Structure of Polish export by groups of countries in 1989 and 1994

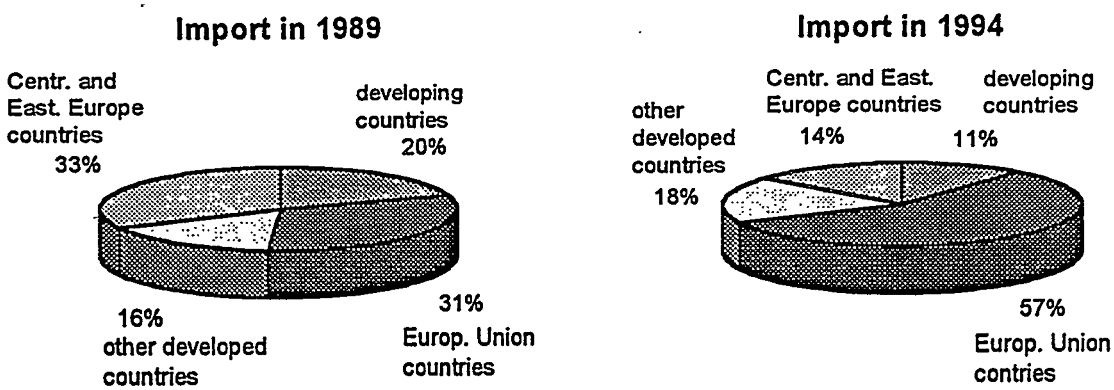

Fig.5.1.7. Structure of Polish import by groups of countires in 1989 and 1994

5.2. Transition period considerations

The Polish economy is at the stage of important system transformations. This, as well as globally introduced changes in energy systems (resulting from technical progress, development of informatics, attempts to break down natural monopolies) are the reasons for the fact that during elaboration of the Study a comprehensive and fully accepted economic model (concerning organization, ownership, law, regulations, market) for the analysed sectors did not (and still does not) exist. This situation makes it possible to introduce elements concerned with GHG's emission reduction into the work carried out in the country over such a model. However it was impossible to propose one mathematical model covering the whole spectrum of problems to be considered. This was finally the reason for which the team of authors has analysed and proposed structural, ownership, organizational and legal changes, aiming at creation of opportunities for consideration of GHG's emission reduction issues jointly with other, currently functioning evaluation criteria. Therefore, activities carried out within the framework of this Study focused on the problems of pragmatic nature and aimed at presentation to decision-makers of alternatives and proposals for verifying current concepts of the country development.

6. Modelling methodology

6.1. Modelling system and procedure of creating GHG abatement scenarios

In the CS the following sequence of questions should be answered:

- What are GHG abatement technological and technical options?
- What are possible and realistic to use policy measures stimulating GHG emission abatement?
- What is the likely reaction of the economy to the policy measures?
- What are possible GHG abatement scenarios at the economic subsystem level (sectoral scenarios)?
- What are the optimal combinations of abatement - and policy measures for given objective functions at the entire economic system level (country scenarios)?

As the economic system is extremely complicated, simplified models are commonly used to analyse the system. The Modelling system elaborated in the CS and for the CS is presented in Table 6.1.1.

Table 6.1.1. General Scheme of the Polish Country Study Modelling System

Purpose	Level	Models	Modelling technique	Results: what	Results: how
Data completion	Technological Sectoral Country	CS-DB CS-DB CS-DB	Data base	Data base for the Country Study	Technolog. data Economic data Emission char. Qualitat. data
Elaborating: • individual options • integrated options • sectoral scenarios	Sectoral: • Energy econ. • Power sector • Other sectors	EFOM ENPEP GACS	bottom-up	• technol. options • integrated options • sectoral scenarios	GHG red (t) Energy (t) Cost (t) LNPC, IRR Sect. MC curve Qualitat. descript.
Creating the MERS	Country	DSM-NE	top-down	MERS	ME functions ME parameters Qualitat. descript.
Creating the MEAS • Defining collisions • Ranking options		CIA HIPRE3+	Decision analysis	• ranked sets of options • MC curves	Collisions GHG red. (t) Energy (t) Cost (t) Qualitat. descript.
• Defining policy measures to activate options	Country	GACS DSM-NE	bottom-up top-down	Policy measures	Taxes, subsidies Custom duties Emission limits Techn. standards
• Identifying the ME impacts of the policy measures		DSM-NE Emis. Mod.	top-down	GHG reduction scenarios	ME functions ME parameters Qualitat. descript.
• Evaluating the reduction scenarios		CIA HIPRE3+	Decision analysis	Final set of ME reduction scenarios	ME functions ME parameters Qualitat. descript.

The entire Modelling system is served by the data base especially organized for the Project. The data base gathers technological, economic and emission data for the abatement options. Qualitative descriptions of options are also included.

The analyses are carried out at two levels of the system - sectoral and country levels. This fact determines the Modelling methodology to be used.

At the sectoral level the energy and power sectors play a significant role since 96% CO_2 emission is caused by fossil fuels burning. Two bottom-up models, Energy Flows Optimisation Model **(EFOM)** *CEC* (1991) and Energy and Power Evaluation Program **(ENPEP)** [Buehring et al., 1991] are used by the energy and power teams of the CS. The other sectoral teams have been equipped with the GHG Abatement Cost Spreadsheet **(GACS)** *Gaj* (1994a). The GACS was elaborated especially for the Country Study. The methodology of the costing procedure is based on the concepts of cost-benefit analysis.

Individual technological options are the base for further analysis. That is why they should be examined in detail at the beginning.

The set of the individual options should be tested by the procedure of generating internally coherent sectoral scenarios. Collisions and overlaps of options should be eliminated. EFOM and ENPEP models are proper tools for this purpose. Step curves of marginal costs and a qualitative description of the scenarios are the expected output of the sectoral analysis. Additionally, GHG emission, energy consumption, cost time functions and policy measures to activate given GHG reduction options are required for further analysis at the country level.

The Dynamic Simulation Model of National Economy **(SDM-NE)** [Radwański et al., 1993] was adoptes as the main modelling tool at the country level. The model belongs to the top-down family. Its methodology follows the general equilibrium philosophy.

The country level activity starts from creating the Macro-Economic Reference Scenario **(MERS)** defined with basic macro-economic functions and parameters. The MERS was elaborated in three variants in order to reflect uncertainty of the forecasts.

Next, the Macro-Economic Abatement Scenarios **(MEAS)** are being elaborated on the bases of the sectoral abatement scenarios and the MERS.

The MEAS creating procedure starts with combining the sectoral scenarios with the country abatement scenario. Two 'Decision Analysis' type models and heuristic methods are used in order to detect collisions and overlaps among the sectoral scenarios. These models are the Cross Impacts Analysis **(CIA)** [Gaj, 1994b] and the Hierarchical PREferences **(HIPRE3+)**.

The CIA model was elaborated in the frame of the CS. The model enables analysts to estimate interrelations among probabilities of a given set of events while the events are activated stochastically.

The HIPRE3+ is a commercial Decision Support System **(DSS)** software distributed by Santa Monica Software Co. (USA, CA).

The CIA and HIPRE3+ models were applied also to rank the resulting abatement scenarios in the final stage of the CS.

6.2. Description of the models

6.2.1. Greenhouse-Gases Abatement Cost Spreadsheet - GACS

Reduction of the GHG emission, likely the main obligation for the FCCC, has significant economic impact. Cost of the reduction of GHG emission is a measure of the impact. That is why the cost-benefit analysis may be applied as a tool for estimating climate policy.

The GACS was elaborated in order to unify the methodology of cost calculations for the entire Country Study, to facilitate work for sectoral teams, and to give a consistent structure to the process of data transmission.

The GACS procedure calculates costs of technological GHG reduction options which is the lowest hierarchical level in the system.
The reduction option is defined by two technologies:

- low GHG emission intensive technology which replaces
- high GHG emission intensive technology.

General cost-benefit formula

Generally, the cost-benefit analysis considers two types of economic components:

- market components, for which market prices have been established, and
- externalities, which are side effects of economic activities, and for which markets do not exist.

Evaluation of externalities with market prices is impossible. For that reason a somehow artificial term 'shadow price' was introduced to enable measuring of values of externalities. The 'shadow price' represents social, marginal willingness to pay for a given non-market good.

In the GACS only the market oriented elements are represented. That is why it reflects the net cost as it is seen by the micro-economic decision maker.

External, non market elements should be compared to macro-economic costs (mainly GDP drift) under the frame of the top-down procedure.

The cost-benefit analysis may be generally formulated as the following equation:

$$NC = \sum C_i - \sum B_i \qquad (6.1)$$

Where:
NC - net cost,
C_i - cost element,
B_i - benefit element.

After introducing the time factor to the formula (6.1) the future costs and benefits are transformed to the present moment value:

$$NPC = \sum_t \sum_i C_{t,i} a_t - \sum_t \sum_i B_{t,i} a_t \qquad (6.2)$$

where:
NPC - net present cost,
t - time distance to the moment of the occurrence of a given element of benefit or cost,
a_t - discount factor $a_t = \left(\frac{1}{1+r}\right)^t$
r - discount rate.

Only the projects with negative NPC are economically effective.

Costs and benefits elements in equation (6.1) and (6.2) may be assigned to the categories:

- capital outlays,
- fixed costs,
- operating and maintenance (including fuels and energy) costs,
- value of final products.

Cost and benefit elements are defined by quantities and prices.

Discount rate

Depreciation of value with time is described by the discount rate. Every project has its own discount rates and the individual judgements give, on average, a social discount rate. The discount rates related to the market elements of costs and benefits may be estimated on the basis of interest rates of the bank credits, although it should not be done automatically but in a flexible way.

Particular cost-benefit formula

Generally, at the lowest hierarchical level of the system analysis, GHG emission reduction results from replacement of technologies. That is why the following elements should be considered:

- **costs related to implementation of new, low GHG emitting technology:**
- capital SYMBOLcosts, I_{imp}
- fixed costs, C_{imp}
- SYMBOLoperating and maintenance costs, V_{imp}
- SYMBOLcosts of fuel used, F_{imp}
- SYMBOLcosts of lost (relating to the non GHG option) production, LP
- SYMBOLcosts of cancelling a replaced technology, RT
- SYMBOLimplementation costs, IMP

- **benefits due to avoided expenses of replaced technology:**
- SYMBOLavoided costs of investments, I_{rpl}
- SYMBOLavoided fixed costs, C_{rpl}
- avoided operating and maintenance costs, V_{rpl}
- avoided costs of fuel, F_{rpl}
- value of additional, enhanced production, EP

All these cost/benefit components contribute to the net costs of the GHG abatement:

$$\begin{aligned} NC = I_{imp} + C_{imp} + V_{imp} + F_{imp} + LP + RT + IMP - \\ - I_{rpl} - C_{rpl} - V_{rpl} - F_{rpl} - EP \end{aligned} \qquad (6.3)$$

Equation (6.3) may be transformed to the discounted form:

$$\begin{aligned} NPC = \sum_{t+t_0}^{h} I_{imp_t} a_t + \sum_{t+t_0}^{h} C_{imp_t} a_t + \sum_{t+t_0}^{h} v_{imp_t} QP_{imp_t} a_t + \sum_{t+t_0}^{h}\sum_{f=1}^{i} qF_{imp_t} PF_{imp_t} QP_{imp_t} a_t + \\ + \sum_{t+t_0}^{h}\sum_{p=1}^{j} PLP_{p_t} QLP_{p_t} a_t + \sum_{t+t_0}^{h} RT_t a_t + \sum_{t+t_0}^{h} IMP_t a_t - \\ - \sum_{t+t_0}^{h} I_{rpl_t} a_t + \sum_{t+t_0}^{h} C_{rpl_t} a_t + \sum_{t+t_0}^{h} v_{rpl_t} QP_{rpl_t} a_t + \sum_{t+t_0}^{h}\sum_{f=1}^{i} qF_{rpl_t} PF_{rpl_t} QP_{rpl_t} a_t - \\ - \sum_{t+t_0}^{h}\sum_{p=1}^{j} PEP_{p_t} QEP_{p_t} a_t \end{aligned} \qquad (6.4)$$

Where:
QP - quantity of the main product,
v - elementary operating and maintenance cost (related to the unit of the main product),
qF - elementary fuel consumption (related to the unit of the main product),
PF - fuel and energy price,
PLP - price of the lost (comparing to the replaced technology) product,
QLP - quantity of the lost (comparing to the replaced technology) product,
PEP - price of the new (comparing to the replaced technology) product,
QEP - quantity of the new (comparing to the replaced technology) product,

a_t - discount factor $\quad a_t = \left(\frac{1}{1+r}\right)^t$

r - discount rate.

The Net Present Cost is the main parameter for estimation of a given GHG reduction technological option. It helps to rank the options and create sectoral GHG abatement scenarios.

Another parameter, Levelled Cost, is used to compare options from the point of view of cash flows. The concept of the levelisation is based on the assumption that the distribution of costs is transformed to equal along the time period. The Levelled Costs are described by the following equation:

$$LC = NPC\frac{r}{1-(1+r)^{-h}} \qquad (6.5)$$

where:
NPC - net discounted cost (net present cost),
r - discount rate,
h - time horizon, number of years in the levelled period.

It is easy to notice, that for long periods, e.g. h>30 years, the levelled cost and the net present cost are different by a discount rate factor, thus their interelation can be quickly assessed.

Spreadsheet organisation

Time period 1988-2030 is considered since 1988 in the base year for Poland under the Framework Convention on Climate Change, while the year 2030 is a time horizon of the Country Study. The implemented and replaced technologies have separate segments in the spreadsheet.

A user loads the following data into the spreadsheet:
- name of the technology and its main product,
- main product output,
- types of fuel and energy used,
- specific energy consumption (related to the unit of the main product),
- byproducts output,
- economic data due to the requirements of equation (6.4),
- coefficients of GHG emission related to fuel consumption and technology,
- coefficients of emission of local pollutants (different than GHG).

On the base of the entered data the spreadsheet calculates:
- fuels and energy related reduction of GHG emission,
- technology related reduction of GHG emission,
- local environmental implications of given reduction option,
- time distribution of the net present cost of implementation of a given option,
- levelled net cost of the option,
- specific levelled net cost of the option related to the unit (1 ton) of GHG emission reduced,
- internal rate of return IRR.

6.2.2. Description of country development macroeconomic model - SDM-NE

The dynamic simulational model of national economy (SDM-NE) [Szukalski, 1993] enables simulation of GDP changes dependant on estimated rate of total investment changes in comparison to GDP used in the whole country and their division into branchés and sectors of economy.

Economy is divided into 13 following branches :
1- fuel-energy industry
2- metallurgical industry,
3- electrical and engineering industry
4- chemical industry
5- mineral industry
6- wood and paper industry
7- light industry
8 - food industry
9 - others industries

10 - construction
11 - agriculture and forestry
12- transport,
13 - other branches of economy.

In the model kinds of equations are presented:

a.) differential (deciding on dynamic character of model) in compliance with rates of growth of variables of model in the general form :

$$\frac{\Delta Y_{it}}{Y_{i(t-1)}} = \Theta_{it} + \sum_{j=1}^{N} \alpha_{ijt} \frac{\Delta X_{j(t-\tau_j)}}{X_j(t-\tau_j-1)}$$

where : Y_i - depend variable i,
t - time,
X_j - independent variable j,
a_{ij} - marginal coefficient of elasticity of variable i in relation to variable j,
q_i - constant rate of growth variable i in time t,
D - increment of variable,
t_j - delay of variable j in relation to variable i,
a, q and t - play role of parameters (they can be variables in time)..

b.) balance equations in the general form

$$Y_{it} = A_{it} + \sum_{j=1}^{N} B_{ijt} \bullet X_{jt}$$

where : A_{it}, B_{ijt}. - coefficients.

All parameters and coefficients may be :
- estimated on the basis of statistical data (e.g. least square method or another one),
- accepted on basis of bibliography data,
- accepted according to opinions of experts.

Generally speaking, a dynamic simulation model of the national economy (SDM-NE) enables simulation of changes of GDP dependant on the assumed speed of changes of investments against GDP used in the country as well as their distridution to branches and sectors of the economy (which reflects to a certain extent the national policy). Most of the economic parameters in the model are given in permanent prices; people's income is treated in nominal terms, which allows for reflecting of equilibrium on the consumption goods market as well as studying impact of changes and parameters of income policy on the consumption demand.

Variables of the model (for each branch and for whole economy) are :
a) for branches:
- output,
- material costs,
- added value,
- investment,
- employment,
- incomes,
- overhead on incomes,
- amortization,
- fixed assets,
- taxes - likewise tax from contents of carbon in used energy carriers,
- profits,
- energy carriers demand,
- CO_2 emission from burned fuels.

b) for the economy as a whole:

- population (exogenous),
- supply of labour force (exogenous),
- unemployment,
- goverment and individual consumption,
- export,
- import,
- foreign debt of the country,
- index of consumption prices,
- country output of coal,
- country output of lignite,
- production of electricity.

as well as prices of energy carriers.

These are the so-called *primary variables.* Relations between primary variables determine the run of the model. Relation between some primary variables allows to calculate values of *secondary variables* (among others) :

- material consumption index of value added in branches and in whole economy (GDP),
- productivity in branches and in whole economy,
- share of investments in the GDP,
- consumption per capita,
- GDP energy-intensity,
- $C0_2$ emission intensity.

GDP is calculated as a total sum of added value along all branches of economy. This model should answer on such questions as : "what would happen if? "; e.g. what would happen if the investment speed is increased or decreased along with the assumed growth of material costs rate with regard to output ?

The following is necessary to run the model:

- initial data including the above mentioned primary variables, but related to historical data (for years : -T, . . . , - t, . . . , -2, -1, 0 ; first year of simulation is being taken into consideration as 1, number of years T for variable j depends on the assumed delays),
- parameters of equations a , q , A , B subsequent to analysis of statistical data and following hypothesis of development national economy such as :
  - relation of growth rate of investment in economy to rate of growth GDP used in the country (considering saldo of foreign trade), that determines the share of investment in GDP,
  - fixed distribution of level of investments along all branches,
  - hipothesis in relation to (among others) :
    - future efficiency of investments,
    - material consumption index of production,
    - efficiency of labour.

The fundamental feedback between investments and production was introduced. This, together with another feedback (considering employment) is the reason that this model has its own internal dynamics. GDP is treated as endogenous variable (calculated), not as the exogenic (outside taken).

A relation between the growth rate (speed of growth) of material costs and growth rate of global value. Ina long run this relations determines the extent of value added. If the material costs grow faster than global value, the added value will be declining, and opposite.

For the long-term prognoses, adoption of the hypothesis on higher or lower elasticity of reaction in the use of materials with production growth and on higher or lower waste of materials in individual sectors, is one of the major assumptions.

6.3. Cross - Impacts Analysis (CIA) procedure

The CIA may be classified as a 'soft' modelling tool formulating and simulating heuristic process of creating scenario. The scenario is defined, in the procedure, as a set of events and their time sequence.

The tool is helpful for ranking probability of GHG abatement scenarios and detecting conflicts among scenarios' events. An algorithm of analysis of scenarios is presented in Figure 6.3.1. in the form of the block diagram.

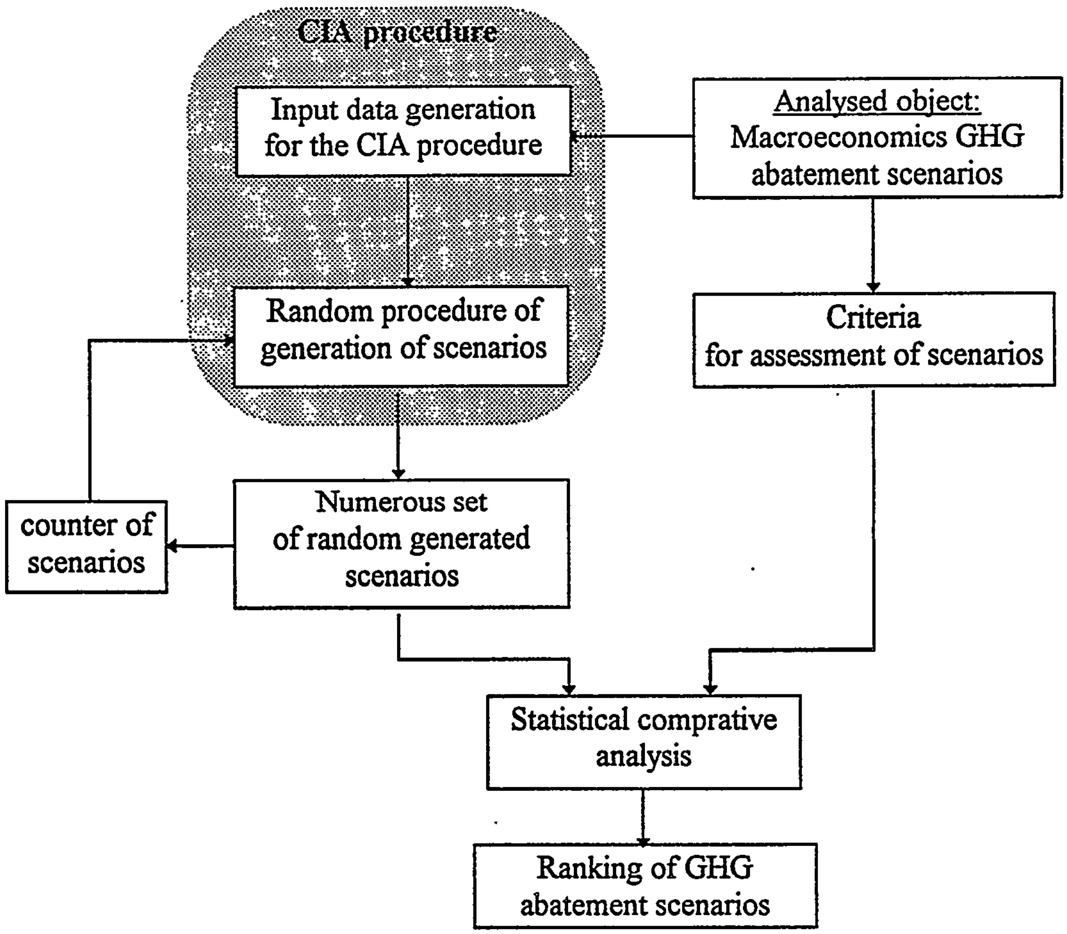

Figure 6.3.1. Algorithm of the scenario analysis

The CIA procedure enables visualisation of some aspects of the system which are commonly hidden for heuristic analysis, e.g.:

- what may the less probable, although realistic scenarios look like,
- what is the probability of their implementation,
- what is the probability of the fact that a given event will appear in the given time period,
- what is the probability of simultaneous appearance of a given sub-set of events (detecting collisions among options) etc.

Procedure description

An algorithm of the CIA procedure is presented in Figure 6.3.2 Generating the random scenario is the purpose of the procedure. This is done by random defining of moments of occurrence of all events and following modification of that moments according to the assumed impacts between events.

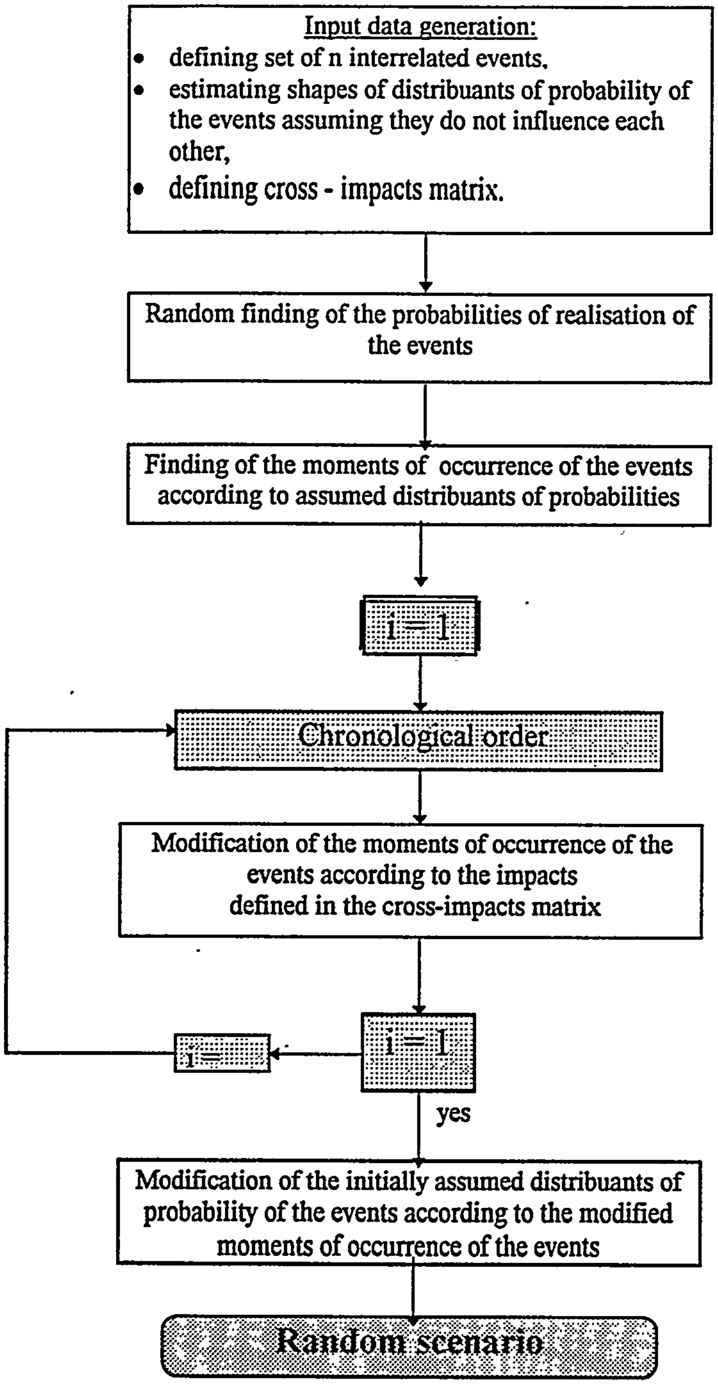

Figure 6.3.2. Algorithm of CIA procedure

Input data for the procedure

First, a set of interrelated events should be defined. While doing that the following rules are recommended:

- the number of events should not be to high (15 events for the present implementation),
- the set should be logically consistent, and should contain the most important events for a given type of scenario,
- the events should be related to each other to a significant degree,
- estimation of the distribuants of probabilities of isolated, not influenced by remaining events should be possible.

Next, the experts define distribuants of probabilities of all events in the set assuming that they are isolated. This is practically done by estimation of the moments of occurrence of the isolated events for two levels of probabilities (p=0.1 and p=0.9 in this implementation). The task may be very difficult because experts are accustomed to think in a system type manner.

After that, a matrix of impacts of all events on the remaining events is estimated.

Algorithm

The steps of the procedure are as follows:

- random defining of probability levels of occurrence of events,
- finding moments of occurrence of events on the basis of previously defined distribuants and randomly guessed probabilities of the occurrence,
- ordering the events chronologically,
- modification of the moments of occurrence of the following events according to the impacts of the preceding events defined in the cross-impacts matrix,
- respective modification of the initial distribuants of probabilities of events.

The procedure may be repeated many times and a numerous set of random, realistic scenarios may be generated in this way. Statistical analysis of the set of scenarios may provide a valuable information while estimating GHG abatement scenarios created according to the methodology described earlier.

Application of the method to the Country Study

The CIA procedure may be applied to the scenario analysis (see the diagram in Figure 6.3.2.)
The set of events constituting scenarios (GHG abatement options, policy measures, states of the economy) may be randomly chronologically arranged respecting interdependencies among the events. A numerous set of realistic scenarios may be generated in this way. Probability of the Country Study scenarios, exogenous to the CIA procedure and created with the macro-economic SDM-NE model, may be estimated by statistical tests of the set of random scenarios.

The following scheme of statistical analysis is proposed:

- finding probabilities of occurrence of different events at different positions in the scenario's sequence,
- finding the most probable scenario,
- finding probabilities of the GHG abatement scenarios elaborated with the SDM-NE model on the basis of sectoral analyses,
- finding, for all pairs of events their most probable position in the scenario sequence.

6.4. HIPRE3+

HIPRE3+ is a Decision Support commercially available[1] software which integrates the two well known and easy to use decision analysis techniques: the Analytical Hierarchy Process (AHP) and SMART - the Simple Multiattribute Rating Technique.

The main objective of the software is to rank set of alternatives according to given preferences (criteria) of the decision maker. The modelling procedure enhance the decision makers' problem

[1] HIPRE3+ was elaborated by R.P. Hamalainen and H. Lauri in the Helsinki University of Technology

understanding. The hierarchical structure of the evaluating criteria gives a concrete feeling of the importance of different factors related to the problem and enables to point out the areas in which the decision makers may need more information.

HIPRE3+ is organised in the user friendly windows type structure.

Prioritisation

For the AHP a special pairwise comparison approach is applied. In the method weights are assigned by the analyst to a given set of criteria. The weights are normalised to sum up to unity.
The SMART procedure is based on direct ratio comparisons. The analyst carries out the measurement of the performance of the alternatives on the lowest level operational criteria - called attributes - by defining a value function for each attribute.

The above assessments are used to derive the overall priority weights or scores for the alternatives. The user need not be concerned about the mathematics related. There are no hidden modelling or optimisation procedures. The AHP only uses a special technique for the averaging of the results derived from the pairwise comparisons. One can imagine that on top of the hierarchy there is one unit of criteria weight which is distributed to the lower level criteria relative to the importance of the criteria. The amount of final composite priority weight that each alternative gets depends on its performance rating on the criteria and on the patterns of the related value functions if that mode is used.

6.5. Evaluation of results

An important part in the decision support process is to analyse the composition of weights. HIPRE provides three different ways of doing this:

- matrix type decomposition of the weights with its numerical or graphical visualisation,
- priority plane which lets you see the performance of the alternatives on individual criteria/attribute dimensions,
- sensitivity analysis allows to see the effects of changes of the criteria weights and ratings of alternatives.

7. Macroeconomic reference scenarios

In literature discussed is the problem of number of reference scenarios which should be used for creation of the reduction emission strategies. In the light of uncertainty which appears in the considered case, it is suggested to use some reference scenarios [Rijsberman, 1995; LBL, 1995]. On the other hand, a variation of reference scenarios substantially complicates process of analysis and could cause the loss of clarity of the obtained results.

In effect it was decided to apply in the Country Study three variants of reference scenarios:

- **base scenario** - based on the political assumptions actually declared by the governmental authorities [Kołodko, 1994; Ecological Policy, 1992; Industry Development Policy, 1995 b; Energy Policy, 1995 c],
- **chance scenario** - based on the assumptions that faster and deeper, than it was assumed within the base scenario, structural changes in the national economy and in society development will be possible.
- **stagnation scenario** - based on the assumption of lack of society acceptation for fast structural changes in the national economy and for costs resulting from this process; it is the scenario with low rate of transformation with regard to the base scenario.

7.1. Scenario creation procedure

The accepted methodology of macroeconomic scenarios generation contains elements of qualitative and quantitative analysis. Commonly applied formalized analytical forecasting methods (used closed models for reaching a high precision of results, which is possible by their sufficient simplifications) in reality, appear less precise and less elucidating (which is very important) than it was expected.

The overt application of heuristics in the scenarios research methodology allows better organization continuation and discipline.

Presented methodology contains the following steps:

1. statistic data collection from:
   - institutions and departments,
   - publications,
   - questionnaire research
2. information collection for qualitative analyses:
   - options presented in publications,
   - options based on questionnaire research,
   - public comments,
3. performance of a diagnosis of the economy state based on the collected data by using computer procedure for statistical analyses.
4. estimation of the parameters of equation used in mathematical models,
5. performance of the qualitative analysis using formalized and informalized methods; in the Country Study for performing qualitative analysis, the methods of strategic planning were used,
6. choice of contrasting scenarios as a very important task,
7. final acceptation of the values of quantitative equations parameters used in models (based on statistical estimations, corrected through qualitative analysis),
8. computer calculations,
9. scenario identification by means of the entire set of results from quantitative and quantitative analyses,
10. joint evaluation of the entire results set and making decision on whether to correct input assumptions and repeat analyze cycle or to end calculation and accept the scenario.

7.2. Assumptions

The base scenario is based on real documents containing the declarations of the governmental authorities with regard to the economy development path. The chance and stagnation scenarios were elaborated in relation to the base scenario. Therefore, in this Chapter explicate assumptions for the base scenario are presented.

In general, they are based on:

- estimation of the possibilities of the country economy development which determines the magnitudes of calculation parameters,
- acceptation of the numerical values of the magnitudes of calculation parameters.

7.2.1. Policy strategy

The transformation of political system in Poland should concern all domains of the society activities. First of all, it concerns the changes of political system for democracy development by regulation of the ownership relations (privatization), changes in the law acts and standards, structure changes in agriculture and industry, and also including new approach to social problems solutions. Those tasks are very difficult to solve taking into consideration the social costs and strains. Poland will, probably, not be able to accumulate sufficient capital to carry out system transformation with smoothing the severe social effects. It must be assumed that the economy policy and inflation policy should be coupled with competition stimulation, demonopolization and commercialization (privatization) of government owned branches and enterprises.

The social-economic structure of Poland differs from the European developed countries. The distance between those countries and Poland amounts to some 30-40 years, which means that structures which are present in Poland now, were the case in the above-mentioned countries 30-40 years ago.

The share of the entire employment in agriculture is nearly 30% (Western countries 2-10%), 80% of primary energy is coal (Western countries 20-40%), 6.5% of population has high education (Western countries 10-20%). Those structural conditions with others, not mentioned, determine problems which must be solved in the economy reconstruction process.

They also determine strategic directions of activities:
- privatization and decentralization,
- restructuring fuel and energy sector,
- restructuring agriculture,
- intensive development of small private industry and service,
- progress of transport and telecommunication,
- development of bank system,
- environment protection,
- education.

The fundamental factor determining long-term perspectives of the economy growth is the manner of resources distribution by the government. From the economic point of view, the best strategy is the one which would bring higher capacity of invested economic activity in long perspective. Ignoring such strategy as a result of the current arrangement of political forces will stop the economic growth. Other factors are taken into consideration in case of short or long-term analysis. The former incorporate the budget deficiency, current inflation or unemployment) and the latter embrace high capital investing in infrastructure for further economic activity development.

In the case of economy transformation process by decision making there appears a strong interaction between short- and long-term factors. The short-term economic decisions making must be analyzed with regard to their impacts on long-term economic activity. The long-term forecasting, as in the case of the Country Study, must take into account the greater uncertainty of the assumptions and the obtained results from analysis. There is no universal method for researching future. Neither is there one universal econometric model. The team for GHG emission reduction strategies generation, taking under consideration the above-described remarks, elaborated its own methodological models, but also long-term macroeconomic and procedure analysis with the aid of the expert opinions and results obtained from sector teams.

7.2.2. Economy

The perspectives of Polish economy development should be considered using two approaches:
- short-term in relation to high dynamic of fundamental economic variables,
- long-term strategy with critically analyzed use of traditional analysis tools because of the collapse of historical trends and also because of uncertainty as for the nearest future.

The long-term forecasting must be based, in the Polish transition conditions, more on analysis of logical relationship between essential variables of economic transformation rather than on calculations. In fact, it is more important to focus, on the one hand, on conditions necessary for reaching the economic growth, and on presenting factors that should be avoided, on the other hand. Anticipation based on consideration of the economic factors only, is often false, regardless of difficulties with defining variables and economic parameters. It often happens that those factors cause contrary effects. in the nearest years' perspective, it is necessary to undertake and popularize the following activities :

- financial and management support for promoting small enterprises, particularly, in regions with high unemployment,
- simplification of the procedures of foreign investment
- acceleration of the liquidation of unprofitable state enterprises (simultaneously smoothing social problems resulting from such activities),
- economic restructuring branches, microregions and regions,
- foreign investment
- acceleration of the sector transformation for the good of development of export with competitive chances on the international market,
- modernization of fuel and energy sector and metallurgy,
- avoidance of rapid acceleration of transformation processes of long-term nature
- stimulation of saving and increasing investing effectiveness.

Poland aims at creating open market economy which results in a problem of competitiveness and making the national economy international.

It seems that the major condition for the long-term development of the country is the perspective of associating with the European Union, which will bring about :

- legal changes as well as changes in various kinds of standards,
- improving Polish economy competitiveness,
- changes in socio-economic structures,
- income of new technologies.

Probable associating of Poland with the European Union needs performing special economic analysis to assess the full set of necessary requirements and detailed determination of costs and benefits.

For the creation of GHG emission reduction macroeconomic scenarios , it is necessary to carry out special analysis to determine the important sector statements influenced by the economy development.

Their survey is presented below:

FUEL AND ENERGY INDUSTRY:

- further decrease of coal mining is expected; the rate of this decrease will be related to the international market coal prices,
- new refineries or sufficient import of liquid fuels is necessary,
- the share of imported natural gas in primary energy balance should sufficiently increase,
- dilemma of nuclear energy introduction?
- privatization of fuel and energy enterprises,
- decentralization of energy sector.

INDUSTRY :

- decrease of capital expenditure in heavy industry and parallel increase of products quality,
- increase of capital expenditure in processing industry, especially, high technology industries,
- necessary investment in the industrial environment protection devices,
- energy efficient management in industrial enterprises,
- industrial regions restructuring.

CONSTRUCTION:

- progress of housing and industrial construction as one of the economy drives,
- introduction of new energy efficient and material saving technologies.

AGRICULTURE AND FORESTRY

- decrease of employment in agriculture,
- restructuring state owned farms or their privatization,
- increase of the number of farms with greater cultivation areas capable of higher productivity,
- development of agriculture infrastructure including farms service,

- increase of efficient irrigation,
- increase of forestation and reforestation,
- recultivation of post-industrial areas.

TRANSPORT
- solving the economic problems as a consequence of Poland's being one of supreme transit country,
- motor-ways building,
- railways building,
- airports building,
- decrease of transport intensity of GDP,
- promotion of the energy and environmental efficient transport and cars.

OTHER SECTORS:
- increase of service in the whole economy branches and society,
- development of telecommunication,
- development of education, especially, increase of high education,
- development of tourism and recreation,
- development of service for international partners owing to the geopolitical position of Poland.

All the above-mentioned problems are mutually connected within the cause-and-effect chain, which makes the determination of assumptions for SDM-NE (Chapter 6.2.2.) difficult.

The assumptions for SDM-NE must be determined at some levels which could be qualitatively characterized as follows:

1. according to investing means : lower or higher value of investment rate with regard to GDP,
2. according to capital expenditure distribution among the sectors,
3. according to hypothesis regarding to effectiveness of investments and employment,
4. according to employment elasticity with regard to the added value of particular branches and employment policy,
5. according to effectiveness of material, raw material and energy costs,
6. according to hypothesis of export increase rate with regard to global value in the whole economy.
7. according to hypothesis concerning the rate of the global increase value in the whole economy,
8. with regard to demographic forecasts concerning amount of population.

It was assumed that the fundamental economy transformation could be finished in 2000 and the economy would not react flexibly in response to changes in investment rates, which means that the economic structures will not change too quickly.

The industry has been divided into three groups:
- fuel and energy industry,
- industry I - including metallurgy, electro-machinery, chemistry and mineral,
- industry II - wood-paper, textile, food and others.

The input parameters to SDM-NE:
- initial data, based on statistics up to 1993,
- macroeconomic elasticity of fundamental model parameters (assumed according to the expert analysis),
- assumed investment distribution by sectors and branches for the period till 2030,
- prognosis of the population and labor supply based on the governmental documents.

The output data from SDM-NE are as follows:
- the same variables as in the initial data : global value, added value, employment, material costs etc.,
- secondary variables : productivity, material intensity, energy intensity, etc..

7.3. Macroeconomic reference scenario - MERS

The notion of „scenario" usually means complex presentation of the future state of the system. In this case it is system of the economy. The scenarios should be based on the logical analysis of the future and possible events.

In the analysis it is purposeful to have, if possible, wide set of scenarios which could present the whole field between extreme cases. From practical and economical point of view the number of scenarios must be limited only to the number of the most probable scenarios.

The scenarios analysis contains :

- diagnosis of the actual state of the economy based on the hitherto trends and international comparisons,
- methodology of prospective research,
- qualitative analysis, taking into account many macroeconomic factors,
- quantitative analysis, using the accessible data sources,
- synthesis of the results of research and elaboration of conclusions and recommendation.

One of the most important factors in the Country Study tasks was elaboration of the Macroeconomic Reference Scenario - MERS.

The notion of MERS originated in connection with GHG emission forecasting within the Country Study.

MERS in this Country Study is the hypothetical scenario without special activities for GHG emission reduction and society adaptation to expected climate changes.

MERS (Appendix 1) presents a vision of the economy development up to 2030 and plays the function of "reference" for macroeconomic costs and GHG emission reduction for other considered development scenarios (variants of scenarios) creating GHG emission strategies (national and sector) in long-term perspective.

The elaborated MERS with tables and diagrams of fundamental macroeconomic parameters up to 2030 was submitted by the Project Leader to the governmental authorities for acceptation (January 1995) and competent institutions for comments.

The country Study team received answers from:

- Central Planing Office,
- Ministry of Industry and Trade,
- Ministry of Finance,
- Ministry of Environment Protection, Natural Resources and Forestry,
- Ministry of Physical Planning and Construction,
- Ministry of Agriculture,
- Ministry of Transportation and Marine Economy,
- Chief Inspector of Environment Protection,
- Central Customs Office,
- National Agency for Energy Conservation.

It was acknowledged, on the basis of the received opinions, that MERS could serve functions in further research work. The particular opinions will be taken into consideration while creating next variants of the scenarios.

The final and fundamental element of MERS is the forecast of GHG emissions. To this end, special computer program - GHG Emission Module has been elaborated by FEWE, which calculates emissions using results of the economic activities and energy demand structure for those activities, obtained by means of optimizing subprogram based on structure of energy carriers process.

The creation of those long-term scenarios will be developed according to the following approaches:

1. The economy transformation period disturbs the hitherto trends and makes the estimation of coefficients in the model equations difficult;
2. The qualitative analysis is necessary at each stage of the succeeding computer calculations;
3. In the long-term forecasting, the Polish economy has to take into consideration two dilemmas: on the one hand, the unemployment, on the other hand, the necessity of economy restructuring (especially heavy and mining industries, agriculture);
4. Reduction of unemployment could delay the rate of the economy restructuring for which high economy growth is necessary, which, in turn, requires high expenditures of money;

5. The adaptation of the society to climate change, and high or slow emission reduction are dependent on difficult for forecasting progress of the economy development;
6. The results of macroeconomic forecasting concerning GDP, its structure, capital expenditures and their structure, energy consumption and its structure, employment and rate of unemployment should constitute important factors in estimation of the expected losses in GDP due to use of special economic measures for GHG emission reduction (e.g. carbon tax and subsidies);
7. All results of GHG reduction scenarios must be analyzed by decision-makers so that they can choose and accept them. This could be feasible if one considers the economic and social conditions as well as Poland's possible commitments in relation to stabilization or reduction within the Climate Convention;
8. Accepted by the decision-makers GHG emission reduction scenario should be checked and estimated before realization in a special verification procedure in order to determine newly corrected assumptions for further economy and society development.

Used abbreviations :

FEWE - Polish Foundation for Energy Efficiency
GHG - Greenhouse Gases
MERS - Macroeconomic Reference Scenario
GDP - Gross Domestic Product
SDM-NE - Simulating Dynamic Model of National Economy

8. Adaptation of economy to climate change

8.1. Climate change scenarios

Within the scope of the project of the US Country Study Program to Address Climate Change in Poland, there were prepared assumptions of climate change for further research on its impact on the Polish coastal zone, agriculture and water resources. For all of these goals different approaches to climate scenarios were assumed. For the needs of water management, the results of nine general circulation models (GCMs) were analyzed, for the needs of farming - results of two GCMs were considered while for the needs of coastal zone management applied were the scenarios of the sea level rise based on observations, trends and researches carried out within the IPCC (Intergovernmental Panel on Climate Change). Independently, regional climate scenarios were constructed to obtain full spectrum of potential climate changes in Poland in global warming conditions. For this purpose the weather generator (LARS-WG) was employed to create two scenarios of climate change as a proposal for further studies on the impact of climate change on various economy sectors.

8.1.1. Climate change scenarios for the years 2020 and 2050 used for water resources analysis

The climatological and hydrological baseline selected for the study has been based on observations held from 1951 to 1990, at 46 meteorological stations and 34 hydrological gauging stations covering the territory of Poland. In order to conduct an assessment of the impact of the climate on water reservoirs, it was necessary to assume a quantitative representation of expected changes in climate. From among various possibilities to formulate climate scenarios, data based on general circulation models (GCMs) were selected for this Study.

GCMs are at present the most popular tools for evaluating the likely effects of increasing concentration of GHG on global climate. Based on the models, the climat changes related to higher concentration of carbon dioxide may be measured (e.g., with doubled CO_2). One important limitation of the models is that the actual simulation is insufficiently precise (test exercise). Therefore, normally, used are the climate changes between the 1x CO_2 and the disturbed 2x CO_2, instead of data directly from the GCM.

A comprehensive review of GCMs may be found in the IPCC Scientific Assessment [1990, 1992], and in a number of published papers. The main types of GCM are: (a) the equilibrium type response to a certain level (usually doubling) of changes in "greenhouse gases" concentration, and (b) the transient reaction of the climate system to time dependent changes of chemical composition of the atmosphere. All GCMs estimate selected meteorological variables for a network of grid points across the globe.

There are two problems with using GCMs data as inputs into hydrological assessment studies at present. Firstly, the spatial scale of current global atmospheric models is much coarser than required for water resources analysis. Secondly, regional climate estimates, particularly in case of rainfall, are very uncertain. For the sake of illustration, a comparison of some characteristics of the current climatic conditions averaged across Poland, and results obtained by means of nine GCM-based scenarios 1x CO_2 are presented in tables 8.1.1 and 8.1..2.

Table 8.1.1. Comparison of mean monthly temperature characteristics [in °C] in the current climate and nine GCM scenarios

Model	CLIM	CCCM	GFD1	GFD3	GISS	MPEQ	HCEQ	GFCT	MPCT	HCCT
Minimum	-2.9	-0.6	-5.2	-8.3	-4.0	-8.1	-16.7	-3.7	-5.1	-12.1
Maximum	17.3	17.9	20.5	20.3	15.9	22.8	9.9	18.2	23.1	16.1
Range	20.2	18.5	25.7	28.6	19.9	30.9	26.6	21.9	28.2	28.2
Average	7.4	8.1	6.4	5.1	5.6	7.0	-2.9	6.2	8.1	8.1

Tabela 8.1.2. Comparison of mean monthly precipitation [mm/day] characteristics in the current climate and nine GCM scenarios

Model	CLIM	CCCM	GFD1	GFD3	GISS	MPEQ	HCEQ	GFCT	MPCT	HCCT
Minimum	1.2	2.2	1.2	1.2	2.1	0.5	1.5	1.5	0.3	1.8
Maksimum	3.0	3.8	2.5	2.5	4.0	2.1	2.6	2.5	2.4	3.0
Range	1.8	1.6	1.3	1.3	1.9	1.6	1.1	1.0	2.1	1.2
Average	1.9	2.7	1.9	1.6	2.8	1.4	2.1	1.9	1.4	2.3

For the water resources impact study several - all feasible - scenarios should be used, in order to assess the possible range in hydrologic implications and to evaluate the performance criteria of water resource schemes under disturbed conditions. At present, it is not possible to assign probability figures to results obtained from various global climatic models.

Methods of projecting regional climate scenarios based on the GCMs may be divided into the following groups: (a) interpolation of changes in both temperature and precipitation assessed in the GCM's grid cells; (b) application of empirical relationships between large-scale free atmosphere processes, and regional surface climatic characteristics [Bardossy and Plate, 1992]; and (c) nesting the meso-scale meteorological models in a coarse resolution general circulation model over region under consideration.

Similarly to most water resources impact studies reported in the literature, our Study was based on interpolation of changes predicted by the equilibrium climate scenarios. The usual procedure is to add the increases ΔT, with dubbled CO_2 in the atmophere, to the measured temperatures. Similarly, observed precipitation values were multiplied by the ratios rP of GCMs precipitation obtained for 2x CO_2 and 1x CO_2.

For a water resources impact study implemented in Poland, two GCM-based equilibrium climate scenarios were used:

* the R-15 version of the Geophysical Fluid Dynamics Laboratory model (GFDL), and
* the Goddard Institute of Space Studies (GISS) model, (1982 version).

These models were selected because they reflect the current climate relatively well, and present differentiated future climates: the first may be described as "warm - dry", while the second as "warm-wet". In both cases model output data were interpolated to a grid of 1° x 1° resolution, covering the area defined by 10°-24° E and 49°-55° N. For illustration, the temperature increments ΔT and precipitation ratios rP for the GFD1 model for 2xCO_2 conditions are shown in figures 8.1.1 and 8.1.2.

In accordance with the IPCC assessment, the equilibrium 2xCO_2 conditions may be approximately associated with the last decades of the next century. In order to project changes in temperature and precipitation for the years 2020 and 2050, an assumption of a linear trend of the climate response to a time-dependent increase of greenhouse gases was made.

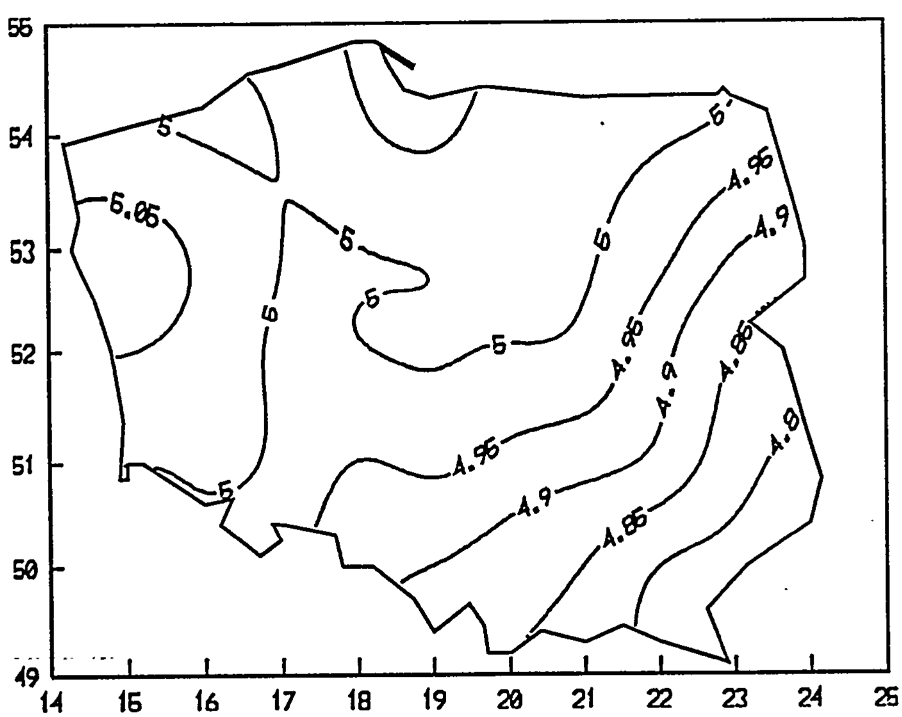

Fig. 8.1.1. Mean annual temperature increase [°C] - GFDL scenario

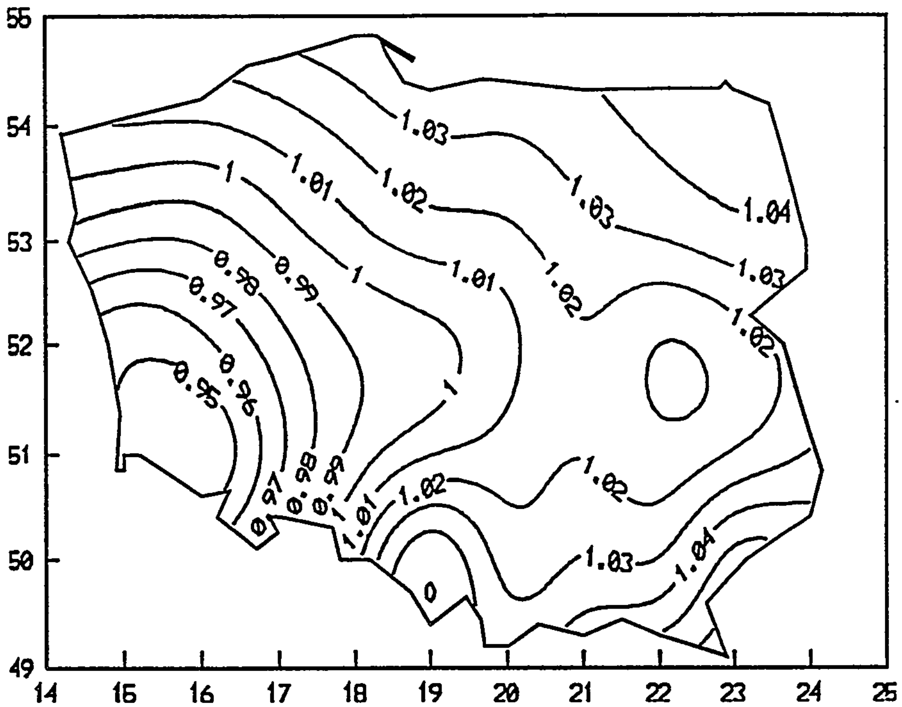

Fig. 8.1.2. Annual precipitation change [ratio] - GFDL scenario

8.1.2. Climate change assumptions for the analysis of vulnerability and adaptation of the Polish agriculture

The analysis of the results of GISS and GFDL, two general circulation models: indicated different future potential changes of temperature and precipitation. According to GISS model, expected is an increase of mean annual temperature by about 3.5°C (4.5°C in winter and 2°C in summer) and sums of precipitation by about 500 mm (20-30 mm in summer and 30-40 mm in winter). The GFDL model predicts a growth of temperature similar to GISS and a decrease of precipitation sums by about 10-20%.

Based on the results of the two general circulation models, four climate change scenarios were carried out, which condition the development of the Polish agriculture to the year 2030:

1. Increase of precipitation by about 20% (700 mm)
increase of temperature by about 2°C
CO_2 concentration in 2030 - 450 ppm

2. Increase of precipitation by about 20% (700 mm)
increase of temperature by about 4°C
CO_2 concentration in 2030 - 600 ppm

3. Decrease of precipitation by about 20% (450 mm)
increase of temperature by about 2°C
CO_2 concentration in 2030 - 450 ppm

4. Decrease of precipitation by about 20% (450 mm)
increase of temperature by about 2°C
CO_2 concentration in 2030 - 600 ppm

8.1.3. Construction of climate change scenarios using weather generator

Most of the climate change impact studies performed at regional scale, require daily, long-term weather data (for instance, in agriculture). Thus, there is a need to create adequate regional climate scenarios for such research. One of the tools helpful in constructing of regional climate scenarios is the weather generator that provides long series samples of daily climatic records based on observed time series and global climate models results.

In order to produce the climate change scenario for a selected station (Zamość) the LARS-WG model has been employed. The model is a stochastic weather generator for simulation of daily climate characteristics.

In order to verify the weather generator and to construct climate scenarios there were used **observed data from Zamość:**

- 14 years series (1977-1990) of daily maximum and minimum temperatures, precipitation amount and radiation

and the following **output data from UKTR**, British General Circulation Model for the grid-box containing Zamość:

- monthly mean values for the temperature, precipitation and radiation for the control simulation ($1xCO_2$) and perturbed one (past decade of the experiment - years: 66-75)
- daily data for mean temperature and precipitation for the ten year series for both control ($1xCO_2$) and perturbed (66-75) simulations.

UKTR is the first transient GCM greenhouse gas experiment which has been completed at the Hadley Centre, (Bracknell, UK) in the 1991[Viner and Hulme, 1994]. The UKTR is a high horizontal resolution model: 2.5° latitude x 3.75° longitude. Initial concentration of carbon dioxide was 323 ppmv in the course of the experiment and was increasing at the rate of 1% per year, resulting in an effective CO_2 doubling after 73 years. Both, the control and the perturbed simulations were prepared for a 75-year period.

Data received from the LARS-WG generator based on the actual climate, should be statistically similar to the observed time series. Therefore, the **verification of the LARS-WG model** against the observations from Zamość has been performed.

The stochastic weather model was constructed for the risk analysis of crop production, where the risk is associated with the stochastic weather conditions [Racsko et al., 1991; Semenov et al., 1995]. Especially a long dry series affect crop growth and can substantially decrease yield. The model gives 30 years of synthetic daily weather data which can be next-applied to the crop growth models.

The weather generator, LARS-WG, is based on a serial approach, that is, sequence of dry and wet days (above 0.1 mm). Long dry series allow better simulations using this approach, as opposed to Markov's chain method of simulating the precipitation occurrence, [Richardson, 1981]. The distribution of other weather variables, such as temperature and solar radiation, is based on the current status of wet and dry series. Mixed exponential distributions were used to model dry and wet series. Daily minimum and maximum temperature and radiation were considered as stochastic processes with daily mean values and standard deviations conditioned by the wet and dry series. The seasonal cycle of mean values and standard deviations was removed from the observation records and the residuals have been approximated by normal distribution. These residuals were used to analyze time correlation within each variable. Fourier's series were used to interpolate seasonal mean values and standard deviations [Barrow et al, 1995].

As input data, were used 14 years (1977-1990), time series of daily data for maximum and minimum temperature, amount of precipitation and mean radiation. The output data from LARS-WG contains a set of 30 years daily data for the same four weather parameters.

In order to compare the observed and generated data, the following statistics were selected to validate the weather generator: monthly mean precipitation amount, mean number of wet days, mean length of dry and wet series, daily mean radiation, daily mean maximum and minimum temperature, mean number of days with $T_{max} > 30$ °C and with $T_{min} < 0$ °C. The results of the comparison are presented in table 8.1.3.

Monthly mean precipitation, the mean daily maximum and minimum temperature as well as radiation generated by LARS-WG model corresponded with the observed data for Zamość. The characteristics reflecting extreme temperatures above 30°C and below 0°C, also complied to observations. The duration of dry and wet series were simulated less accurately in some months due to the limited number of years (14), available for analysis.

The differences between the values simulated by generator and those observed, for precipitation, solar radiation, maximum and minimum temperature, were additionally compared to the standard deviation which defines the parameter variability. Analysis of table 8.1.4 proves that only in the three cases for solar radiation and the one for minimum temperature, the differences between the generated and the observed records slightly exceed standard deviations.

Figure 8.1.3 is an example of the comparison of the two simulations: the observed and the generated one, which reflect the daily annual sums of precipitation in Zamość. Other climatic variables simulated by LARS-WG such as: length of dry and wet series, maximum and minimum temperature and solar radiation both for dry and wet series, indicated high similarity to the observation data.

The LARS-WG validation process using the observation data from the Polish station in Zamość brought, generally, positive results. The model derived statistically adequate series of synthetic daily data which significantly resemble the 14 year series of daily data available from a selected station.

Table 8.1.3. Comparison of observed (obs) and generated (gen) data for Zamość in Poland

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly mean precipitation (mm)												
obs	25.6	20.2	28.6	40.9	56.1	82.2	81.7	65.6	50.5	31.5	33.4	36.9
gen	22.7	21.7	33.5	37.4	49.4	73.7	83.3	67.8	48.1	34.3	31.1	26.2
Mean number of wet days (day)												
obs	16.2	14.4	13.9	11.8	13.4	15.3	14.6	12.1	13.2	11.6	14.8	17.9
gen	13.1	10.8	11.8	9.1	10.7	12.2	12.9	11.1	10.4	9.8	10.1	12.8
Mean length of dry series (day)												
obs	3.19	4:02	3.84	4.09	3.93	3.20	3.13	3.55	3.67	5.29	3.58	2.80
gen	3.99	4.19	4.94	5.40	5.10	3.98	3.67	4.11	5.37	4.46	4.75	3.52
Mean length of wet series (day)												
obs	1.97	2.59	2.06	1.98	2.34	2.18	2.44	2.03	2.26	1.91	2.32	2.39
gen	2.12	1.90	2.29	2.41	2.28	2.24	3.36	2.08	2.42	1.88	1.86	1.96
Daily mean radiation (MJ/m^2/day)												
obs	1.7	3.1	5.2	8.3	12.3	11.5	12.6	11.4	6.9	4.6	1.9	1.3
gen	2.1	3.6	6.1	9.7	12.3	13.7	13.1	11.1	8.3	4.7	2.4	1.7
Daily mean maximum temperature (°C)												
obs	-0.7	0.6	6.3	12.8	19.1	21.4	22.5	22.5	17.8	13.0	5.5	1.6
gen	-0.2	0.9	6.2	13.9	18.7	21.5	22.4	22.0	18.4	12.5	6.0	1.3
Daily mean minimum temperature (°C)												
obs	-7.0	-6.2	-1.9	2.1	7.0	10.1	11.3	10.9	7.7	3.5	-0.6	-4.0
gen	-8.9	-7.6	-3.0	2.1	5.9	9.9	11.3	10.6	6.9	2.8	-1.7	-6.4
Mean number of days with T max > 30 °C (day)												
obs	0	0	0	0	0.1	0.1	0.6	0.5	0	0	0	0
gen	0	0	0	0	0.2	0.7	0.9	1.0	0.2	0.1	0	0
Mean number of days with T min < 0 °C (day)												
obs	26.0	22.7	19.3	9.4	1.6	0.1	0	0	0.9	6.6	15.9	22.9
gen	30.2	26.3	22.9	8.6	1.7	0.1	0	0	1.6	7.8	18.9	28.3

Table 8.1.4. Comparison of differences between generated and observed values for climatic parameters (r) and standard deviation (d)

	mean monthly precipitation		mean daily radiation		mean maximum temperature		mean minimum temperature	
months	r	d	r	d	r	d	r	d
I	-2.9	14.5	0.4	0.3	0.5	3.6	-1.9	5.0
II	1.5	11.3	0.5	0.7	0.3	4.2	-1.4	4.9
III	4.9	16.3	0.9	1.0	-0.1	3.2	-1.1	2.4
IV	-3.1	22.7	1.4	1.2	1.1	1.9	0.0	1.7
V	-6.7	19.1	0.0	2.1	-0.4	1.5	-1.1	1.5
VI	-8.5	34.8	2.2	2.6	0.1	1.6	-0.2	1.0
VII	1.6	35.3	0.5	2.3	-0.1	1.6	0.0	1.1
VIII	2.2	35.2	-0.3	2.0	-0.5	1.4	-0.3	1.2
IX	-2.4	26.7	1.4	1.2	0.6	2.0	-0.8	0.8
X	2.8	26.2	0.1	1.4	-0.5	1.3	-0.7	2.1
XI	-2.3	17.9	0.5	0.5	0.5	2.0	-1.1	2.1
XII	-10.7	13.6	0.4	0.2	-0.3	1.8	-2.4	1.9

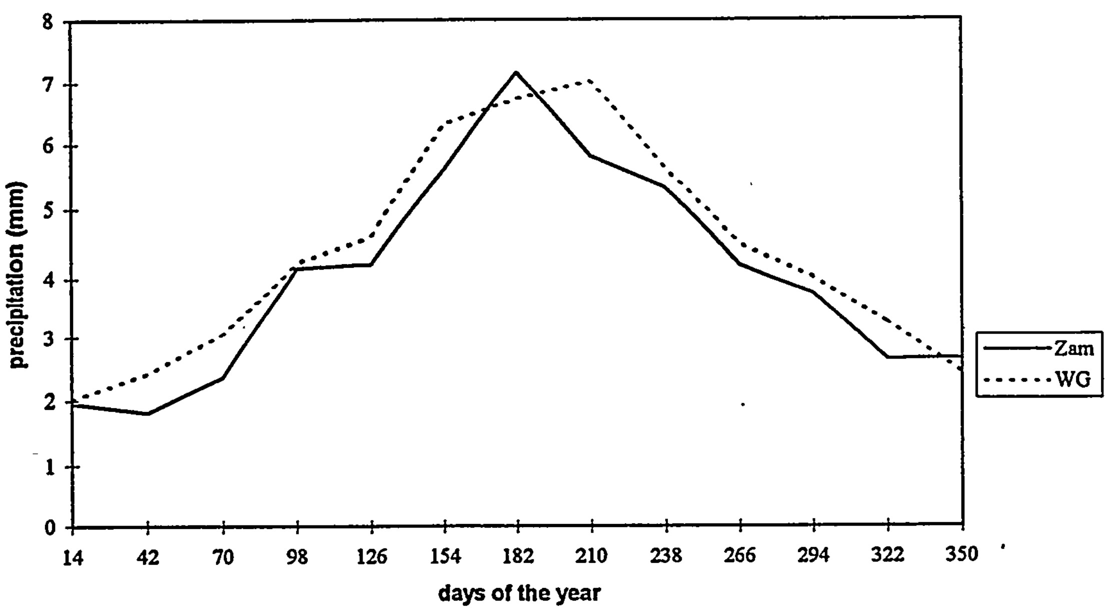

Fig. 8.1.3. Annual run of the observed (Zam) and generated (WG) dialy sums of precipitation for Zamość

LARS-WG was further employed to assess regional climate change scenarios based on the results from the UKTR global model. To generate scenarios LARS-WG uses two parameter files:

- the weather statistics file describing observed or simulated climate at site
- the scenario parameter file describing changes in mean changes and variations of weather variables, which were derived from UKTR GCM.

Two different types of scenario were generated using UKTR projections:

- in the first one, monthly mean changes in temperature and changes in relative precipitation amount were introduced
- in the second scenario, changes in temperature and precipitation variability and duration of dry and wet spells were also incorporated.

Both cases were elaborated using weather statistics calculated for 30 years series daily data generated by LARS-WG and based on 14 years observations.

Information about changes in climatic variability such as temperature variability, duration of dry and wet spells was derived from UKTR grid-box daily data from the last decade of the transient experiment (66-75).

The constructed climate change scenarios based on the results of the UKTR model predict an increase in precipitation amount by ca. 30% in July, according to mean monthly changes scenario, and about 45% according to the scenario which presumes weather variability for Zamość as well as decrease of rain during autumn by ca. 20% and 40%, respectively (fig. 8.1.4). UKTR predicts slight decrease in number of wet days in Zamość. The above mentioned predictions indicate that the rainfall will be more intensive.

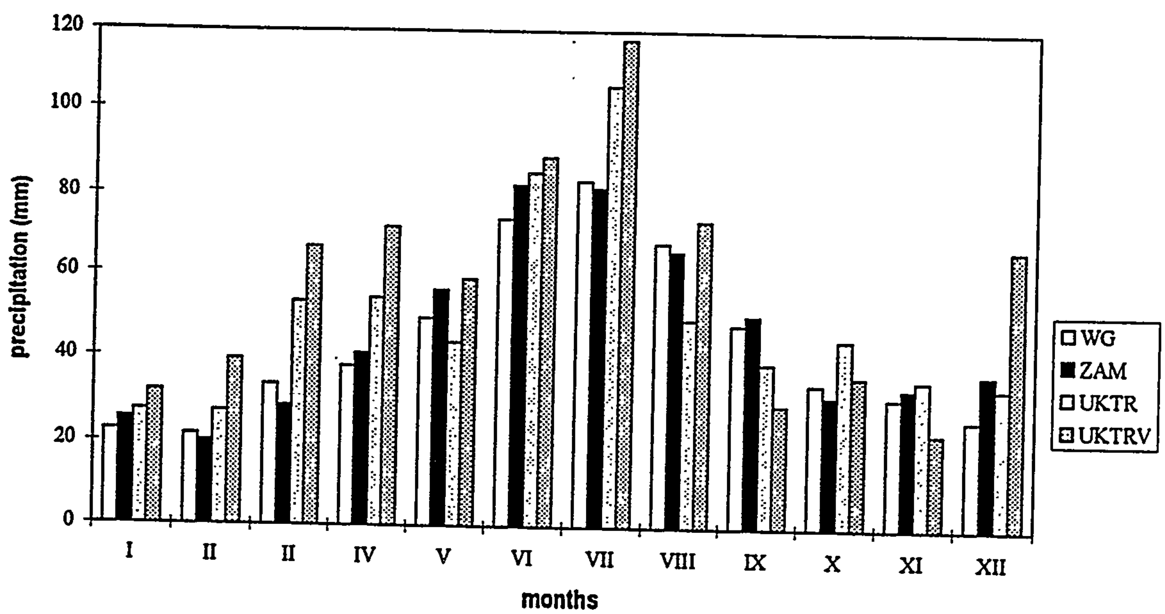

Fig. 8.1.4. Mean monthly precipitation for Zamość: observed (Zam), generated (WG) and predicted by UKTR model based on 2 scenarios (mean monthly changes - UKTR and changes including variability - UKTRV)

The radiation will be generally augmented especially in the summer time by about 1-2 MJ/m^2/day.

There are expected changes in temperature extremes: both the mean maximum and the minimum temperature will be higher (T max even up to 5°C in winter, T min up to 4°C). The number of days with maximum temperature above 30°C will increase (up to 6 days in August), whereas days with minimum temperature below 0°C will decrease in number (even by about 12 days in February).

The biggest differences within the projected changes of climatic parameters according to both scenarios concern monthly mean precipitation, mean number of wet days and mean number of days with extreme temperatures (> 30 °C and < 0 °C). In case of other parameters like daily mean radiation or mean maximum and minimum temperature, the results of the two climate change scenarios are very similar.

To resume, the predicted changes in climatic conditions regarding the enhanced CO_2 concentration in the atmosphere in selected region of Poland, assessed on the basis of the UKTR GCM data, would concern higher temperatures, changes in seasonal cycle of precipitation and its enhanced intensity and increased solar radiation.

The assessed climate change scenarios can be next applied to the crop models that require usually 30-years daily data of primary climatic variables (such as maximum and minimum temperature, precipitation and radiation) and investigate potential changes in plant growth and adaptation of plant cultivation to the changed climatic conditions.

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8.2. Water management vulnerability and adaptation

8.2.1. Introduction

There is no general consensus among Polish scientist and water resources managers on the possible scale of changes in climatic processes, caused by anthropogenic forcing. In spite of all the uncertainties, the impact of such changes on water resources may create serious environmental and social problems, at least in some vulnerable regions. In the long-term thinking on the future of Poland's economy, this issue should not be neglected, and various scenarios of possible trends in geophysical processes must be investigated. In a statement issued at the 2nd World Climate Conference [Climate Change: Science..., 1991] one reads that "Among the most important impacts of climate change will be its effects on the hydrological cycle and water management systems, and through these, on socio-economic systems".

From the point of view of water resources practice three areas of research may be identified:

(a) Detecting changes in hydrological variables by means of measured indicators;

(b) Assessing the sensitivity of water supply and demand to climate characteristics, and consequently on water management;

(c) Studies on the impact of climate change on physical, chemical and biological processes in water bodies.

Progress in all these directions in last years in Poland is evident, but most of the relevant theories need to be improved in order to meet requirements of water resources practice.

With 1,500 m^3 of an annual availability of per capita water supply, unevenly distributed in time and space, Poland is scarce in water in a large part of the country. The spatial distribution of runoff is shown on figure 8.2.1, while figure 8.2..2 presents variations of country's runoff ranging between 34.4 km^3 in 1952 and 79.5 km^3 in 1981.

Due to the interannual and intra-annual variability of hydrologic processes, the reliable water resources, available by 95% of time, are equal to about 22 km^3. Due to environmental constraints only 30% to 40% of these surface water resources may be effectively used by agriculture, industry, or population for residential needs. Despite natural water scarcity, Poland's economy is water intensive. The water shortages observed in some years in several regions of the country are deeply rooted not only in natural scarcity, but also in inefficient water use and in the high level of water pollution.

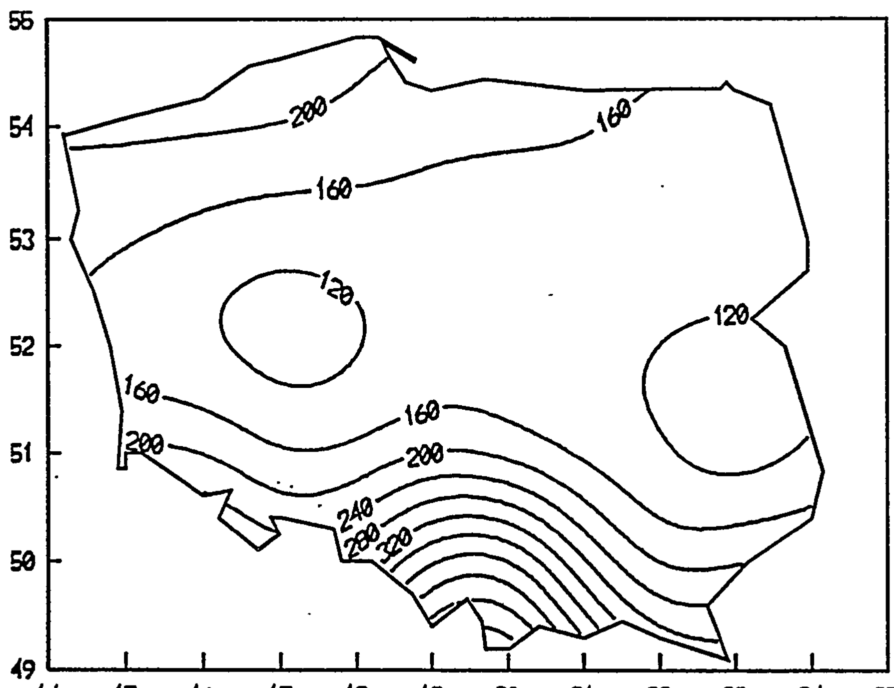

Fig. 8.2.1. Annual runoff [mm/year] in Poland

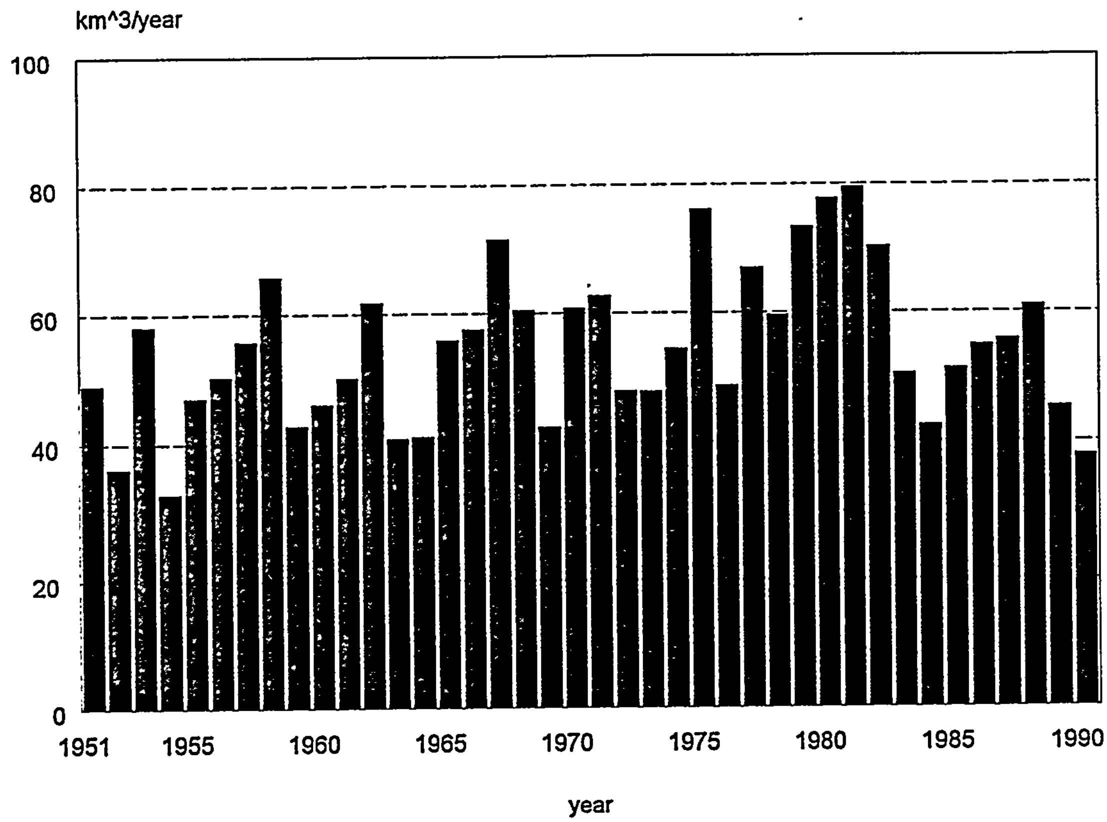

Fig. 8.2.2. Annual runoff from the territory of Poland

Sensitivity analysis [Kaczmarek, 1995] shows that for some climate scenarios the summer runoff of most of the rivers in Poland, as well as the soil moisture in summer months may decrease. At the same time the irrigation water requirement will probably increase. This may lead to increased water deficits, particularly in Central Poland.

The aim of this Study is to enhance our knowledge on the vulnerability of water systems to climate change. However, such assessment must be undertaken with the understanding that the main indicators of water economy projected over the next decades will be influenced not only by climate, but also by population and economic growth, and technological progress. Therefore, water can become a barrier to sustainable development due to several mutually dependent factors, such as:

* Water scarcity depending on the relation between water supply and demand,
* Pollution of rivers, lakes and groundwater aquifers,
* Technological and economic shortcomings,
* Institutional impediments and low public awareness.

Some of these factors are quite removed from physical processes, and only the first two are dependent on climate change. The others are subject to policy decisions which, if rationally applied, may help to adapt water resources systems to non-stationarities of geophysical processes. This report summarizes results of studies implemented in 1994 and 1995 by a group of experts, under the leadership of prof. dr. Zdzisław Kaczmarek and doc. dr. Jarosław Napiórkowski from the Institute of Geophysics of the Polish Academy of Sciences. A list of expert essays, written by a number of specialists from various Polish research institutions is attached.

8.2.2. Warta and Wieprz water resources systems

On the basis of an earlier analysis of possible changes in quantity and quality of the Polish water resources for several assumed climate scenarios, two river basins were selected for more detailed investigation as the most vulnerable regions. The first is Warta river in western Poland and the second Wieprz river in eastern part of the country (see fig.8.2.3).

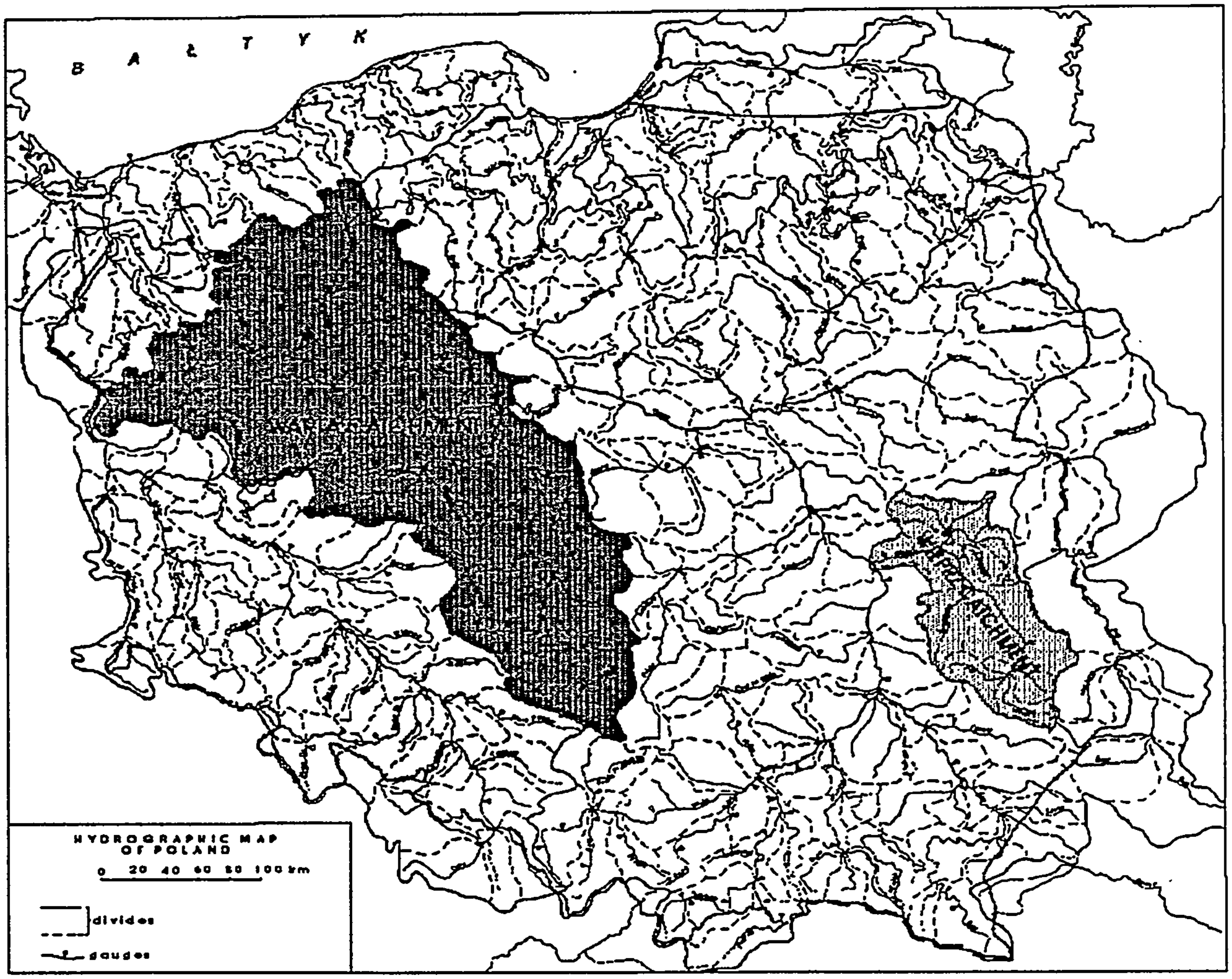

Fig. 8.2.3. Location map of Warta and Wieprz River systems

Warta catchment

The Warta catchment area is 53,710 km^2, i.e. about 17% of the territory of Poland. The main elements of the catchment are shown on fig. 8.2.4.

The region is characterized by a moderate climate with relatively low precipitation of 630 mm/year, and by the annual temperature 8.1°C. Mean annual discharge at the mouth is estimated to be 217 m^3/sec, what gives the average annual runoff 130 mm, while monthly discharges vary from 73 m^3/sec to 730 m^3/sec.

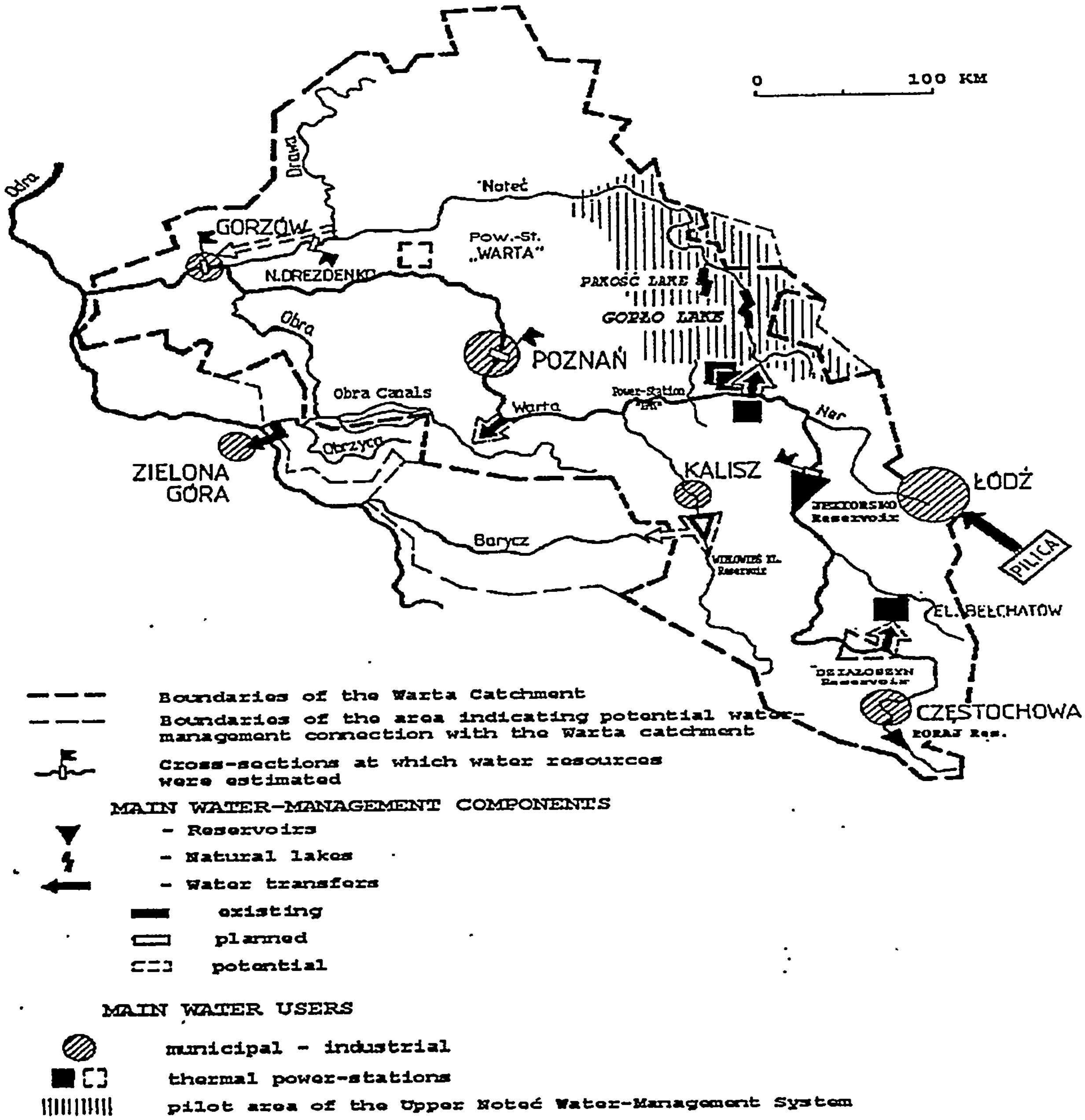

Fig. 8.2.4. Main elements of Warta Catchment system

In the year 1990 about 6.4 million people lived in the basin, 33 percent of them in four main agglomerations: Częstochowa, Konin, Łódź and Poznań. The Warta basin represents one of the most critical water resource regions in Poland due to water scarcity and high level of industrial and agricultural development. Most of the region's agriculture is rain-fed, with irrigated arable lands covering only few percent of the entire basin. Technical infrastructure of the Warta system is very modest. Total storage capacity of 296.5 mln m^3 (4.3% of annual flow) is concentrated in four reservoirs:

- *Poraj Reservoir*, located on the Upper Warta, with storage capacity of 16.6 mln m^3, was constructed to meet industrial demands in Częstochowa region;
- *Jeziorsko Reservoir*, on the Middle Warta, with storage capacity of 172.6 mln m^3, operates with the aim to provide flood control storage, supply water for agricultural irrigation, meet the Poznań municipal demands, and industrial demands the regions of Turek, Konin (thermal power stations Pątnów, Adamów, Konin) Inowroclaw and Poznań;

- *Gopło and Pakość Lakes,* located on the Upper Noteć river, with capacity of 21.2 and 41.0 mln m^3 respectively, which supply water for agricultural irrigation and industry in that region.

The most important water transfers are:

- Warta-Goplo canal supplying water to the Upper Noteć, mainly for thermal power stations in the Konin area,
- transfer from Warta to Obra catchment for irrigation, and
- water transfer from the Upper Warta to power-station Bełchatów in order to supplement cooling system. However, the role of water transfers in catchment's water management is limited.

Wieprz catchment

The Wieprz catchment is located in the eastern part of Poland as the tributary to the Vistula river (see fig. 8.2.5). The entire catchment area is 10.415 km^2.

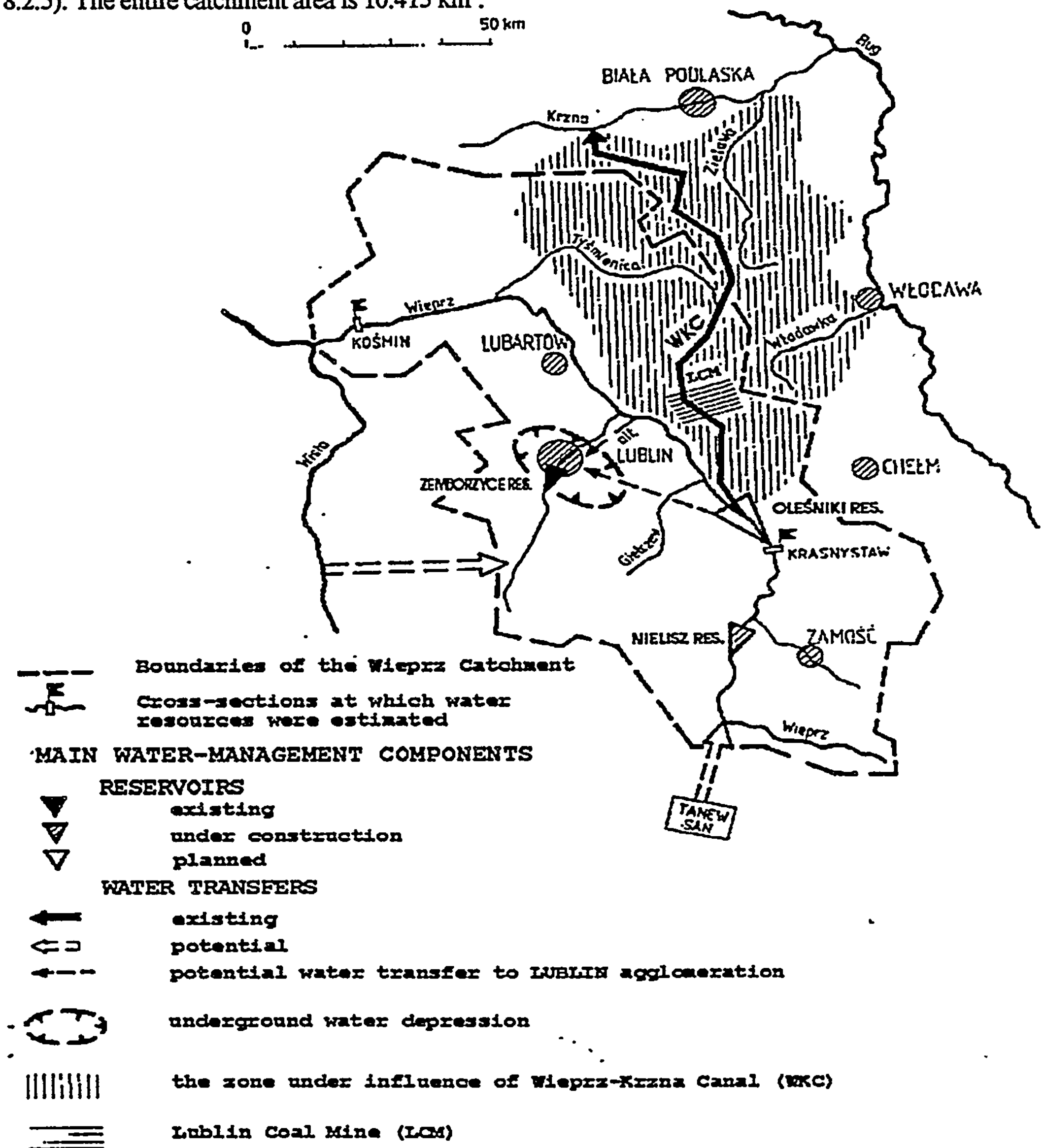

Fig. 8.2.5. Main elements of Wieprz Catchment system

The region is characterized by a relatively low precipitation of 650 mm/year and by the average annual temperature of 7.5°C. Mean annual discharge at the mouth is estimated to be 34.4 m^3/sec, what gives the average annual runoff equal to 106 mm, while monthly discharges vary from 9.2 m^3/sec to 590 m^3/sec. The average coefficient of underground water availability is 60,000 m^3/km^2 (varies from 74,900 in Lublin area to 32,800 m^3/km^2 in Zamość).

In the year 1990 about 1.61 million people lived in the basin, 30% of them in three main agglomerations: Lublin, Świdnik and Zamość .The particular feature of the catchment is the Wieprz-Krzna Canal (WKC) system operating since 1961. The canal together with the system of 6 lakes and 5 reservoirs with total capacity of 35.4 mln m^3) was constructed to intensify agriculture production in the region. The water transfer from Wieprz to WKC is about 130 mln m^3 per year. Shortage of reservoir's storage in the Wieprz catchment limits a possibility of surface water redistribution, what leads to periodical deficits.

Estimated water demands in 1990 for Warta and Wieprz catchments are discussed in chapter 8.2.5. The municipal and industrial demands in the Wieprz water resources system are covered mostly from ground water resources. Due to intensive use and despite substantial resources of the groundwater one can observe a depression funnel of 200 km^2 around Lublin.

8.2.3. Impact of climate change on water supply

Methodological approach

To assess the impact of climate on water resources some kind of models linking the climatic and hydrological processes must be used. There is a possibility of applying a range of approaches, from simple empirical relationships to complex conceptual models based on simplified representation of the processes involved in the hydrological cycle. They usually include certain number of parameters which need to be identified by means of a calibration procedure, or estimated from empirical relationships with measurable catchment properties.

Authors of most of the climate change impact assessment studies apply conceptual hydrologic models, for which the important assumption is that the calibration done for current climatic conditions remains appropriate for changed climate. The effect of this assumption can be evaluated by examining the performance of the model during extreme periods in the currently available data sets. It may be possible to evaluate how a particular model parameters might change (e.g. those reflecting vegetation cover), but very few studies have so far attempted this. The physical background of conceptual models (e.g. the mass conservation law) means that the implied sensitivity to climate change is not as dependent on current conditions, as in the case of empirical methods.

Methodological approaches of transferring climatic forcing to water balance characteristics vary widely. Because the discrepancies among climate change scenarios are still very high, it is not appropriate to spend to much effort to try selecting a "best" hydrological model (as long as the model to be used simulates current hydrological processes reasonably well). The variations between the implications of different scenarios are considerably larger than the possible variations between the simulations based on different models for a given scenario. The key input variables to most of the hydrologic models are catchment precipitation and potential evapotranspiration. The latter can be seen as a "secondary order" climate characteristic being itself calculated from other variables, such as temperature, solar radiation balance, wind speed and air humidity. The user may choose among various methods available for calculating these input variables.

For the assessment of vulnerability of water resources in Poland to climate change, a conceptual water balance model CLIRUN3 (climate/runoff model - 3rd version) has been applied [Kaczmarek, 1993]. The model differs from the previous approaches in two respects:

(a) It is time-continuous, i.e. the water balance components variate as continuous functions of time inside ertain assumed time intervals, e.g. months. In the present version of CLIRUN, the input climatic data are onstant (averaged) values, but in principle they may also be treated as time-dependent.

(b) The stochastic properties of water balance components are expressed either in a form of simulated time series, or by a set of probabilistic matrices based on stochastic storage theory.

Details of the CLIRUN3 conceptualization may be found in the above cited paper. Computer programs for various versions of the model have been developed for IBM-compatible PCs. The input variables are either time series (for simulation model) or statistical parameters (for matrix-type model) of effective precipitation and potential evapotranspiration. The model depends on three parameters, namely S_{max}, a, and e, to be determined by a calibration, based on minimization of the mean square error of catchment outflows.

Expected changes in Poland's hydrological balance

This section presents a short summary of earlier studies [Kaczmarek, 1995] on the sensitivity of hydrological processes to climate change, and impact of various scenarios on water balance characteristics. The concepts of 'sensitivity' and 'impacts' should be distinguished [Kaczmarek, 1990]. Sensitivity means the reaction of a physical system to disturbances in the input variables. In mathematical formulation, if:

$$y = f(x_1, x_2, \ldots, x_n), \qquad (8.2.1)$$

then sensitivity of y to a change of x_i will be represented by:

$$s_{y/xi} = \left[\frac{\partial y}{\partial x_i}\right]_{xi=xio}, \qquad (8.2.2)$$

Similar concept, called elasticity, and defined as:

$$e_{y/x_i} = s_{y/x_i} x \frac{x_i}{y}, \qquad (8.2.3)$$

has been proposed by Schaake [1990].

If, for example, the average annual runoff is related to annual precipitation and annual potential evapotranspiration by the Turc-Pike equation [Pike, 1964], then the elasticity of runoff to precipitation in Poland ranges from 1.7 in mountains to 2.3 in the Warta basin, and the elasticity to potential evapotranspiration varies from -1.27 to -0.74. In average, the 10% precipitation increase may cause 21% larger runoff, while 10% increase of *PET* leads to runoff reduction by about 11%.

Such simple approach can be applied only for simple empirical relationships between hydrological and climatological variables. For conceptual models partial derivatives cannot be easily calculated, and only approximate values of sensitivity parameters may be obtained by an expression:

$$s_{y/x_i} = \frac{y(x_{io}+\varepsilon,\Omega) - y(x_{io}-\varepsilon,\Omega)}{2\varepsilon}, \qquad (8.2.4)$$

where W is the set or forcing factors other than x_i, and e is a small disturbance of x_i.

To find sensitivity and elasticity parameters of water balance one doesn't need to assume alternative climate scenarios. On the other hand a climate change impact on a hydrological variable is defined as the difference of numerical values of that variable, obtained for an alternative climate scenario versus current climatic conditions. An impact characteristic is then represented by:

$$\Delta y = y(\Omega_{alternative}) - y(\Omega_{present}), \qquad (8.2.5)$$

where W is a set of climatic forcing. It means that to perform an impact analysis, one has to specify one or more alternative climate scenarios, and apply them to a model which serves as the transfer function between climatic forcing and hydrological phenomena. In the context of limited knowledge of possible regional climate change, the sensitivity analysis may be very informative for decision making.

Water balance components: runoff, evapotranspiration and storage were calculated by means of the analytical version of the CLIRUN3 model for 31 river catchments and 60 grid cells covering the territory of Poland:

* based on climatic and hydrological data measured in the years 1951-1990 at 41 meteorological stations,
* using GFDL and GISS temperature increments and precipitation ratios to develop climatic scenarios for $2xCO_2$ conditions.

Input variables were mean values and coefficients of variation of monthly precipitation adjusted with regard to snow processes, and mean values of potential evapotranspiration. The output variables are mean values, standard deviations and coefficients of correlation of the water balance elements. Model parameters were identified for river catchments and then interpolated to a grid of the resolution 1° x 1°. As the result, runoff, evapotranspiration and storage (soil moisture) characteristics were collected for each grid cell and each month for current climatic conditions, and for GFDL and GISS equilibrium climatic scenarios.

The output data allow to estimate probability distributions of water balance elements for each scenario, as well as to analyse the changes of hydrological characteristics due to changes in climate. Some of the results are shown on fig. 8.2.6 to 8.2.9 in form of isolines representing percentage change of selected water balance variables. It can be seen that the results differ highly depending on the climate model used. It should be observed that in both cases there is a decreasing trend of runoff and soil moisture during the drought period (usually August and September). Analysis shows also a shift in the floods occurrence from March-April to January-February, caused by changes in snow accumulation and melting processes. These results should be seen as preliminary assessment of possible changes of hydrological regime in Poland due to climate change. Further studies are needed to evaluate a range of expected disturbances in water resources characteristics for improved versions of global atmospheric models.

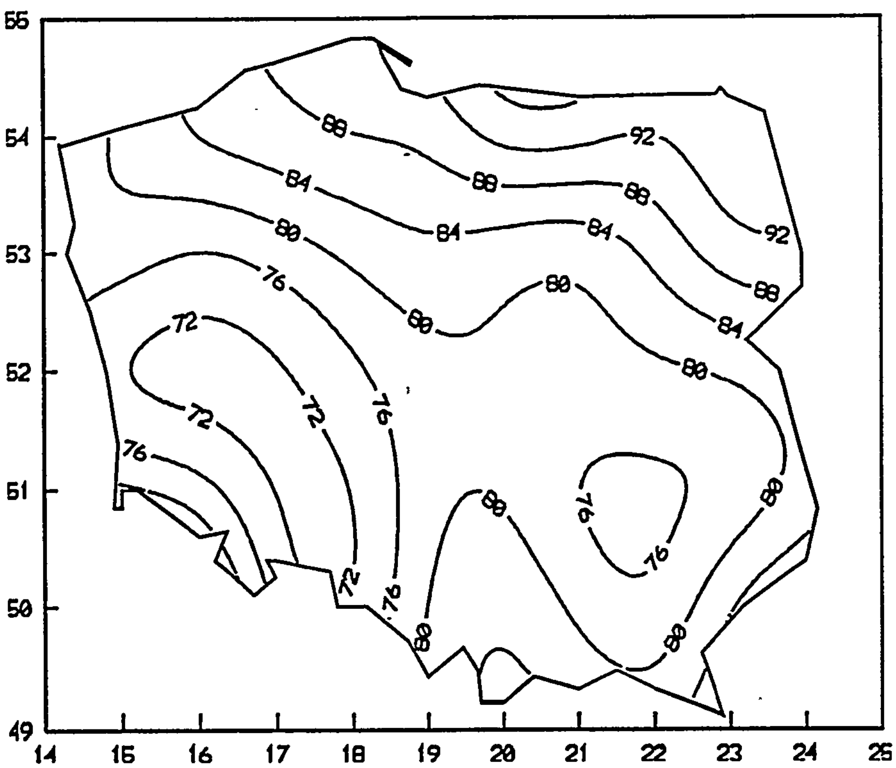

Fig. Change in annual runoff [%] - GFDL climate scenario

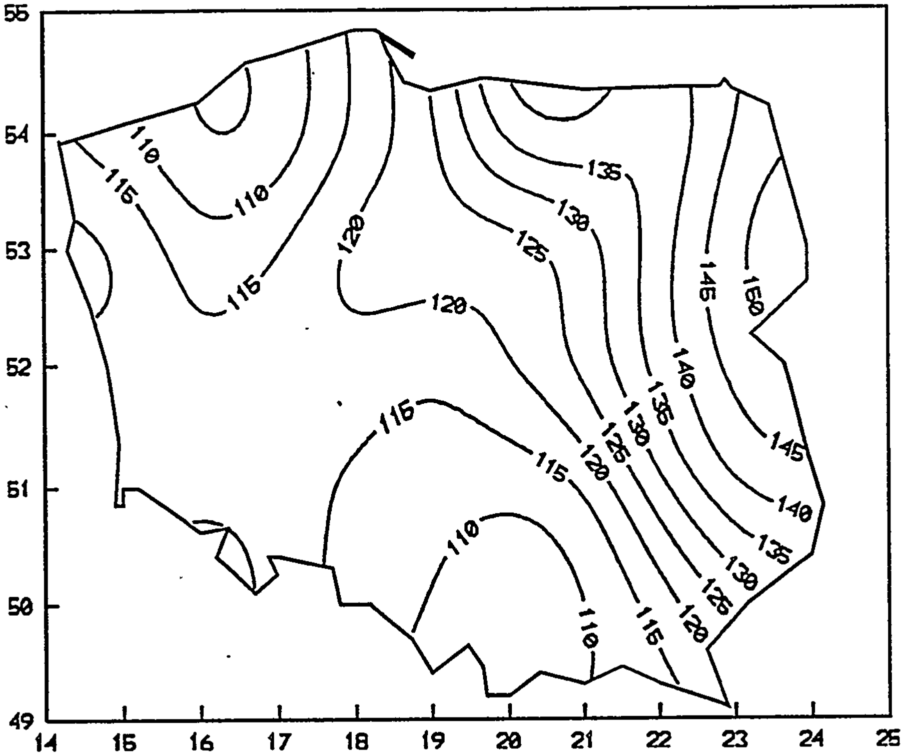

Fig. 8.2.7. Change in annual runoff [%]- GISS climat scenario

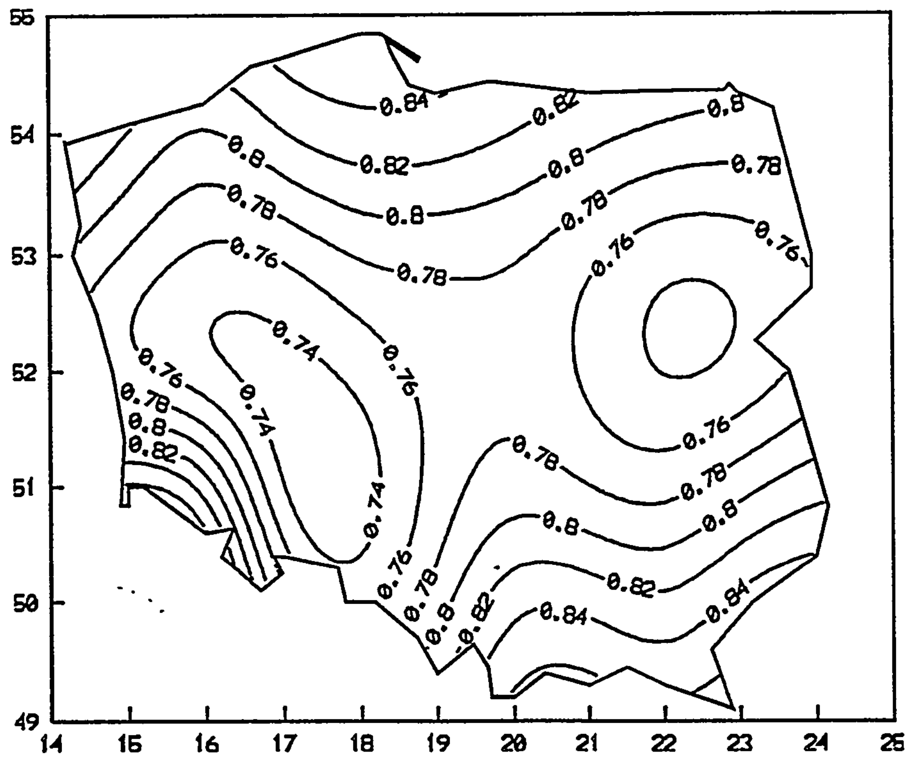

Fig. 8.2.8. Catchment storage change S2x CO_2/S1x CO_2; September - GFDL climate scenario

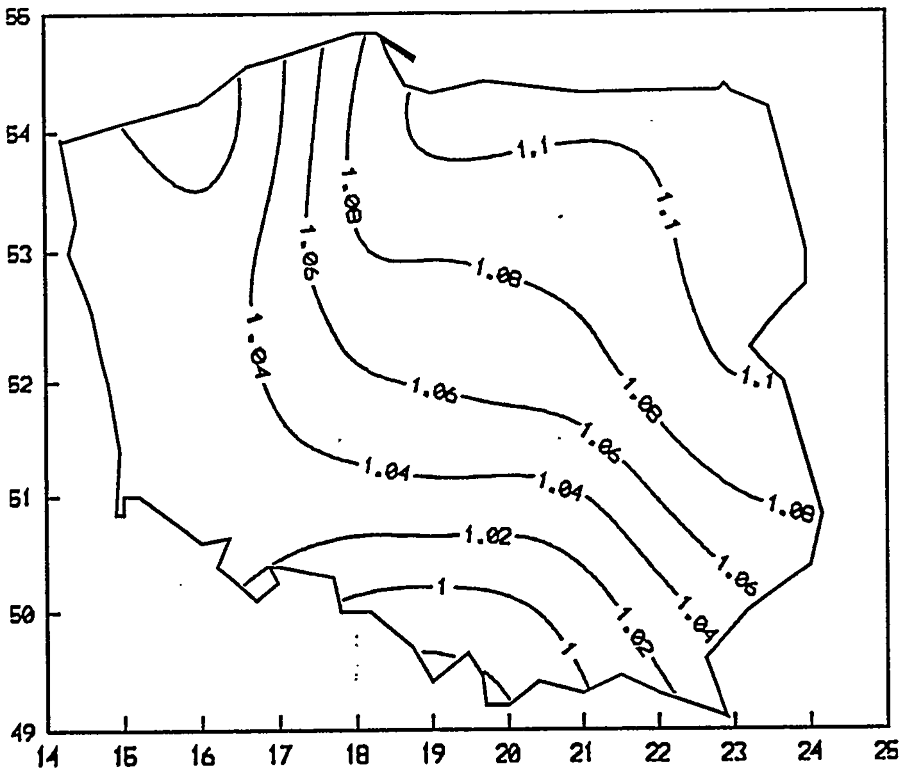

Fig. 8.2.9. Catchment storage change S2x CO_2/S1x CO_2; September - GISS climate scenario

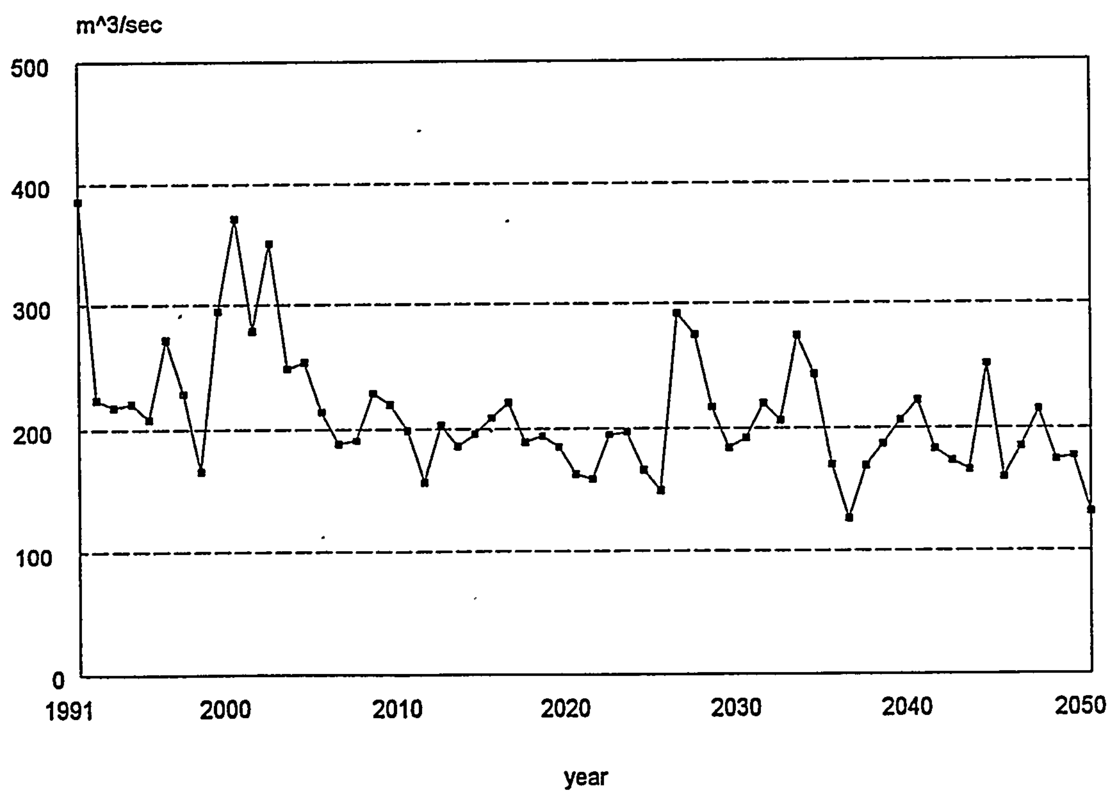

Fig. 8.2.10. Simulated time series of Warta discharches

Expected changes in water supply for Warta and Wieprz catchments

For 6 gauging profiles in the Warta and Wieprz catchments transient runoff scenarios for the period 1990 - 2050 were specified for the GFDL and GISS equilibrium climate scenarios. The simulation version of CLIRUN3 was applied, with precipitation and potential evapotranspiration input time series obtained by means of a non-stationary random generator. It was assumed that the 2 x CO_2 climatic conditions will be manifested around the end of next century, and that the trends in *P* and *PET* are approximately linear.

240 simulation runs were done (40 for each profile), of which one example for the Gorzów gauging station near to the Warta river mouth is shown on figure 8.2.10.

The simulated time series were analysed in order to get main statistical characteristics of runoff for years 2020 and 2050. Average discharge values at the mouth of both rivers are given in tables 8.2.1 and 8.2.2 .

It can be seen that the impact of climate change on water supply in the Warta and Wieprz catchments is rather limited, and the trend is either negative or positive, depending on climate scenario. The simulated runoff series were used for assessing vulnerability of investigated water resource systems to climate change (see following chapters).

Table 8.2.1 Average discharges of Warta river at Gorzów

month	1990	GFDL 2020	GISS 2020	GFDL 2050	GISS 2050
November	189	161	199	155	190
December	219	192	233	183	279
January	237	210	241	199	262
February	280	229	264	225	287
March	325	279	356	252	392
April	320	269	305	241	365
May	231	227	247	212	262
June	178	182	198	173	205
July	158	156	180	148	184
August	156	146	157	128	163
September	151	136	139	117	143
October	157	137	139	119	157
Year	217	194	222	179	241

Table 8.2.2. Average discharges of Wieprz river at Kośmin

month	1990	GFDL 2020	GISS 2020	GFDL 2050	GISS 2050
November	35	25	31	22	32
December	37	27	34	25	40
January	35	29	32	25	42
February	39	33	40	29	48
March	56	41	68	37	77
April	63	44	58	42	85
May	38	40	43	37	50
June	31	34	35	32	39
July	26	29	33	25	40
August	25	25	28	21	34
September	25	22	25	19	28
October	33	22	25	18	27
Year	37	31	38	28	45

8.2.4. Impact of climate change on aquatic ecosystems

As in most developed countries, water resource systems in Poland are increasingly being managed to maintain and improve the quality of aquatic ecosystems. Expected changes in water temperature and flow regime may create some problems related to oxygen balance, thermal pollution, nutrient balance and eutrophication, nitrate contamination, toxicity. Because the rate of chemical reaction and biochemical processes in living organisms are controlled by the temperature, the metabolism of biotic communities will be increased. Groundwater may also be affected, primarily due to changed recharge conditions.

An important feature which influences water quality and ecosystem behaviour is therefore the temperature pattern. The potential thermal impacts on rivers and lakes in Poland for $2xCO_2$ steady state scenarios was studied by Jurak [1992]. Some of the results are shown on fig. 8.2.11 and 8.2.12.

In the Warta river the highest water temperature increase in summer months, predicted for the GFDL scenario, is 4.1°C. This creates a possibility of exceeding the ambient standard temperature (in Poland equal to 26°C). Also the frequency of freezing conditions would fall significantly in both Warta and Wieprz catchments. The length of the ice cover period is an important parameter particularly of shallow lakes and rivers. It influences thermal balance, solar radiation input and mass exchange between the atmosphere and the water body.

A potential change in the surface water temperature, ice cover and lake stratification pattern is likely to affect the aquatic ecosystem and water quality markedly [Orlob et al, 1995; Zalewski and Wagner, 1995]. Because the aquatic processes are influenced by a number of complex, seasonally variable processes, thus no universal statements can be given. For instance, nutrients cycling and toxic blue-green algae are favoured by higher water temperature, but the impact of altered light energy and wind conditions (particularly for shallow lakes due to the sediments resuspension and epilimnion stability) on primary production are difficult to assess. A likely overall statement on eutrophication is that a warmer climate may not cause noteworthy additional problems for oligotrophic water bodies, and it may prolong the time required for the rehabilitation of eutrophic/hypertrophic systems (or it may increase the response time subsequent to control measures). Naturally, not only algae, but the entire food chain may be influenced by a modified climate. This conclusions are supported by observations carried out on heated lakes [Zdanowski, 1994].

Cycling of inorganic chemical compounds to biochemical active components in freshwater ecosystems is possible due to the processes of organic matter decomposition, which at least partly are controlled by thermal conditions. Calculations done for a river in Central Poland allow to conclude that for the $2xCO_2$ conditions the length of period of water temperature appropriate for high decomposition rate may increase by about 30-50% for both GFDL and GISS scenarios. This will result in higher rate of nutrients spiralling in rivers. Consequently, in natural, unregulated rivers lowering of water quality may appear. Besides, in channelised rivers nutrients are transported into reservoirs contributing to intensifying symptoms or reservoirs eutrophication.

Increase of temperature may be especially dangerous for shallow non-stratified lakes and reservoirs. Experimental studies done recently for the Sulejów reservoir, supplying in water the Łódź agglomeration, have shown [Zalewski and Wagner, 1995] high dependence of intensity of toxic cyanobacterial blooms on temperature. It can be then expected that climate warming due to increased concentration of greenhouse gases will lead to extension of blooms appearance time and intensity.

Water quality depends on a number of non-climatic factors such as point source emissions (municipal and industrial), non-point sources and land use management in a broader sense. The pollution problems are in complex and poorly-understood interactions with each others, which may be further complicated by the potential change of the climate. Most of the climate induced water quality impacts depend on changes in a large number of counterbalancing processes and thus it is possible to assess general trends but it is difficult to specify and quantify all changes in the aquatic ecosystem. They depend on the overall level of pollution and water quality management. The impacts are anticipated to be less profound for clean waters, while they can be significant for polluted waters.

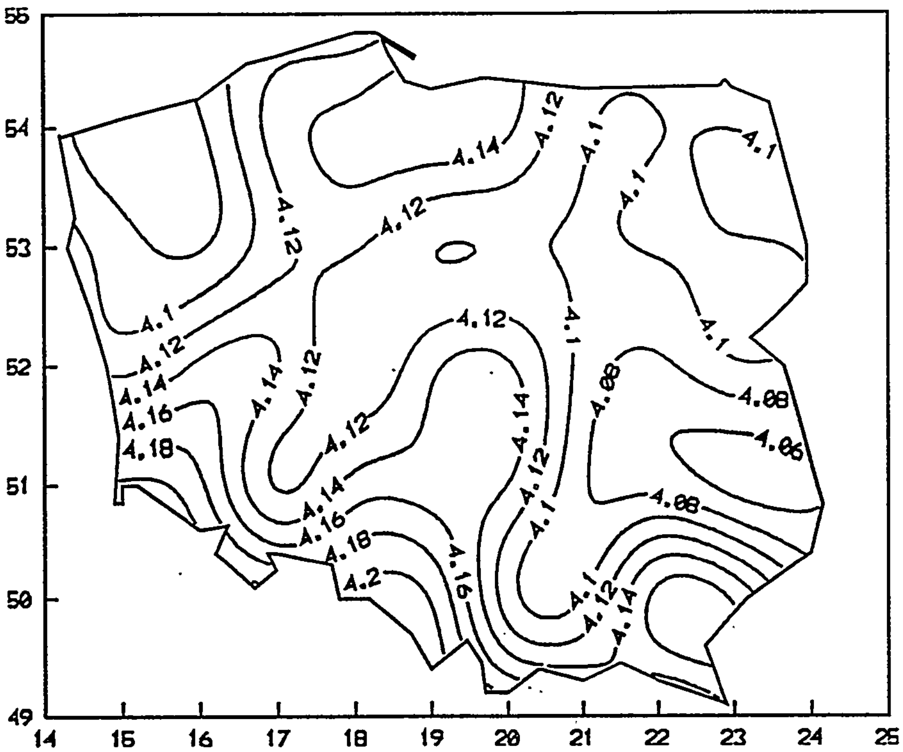

Fig. 8.2.11. Water temperature increase [°C]; April-October - GFDL scenario

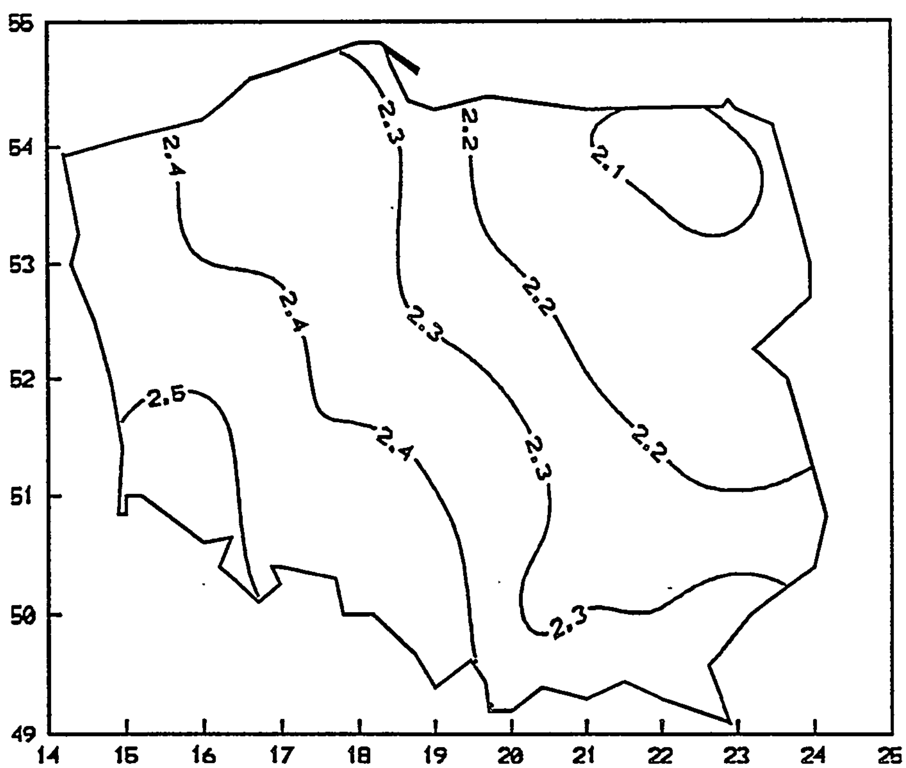

Fig. 8.2.12. Water temperature increase [°C]; April-October - GISS scenario

The most common indirect impacts are related to hydrologic changes. Non-point sources are influenced - under unchanged land use patterns - by alterations in runoff and erosion. Decreased runoff leads to reduced dilution in rivers which then increases the concentration of pollutants. Reduced runoff also leads to increased travel time and residence time in rivers and standing waters, respectively, which then results in larger net effects of biological reactions including dissolved oxygen balance, nitrification and denitrification as well as eutrophication. As far as net impacts are concerned, they are insignificant on upland rivers with their small travel times and generally high quality. On lowland river stretches with larger emissions the impacts can be higher.

In case of the Warta and Wieprz catchments predicted changes in annual runoff are insignificant, particularly for the GISS scenario. Possible decrease of low flows in summer may cause worsening of water quality in critical periods. The current level of organic pollution is much higher in Warta river than in Wieprz river. An expected increase of summer water temperature by about 4°C may lead to decreased oxygen concentration and intensified eutrophication in the middle and lower Warta.

In summary, it may be expected that no drastic water quality changes are anticipated in Poland due to likely climate alteration. This is particularly true for clean water bodies. For contaminated waters, characterized by complex interactions of many different pollution problems, climate change adds an incremental impact which can be estimated only with significant uncertainty at present. The analysis of the incremental impact should be incorporated into future sensitivity studies. Existing energy budget and water quality models can be used for this purpose.

Water quality management has no specific measures to cope with impacts of climate change. Traditional tools combined with biocontrol technics [Zalewski, 1995] should be applied for adaptation. As changes are anticipated to take place slowly, time is available for monitoring and to design potential additional measures linked to the reconstruction of existing control facilities or to the establishment of new ones which may be needed in any case.

8.2.5. Expected changes in water demands

To date, trends in water demands caused by demographic and socio-economic factors are, in most cases, identified without reference to possible changes in environmental conditions, including climate. The experience of water management agencies in various countries shows that socio-economic processes influencing water use cannot be accurately predicted for long time horizons. In most of the past studies done in Poland to formulate long-term nations' water strategies, future demands were highly overestimated. Even more difficult is to assess possible implications of climatic change on future water requirements.

Water withdrawal in Poland in 1990 was equal to 7.93 km^3, distributed among sectors as shown in table 8.2.3. According to author's estimate, water demands in the middle of next century may increase due to non-climatic factors by 70 percent. There is limited information on the possible effect of temperature and precipitation changes on water requirements in various sectors of Poland's economy. Preliminary guess, based mostly on literature, leads to a conclusion that temperature increase will have a moderate impact on industrial and domestic water use. An unknown factor is Poland's agriculture, which at present uses for irrigation relatively small proportion of total freshwater withdrawals. The situation may, however, change because a threshold between irrigated and non-irrigated agriculture may be surpassed in most of the Poland's lowlands territory in warmer climate.

For the purpose of this study it was assumed that the area of irrigated agriculture in Poland should increase from the present value of 1.5% to about 4.0% in 2050. The latter figure corresponds to the current level of irrigation in those West- European countries where the average temperature is about 2°C higher than in Poland. To estimate water requirement for one hectare of irrigated land, a model IRDEM was developed at the Institute of Geophysics and applied in various regions of the country. The key assumption of IRDEM is that the amount of water used for irrigation should allow to sustain the catchment storage level equal or higher than 75% of the catchment capacity. The output files from the simulation version of CLIRUN3 are used as input files to IRDEM. The results show that the per hectare irrigation demand in the Warta catchment may increase by 25% in 2020, and by 52% in 2050 in case of GFDL scenario. Respective values for the Wieprz river basin are 28% and 62%. For the GISS scenario changes in irrigation demand are negligible.

According to the above assumptions water demands were estimated for years 2020 and 2050 for the whole country, and for two selected water resource systems, and are presented in tables 8.2.3 to 8.2.5.

Table 8.2.3. Annual water demands [km^3] in Poland

sector	1990	2020 GFDL	2020 GISS	2050 GFDL	2050 GISS
domestic	2.54	3.25	3.22	3.78	3.71
industry	2.27	4.09	4.09	5.84	5.84
agriculture	2.12	3.00	2.77	3.81	3.19
others	1.00	1.09	1.09	1.12	1.12
total	7.93	11.43	11.17	14.55	13.86

Table 8.2.4. Annual water demands [km^3] in the Warta catchment

sector	1990	2020 GFDL	2020 GISS	2050 GFDL	2050 GISS
domestic	.42	.54	.53	.62	.60
industry	.41	.74	.74	1.06	1.06
agriculture	.36	.50	.46	.63	.54
others	.18	.20	.20	.20	.20
total	1.37	1.98	1.93	2.51	2.40

Table 8.2.5. Annual water demands [km^3] in the Wieprz catchment

sector	1990	2020 GFDL	2020 GISS	2050 GFDL	2050 GISS
domestic	.10	.14	.13	.16	.16
industry	.13	.23	.23	.33	.33
agriculture	.13	.20	.19	.26	.22
others	.03	.04	.04	.04	.04
total	.39	.61	.59	.79	.75

8.2.6. Jeziorsko reservoir case study

Introduction

The Jeziorsko reservoir is located on the Warta river (from 484.3 to 504.0 km) and operates with the aim to meet water requirements in the Konin region. The hydrological and reservoir characteristics are:

- catchment area above the reservoir: $A = 9063$ km^2
- the lowest observed flow: $Q_{min} = 10.1$ m^3/s,
- the highest observed flow: $Q_{max} = 405$ m^3/s,
- mean annual discharge: $Q_{ann} = 45.5$ m^3/s,
- total storage capacity: $S_{max} = 202.8$ mln m^3,
- dead storage: $S_{min} = 30.2$ mln m^3

An optimization technique developed in the frame of the Project was used to analyse the operation of Jeziorsko reservoir for assumed climate scenarios GFDL-R15 and GISS. The reservoir performance was examined for several years, over a 12-month time horizon (water management year from May to April). The optimal simulation of storage levels and reservoir outflow was done for a 40-year long time series of monthly inflows based on data from 1951 to 1990, and for 40 synthetic hydrologic and water demand time series (each for years 1990-2050) for alternative climatic conditions.

To assess the agricultural water demands in five administrative regions (Bydgoszcz, Konin, Leszno, Sieradz and Poznań) it was assumed that the current irrigation level of 1.7% of arable lands (1.967 mln ha) will increase to 4.0% in 2050. To estimate water requirement per hectare of irrigated land, the IRDEM model was used for summer months of all synthetic hydrological series. Industrial needs were evaluated according to expected GNP growth with regard to some rationalization of water use. It was further assumed that domestic water use would increase proportionally to the population growth. In addition, a possibility of water transfer up to 15 m^3/s from Jeziorsko reservoir to the Noteć river catchment, characterised by water deficit in several years, was analysed. A minimum reservoir outflow was assumed to meet hydro-biological criteria from Q_o=10.3 m^3/s in winter to 25.3 m^3/s in March-June.

Formulation of the optimization problem

The water supply system of Jeziorsko reservoir was analysed by means of an optimization technique. In this way one can avoid the influence of subjective decision rule on the water distribution. The object of control is the retention *S*, the inflow denoted by *d*, and the outflow denoted by *u*. The downstream discharge, the water withdrawal from the reservoir and water transfer to the lower part of the basin are treated jointly in the model. The quantities *d* and *u* are considered as piece-wise constant functions, re-presented by sequences of average monthly values.

The objective function of the optimization problem under consideration can be written:

$$Q(u,S) = \sum_{j+1}^{12}\left[a_j^{+}(u_j-z_j)^2 + b_j(S_j-V_j)^2\right] \tag{8.2.6}$$

The performance index Q depends explicitly on controls u_j and the state trajectory S_j (reservoir contains). Other quantities which occur in its formulation are treated as parameters.

Required storage trajectory:

It was assumed that the operation of the reservoir is curried out on annual bases in the following way:

* By late December, the reservoir normally is returned to low level to prepare the system for the next flood season;
* The storage reserve for flood control on January 1 was determined for controlling the flood; During the filling period, January-April, the reservoir should be filled up completely;
* During May-November the water stored is used to meet municipal, industrial and agricultural (irrigation) needs. In addition, some part of the stored water can be transferred to Noteć catchment.

Weighting coefficients:

According to the general objective of the control problem, aimed at the rational protection against water deficits and at reaching the desired state at the end of April, the following values of weighting coefficients are used: $a_j^+ = 1$ if demands are greater than outflow and $a_j^+ = 0.01$ otherwise, for $j = <1,12>$. As far as the second coefficient is concerned, in order to avoid a good performance in one year followed by a poor performance in the next year $b_j = .001$ for j = <1,10>, $b_{11} = .004$ and $b_{12} = .01$.

The objective function assumes the form of a penalty function, and is subject to the following constraints:

* the mass balance equation,
* initial condition of the system, for subsequent years, assuming that the initial condition S_o is equal to the state S^o of the reservoir at the end of previous year,
* constraints on the state of the system S_{minj} Ł S_j Ł S_{maxj},
* flow constraints u_{minj} Ł $_{up}$ Ł u_{maxj}.

Two-level optimization technique

o solve the aforementioned problem we adjoin the mass balance equation with Lagrange multiplier sequence l (prices). The Lagrangian function has the form:

$$L(u,S,\lambda)=\sum_{j=1}^{12}[a_j^{+}(u_j-z_j)^2+b_j(S_j-V_j)^2+\lambda_j(S_j-S_{j-1}+u_j-d_j)] \tag{8.2.7}$$

To include the state-variable and outflow constraints the above problem is solved in a decentralized (coordinated) fashion by means of the two-layer optimization method. At this stage we make use of the additivity of the Lagrangian function and the possibility of separation of the decision variables. The Lagrangian function has a saddle point which can be assigned by minimizing L(l,S,u) with respect to S and **u**, and then maximizing with respect to l. Finally, the optimization problem can be expressed
in the form:

$$\max_{\lambda}[\min_{Su} L(\lambda,S,u)] \tag{8.2.8}$$

with inequality constrains on state and control and no constrains on Lagrange multipliers.

On lower level for given values of Lagrange multipliers we look for the minimum of Lagrange function. The necessary condition is the zero value of the gradient with respect to *u*. The task of the upper layer is to adjust the prices in such a way, that the direct control of the reservoir, affected by *l*, results in the balance of the system (the mass balance equation is fulfilled). In addition to the main objective function, the control effects were evaluated by means of various performance criteria, namely: total deficit time during a year, maximum length of continuous deficit period and maximum relative (percentage) deficit. It should be emphasised that these quality criteria do not occur explicitly in the control algorithm.

Results of simulation

he results of simulation show that in the case of historical records no water deficit has been observed, and for GISS scenario the climate change impact on the operation of Jeziorsko reservoir may have a negligible effect. For the GFDL scenario, serious water deficits may be observed after the year 2010, particularly in the years 2030 - 2050. The water needs for the period 1990 - 2000 are fully met by water supply. However, after the year 2010 the decrease of the average monthly rainfall results in decrease of inflows to the reservoir and increase in water demands for agriculture.

Fig.8.2.13 and 8.2.14 illustrate typical performance of the reservoir in the year 2040 with water deficit. Initial condition is lower then the maximum capacity and actual state trajectory differs from required. In consequence, the optimal control does not meet demands and reservoir will become empty before the end of the vegetation season. It is necessary to stress that the application of the standard decision rule, i.e. when the future inflows are unknown would cause the shorter, but much deeper deficit in July and August. Fig. 8.2.15 and 8.2.16 illustrate the probability of water deficits and relative maximum deficit for the whole period of 60 years of simulation (1991 - 2050).

The study shows that the basin's water supply and demand are both sensitive to changes caused mainly by expected demographic and economic development, but also partly by changes of climatic characteristics, and that the reservoir operation is vulnerable to such changes. In the middle of next century the available freshwater supply may be insufficient to meet requirements in summer months. Optimal operation of existing reservoirs will not solve the problem in the basin as a whole, although may secure reliable supply for its upper part.

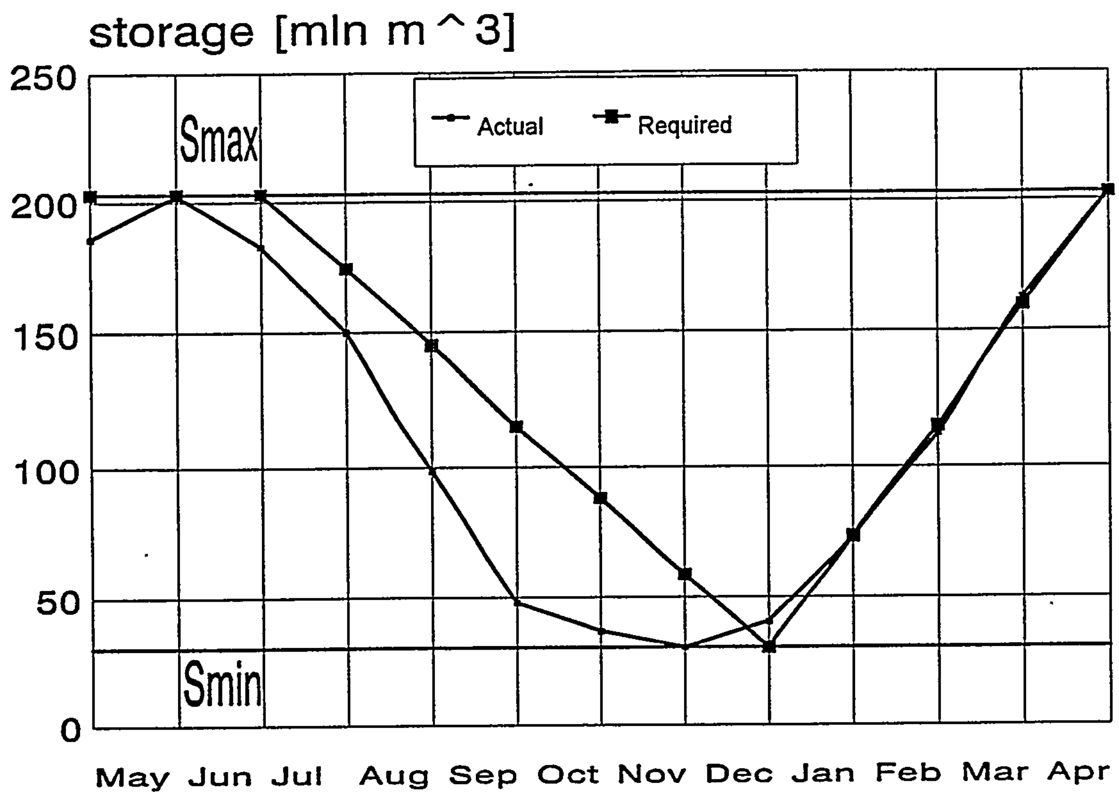

Fig. 8.2.13. Optimal storage trajectory - 2040 climatic conditions

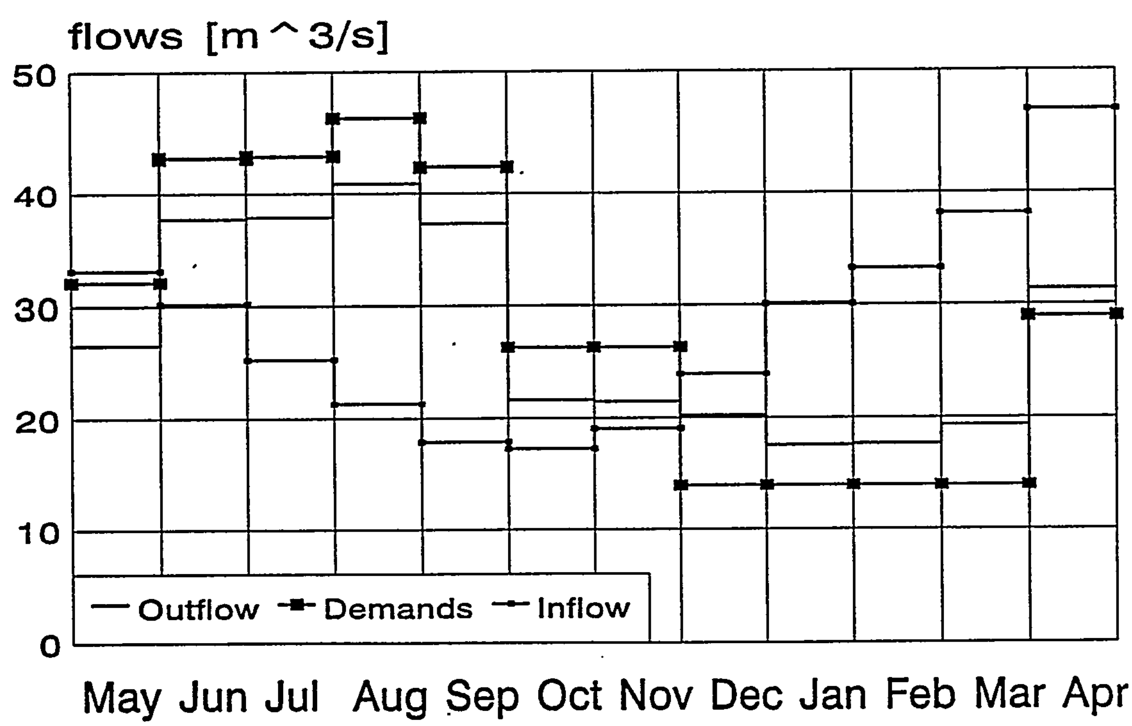

Fig. 8.2.14. Optimal outflow values - 2040 climatic conditions

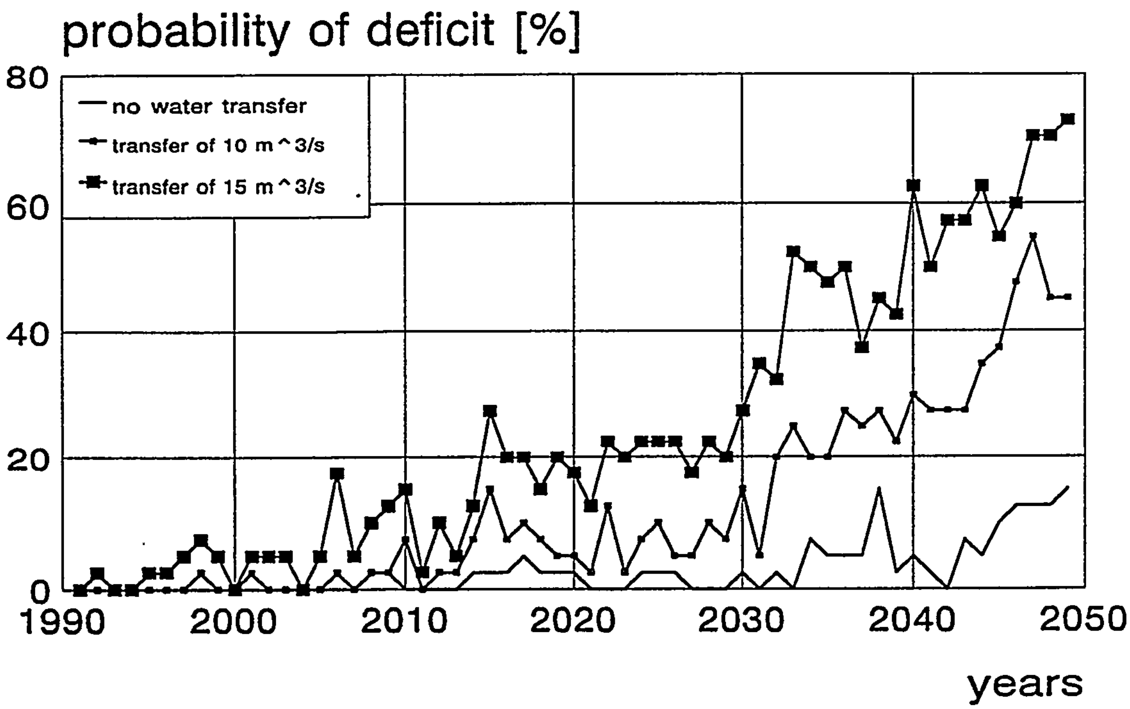

Fig. 8.2.15. Probability of water deficit for Jeziorsko reservoir

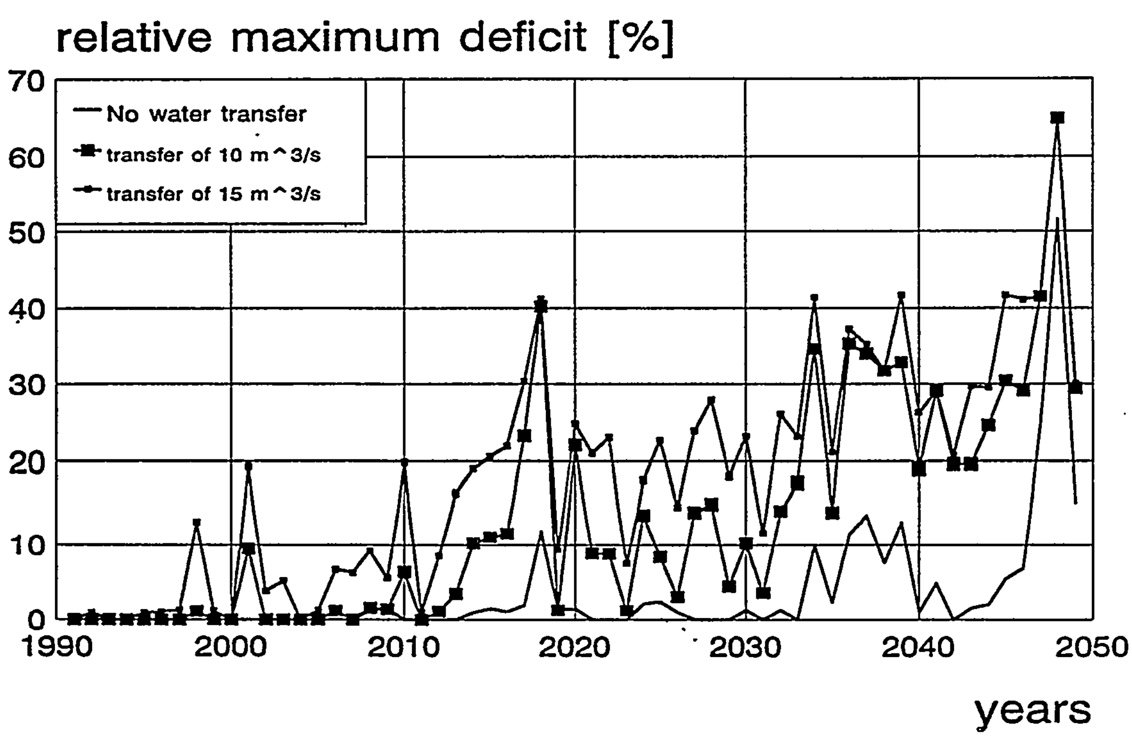

Fig. 8.2.16. Relative maximum deficit [in % of demands] for Jeziorsko reservoir

8.2.7. Vulnerability of Warta and Wieprz water resources systems to climate change and adaptation alternatives

Any climate/water resources impact assessment should allow to answer a number of questions important for policy decision making. These are:

- Does the water system under consideration is able to fulfil all required tasks for the current socio-economic, climatic and hydrologic conditions?
- If not, what action should be taken to improve the situation?
- Will the system be able to meet all instream and offstream water requirements 20 to 50 years from now, assuming stationarity of natural (geophysical) processes? How certain are the predictions?
- If not, what kind of structural and non-structural measures must be foreseen to enhance system's ability to cope with water deficits and/or with floods?
- To what extent a given water resource system may be affected as a result of climate change? How to deal with uncertainties accompanying the issue?
- What are the adaptation options? How the analysts should communicate with decision makers in order to demonstrate that there is a problem to be addressed, conveying at the same time the list of uncertainties attached to climate predictions?

Clarification of some of these questions is the main goal of this Study.

Vulnerability (sensitivity) of water resources to climate change was examined for the Warta and Wieprz catchments. Possible changes in main decisive elements of future system performance were investigated, namely the surface water resources (assuming that climate impact on groundwater resources can be neglected), and water demands of population and various sectors of economy. These changes can lead to deepening of water deficits. To cope with water shortages a possibility of applying the following adaptation measures was analysed:

- policy aimed on more rational water use,
- reduction of economic activities in regions scarce in water,
- water storage investments, and
- transfer of water among river basins.

Warta river catchment

The overall description of Warta water resource system is done in chapter 8.1.2, while information on present and future water supply and demands may be found in chapters 8.2.4. and 8.2.6. In order to examine possible changes in water resources management, an impact analysis was conducted for several cross-sections of Warta river (Jeziorsko, Poznań, Gorzów Wielkopolski, Nowe Drezdenko) on the basis of observed hydrological data, and data responding to the GFDL and GISS scenarios. This analysis concerns:

- minimum, average and maximum flows in 1990, 2020 and 2050,
- changes in flow-duration curves,
- changes in hydrographs,
- storage-draft reliability relationship for hypothetical reservoirs for some assumed relations between required firm outflow in summer and winter season.

The results lead to several conclusions. The predicted changes in runoff in respond to GFDL and GISS scenarios should not have essential negative effects on surface water supply, as well as on guarantied flows and operation of existing or designed reservoirs. Expected decrease of average runoff for the GFDL scenario (about 17-25%) may be partly compensated by the increase of minimum flows (see fig.8.2.17 for example), what may have a positive impact on reliability of supply during drought periods. In case of GISS climate scenario the water supply conditions in the Warta catchment can generally improve. The possible negative effects of climate change on water management may be caused by an increase of concentration of pollutants, and consequently increased cost of water treatment.

The water resource situation in the Warta catchment during the first half of the next century will highly depend on future water demands. As mentioned in chapter 8.2.6, the possible increase in water requirements will be caused first of all by non-climatic factors. The incremental effect of climate change will be negligible, except in case of irrigated agriculture depending significantly on meteorological conditions. In result, the expected surface water supply deficits in 2020 and 2050 will only slightly change in case of disturbed climate comparing with stationary conditions. Surface water deficits for the current climate and for the GFDL scenario, calculated for the present level of Warta system technical infrastructure, are given in table 8.2.6.

Table 8.2.6 Surface water deficits in Warta catchment [km^3/year] with and without climate impact

year	1990	2020	2050
current climate	0.12	0.25	0.25
GFDL scenario	0.12	0.30	0.50

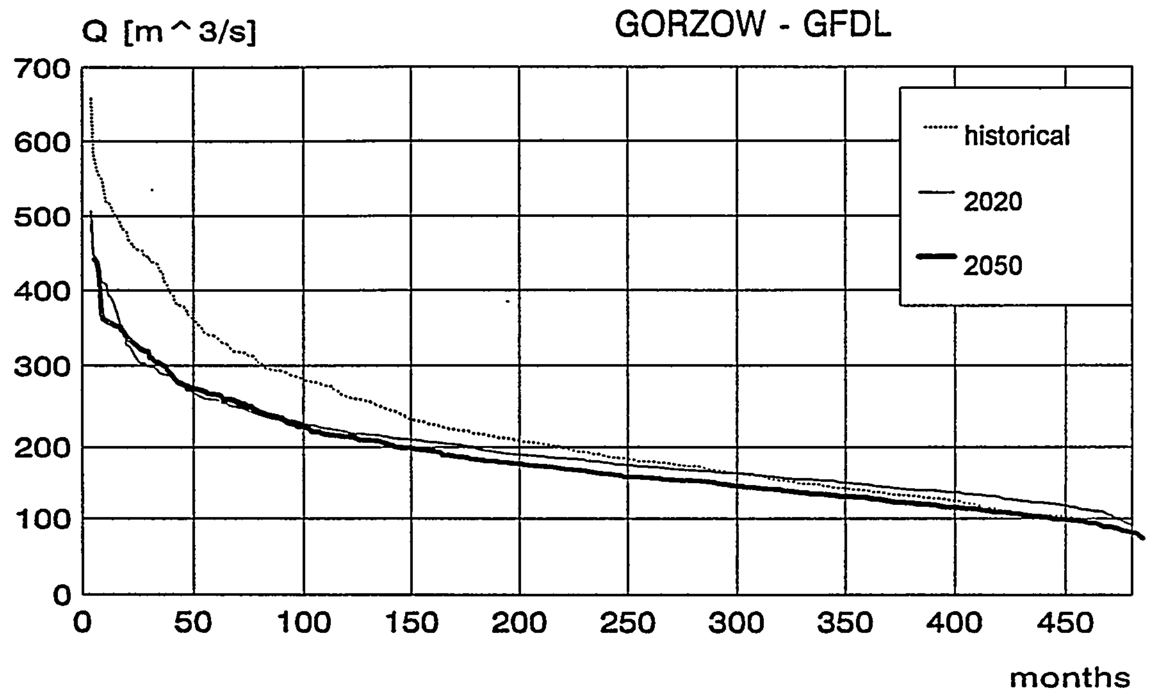

Fig. 8.2.17. Flow duration curve for Gorzów cross-section

The results of vulnerability analysis allow to formulate several conclusions. The Warta river system will not be able to fulfil expected tasks in the 2050 perspective, because of rising demands due to expected demographic and economic processes, even disregarding the climate change. The predicted (for current climate) 90% increase in water demands can not be met by existing technical infrastructure. The risk of deficit will rise from 15% of demands for surface water in 1990, to 23% in 2020, and up to 28% in 2050. The additional rise in water demand under the assumption of GFDL scenario may be significant. The system can be, however, self-sufficient, also in case of unfavourable climatic changes, with increased storage capacity and enhanced water transfers. The upper limit of annual water use that can be met in the system is estimated as 2.6 km^3, i.e. much more than the demand value assessed for the year 2050.

The appropriate adaptation strategies to deal with the rising water demands in the Warta water resources system include:

- strengthening legal and economic policies aimed on protecting quantity and quality of regional water resources;
- rationalization of water use in all sectors of economy;
- optimal use of water stored in existing and designed reservoirs;
- development of technical infrastructure by increasing the storage capacity to 600 mln m^3 (+ additional 60 mln m^3 in the case of GFDL scenario), and by constructing facilities allowing water

transfers up to 100 mln m^3 between various parts of the basin (+ additional 30 mln m^3 in the case of GFDL scenario);

- preference for investments robust to unexpected changes in functions or priorities, and objects that can be further developed.

Wieprz river catchment

The Wieprz river water resource system can be characterized as one of most endangered by recurring water deficits and periodically vanishing streams in Lublin surrounding because of groundwater depression. Its main features are described in Chapter 2 and a synthetic information on water supply and demand can be found in chapters 8.2.4 and 8.2.6.

In order to examine possible changes in surface water supply an analysis was carried out for two cross-sections of Wieprz river on the basis of 40-year observation period and for GFDL scenario. The expected decreases in mean annual flows by 2020 vary from 11.4% in Krasnystaw to 16.7% for Kośmin gauging station, and by 2050 - from 24.0% to 25.1% respectively. These negative effects may be partly compensated by the possible increase of the minimum discharges (see figure 8.2.18 for example). The maybe flow reduction would make it difficult to supply the Wieprz-Krzna canal during the period of intensive irrigation, and to recharge groundwater resources in Lublin area.

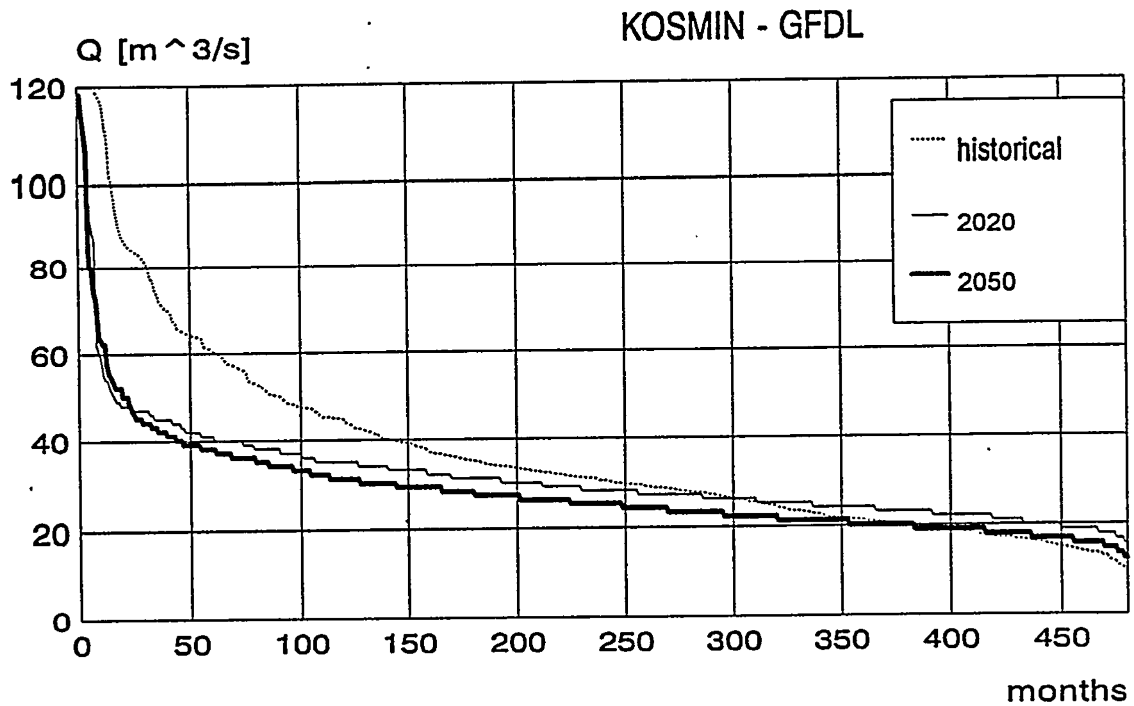

Fig. 8.2.18. Flow duration curve for Kośmin cross-section

Different runoff changes are predicted according to GISS scenario - at the Krasnystaw cross-section mean annual discharge would increase by 7.4% in 2020 and by 14.3% in 2050. The increase of minimum flows by 66.6% and 71.4% respectively is predicted. In that case one can expect a significant improvement of surface water supply in the Wieprz catchment.

Predicted increase in water demand due to non-climatic and climatic factors varies from 90% to 103%, but the role of climate change is in this case insignificant. Such requirements cannot be met without development of system's infrastructure. The highest degree of uncertainty is connected with the agriculture water needs depending not only on meteorological processes but also on a number of unpredictable political and economical factors.

ɜed on the above analysis, and on a number of earlier studies concerning water management in the , one can indicate the following main directions of adaptation activities in case of climate change:

limitation of groundwater water consumption by industry and rationalisation of water use,

modernisation of irrigation systems, e.g. by application of capillary irrigation.

* the use of treated municipal wastes for agriculture irrigation,
* modernisation of Wieprz-Krzna system, i.e. by construction of storage reservoirs of limited capacity each to assure reliable supply for the Wieprz - Krzna canal,
* water transfer from the San river or Middle Vistula to the Wieprz catchment (in case of improvement of water quality in the Vistula river).

It should be also stressed that one of the most important goals of water management in the region is the recharge of groundwater reservoir in the Lublin area, in order to minimize the negative effects of past over exploitation of groundwater resources. This task, however, is quite independent from the climate change issue.

8.2.8. Conclusions

Albeit the Project focused on two river basins, some general conclusions may be drawn for the future Poland's water policy. Summarizing the experience gained from the Warta and Wieprz river case studies, the following preliminary answers may be given to the list of questions raised in the previous chapter:

* Although Poland is scarce in water resources, the present (1990) in-stream and off-stream water requirements may be generally met, with possible local deficits in some years;
* It is doubtful whether future water needs, rising due a number of non-climatic factors, can be easily satisfied by existing structural, economic, and legal policy tools;
* Independent on the climate change issue new structural and non-structural measures will have to be implemented to assure reliable water supply for sustainable development of the country;
* The possible impact of climate change on water supply and demand in Poland is uncertain; in the worst-case "dry" scenario one should expect enhanced drought conditions in summer, particularly in central regions of the country.
* It is difficult to formulate a definite list of possible adaptation options, unless more reliable information on future climate will be available.

Based on the current knowledge, the following final conclusions seem to be justified:

- There are reasons for water resources decision makers to be concerned, because the water supply and demand may be affected by the climate change; irrigation water requirements may significantly increase;
- Water resources systems in Poland may be effectively adapted to changed climatic conditions by a suitable development of the hydraulic infrastructure, however it should be stressed that the general economic conditions and limited financial resources of the country may be a limiting factor to the needed infrastructure development; cost of adaptation in various regions of the country will vary depending on the depth of expected water deficits;
- The vulnerability of water systems to hydrologic non-stationarity decrease as the level of water system development and water management increase;
- Improved water demand management and institutional adaptation are primary components for increasing the robustness of water resources systems under increasing uncertainties due to climate change;
- The current generation of climate models do not offer the requisite degree of watershed-specific information on future climate states; this requires a continuous adaptation of design criteria, development plans, operating rules and water allocation policies to the newly developed climate scenarios;
- Climate impact and vulnerability assessment studies should continue based on improved climatic information; lessons drawn out from a set of hypothetical case studies should in future be generalized in the form of a guideline for adaptation strategies.

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List of Expert's Reports

In the framework of the Country Study the following expert reports in the field of water resources were prepared, and are available (in Polish) at the Institute of Geophysics of the Polish Academy of Sciences:

Prof. dr. hab. Jan DOJLIDO: Strategy of surface water quality management in climate change conditions

Prof. dr. hab. Tadeusz GÓRSKI: Impact of climate change on crop's selection in Poland

Doc. dr. Danuta JURAK: Impact of climate on surface water temperature and on water losses in fish ponds

Eng. Adam KLOSS and dr. Aleksander ŁASKI: Adaptation options of Warta and Wieprz water resource systems in case of climate change

Dr. Eng.. Marek Łoś: Key water management problems in the Wieprz river system with regard to possible climate change

Prof. dr hab. Tadeusz OBRĘBSKI and dr. Marek WĄSOWICZ: Economic and legal tools for adaptation of water resource systems to climate change

Prof. dr. hab. Czesław SOMOROWSKI: Impact of climate change on irrigation water demands

Eng. Janusz WIŚNIEWSKI: Key water management problems in the Warta river system with regard to possible climate change

Prof. dr. Maciej ZALEWSKI: Impact of climate warming on lake and reservoir ecosystems

8.3. Poland's Vulnerability and Adaptation Assessment for the Coastal Resources Sector

A VAA programme for the entire Polish coast (referred to as VA'92) carried out recently [Zeidler. 1992] has provided a background for this extended study (labelled VAAP for the sake of distinction). In the past three years there have been a number of physical, socio-economic etc developments forcing one to revise and update the earlier findings. Moreover, other Polish climate change studies under USCSP created a set of new requirements and boundary conditions which have been addressed in this analysis.

Among the physical boundary conditions, the most distinctive departures from the earlier assessments in VA'92 stem from (a) the recent controversies over the sea level change, (b) re-assessment of Polish SL change trends and re-adjustment to the time horizon set in USCSP Poland as the year 2030, (c) inclusion of the most recent data for annual sea level maxima (ASLM), storm surges and flooding probabilities for the Polish coast, (d) addition of some other CC factors, not only sheer SLR, such as changes in wind conditions and subsequent shoreline evolution patterns.

The socio-economic factors analysed in this VAAP also differ from VA'92 in many respects, mostly because of the price variation for both land (in the retreat strategy) and protection measures (in the protection strategy). In addition, the macro-economic development scenario derived recently under USCSP for Poland provided a valuable framework which could be followed and addressed to throughout VAAP.

The output required by other Polish USCSP studies brought about significant modifications and expansion of VA'92. Among other things, in addition to the two basic strategies of VA'92, 'retreat' ('do nothing' R) and 'full protection' (FP), two other options have been considered in VAAP: limited protection LP and regular shore protection and CZM activities as at present (business as usual BAU). The coupling with the countrywide adaptation strategies (such as reduction of the emission of greenhouse gases) has necessitated the derivation in VAAP of a number of socio- economic quantities and estimates, such as investment patterns and costs, employment patterns, production of some construction commodities etc.

The time span of other Polish studies ends in the year 2030, while the horizon assumed in most CC studies (such as under IPCC or USCSP) is 100 years. In order to meet the requirements of both horizons, this VAAP encompasses estimates for the years 2030 and 2100 (and also includes the year 2025 as a starting date for the so-called 30-year developments scenario in the 100-year assessment, as described below).

This paper deals with the synthesis and revision of VAA for Poland's coast, but does not present the other components of the Author's VAAP studies consisting in the formulation of coastal zone management (CZM) concepts, tools and plans for selected pilot studies identified as vulnerable to CC (CZM-CC). Some CZM-CC aspects are described by Zeidler [1995a].

The feedback with other Polish CC studies is outlined at the end of this paper. The follow-up research stemming from this study embodies primarily the climate-change boundary conditions other than sea level rise.

8.3.1. Methodology, study area and physical boundary conditions

Methodology

The earlier VA'92, a springboard for this VAAP, was based on the Common Methodology (CM) derived by IPCC (Intergovernmental Panel on Climate Change). The present VAAP borrows substantially from many segments of CM-IPCC but also expands its dimension by including new entries, such as re-assessment of Polish sea level (SL) change trends, inclusion of the most recent data for annual sea level maxima (ASLM), storm surges and flooding probabilities for the Polish coast; addition of some other CC factors (effects of wind climate change); and a revised and entirely updated set of prices and socio-economic estimates.

One major methodological addition to CM-IPCC consists in provision of feedback and input data for other CC studies in Poland, in particular some coastal data permitting the assessment of the coastal impact on the emission and reduction of greenhouse gases, thus making VAAP more cross-sectoral.

The socio-economic boundary conditions and the derivation of the 30-year developments scenario are described in Chapter 8.3.4.

CM-IPCC involves the use of a seven step approach to assessing vulnerability to sea level rise. The steps are as follows:

(1) Delineation of case study area and specification of accelerated sea level rise (ASLR) and other boundary conditions;
(2) Inventory of study area characteristics;
(3) Identification of relevant development factors, particularly socio-economic factors (i.a. the so-called 30-year scenario);
(4) Assessment of physical changes and natural system responses (the effects of sea level rise and climate change on the physical phenomena of the coastal zone, particularly erosion, flooding and salinity intrusion);

(5) Formulation of response strategies and assessment of their costs and effects;
(6) Assessing vulnerability and interpretation of results;
(7) Identification of types of assistance needed, based on the so-called vulnerability profile.

Study area

The Baltic Seais a shallow, almost land-locked sea, its salinity being low, barely 7 - 8 ppth along the Polish coastline. The coast forms two major gulfs - the Pomeranian Gulf and the Gulf of Gdańsk, and two water bodies connected with the sea via narrow straits, the Szczecin Bay the Vistula Lagoon.Two major estuarine systems occur on the Polish coast - of the Odra River in the west and the Vistula River in the eastern part, about 700 and 850 km^2 in size. A substantial part of the Vistula Delta, the Żuławy, is a depression reaching almost 2 m below mean sea level.

Out of the total length of the Polish coastline, the 'open sea' coast is almost exactly 500 km (of which 72 km on both sides of the Hel Peninsula), while on the inland side the banks of the Szczecin Bay measure about 240 km, and those of the Vistula Bay about 100 km.

The Polish coast consists of two basic types - dunes and barrier beaches, and cliffs. The former stretch along most of the coast while cliffs occupy less than 20 of the total length. Coastal barriers between the sea and lakes are well developed in the central and eastern parts of the coast.

The Hel Peninsula is a unique spit system separating the Gulf of Gdańsk from the open sea. Because of its intensive erosion and multifarious importance, it has become a subject of concern to both Polish and international authorities.

Because of its diversified features, Poland's coast, referred to as 'Study Area' henceforth, has been split up into four segments seen in Table 8.3.1 and Figure 8.3.1. The four major coastal areas distinguished are the Odra Estuary (Area 1), western dunes and barrier beaches (Area 2), central-east dunes and barrier beaches with the Hel Peninsula (Area 3), and the Vistula Delta (Area 4). Area 1 includes the agglomeration of Szczecin (and Świnoujście), while Area 4 encompasses the conurbation of Gdańsk, Gdynia and Sopot, together with Elbląg. The areas were chosen in such a way as to reflect, in general, the major geomorphic differences along the Polish coast. Their peculiar features are depicted in Figure 8.3.2a and b.

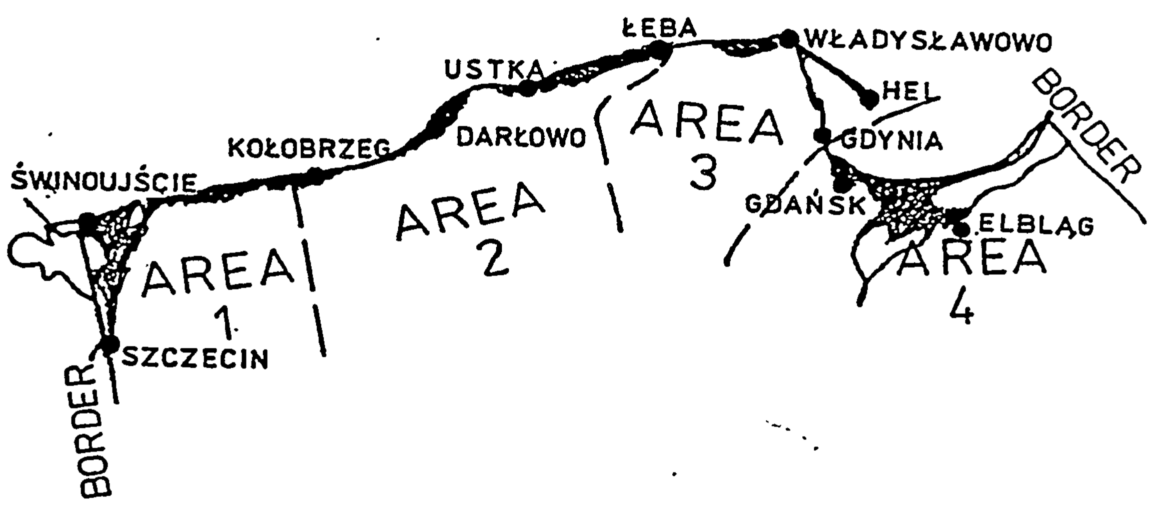

Fig. 8.3.1. Poland's coast split up into four areas for VAA; impact zones by 2.5 m - isoline are hatched

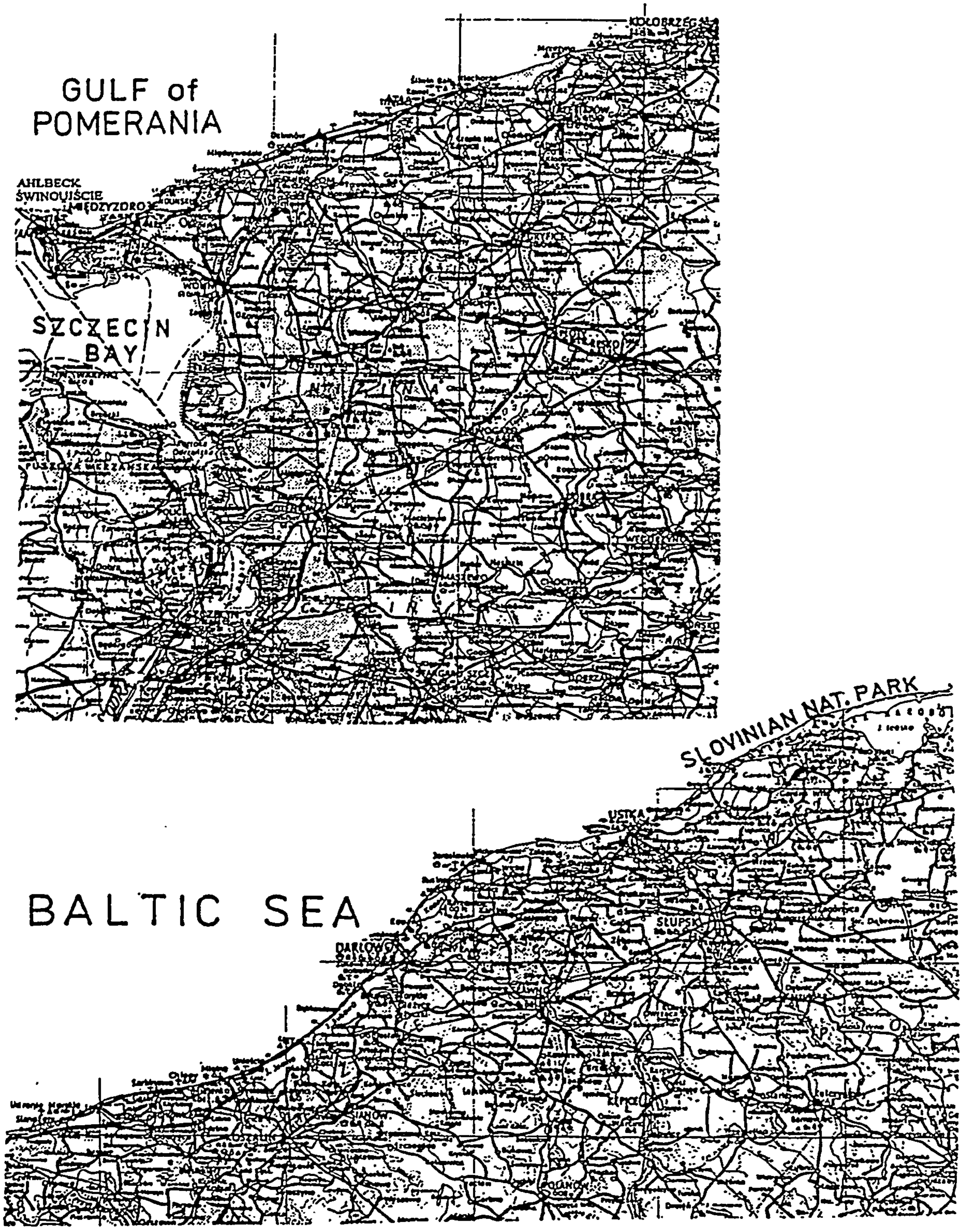

Fig. 8.3.2a. Physiographic features of the areas distinguished along the Polish coast: Area 1 with the Odra system (top) and Areas 2-3 with coastal lakes (bottom).

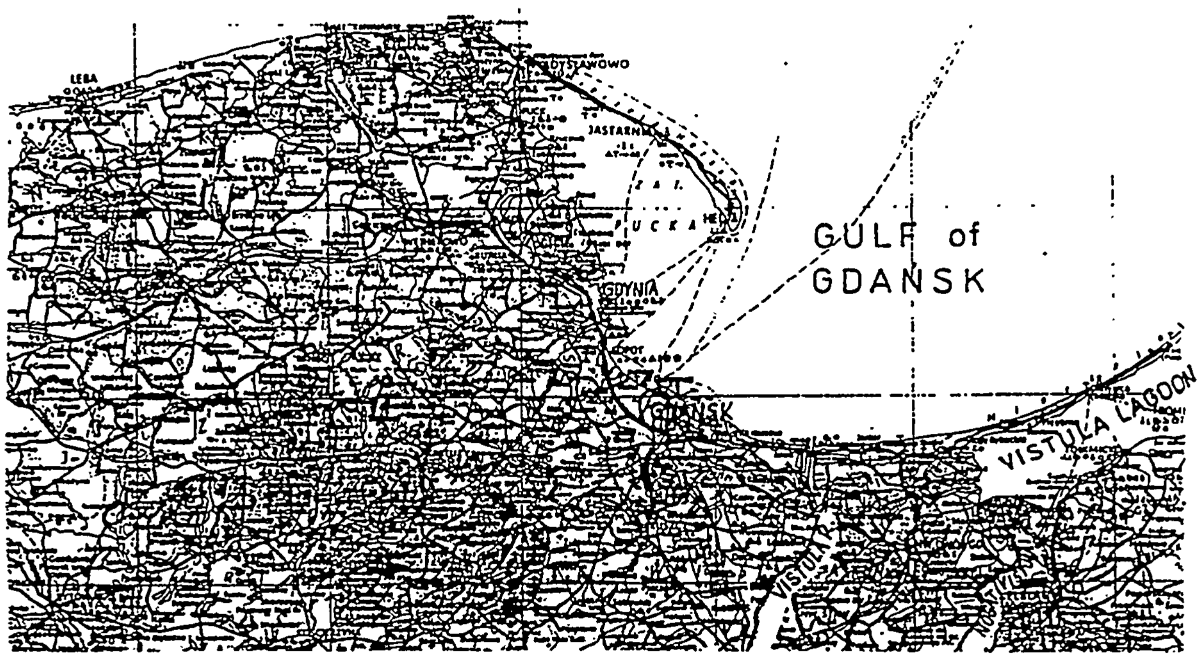

Fig. 8.3.2b. Physiographic features of Areas 3 - 4, with the Vistula Delta and Lagoon.

Table 8.3.1. Division of Poland's Climate Change Coastal Study Area

Area	Description	Length, km	Surface area, km ^{2}
1	Western state border to River Rega $^{(1)}$	320 $^{(2)}$	595
2	River Rega to Łeba	170	244
3	Łeba to Gdynia North	160	173
4	Gdynia North to Eastern state border	190	1217

(^{1}) west of Kołobrzeg; (^{2}) including 240 km of the Szczecin Bay.

8.3.2. Sea level and climate change in Poland

The Baltic Sea is a peculiar reservoir with a surplus of precipitation and river discharge over the outflow to the North Sea thus causing a steady sloping of the water surface towards WSW along the Polish coastline, estimated at 9 cm from Świnoujście (mean datum of 491) to Gdańsk (mean datum of 500).

Recent examination of trends and statistical distributions in sea level datasets, revised and updated for the Polish coast, has partly confirmed some earlier conclusions drawn for mean sea level (and exposed new findings for extremum sea levels). The trends are illustrated in Table 8.3.2.

Table 8.3.2. Sea level at ten Polish stations: mean values and rise rate for the years 1951-1985

Station	Mean sea level	Growth rate, mm/yr
Trzebież	504.8	2.0
Świnoujście	497.1	1.4
Kołobrzeg	498.1	0.8
Ustka	499.9	2.0
Łeba	500.1	1.5
Władysławowo	499.5	1.7
Hel	501.4	1.7
Gdynia	502.9	2.2
Gdańsk-Nowy Port	504.0	2.9
Tolkmicko	502.2	1.5

Note: Tide gauge zero = -500 cm NN_{55} (Amsterdam)= -508 cm H_r (Kronshtat)

In multiyearly forecasts and VAA it becomes important to determine both mean and maximum sea level, together with their statistical distributions and the support methodology of estimation, hypothesis testing, confidence intervals etc.

The maximum sea levels at the Polish coast are coupled with cyclonic circulation with a centre within or close to the Baltic basin, when NW, N and NE winds blow onto land. Storm surges are a complex hydrodynamic phenomenon involving numerous forcing factors. Most important for the Polish coast are the amount of water in the Baltic Sea ('fill-up'), controlled by the exchange with the North Sea (often in the course of dramatic, rapid surge events), and the wind set-up. Seiches, both general and regional, tides, and direct atmospheric pressure are secondary factors. Multiyearly periodicities (periodic components) of sea level are also little pronounced in storm surges. On the other hand, atmospheric pressure and wind play important roles.

For identification of flooding scenarios one must know the probability distributions of extreme water levels such as annual sea level maxima (ASLM). Some work in the domain of ASLM for the Polish coast was done recently [Dziadziuszko, 1992; Wróblewski, 1993a; Zeidler et al., 1994]. Long time series of sea level records stretching from 1867 for Kolobrzeg, 1886 for Gdańsk and 1901 for Świnoujście make possible a reliable analysis.

The difficulties encountered encompass the absence of a constant discretization step, ambiguous statistical independence, and the inherent trends and periodicities. The ASLM trends have been assumed linear (checked by the Student test at 0.05 significance level) and have been found to approach 0.53mm/yr at Świnoujście, 0.07mm/yr at Kolobrzeg and 1.73mm/yr in Gdańsk. Autospectral functions with Hamming windowing (better than the maximum likelihood in this case) displayed weak periodicities about 8-11, 5-6 and 3 years. Bartlett testing and cumulative periodogram confirmed the data independence for Gdańsk and weakly pronounced dependence for the other stations. Seasonal occurrence of the maxima is obvious - 74 % of all ASLM occurred between November and February, these months encompassing all ASLM with 10 % exceedance and 91% of 25 % exceedance (remaining 9 % in October and March).

After detrending the probabilities of ASLM exceedance *P(h)* basing on the Gumbel distribution read as shown in Figure 8.3. 3. These exceedance curves have been employed in subsequent VAA for the Polish coast.

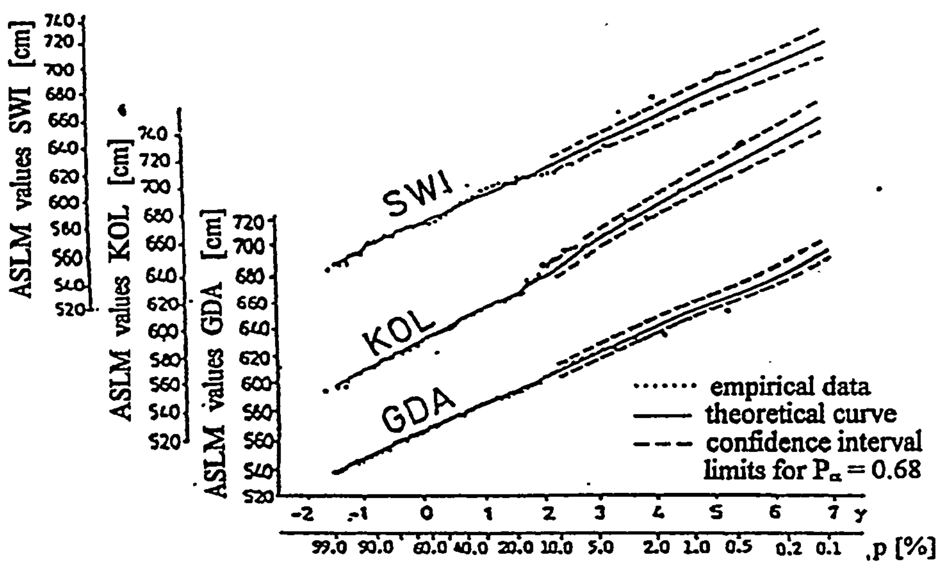

Fig. 8.3.3. Detrended ASLM exceedance curves fitting the Gumbel distribution [Wróblewski, 1993a].

Aside from sea level change and storminess (ASLM), analysed under VAAP was also the effect of wind change. Climatic changes in temperature, precipitation, evapotranspiration and their derivatives undergo analysis within the coastal zone management (CZM) segment of theAuthor's CC studies.

Upon analysis of wind change in the Baltic Sea, one can resort to some recent Polish findings [cf. Zeidler et al., 1994]. Accordingly, Zeidler [1995b] took for granted the wind change trends so outlined and computed sediment transport along the Polish coast in 50 years. Despite a sharp change in wind direction (but not speed) the changes in sediment transport, and subsequent shoreline evolution, are not dramatic, due to the wind change alone. Yet they might become quite conspicuous if the wind change is added to the accompanying storm surge, which seems to be correlated with wind direction.

8.3.3. Physical boundary conditions and impact zones

The sea level rise scenarios assumed for the years 2030 (denoted by SLR) and 2100 (labelled ASLR), and shown in Table 8.3.3., have been based on CM-IPCC assumptions. The lower values, SLR1 for 2030 and ASLR1 for 2100, are close to the present trends measured on the Polish coast, while the upper figures (SLR2 and ASLR2) are almost twice as high as the recent predictions (about 60 cm per century) [Titus and Narayanan, 1992]. Yet the four scenarios delineate the range of extreme possibilities, with SLR1 and ASLR1 as the lower envelope and SLR2 and ASLR2 for the most severe hazards.

Table 8.3.3 Sea level rise assumptions for VA'92 and VAAP

Sea level rise scenario Acronym	Year 2030 Value, cm	Year 2100 Value, cm
SLR1	10	-
SLR2	30	-
ASLR1	-	30
ASLR2	-	100

The inland boundary of the study area was chosen as the +2.5m contour, for both VA'92 and VAAP. This stems from the sum of a sea level rise of 1m and a 100 year return period storm surge for VA'92 and, at the same time, the sum of 30 cm of SLR2 and about 10,000- yr return period storm surge for VAAP. Hence the uppermost landward boundary is taken identical for VA'92 and VAAP, just for the sake of simplicity and to make the present analysis on the safe side of an upper envelope of all possible hazards and risks that might happen by the year 2030. Yet the internal boundaries of Impact Zones are different in the two studies (VA'92 vs. VAAP).

Three Impact Zones have been selected as seen in Table 8.3.4, and the coast's vulnerability has been assessed as at loss or risk (Table 8.3.5).

Table 8.3.4. Definition of Impact Zones for Poland's Climate Change Coastal Study Area under VA'92 and VAAP

Impact zone	VA'92	VAAP
I	0.0-0.3 m	0.0-0.1 m contours
II	0.3-1.0 m	0.1-0.3 m contours
III	1.0-2.5 m	0.3-2.5 m contours

Table 8.3.5. Inundation and risk in terms of Impact Zones for Poland's Climate Change Coastal Study Area

Scenario	Area inundated	Area at risk
ASLR1, SLR1	Impact zone I	Impact zones II + III
ASLR2, SLR2	Impact zones I + II	Impact zone III

The data collected from maps (mostly 1:25,000), reports, computations, studies and other sources (e.g. land-use, socio-economic etc) were entered pertaining to each of the impact zones separately in working tables. Inundated, or permanently flooded (i.e. 'lost') areas could then be readily deduced as zone I at SLR1 (ASLR1) and zones I+II at SLR2 (ASLR2), while the areas at risk were defined as II+III at SLR1 (ASLR1) and III at SLR2 (ASLR2).

For identification of flooding scenarios one must know the probability distributions of extreme water levels such as annual sea level maxima ASLM. The work done recently in the domain of ASLM for the Polish coast [Dziadziuszko, 1993; Wróblewski,1993a; Zeidler et al., 1994] was incorporated in VAAP by inclusion of the findings presented above.

For each endangered area one has tracked the possible ways of inundation due to rising storm level, and has identified the vulnerable locations (dykes, rivers, channels, enhanced subsurface flow etc) permitting the entrance of water. Then it was assumed that the duration of storm surge is 16 hours, and the amount of water inundating the endangered area was computed. This resulted in derivation of a figure for the surface area of inundation. The ratio of that area to the entire area (e.g. Area 4) was found, and that ratio (referred to as 'area factor') was multiplied by the probability of exceedance of the input storm surge level. The product was deemed the probability of flooding for that Area. The numbers so derived for flooding frequencies 6 result from the analysis of possible flooding scenarios, computations, and the use of the sea level exceedance curve. Of course, distinction is made between Impact Zones II and III.

Other CC effects analyzed and assessed include changes in wind direction and speed, which in turn cause changes in sedimentation and shore evolution patterns. The latter have been computed by a variety of computer-aided beach and dune erosion models, among which the Bruun rule provided the simplest estimates.

8.3.4. Socio-economic factors

Poland vs. study area

VAA requires quantitative assessments of costs and benefits coupled with CC vulnerability and adaptation strategies. CM-IPCC imposes the 30-year scenario of likely socio-economic developments, to generate another reference date (2025 instead of 1995) and boundary conditions as a starting point for VAA. Both 1995 and 2025 should be looked at in the broader context of Poland, not just the coastal zone.

Major socio-economic characteristics of the study area are sumarized in Table 8.3.6 versus Poland's figures. The 30-year scenario of socio-economic growth has been analyzed to serve as reference for assessment of the vulnerability in future, within newly transformed coastal zone. Activities in the coastal zone, or their neglect as well, add to the emission or reduction of GHG.

Accordingly, a review of possible development patterns has been provided for socio-economic developments all over the Polish coast, with emphasis on recreation and tourism; ports, harbours and shipyards; mining and industry; urban and rural development; transportation; agriculture, fishery and forestry etc.

Prices and land cost structure

It has been quite an exercise to determine the current prices of different land-use categories in Poland. An almost balanced market does already exist for agricultural land, forests, and land as such. Although these prices vary across the country, they have been established with a reasonable accuracy.

More variation and scarcer information was encountered for urbanized lots, particularly various branches of industry. Larger lots of established housing, and industry are not often offered for sale, and the prices may be distorted due to the transient nature of Polish economy, debt burden of many companies going for sale, uncertainties about the shape and future of nationwide privitisation etc. One is forced to rely mostly on estimates available with internal revenue offices, insurance companies, advertisements and inquiries within different property dealers offering houses, workshops, and factories, and then to extrapolate their prices to larger urban, industry, rural etc categories of interest. Substantial assistance has been provided by design offices for roads,
urban planning, railways, and ports.

The capital value of the study area was found by multiplying the current market prices by respective categories of land use.

The prices in 35 years have been adopted from the Netherlands market upon assumption that Poland's economy in the year 2025 will approach the Dutch one as of now. Table 8.3.7 summarizes the findings and assumptions for land values in the various categories.

Table 8.3.6 General socio-economic data for 1995 and 2025.

Type of data	Units	Data value: 1995		Data value: 2025	
		Nation	Study area	Nation	Study area
GDP	10^9 USD	80 (1)	0.7 (3)	315 [1]	2.8 (4)
Agric. &fishery	%	7 (2)	10 (3)	4 (2)	7 (5)
Forestry	%	1 (2)	1 (3)	1	1 (5)
Building	%	10 (2)	10 (3)	7 (2)	10 (5)
Transp. & commun.	%	3 (2)	5 (3)	2 (2)	5 (5)
Industry	%	38 (2)	35 (3)	26 (2)	28 (5)
Services, trade, municipal & all other	%	41 (2)	39 (3)	60 (2)	49 (5)
Education		4 [2]	5 [3]	5	5 [5]
Health		4 [2]	4 [3]	5	5 [5]
Population [6]	thou	38,600	2234.9	41,500	273
Area 1 (IZ I/II/III)	thou	-	5.1/30.7/31.9	-	107(8/48/51)
Area 2 (IZ I/II/III)	thou	-	0.3/5.8/3.8	-	15.4(0.4/9/6)
Area 3 (IZ I/II/III)	thou	-	0.1/10.1/4.0	-	23.2(0.2/16/7)
Area 4 (IZ I/II/III)	thou	-	35.4/58.6/49.1	-	226(56/93/77)
Surface area	$10^3 km^2$	312.7	2.2	312.7	2.2
Agriculture	$10^3 km^2$	150	1.93	-	1.2
Forestry	$10^3 km^2$	86	0.2	-	0.3
Fishery	$10^3 km^2$	2	≈ 0	-	0.01
Industry	$10^3 km^2$	≅ 5	0.01	-	0.01
Harbours	$10^3 km^2$	≅ 0	-		
Recreation	$10^3 km^2$	(28)	0.01	-	0.3
Urban	$10^3 km^2$	(20)	0.02	-	0.1
Rural	$10^3 km^2$	≅ 18	0.1	-	0.2
Nature reserve	$10^3 km^2$	(3)	0.01	4	0.05
Subsistence pop.		0	0	0	0
Capital value (7)	10^9 USD	240	3	1000	12
Growth rate:					
GDP	%yr	4	4	-	-
Population	%yr	0.25	0.5	-	-
Capital value	%yr	4	4	-	-

NOTE. All monetary values in prices of 1992;

(1) GDP for Poland in 1992 at the exchange rate 14,000zl/USD assumed for 1995 while GDP for 2025 extrapolated from 1995 by SE1;

(2) shares of branches derived from SE1;

(3) shares of branches in GDP derived from statistical yearbooks for the Gdańsk Province taken as representative of the study area;

(4) Study area's growth at pace with the nation;

(5) redistribution of share due to restructuring of land use patterns;

(6) as predicted for 1995; (7) gross as of 1993; CV for 2025 predicted to grow at the rate of GDP.

Sources: Statistical yearbooks and macro-economic forecast by USCSP Poland (SE1).

Table 8.3.7. Land-use values

Cost USD/1 m ^{2}	Data value in 1995					Data value in 2025				
	AR 1	AR 2	AR 3	AR 4	AVE	AR 1	AR 2	AR 3	AR 4	AVE
Beach B [(1)]	10	10	10	10	10	20	20	20	20	20
Agriculture - high AH	3	3	3	3	3	6	6	6	6	6
Agriculture - low AL	1	1	1	.1	1	2	2	2	2	2
Wasteland AO	0.5	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.7
Forest - F	2	2	2	2	2	3	3	3	3	3
Recreation - R	20	20	20	20	20	33	33	33	33	33
Nature res. - NR (1)	20	20	20	20	20	20	20	20	20	20
Rural - W	120	120	120	120	120	250	250	250	250	250
Urban - U	700	200	500	900	700	1300	600	800	1500	1300
Industry - I	600	200	300	600	600	600	200	300	600	600
Harbours - H	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Fishery - FR					5					fbox FrH
Road. (per m) etc - T	900	500	500	900	900	1200	800	800	1500	1200

Notes. All values in prices of 1992. [(1)] for nonmarket value. 2.35 zł ≈ 1.00 USD as of June 1995. Old Polish zloty. in circulation by 31st December 1996 is 0.0001 zł (PZN, from 1st January 1995).

8.3.5. Development vision for the Polish coast (the year 2025)

Along the lines of VA'92, the year 2025 becomes a starting point for an alternative assessment (in parallel with the year 1995), in which the land-use structure, prices etc are taken for the comparison of adaptation strategies. The year 2025 should not be confused with the year 2030, which marks the end of the 35-yr time span under consideration in VAAP, with SLR1 and SLR2, wherein requirements have been imposed in order to see how coastal activities add to the emission or reduction of GHG, in line with other Polish USCSP studies.

In the 30 years to come, the present rate of population growth is slowing down. We have taken a certain average trend of last five and ten years for the nation. For the study area, the anticipated growth is faster. as the worldwide tendency shows a growing population of coastal communities. Moreover, some centres, such as Elbląg will also grow faster than average. As to the land-use patterns over 30 years, there will occur a general transition from agriculture, particularly low-intensity one, to recreation, services and infrastructure. Moreover, for the study area one had to assume severe cuts on agriculture since one deals with a rather narrow strip of coast of specific destination and multifarious uses.

On the central coast (Areas 2 and 3), one can expect that the present functional links between Koszalin and Kołobrzeg, and Ustka and Słupsk, will give birth to two additional urbanized units of diversified marine-oriented functions. On the east coast (Area 4), Elbląg will play a more and more important role, not only for its geographic situation close to the developing Baltic states of Lithuania, Latvia and Russia but also because it is well industrialized and experiences more and more access to the sea (via the Vistula Lagoon). One can assume that the following maritime agglomerations are likely to materialize in the future, from east to west: Elbląg, Gdańsk-Gdynia, Ustka-Słupsk, Koszalin-Kołobrzeg, and Szczecin-Świnoujście. One can also identify a few major recreation strips to develop more rapidly in the coming years.

Oil and gas have been prospected in Poland's zone; it is estimated that the amounts extracted off Rozewie and a few other sites will secure about 5 of Poland's demand for liquid fuel. The inherent infrastructure such as pipelines, transportation, standby vessels, storage areas etc can cause some increase in the use of land. Gravel and sand on an area of 10 km^2 are disponible at Ławica Słupska as some 24 million tons, which are already mined.

The existing industry will not make any dramatic moves but its heavier branches will be on decline. The loss of agricultural land is an irreversible trend. The primary roads and railways of northern Poland are latitudinal, with the major link Gdynia-Koszalin-Stargard Szcz.-Szczecin. One new motorway should materialize on the route from Scandinavia via Gdańsk (somewhere east of downtown) to the Balkan Peninsula and the Middle East. A large ferry terminal with motels etc can be located between Wisła Śmiała and Sobieszewo. Another motorway should lead from Świnoujście and Szczecin to Czechoslovakia and the all-European north-south network.

8.3.6. Retreat strategy: land loss, impacts on population and other results of VAA

Scope of losses and risks

Three major strategies have been assessed: 'no measures' or Retreat R, Limited Protection LP and Full Protection FP.

Tables 8.3.8 and 8.3.9 summarize the ASLR impact on the Polish coast, with a distinction of Areas (1-4) and Impact Zones (I-III). The land-use categories identified for the VA purposes are highly productive agriculture (AH), low-productivity agriculture (AL), wasteland (AO), forest F, rural W, urban U, industry I, recreation R and nature reserve NR.

Table 8.3.8. Distribution of land-use categories in impact zones I, II and III for the year 2100 (VA'92); area in hectares, length in kilometres.

Impact Zone I - 0.0-0.3 m.										
Area	AH	AL	AO	F	W	U	I	R	NR	RD//LR//TL//RL//NT//B
1	90	11,955	2,635	1415	30	40				30//25//41////////
2		30	400					.	430	
3		130	40							
4	4,870	130	1,685		352	130	150			291//108//302//29//6//
Tot	4,960	12,245	4,760	1,415	382	170	150		430	321//133//343//29//6//
Total Impact Zone I Surface Area = 84,512ha										
Impact Zones I + II - 0.0-1.0 m										
1	297	34,338	5,435	7,290	550	640	505	35		70//89//74//15//1//17
2		11,100	995	2,745	110	90			465	27//11//30//1//1//4
3		11,531	118	24	17	5	8	12		6//8//7//2//////
4	6,910	1,930	2,265	1,260	2,590	705	430	95	275	428//179//415//61//65//26
Tot	87,207	58,899	8,813	11,31 9	3,267	1,440	943	142	740	531//287//525//79//66//47
Total Impact Zones I+II Surface Area = 172,770ha										
Impact Zone III - 1.0-2.5 m										
1		7,935	145	1,690			300			36//9//35//6//2//4
2		5,380		2,315	370					36////7//5//3////1
3		3,210		330	155	85		730		28//10//7//11////////
4	21,520	200		795	1,215	815	370			97//12//60//8//9////
Tot	21,520	16,725	145	5,130	1,740	900	670	730		197//38//107//28//11//5
Total Impact Zone III Surface Area = 47,560 ha										

NOTES : The land-use category 'Industry' (I) includes 'Ports' here (!)
(RD) road; (LR) local road; (TL) power transmission line; (RL) railway; (NT) narrow-track rail; (B) bridges

Table 8.3.9 Population of the Study Area (VA'92)

Area	Zone	Urban	Rural	Total
1	I (0-0.3~m)	1,630	3450	5,080
	II (0.3-1.0~m)	21,080	9,630	30,710
	III (1-2.5~m)	28,960	2,940	31,900
2	I	0	270	270
	II	1,210	4,580	5,790
	III	870	2,880	3,750
3	I	0	110	110
	II	740	9,310	10,050
	III	1,550	2,490	4,040
4	I	9,590	25,810	35,400
	II	40,980	17,650	58,630
	III	36,080	13,030	49,110
Total		142,690	92,150	234,840

Some details concerning the vulnerability of specific systems

Odra estuary area

The Odra estuary is a hydrographic system consisting of many natural and man-made channels and waterways. The major ASLR impact will consist in inundation of numerous low lands and aquatic bodies extending at ASLR2 up to River Rurzyca (km 695). Polder dykes have crests about 1.5-2m above MSL. At higher stages most polder dykes will be overtopped. The inundated polders will include those of Miedzyodrze (between East and West Odra), around the Szczecin Bay, Świna and Dziwna.

Equally endangered by flooding are urban areas of Szczecin (primarily Dąbie district), Świnoujście, Trzebież and other towns. Indirect effects encompass damage to sewerage and other infrastructure. Parts of the Ports of Szczecin, Świnoujście and Police are also vulnerable. Because of the increasing flow velocities, hazards are posed to the stability of Świnoujście wharves. Ship waves can enhance the instability of navigation channel banks.

The impact zones I and II within Area 1 measure in total about 162 and 330 km^2, respectively. These areas are vulnerable to permanent flooding under ASLR1 and ASLR2 scenarios.

The polder systems

There are two general groups of Polish coastal polders - without natural drainage, and with temporary natural drainage. The first group encompasses depressions and cryptodepressions such as the Vistula delta.

All Polish coastal polders can be arranged in eight complexes of 243 polders measuring 183,557 hectares. They all can be affected by ASLR, mostly ASLR2, and much less by SLR scenarios.

Coastal barrier lakes

A very particular feature of the Polish coastline consists in the presence of a chain of coastal barrier lakes. Narrow coastal barriers between the sea and low-lying lakes, lagoons or embayments might erode, again primarily due to ASLR2 but not under SLR2 or SLR1, making inland areas widely accessible to sea water.

The higher levels attained by storm surges in ASLR scenarios, and perhaps partly at SLR2, can destroy foredunes and bring about erosion of barrier islands and spits. The lowered barriers will then be susceptible to storm washover, which will lead to inlet breaches and sedimentation on the backside of barriers. The lakes will grow more saline.

Słowiński National Park and Łeba dunes

Situated to the west of the old fishing village of Łeba are lakes and sand dunes of Słowiński National Park, one of the country's strangest but most memorable natural landscape, special enough to be included on UNESCO's list of the world's biosphere reserves. Its natural components encompass waters (9,835 ha), swamps (1,410 ha), sands (953 ha) and some other areas of ecological importance (1,571 ha). Since it is low-lying, the park is vulnerable to both ASLR and SLR2.

Hel Peninsula

The Hel Peninsula is a fairly unique spit formation separating open sea from the Gulf of Gdańsk. Its shoreline is 72 km long. The peninsula is narrow (below 300 m) and very low at places, so it is vulnerable already at present, in particular at higher water levels. Accordingly, enhanced erosion is expected at all four scenarios of ASLR and SLR.

Gdynia and Gdańsk ports

Gdańsk is an important Baltic port near the mouth of the Vistula River. It is a universal port for vessels of medium size to berth in the old parts of the port and for the largest Baltic vessels to be handled at the deep docks of the Northern Harbour.

The Port of Gdynia is a universal-cargo port built from grassroots in the period between wars when Poland had no other acces to the Gulf of Gdańsk. The internal segments of the port were digged out in land.

The altitude above sea level of wharves, jetties, breakwaters, and other facilities also varies from port to port, but many locations are vulnerable to ASLR.

Gdańsk city area

Gdańsk was already known in the 10th century for its castle and settlementof the princes of Pomerania. Having become a city in 1235, it was the possession of the Teutonic knights from 1308 to 1454, when it was returned to Poland.

Gdańsk is now a lively industrial, scientific and cultural centre of northern Poland. It is a seat of a dozen institutions of higher learning, four museums, several theaters, and the Baltic Symphony Hall. The Gdańsk Shipyard is one of the oldest and best established entreprises. Some port areas, urban districts, industry, trade and transportation routes of the Gdańsk area are vulnerable to ASLR impacts. The industry (ports included) occupies 760 hectares in impact zones I-III, while the endangered urban areas cover 1130 hectares. Full prevention measures should be taken to avoid any loss of this valuable and historical piece of the study area.

Żuławy polder area

The Vistula Delta is referred to as Żuławy. It covers an area of 2,320 km^2 with major cities of Gdańsk, Elbląg and Malbork. The gross agricultural area of Żuławy polder district, quite similar to some Dutch areas, covers 180,000 hectares (0.6 % of Poland's land area). Most of its depressions and low land will be damaged under both ASLR and SLR. The dikes already built will be too low for the new hydrological conditions, especially ASLR2. They have been designed to stay under water not longer than a couple of days. The dikes will be subjected to excessive saturation caused by higher water levels, increased groundwater flow due to higher water heads and ice jamming at the river mouth.

8.3.7. Full protection strategy

The 'full protection' adaptation strategy is defined as the implementation of all feasible protection measures to minimise losses of any coastal land or values.

Described by Zeidler [1992] are various protection techniques adopted in VA'92, together with an overview of specific subareas and the solutions proposed to secure their protection. Identification of specific systems on the 'inland' side is followed by an examination of the protection strategy along the entire 'open sea' coast, scanned kilometer by kilometer, from east to west.

The total length of new measures along the coastal ('open sea') segments for SLR and ASLR is obviously the highest at ASLR2, when it becomes 16.3 km of dykes, 21.7 km of seawalls, and 1 km of offshore breakwaters (adapted included). The total length of adapted measures along the coastal ('open sea') segments for SLR2 is 0 km for dykes and 6.7 km for seawalls. The maximum total volume of artificial nourishment is proposed as 1,232,500 m^3 per year per 1 km along shore.

Specific protection measures must be taken in each of the four Areas. *Inter alia* , full protection of the Odra estuary means preservation of the polders on peripheries of the estuary. 107 and 280 km of new dykes must be constructed in Area 4 under ASLR1 and ASLR2, respectively; the lengths of adapted dykes are 243 and 324 km.

In Areas 2 & 3, new polders require new facilities such as pump stations, drainage and other infrastructure, while older polders must be redesigned. The presence of polders is a typical feature arising on the inland segments of the study area. The polder system must be redesigned by rising the dykes, adding new pump stations, increasing the rate of pumping, and applying other measures to preserve, or even improve, the present condition of polders.

The concept of Hel Peninsula protection has largely relied on artificial nourishment.

If one takes Area 4 for a broader illustration, it seems imperative to keep the present agricultural use of the Vistula Delta (much as the lower Odra Valley in Area 1), especially in the polder areas.

Hence full protection of Żuławy polders at ASLR2 requires a bulk adaptation of the existing dykes and the construction of some new dykes and storm and flood prevention facilities.

8.3.8. Economic analyses and evaluation of adaptation policies

Comparison of strategies

Tables 8.3.10 and 8.3.11 summarize VAA results for the three strategies adopted.

Table 8.3.10a. Poland's coastal zone vulnerability: ASLR1 of VA'92

Impact category	Unit	BAU	R-1995	R-2025	FP-1995	FP-2025
Capital value lost	10^9 USD	-	6	9.8	-	-
People relocated	thou	-	8.5	10.3	< 0.1	< 0.1
People at risk	thou	5.8	31.7	41.2	< 1	< 1
Cap. value at risk	10^9 USD	10	40	62	< 5	< 5
Damage (salinity)	10^9 USD	-	< 0.01	< 0.01	< 0.01	< 0.01
Ecolog. area lost	sq.km	-	1.2	3.1	-	-
Special area lost	sq.km	-	2.7	7.3	1	1
FP implement.cost	10^9 USD	-	-	-	2.3	3.8
Annual maintenance	10^9 USD	-	-	-	0.01	0.02

Table 8.3.10b. Poland's coastal zone vulnerability: ASLR2 of VA'92

Impact category	Unit	BAU	R-1995	R-2025	FP-1995	FP-2025
Capital value lost	10^9 USD	-	28	46	-	-
People relocated	thou	-	146.1	176.3	0.1	1
People at risk	thou	5.8	50.3	108.5	< 5.8	< 10
Cap. value at risk	10^9 USD	10	18	26	< 5	< 5
Damage (salinity)	10^9 USD	-	< 0.01	< 0.01	< 0.01	< 0.01
Ecolog. area lost	sq.km	-	3.4	10.7	1	2
Special area lost	sq.km	-	7.9	25	3	5
FP implement.cost	10^9 USD	-	-	-	6.1	9.8
Annual maintenance	10^9 USD	—	-	-	0.03	0.5

Table 8.3.10c. Poland's coastal zone vulnerability: SLR1 & SLR2 for Retreat R, Limited Protection LP and Full Protection FP in VAAP

Impact category	Unit	BAU 1995	R SLR1	R SLR2	LP SLR1	LP SLR2	FP SLR1	FP SLR2
Capital value lost	10^9 USD	-	2.3	6	1	2	-	-
People relocated	thou	-	18.4	40.9	0.1	1	< 0.1	< 0.1
People at risk	thou	5.8	6.5	17.3	< 5	< 5	< 1	< 1
Cap. value at risk	10^9 USD	17.5	18	40	< 2	< 5	< 1	< 5
Damage (salinity)	10^9 USD	-	< 0.01	< 0.01	< 0.01	< 0.01		
Ecolog. area lost	sq.km	-	0.4	1.2	0.3	1	-	-
Special area lost	sq.km	-	7.9	25	1	1	1	1
LP/FP implement.cost	10^9 USD	-	-	-	0.6	1.2	0.9	2.3
Annual mainten.	10^9 USD	-	-	-	0.003	0.006	0.005	0.01

In reality, the actual adaptation strategies to be followed will depend on a careful assignment of funds to the areas at major risk. An in-depth analysis of very local areas and priorities will be required to define the likely realistic response strategy yet this is beyond the scope of this study.

Table 8.3.11 Gross evaluation of CC adaptation strategies for Areas 1-4; values in 10^9 USD

	AREA 1	AREA 2	AREA 3	AREA 4
Total Capital Value :	6.9	0.28	0.48	12.6
Cap.val. lost SLR1 :	1.0	0.21	0.02	1.1
Protection cost SLR1 :	0.22	0.18	0.03	0.46
Protection cost as % of Cap. val. at loss :	22 %	86 %	150 %	42 %
Total Capital Value :	15.6	0.55	1.1	28.6
Cap.val. lost ASLR1, SLR2 :	2.7	0.54	0.06	2.7
Protection cost ASLR1, SLR2 :	0.57	0.46	0.09	1.18
Protection cost as % of Cap. val. at loss :	21 %	85 %	150 %	43 %
Total Capital Value :	15.6	0.55	1.1	28.6
Cap.val. lost ASLR2 :	7.4	5.7	0.84	14.1
Protection cost ASLR2 :	2.07	1.4	0.3	2.31
Protection cost as % of Cap. val. at loss :	28 %	24 %	35 %	16 %

Upon comparison of the strategies, the following conclusions may be drawn.

1. In all cases but Areas 2 and 3 for SLR1, SLR2 and ASLR1, the protection cost is substantially lower than the value potentially lost. The costs to protect Area 3 in the cases of ASLR1, SLR1 and SLR2 are much higher than the capital value of this area and this could affect the motivation to spend scarce funds on protective measures under these ASLR and SLR scenarios.
2. The cost to fully protect Areas 1 to 4 under ASLR2 appears justified in terms of the low cost relative to the capital value 'saved'. For Area 3 this motivation is slightly lower.
3. In Area 2, the priority nature reserve areas are located (Słowiński Park) and these are only protected at a high cost relative to their capital value. It is unlikely that these areas will receive priority attention in a climate of very scarce funds where strategic economic areas facing equal risks are likely to capture the available funds. Moreover, the transformation ofa nature reserve into an artificially protected area may sometimes be controversial.
4. Limited protection LP for both SLR1 and SLR2 yields protection costs comparable with the value at loss (cf. Table X.3), so the motivation to apply LP could stem primarily from the high value at risk, not the value lost alone.

Similar trends result from the analysis for ASLR1 and ASLR2 in the socio-economic scenario assuming the year 2025 as reference (the 30-yr scenario).

The above demonstrates the likely outcome of a very coarse cost-benefit analysis. Specific decisions for particular sites must be made on the basis of a much more detailed local area analysis.

Vulnerability profile

For the purpose of general assessment and comparison of various strategies and scenarios, four em vulnerability classes have been specified in accordance with the IPCC Common Methodology and some amendments made under VA'92. The classes chosen for values at loss, values at risk, ecological and other impacts, are labeled 'low', 'medium', 'high' and 'critical'.

For the retreat strategy R it is shown that losses are expected to be CRITICAL in ASLR2 if expressed as a percentage of GDP. Losses are LOW for SLR1 but become MEDIUM to HIGH for ASLR1 and SLR2 with present development. Of note is that there is already a MEDIUM risk classification for numbers of people flooded annually. This rises to HIGH in ASLR2 with 30 year development. Salinity and ecological areas show LOW vulnerability.

For the full protection strategy FP the values at loss reduce to LOW by definition of the protect strategy. The cost of protection measures as of 1995 varies from LOW for SLR1 through MEDIUM for ASLR1 and SLR2 but would be HIGH for ASLR2 based on present development and CRITICAL based on the 30 year development. This clearly shows the need to und act sooner rather than later with preventative measures due to increasing costs.

Preference should be given to protection strategies, yet some limitations arise for Areas 2 and 3 subject to SLR1 and SLR2, in view of the protection costs higher (Area 3) than or comparable (Area 2) with the value at loss. Still the need for protection is reinforced by the fact of having high value at risk if unprotected.

A concluding point of concern is that there is a real danger that funds will not be allocated to coastal defence measures to protect against sea level rise until serious losses begin to occur and until a far higher degree of confidence in a predicted figure for the degree of sea level rise greater than 0.3m and closer to 1.0m can be relayed.

Inter alia, some constraints stem from the medium to high cost of protection compared to Poland's GDP. This ratio is about 3 for the entire Poland's coast. In order to reduce the burden on the nation's GDP it seems reasonable to adopt limited protection for selected areas, perhaps Areas 1 and 4 in VAAP terms.

The important conclusion has to be made that without additional protective measures and a real awareness among coastal managers of the dangers and possible losses associated with sea level rise, a serious loss of the viability of important coastal areas, both economically and ecologically, will occur. This will hamper growth of an emerging Polish economy and its important coastal regions.

Feedback with other USCSP Study Elements

The analysis presented so far in this paper is centered around the issue of coast protection facing climate change. Yet the major concern of USCSP Poland lies not only in adaptation strategies for specific sectors of economy or particular areas, such as the Polish coastal zone but also in reduction of the emission of greenhouse gases (GHG). Hence it is appropriate to look at VAA in the latter context as well, although it might turn out in the end that the emission of GHG remains unaffected by any transformation in coastal activities due to climate change.

Table 8.3.12. summarizes the issues stemming from other CC studies under USCSP Poland addressed to within VAAP.

Table 8.3.12 Input information from VAAP needed by other Polish CC studies (SE1)

Coastal strategy vs. CC study output	Full protection (FP)	Limited prot. (LP)	Present status (BAU)	No measures (Retreat R)
Description	+	+	+	
Investment	+	+	+	
Commodities (steel etc)	+	+	+	
Employment	+	+	+	+
Land loss & shore erosion		+	+	+
Productivity loss		+	+	+
Property loss		+	+	+
Population migration		+	+	+

8.3.9. Investment needs for partial and full protection strategy

The costs of the implementation of the partial and full protection strategies, LP and FP, stem from the products of the protection measure scope times the unit prices given in respective tables. Some additional costs of infrastructural upgrading are also included. The total costs under SLR1 and SLR2 are 0.6 and 1.2 USD billion for LP, and 0.9 and 2.3 USD billion for FP. The investment for FP and LP should go basically into Areas 1 and 4, where it makes most sense in terms of cost and benefit. In the LP strategy the investment is spread slightly more uniformly; for instance the Hel Peninsula in Area 3, together with some cliffs in Area 2 could deserve local protection.

The annual investment for protection at present is below 5 USD million.

The future investment would go mostly into construction works, such as for seawalls and dikes, together with beach and bank nourishment, dune and cliff stabilization, dredging operation and infrastructure. Some road construction would accompany the primary protection activities. At present, the investment and maintenance are typical of coastal engineering activities.

The derivatives of the coastal adaptation strategies, such as the production of steel and cement, energy consumption and employment, have been calculated in order to assess their impact on the emission and reduction of greenhouse gases.

8.3.10. Conclusions

According to carried out analysis and research the whole Polish coastal zone is endangered by the sea level rise as a result of climate change. However priorities should be given to western (Szczecin area) and eastern (Gdańsk-Elbląg region) as especially endangered regions. Such approach is also justified by cost-benefit analysis and limited amount of available financial resources.

Further following research are necessary:

- river floods processes under sea level rise condition,
- salt water influence on fresh water supplu and agriculture,
- changes in coastal ecosystems and quantification of envieonmental losses as a result of climate changes.

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List of major abbreviations

AMSL	Annual Mean Sea Level
ASLM	Annual Sea Level Maximum
ASLR	Accelerated Sea Level Rise
BAU	Business as Usual
CC	Climate Change
CM-IPCC	Common Methodology for VAA derived by IPCC
CZM	Coastal Zone Management
CZM-CC	Coastal Zone Management versus Climate Change
FP	Full Protection strategy for coastal zone
GHG	Greenhouse Gases
IBW-PAN	Polish Academy of Sciences' Institute of Hydro-Engineering, Gdańsk
IGBP	International Geosphere-Biosphere Programme
IOS	Environment Protection Institute, Warszawa
IPCC	Intergovernmental Panel on Climate Change
IZ	Impact Zone
LOICZ	Land-Ocean Interactions in the Coastal Zone (IGBP)
LP	Limited Protection strategy for coastal zone
MSL	Mean Sea Level (multiyearly)
OOK	Climate Protection Centre, IOS Warszawa
R	Retreat ('do nothing') strategy for coastal zone
SE	Study Element (under USCSP Poland)
SL	Sea Level
SLR	Sea Level Rise
USCSP	United States Country Studies Program
VA	Vulnerability Assessment (vs CC and/or SLR)
VA'92	Vulnerability Assessment for Poland as of 1992
VAA	Vulnerability and Adaptation Assessment
VAAP	Vulnerability and Adaptation Assessment for Poland's Coast as of 1995

8.4. Adaptation of Polish agriculture to climate change

Agriculture is one of few human economic activity sectors, which reacts to climate change in a direct way. This concerns particularly those climate changes which are related to a potential increase of CO_2 concentration in the atmosphere, which might result in:

- increase of mean annual temperature;
- decrease (or increase) of mean annual precipitation and their seasonal distribution;
- increase of CO_2 concentration in the atmosphere.

All the above listed climatic factors belong to basic factors of the growth and developemnt of plants - primary food producers for man, fodder for livestock and plant-origin raw materials for the industry and energy generation. Temperature, for example, has impact on the length of vegetation period, dates of anthesis, rate of growth and dynamics of plant biomass accumulation. Over 90% of dry plant mass is produced from carbon dioxide as a result of photosynthesis process. To produce a unit of mass of a crop (e.g. one tone) plants use between 175 and about 800 units (tones) of water, depending on the species and variety. Those factors might have a synergic impact (e.g. increase of humidity along with increase of mean annual temperature), antagonistic impact (e.g. decline of humidity along with increase of temperature) or independent impact (e.g. increase of atmospheric CO_2 concentration in each of the analysed variants results in increase of C3 plants intensity of photosynthesis).

Therefore, depending on the character, predicted climate changes may be either a stimulating (e.g warm and humid climate with average increase of CO_2 concentration in the atmosphere) or a deterring (e.g. hot and dry climate with large increase of CO_2 concentration in the atmosphere) factor of plant production growth. Assessment of impact of projected climate changes on agriculture should therefore take into account both evolutionary developed adaptation capacity of plants and livestock as well as broad spectrum of activities undertaken by agricultural producers to counteract adverse implications of those changes. Indirect impact of climate changes on cultivated plants through a change of physical, chemical and biological features of soils and through a change of interrelations between cultivated plants and pests and pathogens should also be considered.

In the light of the above listed facts and conditions, adaptation process of Polish agriculture to the predicted climate changes, depending on the direction of those changes, ~~will~~ include: could

- significant lengthening of agricultural economic period within which it is possible to conduct any field work. In the Western Poland this period will practically be unlimited while in the east of the country it will be extended by about 70 days a year;

- lengthening of climatic plant vegetation period (with mean temperature over 5°C) in the east of 2 and in the west of 3 months, which will result in significant reduction of winter crops production;

- extension of possibilities of thermophilous crops production (corn, soybean, oilseed sunflower, oilseed squash, castor-oil plant). It can be expected that even late varieties of corn will ripen in the whole country and their yield will be by 3 t per ha higher that currently;

- shortening by about 2 weeks of production period of cereals, which will enable a wide use of stubble field aftercrops whose yield will be two-fold higher than currently;

- growth by about 30% of photosynthesis intensity (and increase of biomass) of most of our cultivated crops when the current CO_2 concentration in the atmosphere doubles;

- deterioration of the quality of agricultural production (mostly green fodders) as a result of the increase of C:N ratio in their biomass;

- reduction of yield by about 15% as a result of increase of wintering pest population as well as fungal, bacterial and virus diseases;

- interruptions, in higher temperatures, of the process of seed germination (especially in *Papilionaceae* family) as well as processes of seed development in generative phase of plant life-cycle, which might bring the reduction of seed yield by 10-20%;

- reduction of level of plant damages by atmospheric pollution with sulphur dioxide and ozone as a result of increased concentration of CO_2;

- decline of soil humidity resulting from its increased evaporation by 5% along with growth of mean temperature by 1°C;

- increase of livestock production efficiency as a result of growth of cheap fodder production (such as corn or plants of permanent green crops);

- increase of costs of livestock production as a result of necessity of air-conditioning of cow-sheds along with the risk of livestock perish being a consequence of overheating and decreased level of reproduction in higher temperatures.

The projected climate changes might cause more frequent "natural calamities" in agriculture resulting from long-term droughts, torrential rains, and gales, which might lower the yield by 10-30% per annum. Summers with beneficial composition of climatic factors might, however, bring significant increase of yield and be the reason for the so called "bumper crop calamities". Taking into account their alternate occurence, a national policy should be prepared to address the issue of creation of sufficient food and fodder reserves without an additional import.

In the case of a warm and humid climate, a projected growth of plant production will result in a necessity to withdraw from field production of about 4 mio ha of arable land (see the ranking in 9.5.6), which can be utilized for production of plants serving as renewable energy sources and raw materials for the industry, which might have a significant impact on the reduction of GHG emission to the atmosphere.

It is foreseen that the projected climate changes will have a multidirectional impact on agricultural production in Poland, and that most of those changes will have a beneficial character, providing the cultivated crops are supplied with a sufficient amount of water. If the concentration of CO_2 doubles and temperature rises we can expect a growth of the yield of most of presently grown crops. Longer vegetation period will create conditions favoring extension of the scale of pasture management. Reduction of the area taken up by potato production will take place along with increase of the area under thermophilous crops, such as corn and soybean. On the other hand, however, intensity of various diseases and plant pest invasions will grow, as well as a deficit of water requiring intensified drainage and irrigation.

Summing up, a resultant impact of climate changes on global agricultural production net is difficult to estimate. Higher yield in some regions (or years) might counterbalance a drop of yield in other regions (or years), however this will depend on many controlled and producer independent factors. Extent of potential losses related to climate changes threatening food producers are also difficult to predict, as well as their influence on changes in production profile and structure. Specific character of agriculture shows through, *inter alia*, the fact that changes of profile and structure of production are "forced" by climate changes, while speed and costs of those changes depend on the adaptation capacity of national agricultural policy and efficiency of actions and funds allocated towards mitigation of adverse effects of climate changes.

Taking into account the very complex and hard to predict nature of the impact on agriculture from climate change in a perspective till 2030, immediate research are necessary focused on preparation of Polish agriculture for effective functioning in the conditions of expected climate changes. Research of such type are already widely conducted in many countries of the world.

9. Strategies of GHG Emission Reduction

9.1. Power Generation Sector

9.1.1. Aim of Research

The fundamental aims of the research within this sector were:

- suggesting the methodology using the formal tools for the needs of creating state policy regarding the greenhouse gases emission reduction from power and heat generation subsectors,
- varianted evaluation of GHG emission reduction possibilities in above mentioned subsectors,
- recommending the frames and directions of state policy in this area.

9.1.2. Methodology and Mathematical Models

Considering the transition character of Polish economy, the undertaking being conducted within this work were concentrated on pragmatic problems to show the alternatives and suggestions of verifying actual country development concepts to decision makers.

Figure 9.1.1 presents the methodology of building scenarios by iterative consistency improvement. Available and benchmarked in Poland models were used (ENEP-BALANCE and ELECTRIC/WASP, ELFIN) together with dynamic, simulation macroeconomic model (SDM) developed at FEWE and expert opinions.

The research was started from the trial of creating development scenario aiming to represent the actual biases of energy subsectors development. Next, the corrections were made by iterative consistency improvement of results and assumptions of top-down model (SDM) effecting from macroeconomic and political assumptions with results of bottom-up models that describe costs, emissions and market changes basing on microeconomic and technical assumptions regarding specific technologies and the possibility of their cooperation within the system.

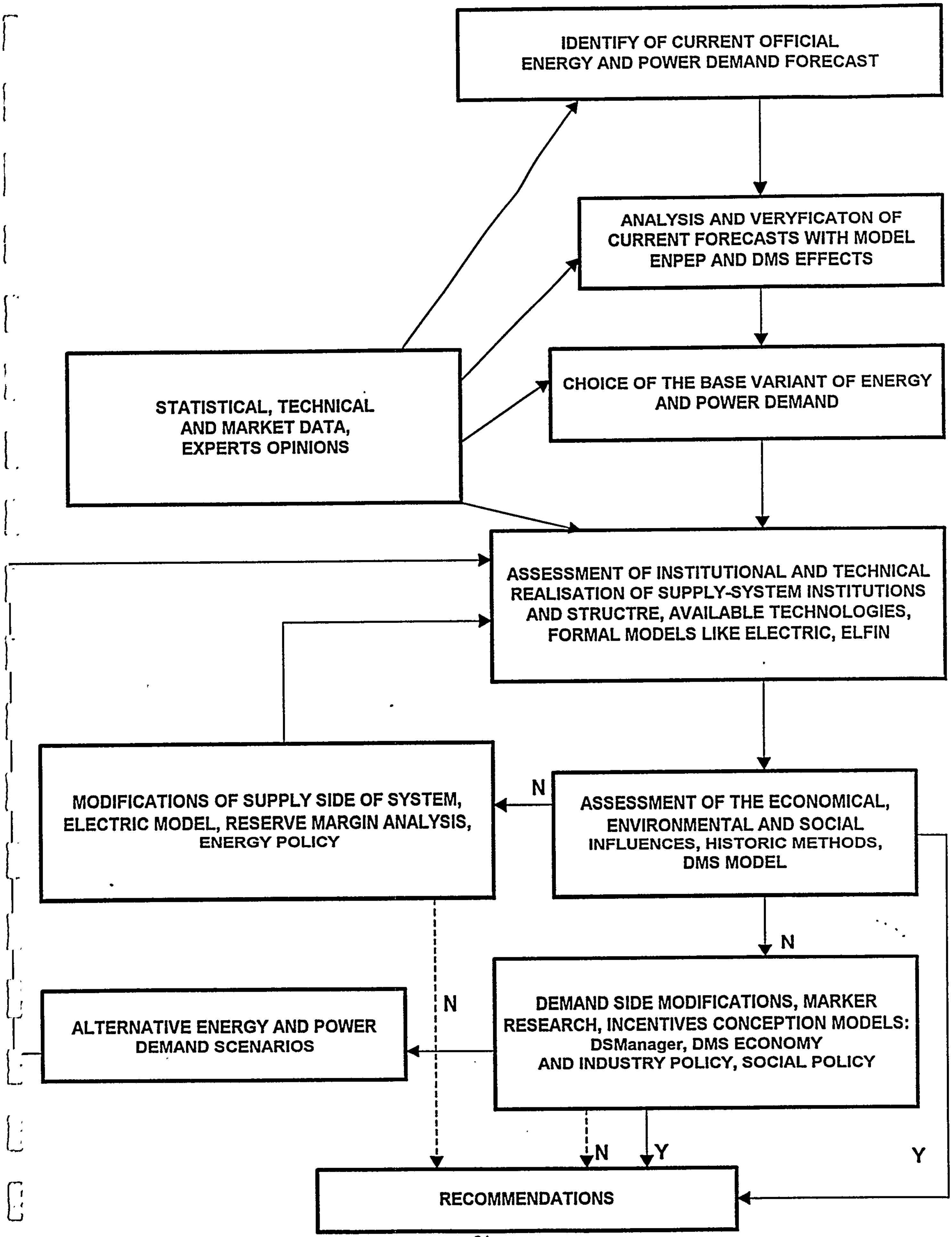
The assumptions were verified by expert teams dealing with the analyses of energy sector development in Poland. The development assumptions prepared for central administration offices in Poland like Ministry of Environmental Protection, Ministry of Industry and Trade and Central Planning Office were used together with the preliminary macro- and micro-economic assumptions prepared by Study Element Teams.

Regarding the statistical data describing changes in state power and heat generation system both in the supply and demand side the statistical data from GUS were used.

To improve the possibility of evaluating the phenomenons influencing the emissions of pollutants to the natural environment, FEWE together with CIE modified the methodology of utilizing the models used for preparing the state policy. Adding the analyses of energy consumption at the end user at households and public sector was suggested. Such analysis enables to evaluate the influence of equipment at the end users on the level and structure of energy demand. The analysis of equipment structure and its usage patterns at the end users was conducted for 1994. The structure of energy consumption by different equipment categories was analysed and balanced. The results show good consistency between demand evaluation and official statistics for direct energy consumption. To achieve full consistency with the statistics some corrections of equipment usage patterns were done.

Simultaneously the review of alternative technologies capable to fulfill end needs has been done. Basing on this review the aggregation of technological alternatives for prognostic calculations was prepared. Each technology is associated with energy carrier, cost per unit, capacity demand, O&M costs, efficiency and durability. The assumptions result from literature and market data analysis, regarding existing and future technologies available on Polish market. Finally the suggested values result mainly from heuristic evaluation of experts. The requirements of BALANCE model oblige to reduce the number of analysed technologies significantly. From the other hand there is vast quantity of appliance types, differing in technical, operational and economic parameters and market responses for imaginable signals strongly depend on many factors like welfare of households, economic discloseness and resulting relationships between energy prices and appliance prices, social awareness, fashion etc. This is why each of the proposed parameters is ascertained by subjective evaluation regarding possible market penetration by various appliances in the same category. To make these assumptions more realistic foreign experience, results of questionnaires were utilized and we tried to consider the macroeconomic assumptions regarding economic growth rate and GDP share structure.

Fig.9.1.1. Methodology of building scenarios



Each of the scenarios was analysed using varianted assumptions for covering it's demand by energy subsectors. Diversed constraints and restrictions were assumed. Regarding the forecasts of covering energy and heat demand patterns in various scenarios FEWE experts cooperated closely with Power Engineering Institute specialists in the area of power sector and with Heat Union specialists concerning the heat sector. The conceptions of structural/organisational changes in power sector was consulted with the representatives of Polish Power Grid Co.

To model the development of power and heat generation system we used the data for power and heat producing appliances collected basing on literature review. Macroeconomic simulations were conducted in cooperation with the team of professionals dealing with macroeconomic scenarios preparation on the base of statistical, literature and questionnaire data.

The cost and level of GHG emission was estimated for each of the scenarios.

After achieving the sufficient internal consistency of the scenario, the alternative one was being prepared. The possibility of introducing the specific tax and DSM mechanisms was assumed together with assumptions on changes in Polish market's openness to foreign competition, by building hypothesis of changes on equipment market and making the alternative scenarios of changes in the demand for various final needs. The possibility of discount rate changes was also assumed. Scenarios were evaluated considering macroeconomic and social effects. Then the procedure of improving the consistency was repeated.

Finally the presented results stand for, assumed as probable, economic situations differing in the macroeconomic and market assumptions. The results presented in variants results from differences in microeconomic assumptions concerning the supply side of energy subsectors within scenarios.

9.1.3. Emission Scenarios

Emission factors

The emission factors for analysed gases relate to chemical energy of burned fuels and are assumed as constant for the time horizon of the project for all variants presented in table 9.1.1 [g/GJ of input fuel].

Table 9.1.1. GHG's emission factors [g/GJ]

	CO_2	CH_4	N_2O
Coal	93,82	0,0006	0,0014
Lignite	111,05	0,0006	0,0014
Gas	55,84	0,0001	0,0001

Any technical restrictions of emission are not assumed to apply within listed pollutants. The only one greenhouse gas that is the subject of emission restriction are nitrogen oxides.

The range of NO_x emission factors for the majority of boilers depending on fuel type is the following:

1. Lignite 150-215 g/GJ
2. Hard coal 240-400g/GJ

The average emission level in 1992 was 169g/GJ in lignite plants and 312g/GJ in hard coal plants respectively. The reduction of total NO_x emission during the last years was caused by decrease of electricity production and partially by the means of environmental protection. To fulfill new requirements resulting from international agreements, the NO_x reduction program assumes the following undertakings:

1. modernization of existing boilers,
2. research, development and installation of low emission burners,
3. introduction of fluidized bed boilers.

<u>Heat Subsector</u>

During the analyses of heat and power generation sector we focused mainly on state heat generators and, only when necessary to evaluate the operation of power system, on industrial heat generators.

The forecast of total heat demand (table 9.1.2) was prepared using the macroeconomic model taking into account statistical trends, assumed structural changes in economy and expected technical development.

Table 9.1.2 Forecast of total heat demand [in PJ]

YEAR	Heat basic	Heat verified by SDM	Heat from CHP
1990	819.9	819.9	242.4
1995	772.0	747.1	234.5
2000	794.5	779.5	221.5
2005	827.1	837.2	227.4
2010	860.0	878.3	239.4
2015	892.7	905.5	252.1
2020	923.8	905.2	265.4
2025	946.6	870.5	279.5
2030	971.1	797.0	294.3

The projections of forecasts of heat demand from state heat generating units and industrial heat generating units were taken from [Czarkowski et al., 1994] taking into account:

- heat capacity demand for the existing situation,
- estimation of heat demand increase, considering available data and analyses related to estimated increases of heat demands resulting from multi-family, and some of single-family public building sector development, refurbishment of existing communal heat stations.

The forecast of heat energy demand from state heat generating sector was calculated basing on the forecasts of heat capacity demand considering climatic conditions, length of heating season, hot water demand and heat consumption savings.

Considering the assumption of some reduction of dependence of Polish economy on natural gas due to energy system safety it was assumed that the huge CHP's will operate be basically hard coal fired. This assumption results from the fact that in case of burning hard coal it is possible to achieve more significant efficiency increases among condensing units and combined units (from approx.41% to 89%) than in case of burning natural gas (from approx.57% to 91%). Considering this, it was decided that the whole amount of gas, estimated for 15bln m3/year till 2030 will remain assigned to power generation in condensing units.

Existing and new combined heat and power resources are divided onto the following groups:

- existing CHP's without further modernization,
- CHP'suspected for further modernization and reconstruction,
- new CHP's and CHP's replacing existing ones,
- system plants used as heat sources.

In the analysis we took into consideration the following basic units/capacities:

BCK 30 - condensing mode 35MWe, CHP mode 30MWe, 60MWt
BCK 50 - condensing mode 63MWe, CHP mode 50MWe, 110MWt
BCK 100 - condensing mode 125MWe, CHP mode 125MWe, 210MWt
BCK 150 - condensing mode 180MWe, CHP mode 150 MWe , 300 MWt

The conducted analysis considering the possibilities of launching potential resource development programs enabled to create the projections of power development forecasts in CHP's. Electricity production was calculated taking into account the location of particular heat unit on yearly load duration curve. The data regarding CHP resources were utilised as blocked set of input information to WASP III (ELECTRIC) model.

Power generation subsector.

The starting point was the review of electricity demand and supply forecasts (considering both energy and capacity) and heat forecasts prepared by the Ministry of Industry and Trade [MPiH 1992,1995d, ZPE IPPT 1993, KPE PAN 1994, PSE SA 1994] in 1994 and 1995 for the needs of creating state energy policy. Available forecasts did not cover assumed time horizon till 2030, the longest ones were ending in 2020. The analysed forecasts incorporated also the evaluation of possibilities of covering the heat demand from system and non-system resources.

Stagnation scenario

For the needs of creating the first scenario of energy and capacity demand, the forecasts from PPGC were used as newer and reflecting the problems of power and combined heat and power generation in the best way. Developing the works of PSE SA we prepared two "branch" energy and capacity demand forecasts (lower and upper) till 2030 considering actual assumptions regarding state energy policy suggested by the Ministry of Industry and Trade, assumptions regarding organizational/ownership changes within state power generation sector, presumed production costs, including investment needs, presumed changes in prices and tarrifs. This forecasts were prepared using the set of MAED models from ENPEP system.

Simultaneously for the needs of this evaluation the set of preliminary assumptions regarding national economy development path using the SDM model was created. It was assumed that:

- during the beginning period the path should be consistent with "Strategies for Poland",
- the major structural changes to market economy will be finished till 2010,
- the investment rate will be increasing till 2000, then it will be stationary till 2010, then it will fall down,
- the investment structure will be changing in moderate way to shift the magnitude of investments from fuel/energyindustry, heavy industry and agriculture to services (incl. transport) and light industry,
- the export rate will be approx. 0.6% faster than import rate and approx. 0.5-1% faster than GDP growth in the whole period.

The forecasts were compared. In effect it turned out that the lower "branch" scenario is compatible with the forecast from macroeconomic model till 2020 with a bit lower economy growth rate. As a "branch" one this forecast does not involve some overall economic mechanisms and feedbacks modifying the demand evaluation and important in the second period of forecast changes in economy structure driving to increasing the share of trade and services together with hi-tech industry. This causes the different characteristics of demand changes evaluated by macroeconomic model and significantly lower demand level after 2020. Moreover, similarly to "branch" ones, the scenario created with SDM model bases on the viewpoint of energy producer. This causes that it models the demand changes from the point of view of utilizing supply capabilities of the system. It does not include the evaluation of potential medium term behaviouring reactions of the consumers to the signals resulting from full uncovering of marginal costs. This means that such scenario has stagnation character in terms of economic mechanisms. It is probable only in case of keeping the cross subsidizing causing the supply and demand to be far from economic optimum.

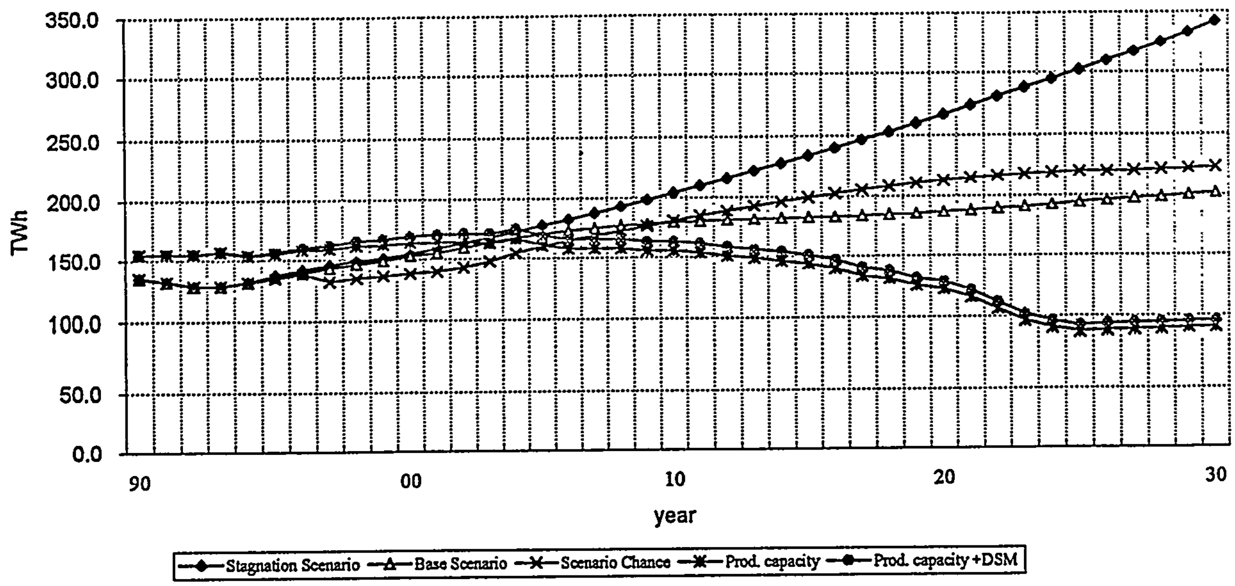
Finally it was evaluated that the "branch" forecast has the tendency to overestimate the demand since it does not consider sufficiently the following effects: possibility of improving the competition between various energy carriers, natural improvement of DSM and possible technical development, actual proecological incentives, the influence of big investments in power generation sector on demand changes in other economy branches. At the same time significant coincidence between scenario evaluations till 2020 makes the assumptions of macroeconomic model more credible. As a stagnation scenario we used the lower "branch" scenario (table 9.1.3) as the adequate one to the attitudes of Polish politicians. However the economic growth rate was assumed basing on SDM calculations. The described scenarios are presented on figure 9.1.2 (likewise other scenarios described in the report).

Table 9.1.3 Electric energy demand according to considered scenarios [TWh]

Scenario	Stagnation	Base	Chance
1990	135.4	135.4	135.4
1995	137.4	136.0	134.6
2000	156.3	152.8	138.2
2005	177.6	170.3	160.0
2010	203.9	179.7	180.9
2015	233.7	182.9	199.3
2020	267.0	186.9	212.6
2025	302.0	194.3	219.3
2030	330.0	201.6	222.5

The forecast was given to representatives of central governmental institutions with ask for opinion and was generally accepted.

Fig. 9.1.2 Electricity Demand



The discount rate of 12% was assumed for modelling the supply side, that results from the assumption of high risk situation and market barriers during the whole prognostic period. Such high discount rate results from tendencies to operate some non effective enterprises (in the area of hard coal mining, power generation or agriculture) for political and social reasons which is additionally under pressure of lobbies (the phenomenon of cartelization and protection of the most unefficient enterprises within the cartel). Unstable law conditions, still existing restrictions of profit transfer and too low purchasing power of the society cause the high risk for investors (including foreign ones). The effect of such policy would be high investment needs and hampered capital availability and finally high discount rates.

The following assumptions has been made:

till 2000:

- determined introduction of blocks 1-4 at Opole power station,
- finishing the reconstruction of blocks 1-6 at Turów power station,
- introduction of Czorsztyn hydro power station in 1997,
- planning period:2001-2030,
- calculations are in fixed prices (USD 1992),
- cost are discounted to 1992 year,
- the forecasts of energy and capacity demand to be covered by domestic resources till 2030,
- available capacity and electricity production in state CHP's differing the existing and new units,
- fuel prices assumed according to the following approach: till the year 2020 price forecast according to PSE SA forecast, after 2020 yearly escalators: 1% for nuclear energy. hard coal and lignite; 1.5% for fuel oil; 0.8% for natural gas. The fuel process differ from suggested by the set of macroeconomic scenarios, owever fuel prices for the needs of power and heat generation differ from averages due to fuel quality and purchasing on wholesale market - after consultations the differences were assumed as acceptable,
- number of new technology units (candidates) and their scheduling are the subject for optimization.

The analysis of results shows that in the described scenario first required capacity surpluses appear in the year of 2001. The magnitude of these depends on peak capacity demand growth and the level of refurbished capacities. It is possible to see that the pattern of new capacity requirements is not continuous. For example:

1. in the year of 2005 approx. 2200MW,
2. in 2016,2018 approx. 2300-2500MW,
3. in 2021,2023 approx 3200MW.

Few variants were prepared considering different assumptions regarding the supply side configuration. Generally two system variants were defined:

a. central consistent with actual organisation called the reference variant,
b. regional - decentralised.

Basically variant "a" has the capability the unbounded choice of units from the portfolio of candidates aiming on fulfilling the goal function (FC) that means minimizing the overall costs of KSE till 2030. Of course the reliability criterions of UCPTE have to be fulfilled too. In the structure of variant "a" this means huge reserve margin (24% were assumed according to PSE SA).

Variant "b" assumes the necessity of modern small size power generating units characteristic for decentralised system, which due to higher costs per unit were not chosen in variant "a". For example a number of 50MW steam-gas units totalling 20GW was assumed to be on line in 2030. Simultaneously we assumed the reduction of reserve margin to 17% without lowering the reliability of the whole system (this is due to change of system structure).

All variants assume the restricted availability of natural gas for state power generation and state heat generation. The numbers are the following: 2010 - 7 bln m3, 2020 - 10 bln m3, 2030 15bln m3. The reason of these restrictions was the energetic safety of the country and reduction of country's dependence on natural gas supplies (mainly imported).

Assumed increase of small size gas technology penetration in variant "b" - dispersed energy (ER) causes higher investment requirements and O&M costs, and lower efficiency than in gas fired system plants. However such concept lowers the need for power grid investments. The investments in high voltage power grids (NN) were considered in WASP III in the following way:

1. calculation of investment cost K_{NN} per 1kW of available new-tech capacity connected to NN grid.
2. assumption that K_{NN} costs will be the adder to investment costs of new technologies.
3. System power plants take 80% of investment costs of NN grid. Technologies not connected to NN grid take only 20% of costs.

The investment costs per unit K_{NN} were calculated basing on [Jastrzębski et al., 1995] where the costs were estimated as the element of long term marginal cost of grid. The number of K_{NN}=150USD/kW in fixed prices of 1992 was estimated basing on planned investments during 1993-2002 and the forecast of capacity transfer through NN grid.

The WASP III calculations were conducted for the following subvariants:

variant I	new power scheduling as in reference variant, investments cost for all technologies increased by 150USD/kW (assigning the transmission and distribution costs to the resources) - this variant will be the reference variant for comparison of goal function, fuel consumption and emission remain unchanged.
variant II	replacing the gas system plants (peak and steam/gas turbines) with small size gas units,
variant III	replacing steam/gas system plants with small size gas units (peak plants as in reference variant),
variant IV	is the same as variant I considering LOLP=0.137%,
variant V	reflects variant III with reduced transmission losses.

Optimization of resources from the point of view of consumers has been done in variant II, III and IV that means taking into account different investment needs in NN grid. Investment costs of system plants increased by 80%K_{NN} and investment cost of small size technologies increased by 20%K_{NN}.

Lowering the reserve margin from 24% at the beginning of XXI century to 17%[1] at the end of investigated period was assumed in variant III and V.

The results of calculations regarding fuel consumption structure for power and heat generation for different variants are shown on figures 9.1.3 to 9.1.5.

The variants I, IV and V were the subject of GHG emission analysis as considering system organization assumptions in the most complex way. The results are presented in the figure 9.1.6 - 9.1.7a-b. All variants show full usage of the available natural gas by new gas units: peak and steam/gas. First new capacity increases necessary to cover the demand appear in gas fired plants. Existing hard coal and lignite fired capacities decrease successively after 2000, there is constant increase in CHP capacity, the share of gas condensing units significantly increases, it is necessary to build new hard coal and lignite units.

[1] The analyses show that having the dispersed generation structure it is possible to achieve the same reliability with lower reserve margin.

Fig.9.1.3. Fuel Consumption
Stagnation Scenario/Reference Variant

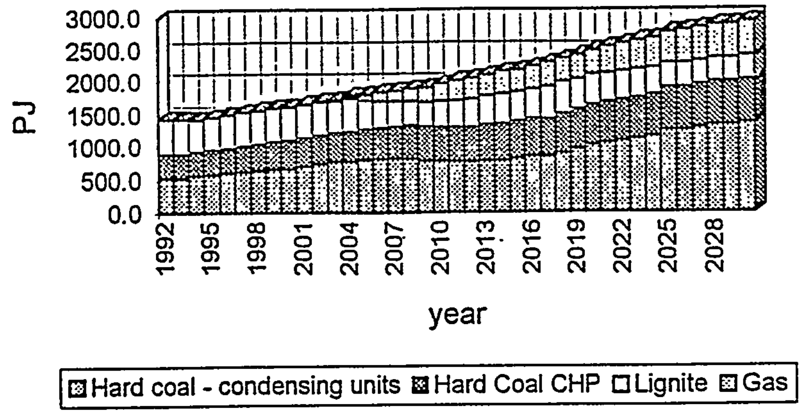


Fig.9.1.4. Fuel Consumption
Stagnation Scenario/Reference Variant Modified

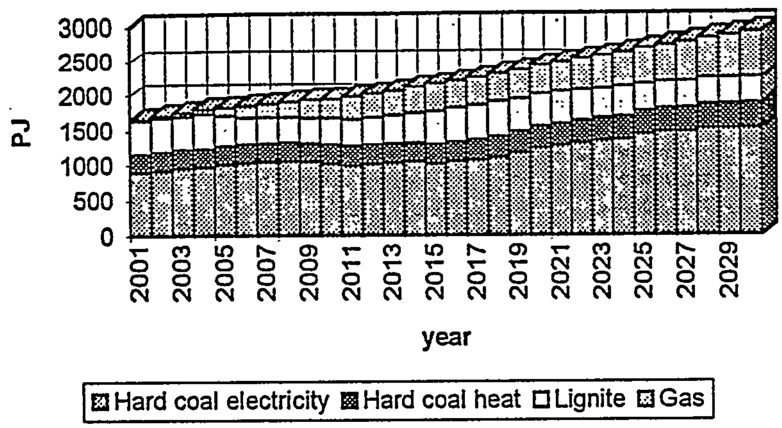
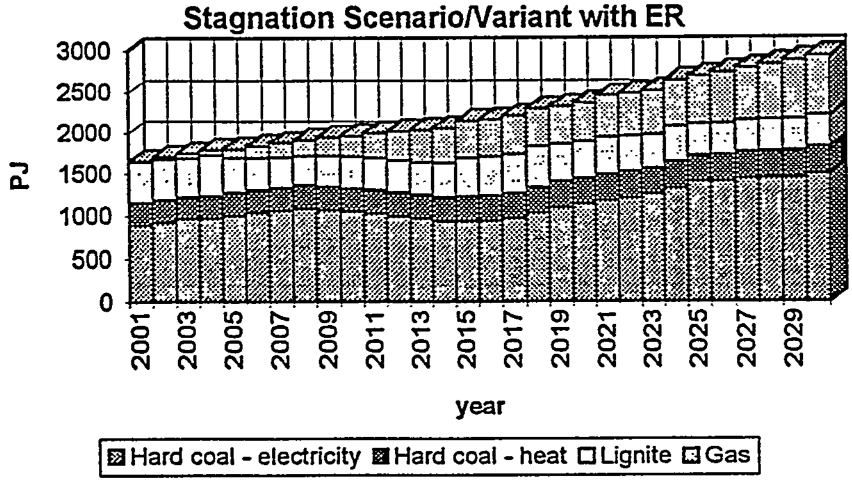


Fig.9.1.5. Fuel Consumption
Stagnation Scenario/Variant with ER



To cover the assumed demand till 2030 the following investments are needed:
- 22920MW in hard coal fired plants,
- 4750MW in lignite fired plants,
- 8700MW in peak gas plants,
- 13760MW in steam/gas plants.

Modified variant present higher values of goal function than reference variant, due to increase of investment costs of all technologies by adding transmission and distribution costs, but the function for variant IV and V is lower than for variant I (table 9.1.4). This effect was achieved despite forcing more expensive resources to operate. This improvement is not significant but one has to remember that the effects of cost reduction due to increased attractiveness of dispersed power system has not been considered yet. One has to expect that the reduction of costs of covering demand resulting from the system's decentralization will be significantly greater. In this moment small steam/gas and especially cogeneration units are becoming needed.

Variants IV and V show approx. 3% reduction of GHG emission compared to variant I in 2030.

Fig. 9.1.6. GHG Emission
Stagnation Scenario/Reference Variant

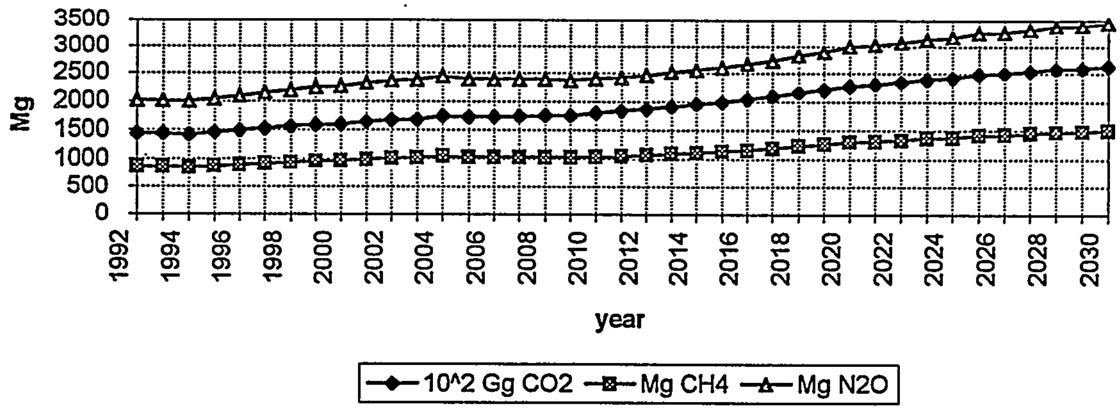


Fig. 9.1.7a. GHG Emission
Stagnation Scenario/Reference Variant - Modified

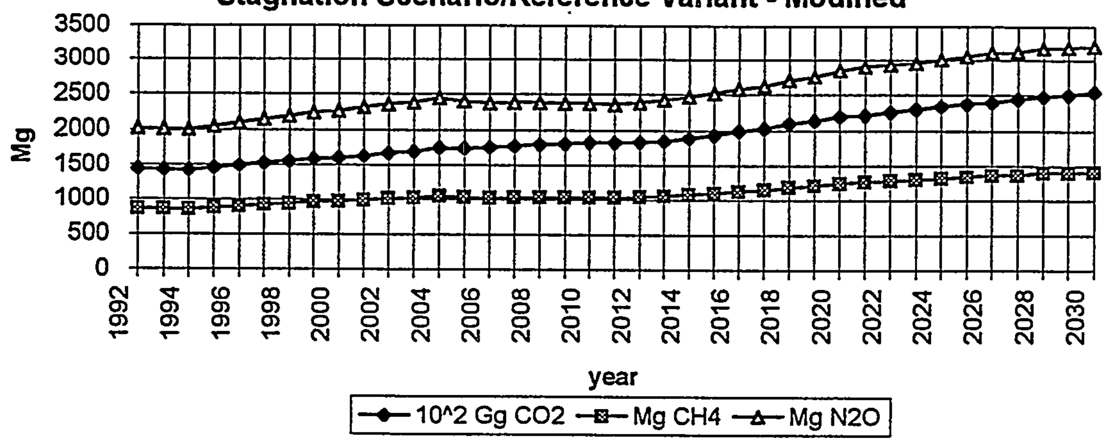
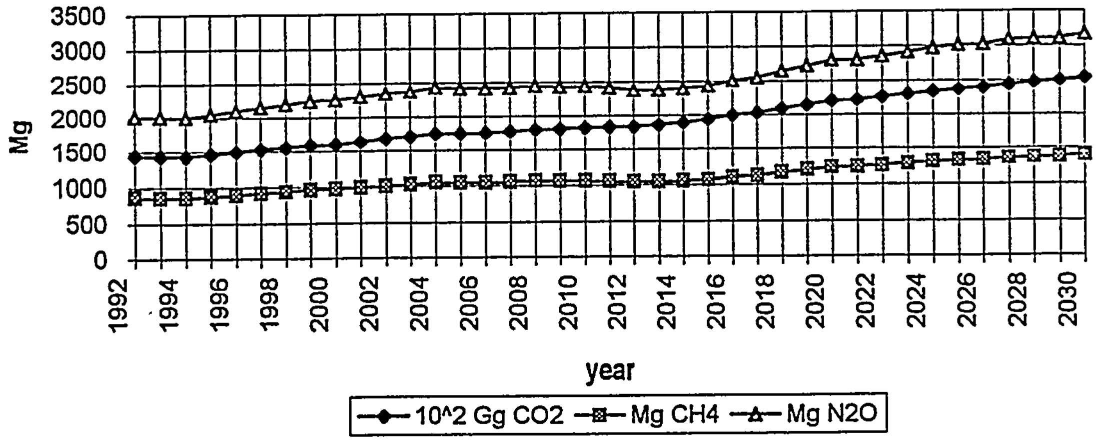


Fig. 9.1.7b. GHG Emission
Stagnation Scenario/Variant with ER



Base Scenario.

The second scenario comprises of several assumptions modifying the assumptions of evaluation of stagnation scenario regarding electricity demand.

The general assumption was that the economy will be changing to market economy without any obstacles. Basing on the analysis of current situation and transformation directions and tempo, the hypothesis that it will be possible to continue qualitative not quantitative economy growth, causing slow demand growth was built.

This results from:

a. further changes in economy branches structure, especially decreasing the share of metallurgic, cement industry, hard coal mining, power generation;
b. slow (natural) eliminating of marginally ineffective enterprises within branches and reducing the share of ineffective technologies and productions in the frames of enterprises' activities;
c. increasing the economic efficiency by making use of other (more effective) technologies up to the nominal ranges;
d. consumption reduction by energy savings (result of relatively high prices) and reducing the living standard of individual consumers;
e. slow, natural changes in end use equipment to the modern efficient one.

Additionally it was assumed that:

- these changes appear being assigned to current political criterions, especially do not cause
- unemployment increase in case of lack of active policy of creating new labour places in hi-tech industry and services which means market transformation by means of intensifying the economy);
- these changes do not deplete economically proved existing possibilities of demand reduction;
- these changes are not hampered by lack of technologies because full portfolio of most modern technologies is available on Polish market;
- purchasing power of Polish society, reduced by the policy of protecting domestic agriculture and heavy industry against international competition increases due to continuous appreciation of PLZ (equalling bank exchange rates and PPP around 2005) and eliminating custom and tax barriers accordingly with nternational agreements;
- natural character of changes is based on lack of intervenes on demand level that means these are not stimulated by state policy by the means of modified financial instruments or creating legislative possibilities for such stimulation by the utilities (DSM);
- incentives from utilities stimulating the shape of load duration curves by introducing marginal cost based tarrifs will appear.

Table 9.1.4 Comparison of main results obtained under this study.

	Year	Stagnation scenario			Base Scenario				Chance scenario			
GDP/el..en. [costs/TWh][1]	2000	775.2 / 156.3			780.1 / 152.8				788.4/138.2			
	2010	1190.1 / 203.9			1250.1 / 179.7				1304.7/180.9			
	2020	1791.2 / 267.0			1831.9 / 186.9				1924.5/212.6			
	2030	2451.5 / 330.0			2488.7 / 201.6				2633.5/222.5			
Variant		Reference	Verified reference	ER	Reference	ER	EJ1	EJ2	Reference	ER	Bez EJ	Odnaw.
CO_2 emission [Gg]	2000	159.98	159.98	159.98	158.86	158.86	158.86	158.86	144.11	144.11	144.11	144.11
	2010	180.07	178.26	181.92	166.56	167.17	167.19	167.19	169.50	170.00	170.00	168.26
	2020	226.68	219.18	219.42	156.04	155.97	155.97	152.90	147.97	144.87	182.53	179.28
	2030	262.34	254.17	254.01	152.67	153.42	146.93	128.10	124.29	121.26	185.69	180.43
Cumulative value FC [bln USD]	do 2010	8.47	8.37	8.40	7.15	7.12	7.12	9.05	6.23	6.23	6.23	6.42
	do 2020	13.90	13.55	13.59	10.01	9.98	9.78	13.39	11.26	11.41	11.19	11.29
	do 2030	16.23	15.88	15.96	11.33	11.38	11.38	15.81	13.95	14.20	14.37	14.39
CO_2 emission/ GDP [in Gg/ costs][1]	2010	0.151	0.150	0.153	0.133	0.134	0.134	0.134	0.130	0.130	0.130	0.129
	2020	0.127	0.122	0.122	0.085	0.085	0.083	0.083	0.077	0.075	0.095	0.093
	2030	0.107	0.104	0.104	0.061	0.061	0.059	0.051	0.047	0.046	0.071	0.069

[1] costs - in thousand billion zls for 1990

This scenario presents probable phenomenon - due to increase in efficiency of end using equipment it is probable to keep the capacity demand at the households at actual level. However the increasing number of appliances and changes in it's usage patterns may cause raise of demand. This means that using the same capacity of utilities it is possible to cover the demand from this part of market.

In long term time horizon one should not expect strong incentives from utilities to reduce energy demand resulting from use of such appliances as refrigerators or heating systems using energy during off peak hours. One should rather expect new actions promoting energy use to cover other needs like heating or air conditioning.

According to the concept presented above the evaluation of probable changes regarding 18 groups of appliances designed for residential and commercial sector. It was assumed that the results of these assumptions will be the driving force of economical changes. To evaluate the rest of economy SDM model was used (see table 9.1.2 and figure 9.1.2)

To calculate the optimum set of generating resources the following assumptions has been done:

- the research will be oriented to variants including group of small resources as dispersed power generation;
- all variants will be analysed in two cases - with and without nuclear energy;
- the nuclear variant assumes that after 2010 there will be modern nuclear units which might be installed in Poland;
- similarly as in the base scenario there will not appear a need for new generating capacity before 2000;
- all calculations will be in USD 1992 in fixed prices;
- all cost will be discounted to 1992 using the discount rate of 12 and 10%
- the following is assumed to be determined:
- introduction of blocks 1-4 at Opole power plant,
- finishing the reconstruction of blocks 1-6 at Turów power plant,
- introduction of Czorsztyn hydro power plant in 1997,
- the fuel prices are analogical as in reference variant;
- available capacity and energy production in state CHP's is calculated in the same way as in the base variant.

The WASP III calculations were done for 4 variants of power sector development in Poland:

a. reference (base) variant,
b. dispersed power generation variant (ER),
c. variant nuclear 1 (discount rate of 12%),
d. variant nuclear 2 (discount rate of 10%).

The second (base) scenario is significantly lower than stagnation scenario. It influences the necessary increases in new capacity to cover the demand. This was the reason of the assumption that the number of gas peak units cannot exceed 20.

It was assumed that optimal solutions of examined variants have to fulfill the criterion of LOLP=0.137% (0.5 day/year).

Capacity changes resulting from power sources modernization and development program were assumed analogically as in stagnation scenario.

The characteristics of variants are:

a) reference variant - candidates do not include small size units represented in calculations by 50MW units,
b) variant with ER - combined steam/gas blocks are substituted with dispersed power generation (small units) other assumptions as in "a",
c) variant nuclear 1 - shortening construction time for nuclear candidate from 9 to 6 years, includes ER, other assumptions as in "a",
d) variant nuclear 2 - change of discount rate from 12 to 10%, other assumptions as in "c".

As the calculations show (considering c and d) nuclear units eliminate in optimal solution 600MW hard coal units. A bigger reserve margin is also necessary due to worse reliability of nuclear units compared to hard coal ones.

All variants assume 3GW of gas peak turbines in 2030. In comparison to reference variant where 12GW exist in other variants this share (53-54%) it taken by small size units. Shortening the construction time of nuclear units to 6 years causes that optimal solution includes 2 nuclear units (1.2 GW - 5.4%) in variant nuclear 1. Change of discount rate from 12 to 10% causes the increase of nuclear units share to 4.8GW (21%).

The results of calculations are shown on figures 9.1.8 to 9.1.15.

All variants assume 30% share of CHP's, 2% share of hydro units, 35-37% share of gas units. In variant nuclear 1 the nuclear units replace hard coal units and in variant nuclear 2 hard coal and partially lignite units. In variant nuclear 2 15% of electricity in 2030 will come from nuclear units.
The share of natural gas (26-29%) and lignite (12-15%) remains on similar level in all variants. The share of hard coal consumption decreases to 52% in variant nuclear 1 or 43% in variant nuclear 2 though. However hard coal still remains the basic fuel in all variants.
The evaluation of GHG emission was similar as in the base scenario.

The GHG emissions on figure 9.1.16a-d do not show any significant differences between reference and ER variant. In nuclear 1 variant there is a slight decrease of emission level (4-7% but only 1% in CO). In variant nuclear 2 this decrease is significant: CO_2-19%, CH_4-25%, N_2O-26%, NO_x-24%, CO-14%, NMVOC-23%.

Resulting values of goal function (sum of discounted investment and O&M costs) for described variants and additionally calculated for comparison reference variant I (shown in table 9.1.4 as reference variant) show that variants including ER are comparable in the terms of costs. The higher value for the variant nuclear 2 results mainly from lower discount rate.

Fig.9.1.8 Electricity Production by fuels - Base Scenario/Reference Variant

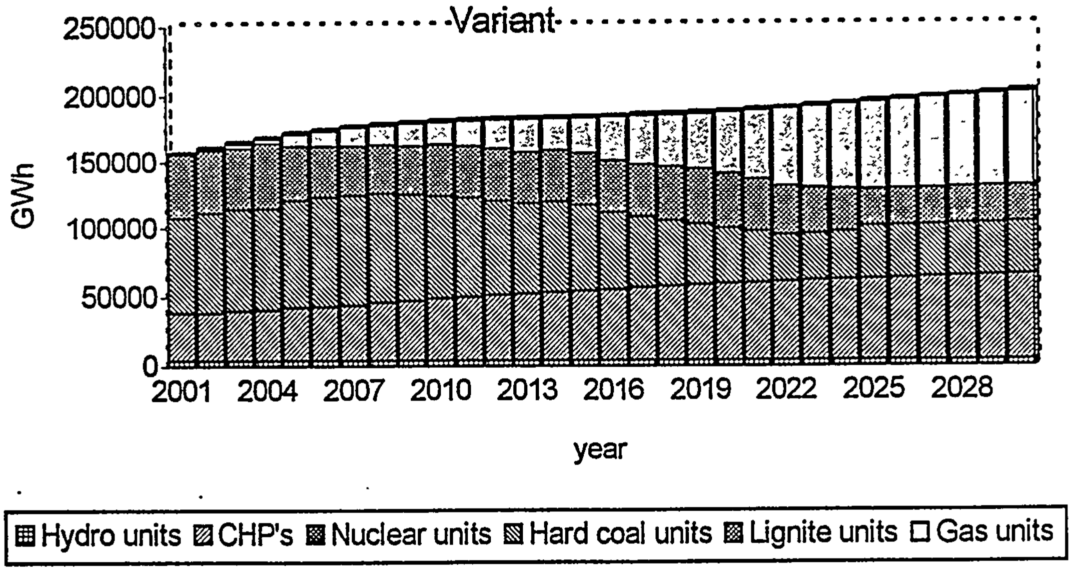


Fig.9.1.9 Fuel Consumption - Case Scenario/Reference Variant

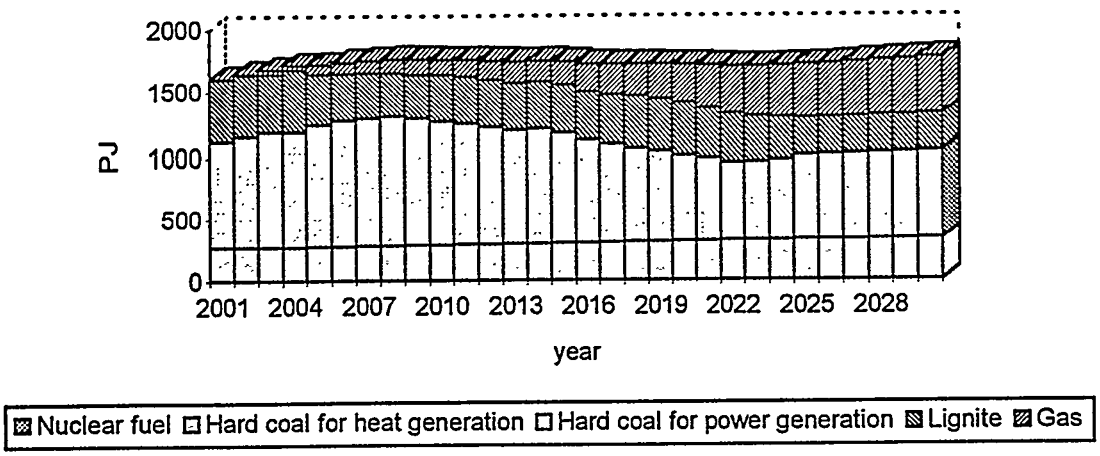


Fig.9.1.10 Electricity production by fuels
Base Scenario/Variant with ER

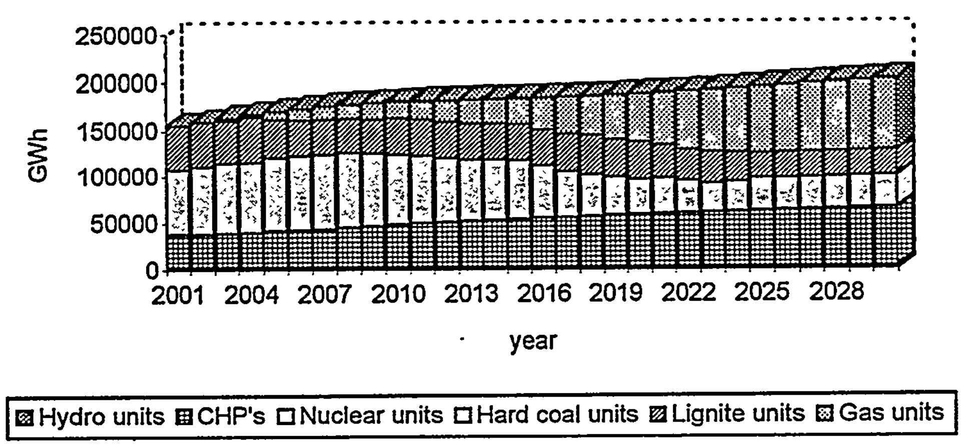


Fig.9.1.11 Fuel Consumption - Base Scenario/Variant with ER

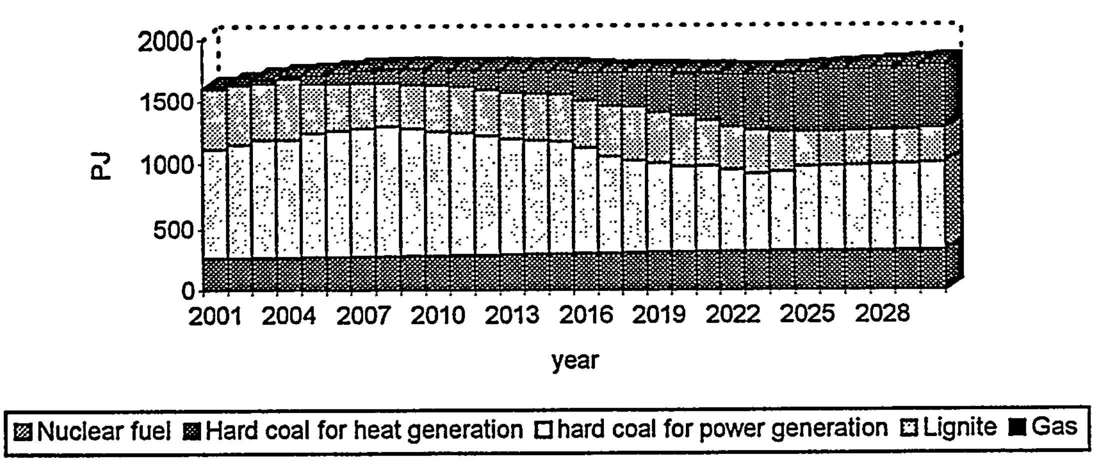


Fig.9.1.12 Electricity Production by Fuels
Base Scenario/Variant Nuclear 1

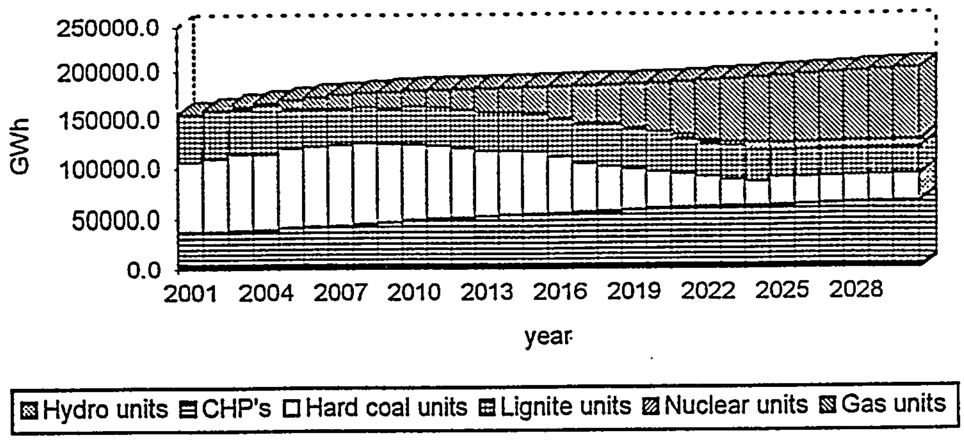


Fig.9.1.13 Fuel Consumption - Base Scenario/Variant Nuclear 1

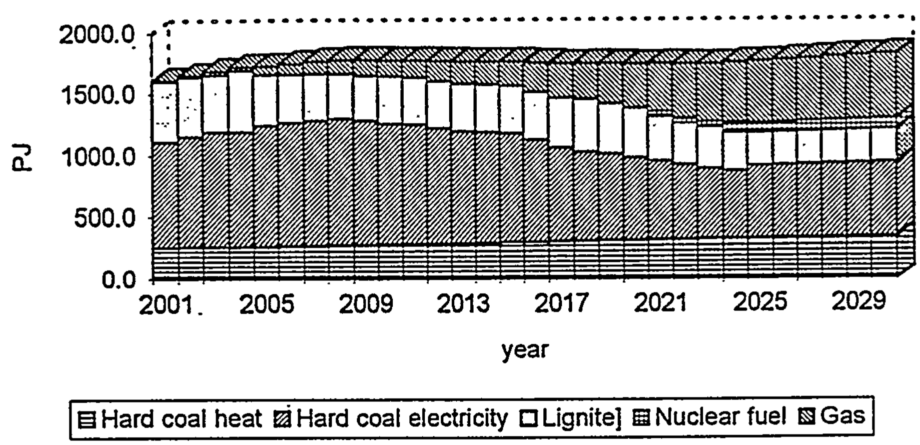


Fig.9.1.14. Electricity Production by Fuels
Base Sceanrio/Variant Nuclear 2

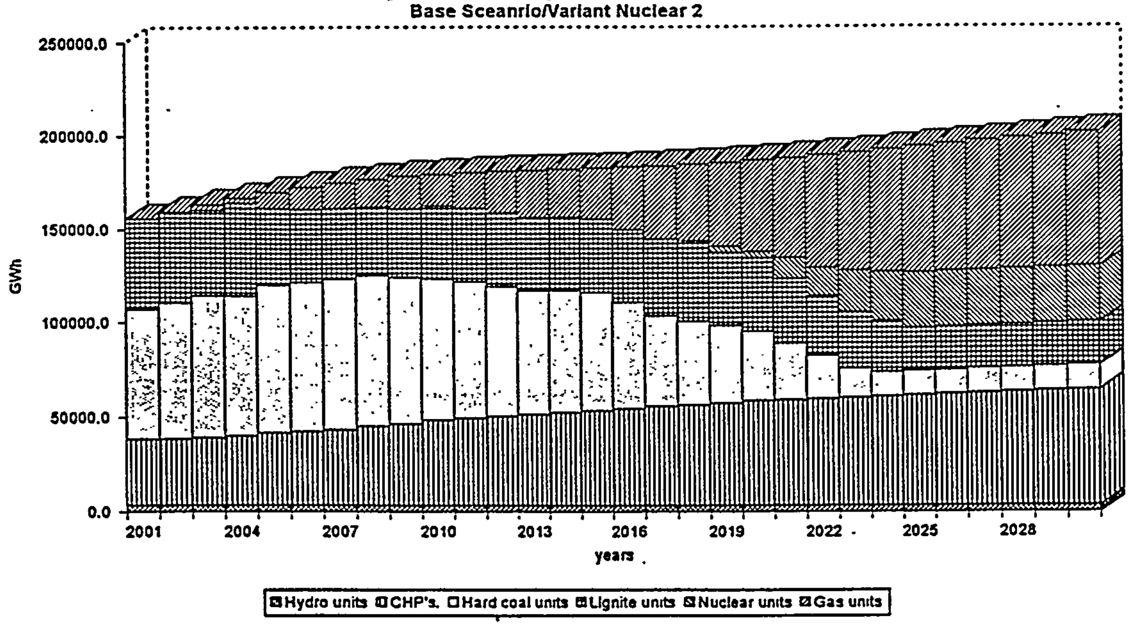


Fig.9.1.15. Fuel Consumption
Base Scenario/Variant Nuclear 2

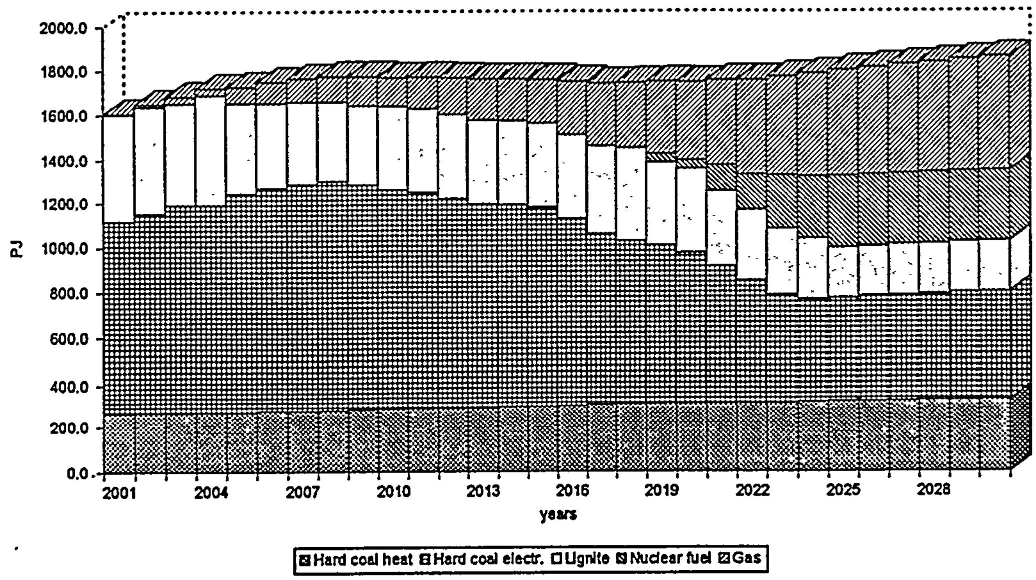


Fig. 9.1.16a. GHG Emission
Base Scenario/Reference Variant

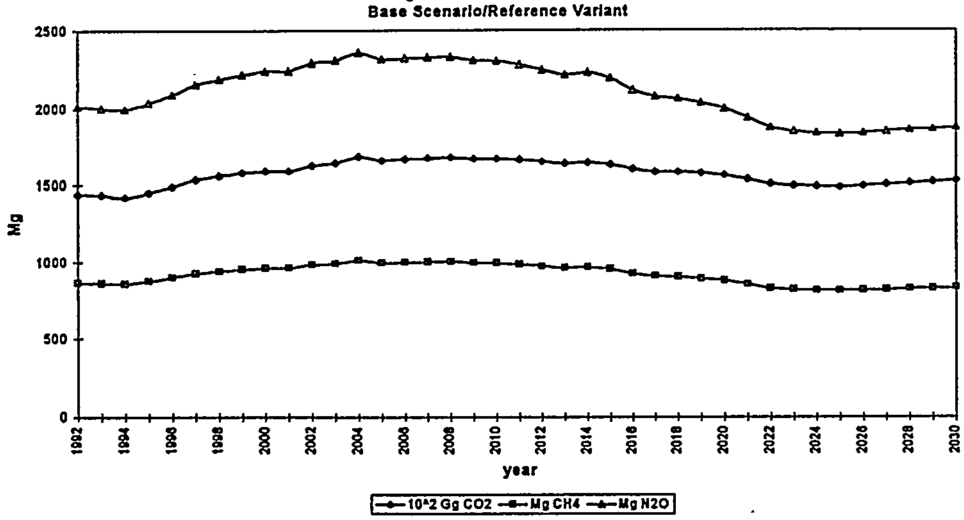


Fig. 9.1.16b. GHG Emission
Base Scenario/Dispersed Generation Variant

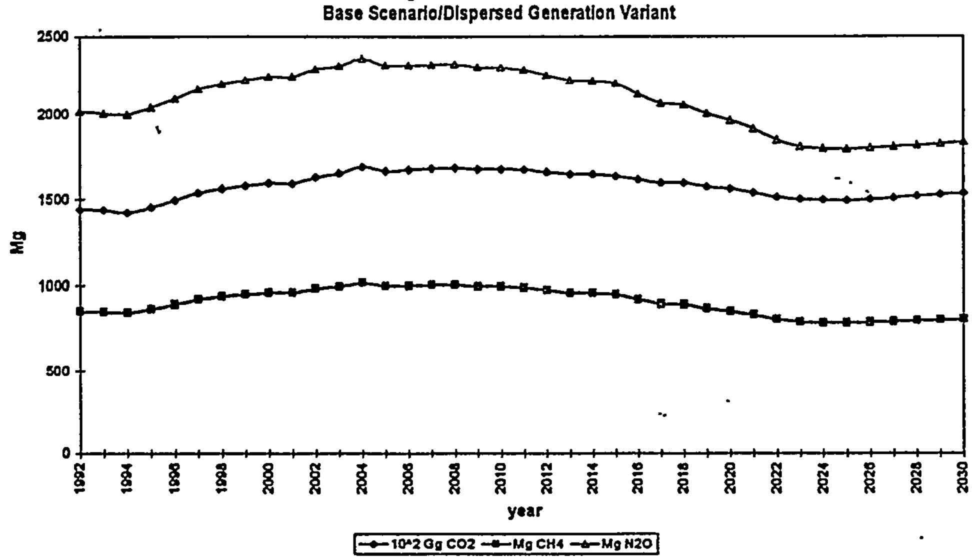


Fig. 9.1.16c. GHG Emission
Base Scenario/Nuclear 1 Variant

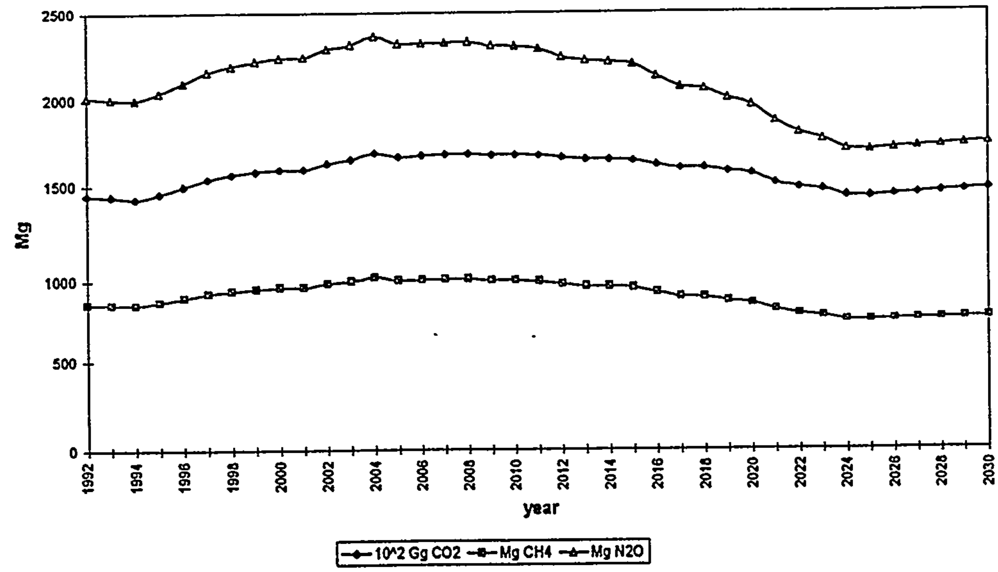
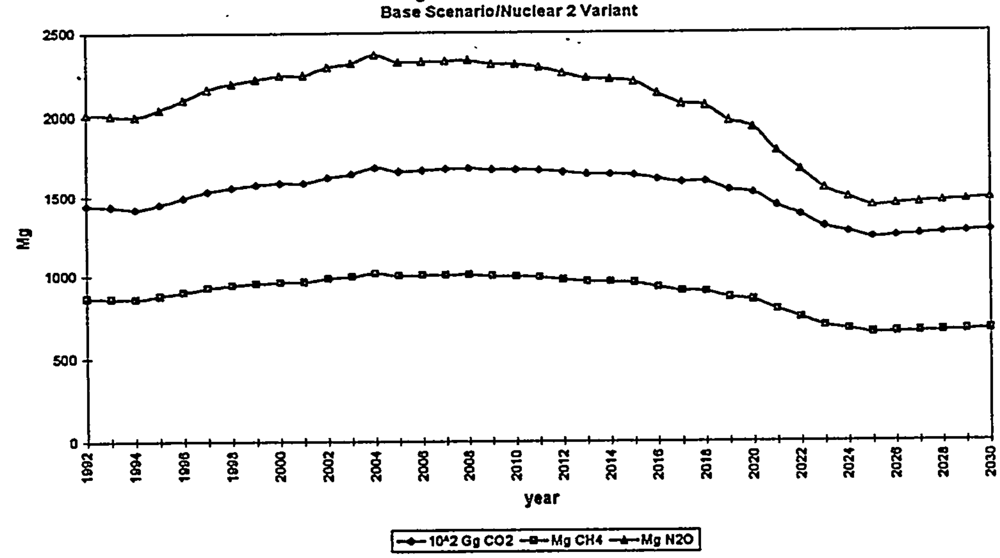


Fig. 9.1.16d. GHG emission
Base Scenario/Nuclear 2 Variant



Chance Scenario

Third from analysed scenarios assumes that it is possible to move faster from quantitative to qualitative economic growth.

As the instrument the change in tax policy and promoting use of efficient appliances and their production in Poland during the first period of the forecast was assumed. It was also assumed that the risk of investors will be decreased by improving the credibility and economization of demand that will cause decrease of discount rates together with improving the openness of the economy. As a result of intensifying economic growth a demand reduction was achieved in the first period of the forecast, an increase of purchasing power of the society together with changing the society's attitude to buy energy efficient appliances and increased economic growth rate. As a result this scenario requires the demand increase during the second phase of the forecast. Using SDM model the average financial rates of 5% were estimated for the end of the forecast. It was assumed that the discount rate for power industry will be 6% due to capital effectiveness, long term character of investments and related risk. The above calculations were not done for lower discount rates resulting from social discount rates because it was assumed that the decisions would result from rather economic than social conditions. It will result mainly from assumed capital structure in power industry where the shift from huge state share to private and foreign one is expected. Moreover it was assumed that the Polish society will not be rich enough at the end of forecast period to afford bigger reduction of actual benefits to help next generations.

The following phenomenons are assumed to appear during realizing such policy:

- transformation of market for household appliances,
- increasing the demand for particular appliances,
- during the first time period increase of equipment prices,
- increase of benefits to equipment producers due to increasing sales and prices,
- increase of foreign capital to invest in selected industries (+know how introduction), increased accumulation of own capital due to increasing profits,
- competition improvement and achieving competitiveness by Polish products without an protecting actions (taxes, duties, exchange rates);

The following results are expected:

Households:

- increase of energy effectiveness among the appliances and keeping the energy and especially capacity demand on actual level during the next 10 years despite increase of richness and living standards,
- better assimilation to higher energy prices (possible effect of lowering the costs as a multiplication of reduced consumption and higher price).

Power sector:

- lowering the growth rate and the level of energy demand - possibility of delaying investments up to 3-5 years - reducing so called economic costs in power sector in case of reducing the activity or even eliminating marginally ineffective object,
- achieving positive income/cost ratio at these producers who are sufficient to balance the lowered demand,
- achieving financial incomes and profits enabling to create economically healthy enterprises, making the foreign capital more interested in investing in Polish power sector (low risk market).

Ecology:

- reduction of pollutants emission as a result of final energy demand reduction (synergic effects related to transmission and distribution losses and eliminating marginally unefficient objects at the beginning),
- the possibility of concentration of investments reducing the environment pollution and reducing the total investment for this purpose in Poland,
- possibility of introducing higher requirements regarding pollutants emission reduction (emission standards, fees, penalties) with the possibility of keeping Polish producers competitive without economic straits at the consumers.

Basing on these assumptions and results of evaluation the possibilities of demand reduction in industry (see chapter 9.2) and other assumptions same as in base scenario a forecast of energy and capacity demand was prepared (table 9.1.2 fig.9.1.2): This forecast was modified by SDM model.

To calculate the optimal set of energy generating resources the following assumptions were used:

- variable discount rate will be introduced beginning from 12% in 1992 year 6%,
- development variants will be analysed in two cases with and without nuclear power,
- dispersed power generation variant will be analysed,
- the nuclear variant assumes that after 2010 there will be modern nuclear units which might be installed in Poland;
- similarly as in the base scenario there will not appear a need for new generating capacity before 2000;
- all calculations will be in USD 1992 in fixed prices;
- all cost will be discounted to 1992 using the discount rate of 12 and 10%
- the following is assumed to be determined:
- introduction of blocks 1-4 at Opole power plant,
- finishing the reconstruction of blocks 1-6 at Turów power plant,
- introduction of Czorsztyn hydro power plant in 1997,
- the fuel prices are analogical as in reference variant;
- available capacity and energy production in state CHP's is calculated in the same way as in the base variant.

WASP III calculations were conducted for 4 variants of energy sector development. These are:

a. reference (base) variant,
b. variant with dispersed power generation (ER)

c. variant without nuclear power.

d. variant without nuclear power assuming maximum usage of renewable energy (chapter 9.6)

Total fuel demand in scenario chance is the lowest among all considered scenarios. In ER and reference variants one can observe significant reduction of coal share and increase of natural gas share till 2015 and nuclear fuel since 2016. Considering the settled level of hydro production and constant share of combined heat and power generation (30-32%) the resulting fuel shares in 2030 are the following: 2% of hydro energy, 19% of natural gas and 34% of nuclear fuel. In the variant excluding nuclear power the share of natural gas increases up to 22.5% with the same share of hydro energy. In the variant that maximizes the use of hydro and wind energy the share of gas reaches 22.8% and the share of promoted renewable energy 4.3%. The results are shown on figures 9.1.17-9.1.24.

Fig.9.1.17. Electricity production by fuels
Chance Scenario/Variant Reference

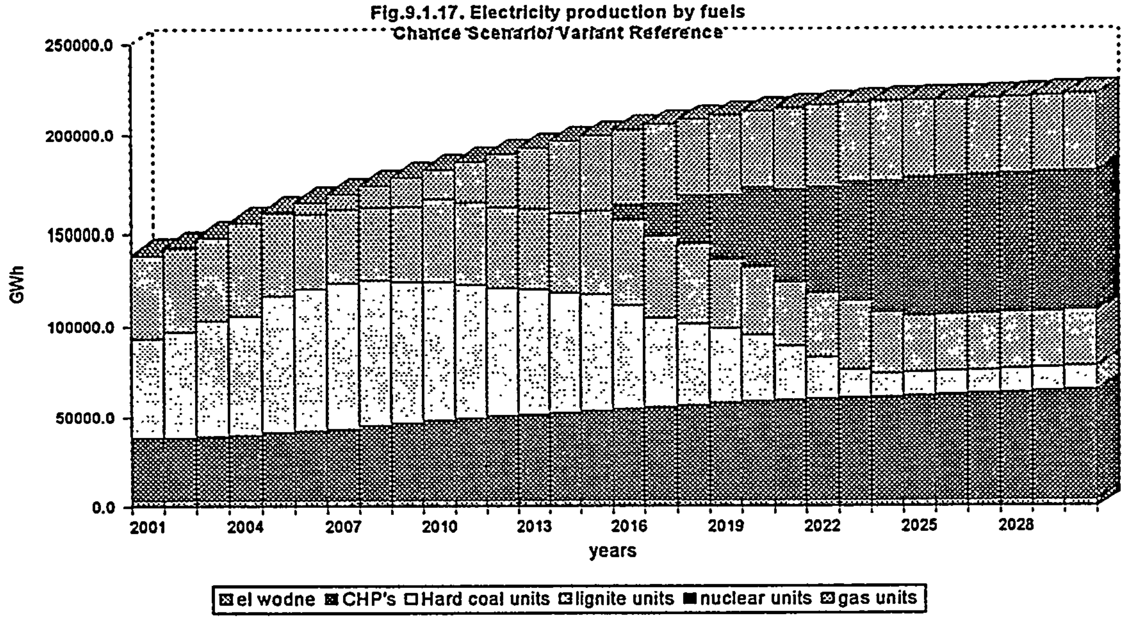


Fig.9.1.18 Fuel consumption
Chance Scenrio/Variant reference

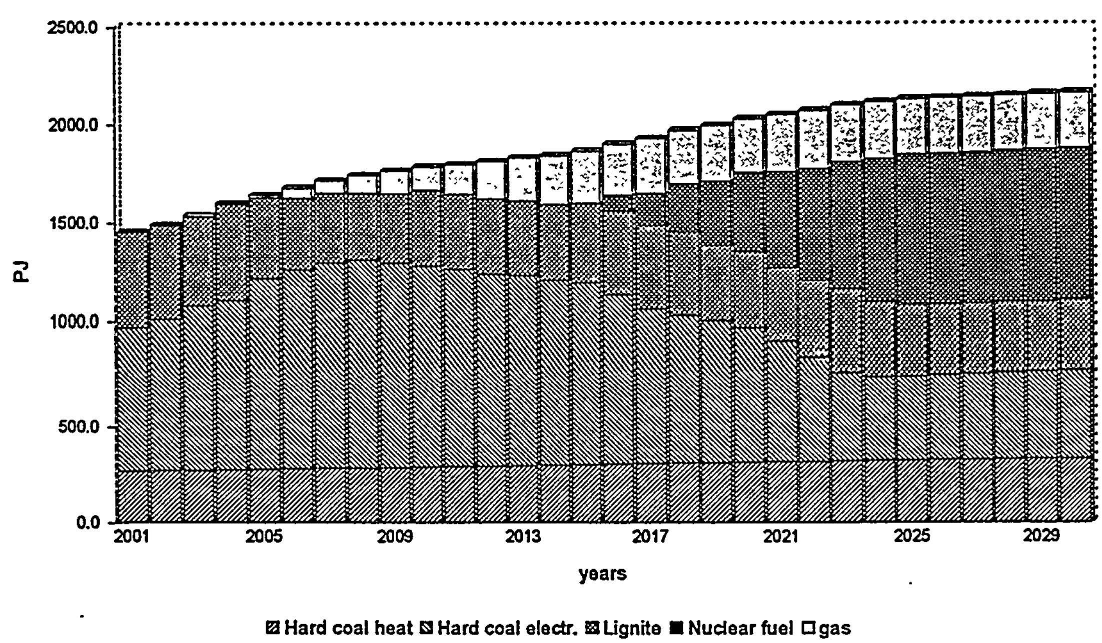


Fig.9.1.19.Electricity production by fuels
Chance Scenario/Variant with ER

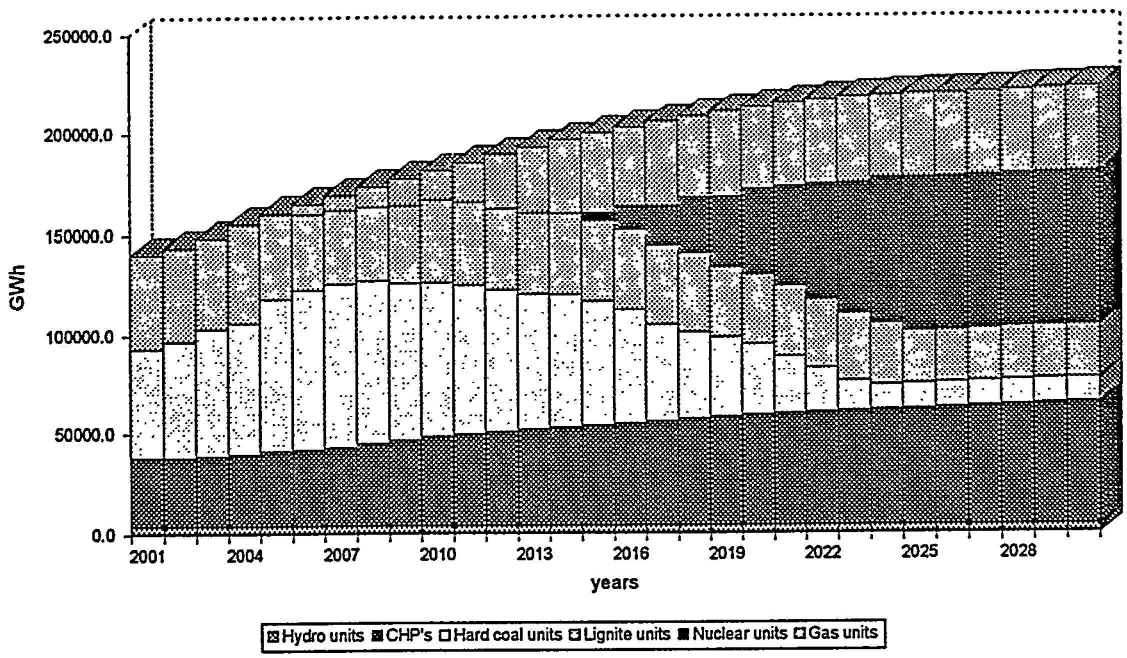


Fig.9.1.20. Fuel consumption
Chance Scenario/Variant with ER

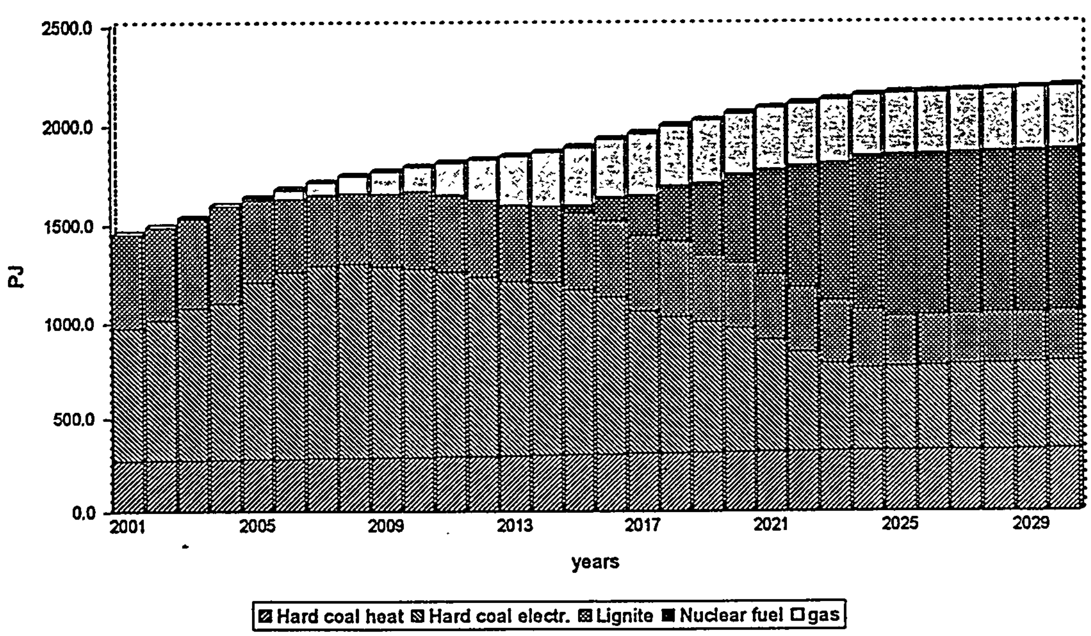


Fig.9.1.21. Electricity production by fuels
Chance Scenario/Variant with ER, no nuclear power

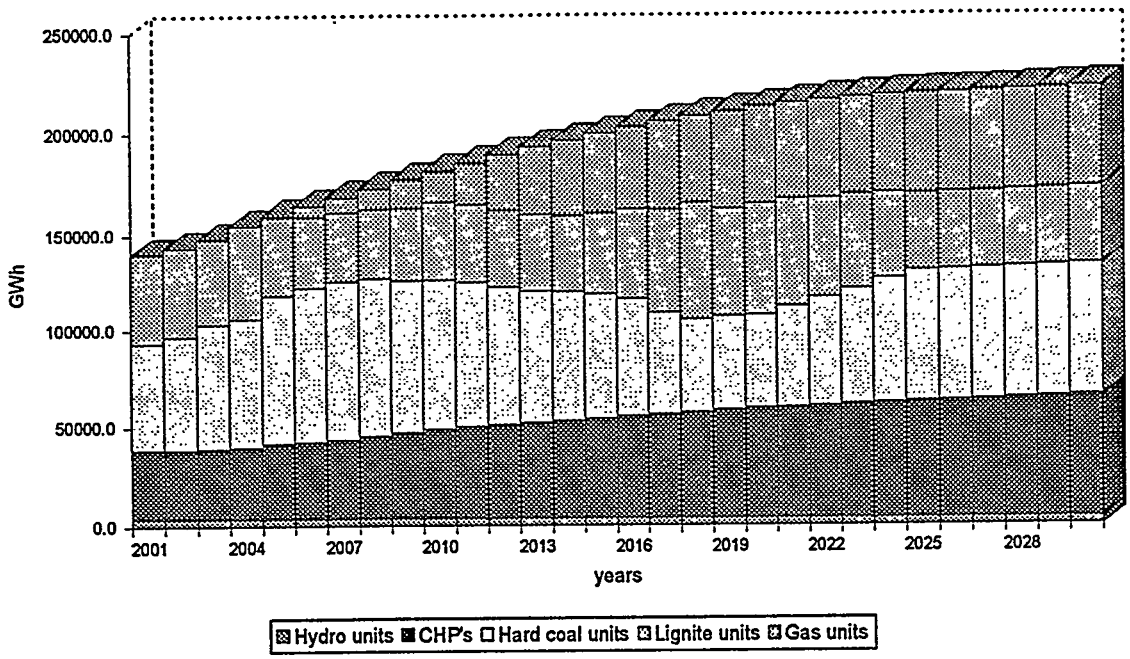


Fig.9.1.22. Fuel consumption
Chance Scenario/Variant with ER, no nuclear power

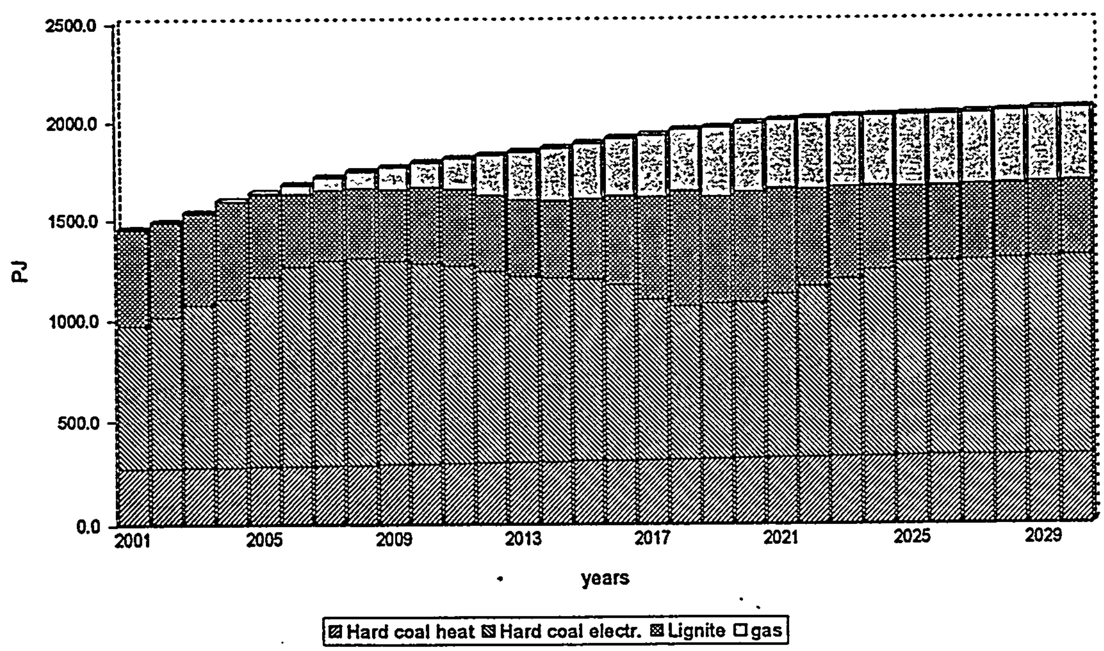


Fig.9.1.23. Electricity production by fuels
Chance Scenario/Variant with ER, hydro and wind power, no nuclear power

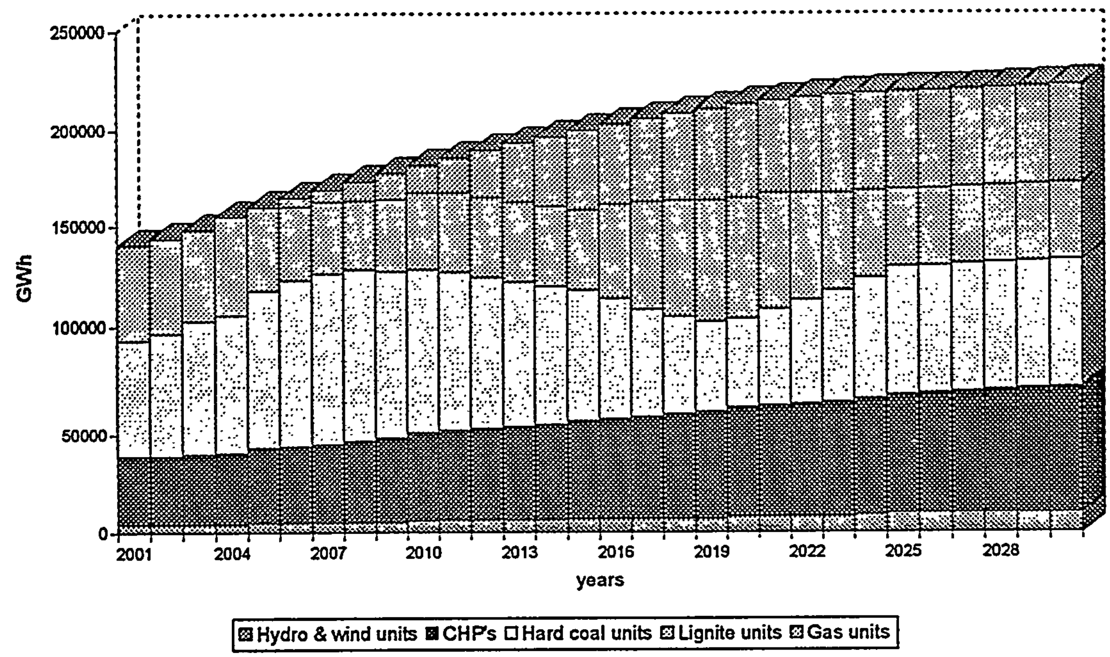
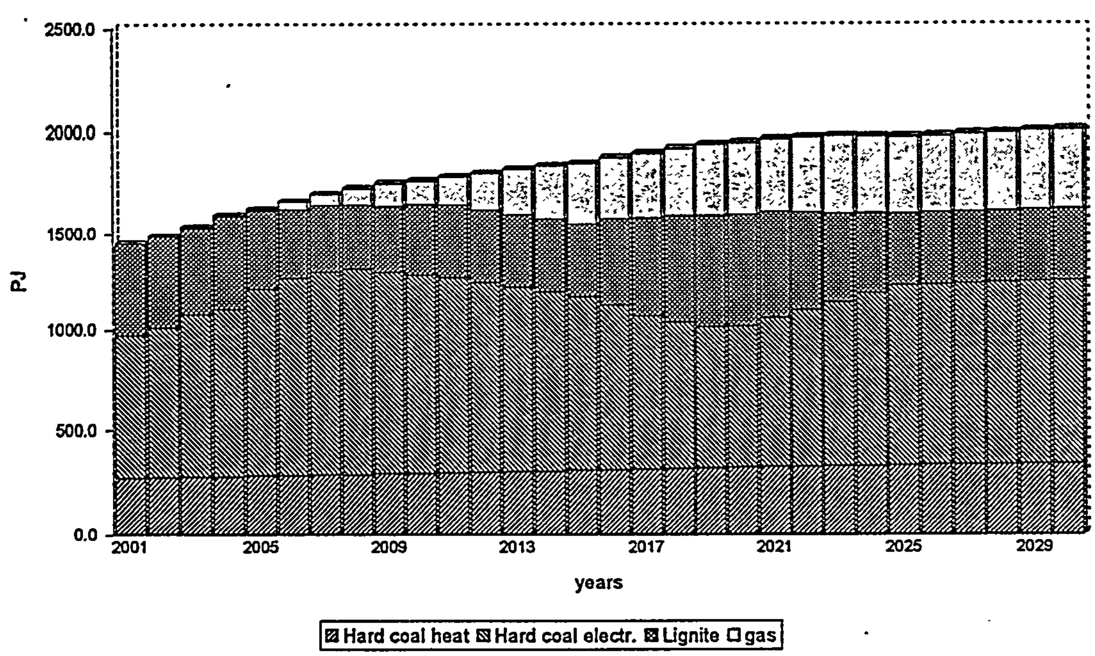


Fig.9.1.24. Fuel consumption
Chance Scenario/Variant with ER, hydro and wind power, no nuclear power



The evaluation of GHG emission was done with the same assumptions as in base scenario. The results are shown on figure 9.1.25a-d.

Fig. 9.1.25a. GHG Emission
Scenario Chance/Reference Variant

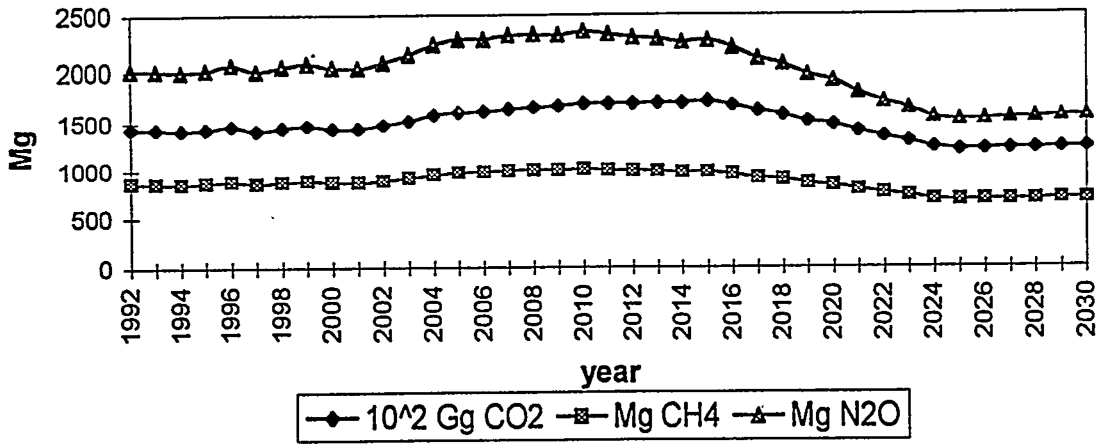


Fig. 9.1.25b. GHG Emission
Scenario Chance/Dispersed Generation Variant

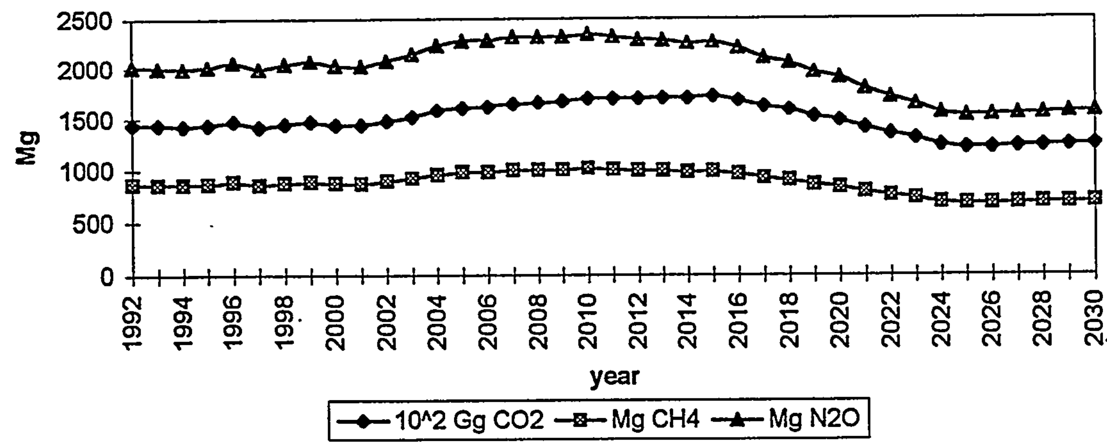


Fig. 9.1.25c. GHG Emission
Scenario Chance/No-nuclear Variant

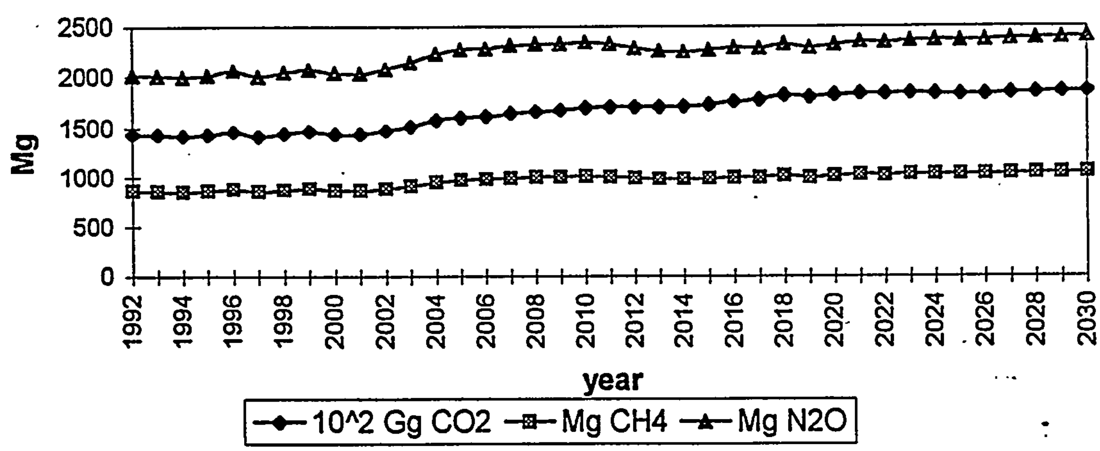
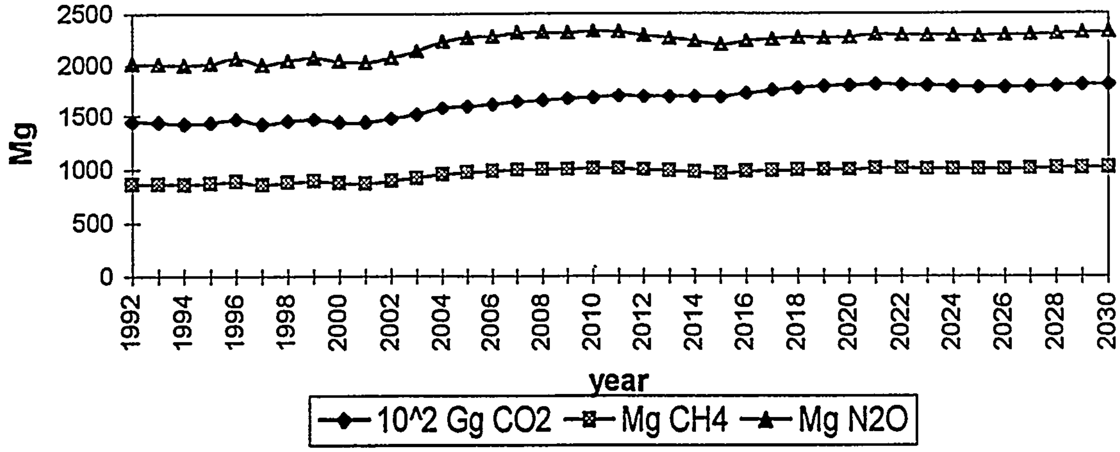


Fig. 9.1.25d. GHG Emission
Scenario Chance/Hydro&wind Variant



Due to changes in electricity and heat demand level and fuel structure changes for 2030 a significant absolute decrease of GHG emission was obtained in reference and ER variant. The emission levels are: 84-86% for CO_2, 77-80% for CH_4 75-78% for N_2O, 45-47% for NO_x, 81-83% for NMVOC relating to 1992, with slight increase of CO emission (1-2%). Lower values are achieved in decentralised variant (ER). In the time period 2010-2013 one can observe emission increase (eg. 18% for CO_2) relating to 1992.

Variants without nuclear power do not enable to achieve such reduction effects. For the year 2030 one can observe the emission increase for all except NO_x greenhouse gases relating to 1992 (eg 29% for CO_2). Maximum (see chapter 9.6) use of hydro and wind energy improves the situation insignificantly (eg CO_2 emission increase fall to 25%).

The values of goal function (table 9.1.4) get worse insignificantly in case of adding next conditions.

Decentralization of the system helps to use local renewable fuels for heat and power generation. In this case it could be necessary to verify the energy and capacity demand forecast.

The evaluation of local energy sources with energy from system (especially on rural areas) is to speculative now. This is because it depends strongly on restructuring processes, mainly the level and shape of demand. Moreover to evaluate a fuel like biomass having huge GHG emission reduction potential it is important because the positive effects are being reduced by the increase of emissions during transporting the fuel. So locations of energy and demand sources will be of great importance.

9.1.4. Comparison of Scenarios.

Table 9.1.4 and figures 9.1.26 and 9.1.27 show main results describing considered variants.

Simple comparison of direct costs of covering the energy demand of economy and transferring it to achieved effects in emission reduction is inappropriate in case of comparing scenarios in such long time horizon. While analysing development problems for whole society costs are not synonymously negative phenomenon because they are measure of achieved richness. Costs determine the society's future including economic development. The problem related to this is the cost structure. Considering the study goals all costs related to natural resources usage should be considered as undesirable, and costs resulting from humans activity as positive. From the statistical and static point of view achieving low share of energy costs in total economic costs shows energy effectiveness of economy. Transferring this by clear short term market mechanisms to behaviour of enterprises does not drive to lowering the share of these costs in total cost. This could cause the increase of energy intensity in the future. In this case due to GHG emission reduction it would be necessary to introduce correcting signals like taxes. In case that these costs are high in whole cost structure there is no need to introduce such signals if the economy is organised in the way stimulating increase of its competitiveness.

Fig.9.1.26 CO2 Emission

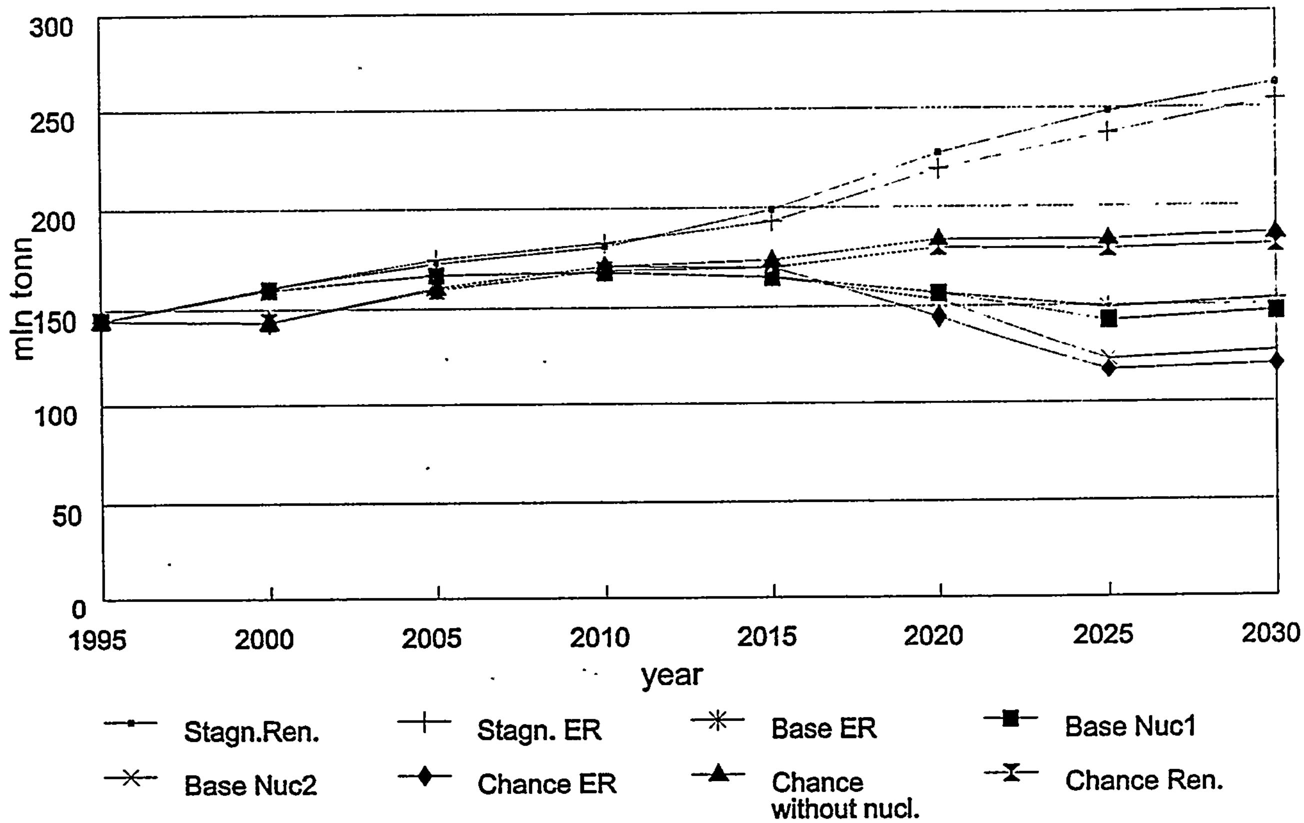
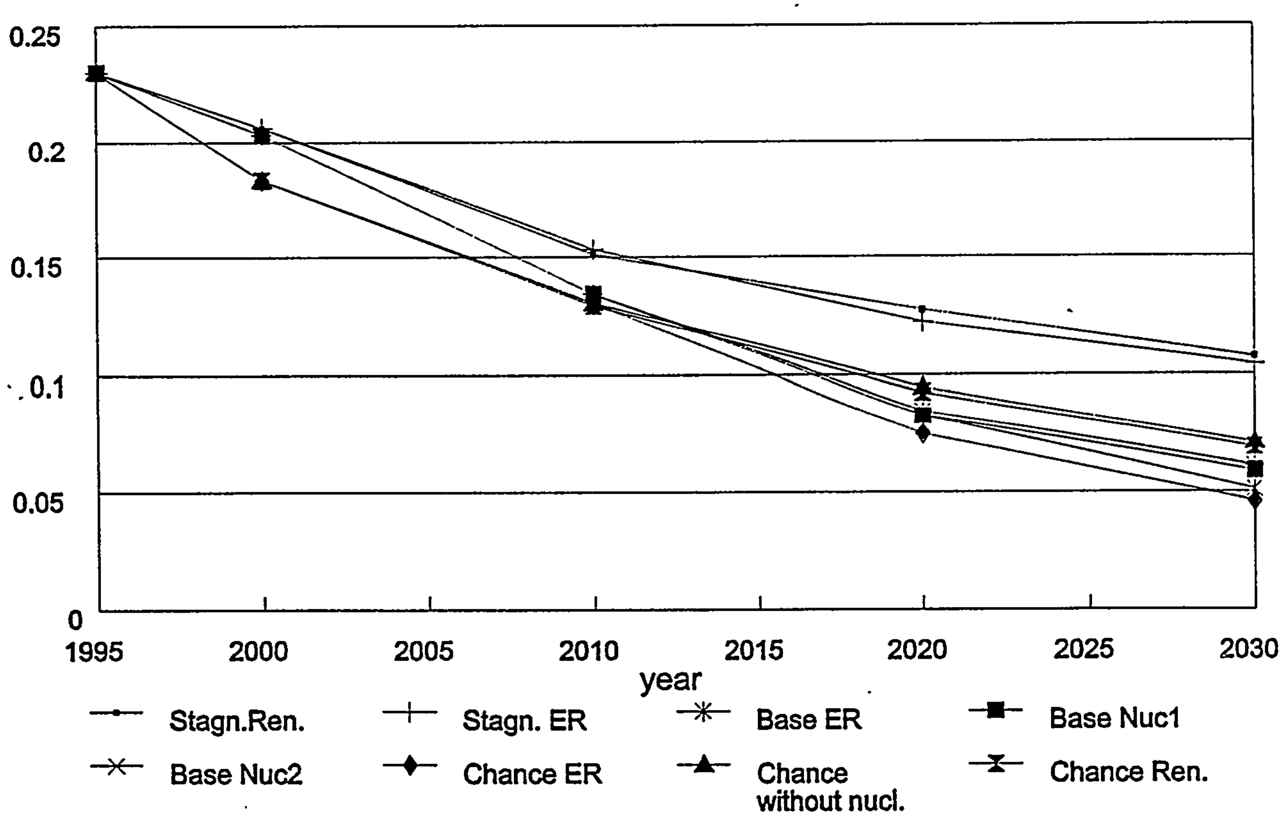


Fig.9.1.27 CO2 Emission/GDP



In case of Polish economy the share of energy costs in GDP is still high. Consequent elimination of existing inappropriateness (eg. calculating costs basing on marginal costs and value of competitiveness increase) and removing existing market barriers (eg. by improving the competitiveness) should drive to very positive effects regarding energy needs reduction (base scenario). The problem with evaluation of the scenario are not the benefits or losses in terms of finances, but negative, short term social and economical phenomenons related to economic transformations. These are the unemployment level, foreign trade balance, the possibility of adopting to changing conditions, resulting from possibilities of changing the location of capital concentration, areas of technical development and societal education. In such a case accelerating the changes in economy beyond the natural tempo, by introducing additional long term incentives (like financial instruments) can bring negative medium and long term results. The example of this could be increasing the energy prices in case when low purchasing power of the society does not enable to react positively (eg. by modernization of equipment). This is why accelerating the changes now has to be associated with corrections of existing incentives to improve the adaptation capabilities of society and economy and positive reactions on changes already introduced.

The place for eventual increasing the strength of incentives will appear when the economic changes will be slower than the adaptation capabilities of the society. It is difficult to estimate when it could happen. It will depend on dynamics of changes and on the society development, endowment and education level. The basic information about such readiness could be unemployment dynamics.
Finally as a base for recommendations among scenarios the information on the relative costs related to GDP.

However costs in monetary terms remain besides the GHG emission the base of evaluation of methods of covering energy needs within the particular scenarios (variants) standing for financial measure of their effectiveness.

9.1.5. Research problems - conclusions

Poland is being under transition when simultaneously rules for energy economy are created and introduced. This is difficult process what needs constant modifications and improvements. This is reason for needs of three categories of researches:

- Researches based on conceptions of society development and its long term goals and requirements as well as conceptions directed for strategic energy economy issues like energy law, energy directives, ownership issues, institutions and instruments;
- Researches on long term strategies of energy enterprises with market competitive environment and within frame of new legal and ownership decisions;
- Researches for methods of integration of results of above mentioned categories of researches for mutual verification.

The basic one problem for near and long term future will be answer question: what should be methodology for construction of practical energy strategies, remaining that most important issue is integration of goals of energy systems with non energy macro economical and societal goals. For choose will be available some formal models and methods as well as market methods and institutions and instruments with capacity be modified.

As most urgent one partial investigations for improvement of credibility of proposals of energy policy and for general direction of socio-economical policy are:

- investigations on demand side management as a function of legal rules and changes of income level of energy customers as well as society consumption preferences,
- investigations on finance instruments under multi-shape ownership environment. As an example could be mechanism of profit tax effect when private versus state ownership of energy enterprises.
- investigations on influence of market organisation and tariffs rules for energy enterprises and customers behaviours under short and long therm perspective. Especially interesting is assessment of influence of above mentioned rules on specific decision character and relation between short and long term goals of utilities.
- investigations on economically sound scale of monopolisation / regulation and continuation of investigation on possibility of improvement of reliability of electricity and heat systems due to institutional changes and decentralisation.

All above mentioned investigations should result with braking down barriers and deffects of market being against energy efficiency improvement and reasons for energy loses. They should accelerate energy equipment and appliances market transformations especially increase penetration of hi-tech and change structure of final consumption to the less energy intensive one direction.

From the another side those investigations should direct production of electricity and heat to the required mixture of fuels and technologies and systems guarantee as high as possible efficiency of energy conversion as well as manifold utilisation of energy. It means necessity of development of research on limitation of losses of energy by technologies and increase of recycling rate of energy.

For GHG emission reduction problem investigation on nuclear power technology are important. Direct research for technology seems us unrealistic in Poland. Nevertheless it is necessary conduct investigations for security of technologies raised from local circumstances and for utilisation of nuclear wastes. Additionally very important and inevitable are sociological investigation for defining of conditions required for societal acceptance of those technology.

Very interesting one for GHG emission reduction are investigations on increase of share of renewable fuels and energy in Poland especially when nuclear power will be not allowed. These investigations should be directed both for technologies and legal and economical rules. In this case geothermal energy and after the biomass are interesting from existing energy potential point of view. Water, wind and sun energy issues should not be neglected but their energy potential in Poland is very limited in comparison to the demand.

9.1.6. Conclusions.

1. Intensification of economic development drives to:
- improvement of economic competitiveness, creating new attractive labour places, increase of society's incomes, changing the awareness and interests of society,
- changes of structure of final needs of society with shifting to bigger share of services, hi-tech industry and decrease the share of heavy industry.
- limitation of the production factor per unit of products to enable realization society's aspiration (increase of income, diminishing the unemployment, improving the shape of natural environment).

2. For the quite long time the global effects coming from reducing the specific energy needs and structural changes in the economy may overlap the increase needs resulting from direct economic growth. Stimulating the demand reduction as a result of energy efficiency improvement to compensate its growth resulting from economic growth gives time for more detailed studies on Polish society and it real current and future needs and elaborating long term economic development strategies.

3. Accelerating the changes in economy over the tempo resulting from adaptation capabilities by introducing additional incentives using short term instruments (eg. pure financial instruments) can bring negative medium and long term results. Accelerating these changes now has to be associated with increasing the adaptation capabilities of the society and economy to transformed economy. It mainly deals with increasing the possibilities of positive reacting on strong in relation to purchasing power of the society and financial condition of enterprises pricing signals from energy market.

4. It is necessary to conduct the analyses of appropriateness of incentives like carbon tax to introduce in the moment when the economy restructuring rare is slower than adaptation capabilities of the society.

5. Chance scenario based on the assumption of intensifying the economy on the base of equipment market transformation shows the method of getting the need of realization of current priorities with promotion of new priorities and development chances, and creating the possibilities of their realization in the future together. The policy suggested in this scenario enables the society and economy to react on existing incentives faster and with positive feedback effects. It helps to undertake the decisions resulting in significant reduction of GHG emission by changing the structure of energy production.

6. Delaying the development decisions in power industry is possible as a result of market transformation effects and demand stabilization. It is truth considering very dynamic changes regarding power and heat production technologies and changes regarding the structural organization of these economy branches.

7. Delaying the investment decisions in power and heat generation sectors during the economic growth improves the economic and financial investment possibilities in the future (lower discount rate and improves income/cost ratio in power sector). This enables to introduce modern and expensive but environmental friendly projects that are thrown away nowadays (due to discount rate, prices disabling payback). The number of

alternatives grows resulting not only from technical development but also the possibilities of their acceptation in economy.

8. In the case resign of possibility to delay investment decision for new power generators the most attractive option (both from economical and environmental point of view) for next 15 years are gas based generation for base load as well as for peak time.

9. Decentralization of the electro-power system is linked with increase of share of small capacity facilities. This is the reason of increase of investment cost per capacity unit and some decrease of efficiency of separate generators. From the another side dissemination of generators limit transmission loses and probability of simultaneous brake down of facilities. This could be eligible source of investment savings due to better system reliability. Finally competitiveness within the system cost point of view is similar for small and big units although assessments were very precautionary for transmission loses savings and limitation of the system reserve margin. Higher elasticity of diversified system and more capacity for cogeneration of electricity and heat when more market in the electricity system are very positive one features. Finally decentralisation is being benign for increase of system efficiency as a whole.

10. GHG emission is similar for centrally organised and decentralised system when fuel structures are similar one. This is due to limited access to natural gas for both cases and full utilization of that limit.

11. For decentralised system especially attractive are gas fuels.

12. Decentralised system is being attractive for renewable. For increasing of economical attractiveness of renewable especially important are tariffs relay on value and marginal cost base as a function of localisation.

13. Capacity of generators fuel by renewable could be up to 5% of total capacity demand for low scenarios of electricity demand. For base scenario those share is c.3%.

14. Nuclear power is for every case source of GHG emission limitation. Those generators are chosen by models after 2020 when discount rate is 10%. When discount rate is limited such electricity sources are attractive for system from year 2016. Nuclear power is alternative for hard coal generators.

15. In the case lack of society agreement for nuclear power increase of GHG emission seems inevitable to the range of 19-53% relatively for variants and with little bit higher costs.

16. Intensification of utilisation of renewable up to level proposed by SE7 team makes possible reduce emission for 3% for chance scenario when cost are negligibly higher. Only 3% reduction of GHG when 5% capacity is due to limitation of time of operation.

17. For analysed scenarios share of cogeneration rise when demand growth for electricity is being limited. This is due to limited capacity to use heat from cogeneration.

18. In the case of stagnation scenario one should expect GHG emission growth for c. 80% in 2030 in comparison to emission of 1992, when stabilised emission of NO_x and more then double emission of CO. These effect are expected in spite of fuel structure changes especially increase of natural gas share up to 18%.

19. Increase of demand under base scenario and related supply variants effect:

- in 2030 when nuclear power is allowed GHG emission is slightly lower emission 1992 with CO exception,
- during the period 2007-2010 17% absolute growth is observed over 1992 level due to economy development and still coal dominated fuel structure of production,
- later on as a result of fuel mixture changes growth of emission is slowed down and limited on the absolute level at the end of forecasting period,
- highest absolute 11% reduction of GHG emission at 2030 year one can observe for variant nuclear 2,
- reference and ER variants present small 6% absolute growth of emission of GHG in comparison to 1992 level,
- relative emission related to GDP drops down for base scenario times 1.13 for 2010, times 1.5 for 2020 and times 1.8-2.1 for 2030 in comparison to the stagnation scenario.

20. Increase of demand under chance scenario and related supply variants effect:

- in 2030 when nuclear power is allowed strong, 14% decrease of GHG emission under 1992 level (with stabilisation of CO_2 emission),
- for nuclear variants temporary up to 19% increase of emission over 1992 level until 2014-2015,
- for variants with restricted nuclear power one can observe absolute 29% increase of emission over 1992 level until 2030,
- intensification of renewable utilisation according SE7 team proposal make possible limit emission to 25% only increase of emission over 1992 level until 2030,
- relative emission related to GDP drops down for chance scenario times 2.3 for nuclear variants and times 1.5 for no nuclear variants for 2030 in comparison to the stagnation scenario.

21. This study proposes likely directions of changes. They require continuation. Especially interesting one is local market attractiveness of different sources of heat as a function of new legislation rules and institutional statements for energy economy. In spite of that we know technical characteristics of facilities there is strong dependence of their attractiveness on local system feathers (available technical alternatives, characteristics of demand, scope of market) when in general they are unique one. In case of CHP especially important is conception for rates for two energy markets: electricity and heat.

22. Every constructed variants present tendency for limited growth of emission of GHG until 2015 in comparison to the 1992 level. After then one can observe alternatives depend mainly on demand growth and agreement for nuclear power. In case of no nuclear power variant most optimistic situation is 25% growth of emission.

23. Every variants present eligible drop down of relative to GDP emission of GHG. For 2030 those improvement is from 2.1 to 4.5 times in comparison to 1992 situation.

24. Assessments and results concerning heat production from state central sources as well as conclusions related to expected effects of decentralisation require be verified during coordination stage under task SE1 when results from task SE10 will be available.

Abbreviations

ENPEP	*-Energy and Power Evaluation Program*
SDM	*-Simulation Dynamic Model*
ER	*-Dispersed Energy Subsystem*
EJ	*-Nuclear Power*
MO ZNiL	*-Ministry of Environmental Protection*
MPiH	*-Ministry of Industry and Trade*
CUP	*-Central Planning Office*
GUS	*-Central Statistical Office*
CIE	*-Center for Energy Information*
SE ...	*-Study Element no. ...*
GDP	*-Gross Domesticl Product*
PSE SA	*-Polish Power Grid Co.*
IE	*-Electro-power Institute*
DSM	*-Demand Side Management*
NN	*-Highest Voltages Network*
UE	*-European Union*
KSE	*-Electricity Subsystem*
LOLP	*-Lost Of Load Probability*

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9.2. Industry

9.2.1. Sector description

Energy-intensity of industry - historic conditions

Analysis of industry energy-intensity was made regarding the period 1970-1989. Final energy consumption was considered regarding the sold production in fixed prices of 1990. Because of change of accounting methodology of national income which took place in 1989, the notion of a Gross Domestic Product was introduced in the Statistical Yearbooks of Central Statistical Office (Główny Urząd Statystyczny). This fact, however, had not the essential impact on the effects of the analysis.

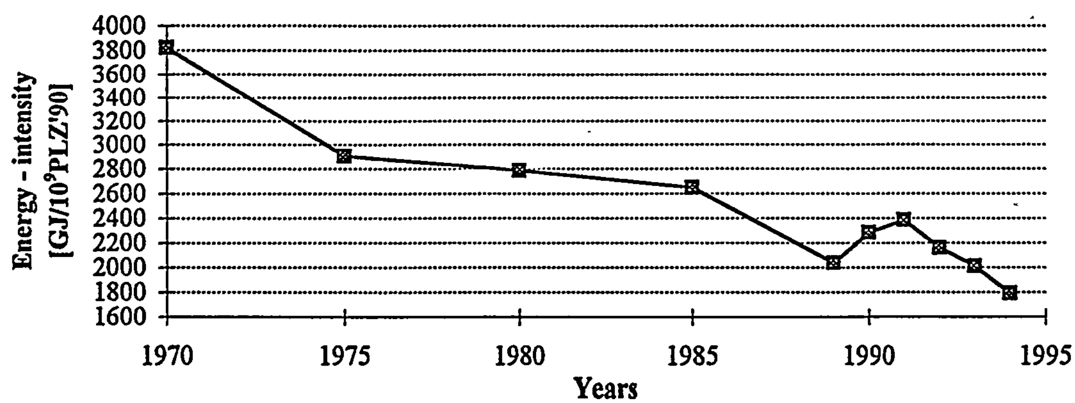
Energy-intensity of the Polish industry in 1993 reached the level of about 2 TJ/billion PLZ, i.e. it decreased in comparison to 1970 by about 47 %, and achieved the lowest level in the entire analyzed period. It only insignificantly exceeded the energy-intensity level from 1989, i.e. from the beginning of the period of transition from a centrally planned to market economy.

In the transition period 1989 -1993 the final energy consumption decreased by about 20% as compared to 1989. The main reason for this was a production decline in this period by about 27%. The lowest production level, e.i. about 500×10^3 billion PLZ, was recorded in 1991. The largest decrease of final energy consumption in the analyzed period took place in metallurgy - by 32 % (sold production decrease by 46 %), chemical industry - by 37 % (sold production decrease by 23 %) and mineral industry - by 33 % (sold production decrease by 20 %). It shows that the second reason of energy consumption decrease was the energy-intensity reduction in these branches where the total final energy consumption amounts to nearly 80 %.

In the years 1989 - 1991 the final energy consumption was declining and at the same time the sold production was growing. This positive tendency returned in the period between 1991-1993. In this period a production increase, energy-intensity decline as well as energy consumption decrease were recorded (Fig. 9.2.1. to 9.2.5, table 9.2.1).

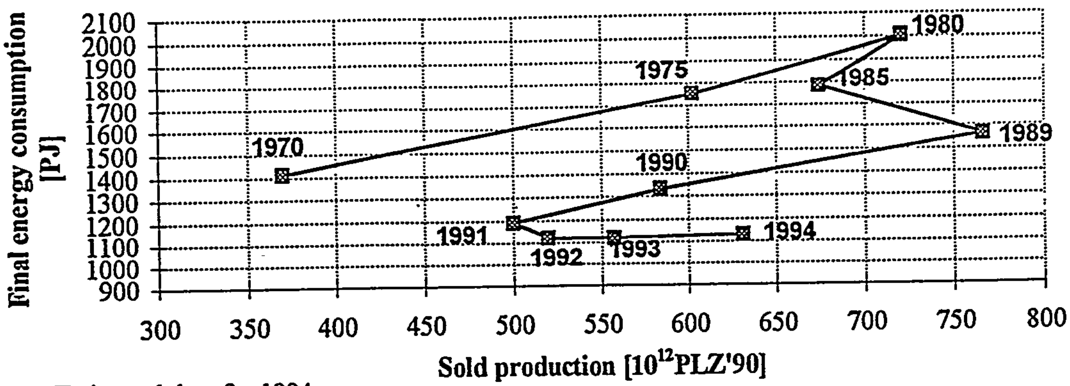
The energy-intensity comparisons of steel, ammonia, cement and paper production in the European Union countries and in Poland show a potential for the energy-intensity reduction (Fig. 9.2.6 to 9.2.9). The equivalent 1 kWh = 10.47 MJ (used in EU) instead of 1 kWh = 3.6 MJ (used in the Polish statistics) [Worrell E., 1992, Katalog, 1994] was used for comparison of specific energy consumption coefficients for particular products in the European Union countries and Poland. Energy-intensity of steel production in Poland referring to average, the best energy-intensity in practice, would be possible by more than 40 %, ammonia production by 24 %, cement by 49 % as well as paper by 28 %. The average weighted energy-intensity reduction for the four above mentioned products amounts to over 38 %. The analyzed measures regarding the year 2010 shows a potential of reduction of final energy consumption in comparison to the base scenario by more than 30 %. Thus the above comparison allows to formulate the conclusion that these measures do not use all available opportunities.

Fig.9.2.1. Sold production energy - intensity of industry in 1970 - 1994



Estimated data for 1994

Fig.9.2.2. Final energy consumption and sold production of industry in 1970 - 1994



Estimated data for 1994

Fig.9.2.3. Final energy consumption in industry in 1989-1993

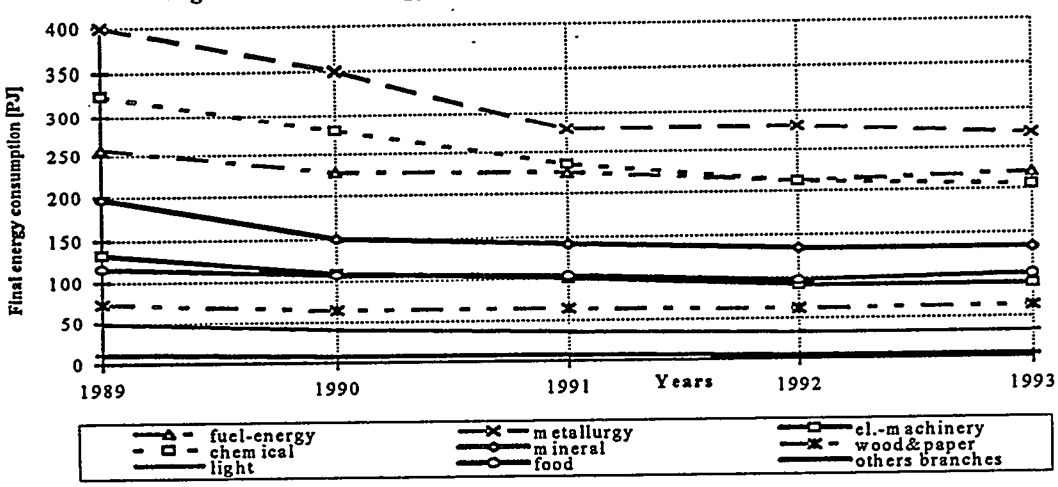


Fig.9.2.4. Energy - intensity of industry in 1989-1993

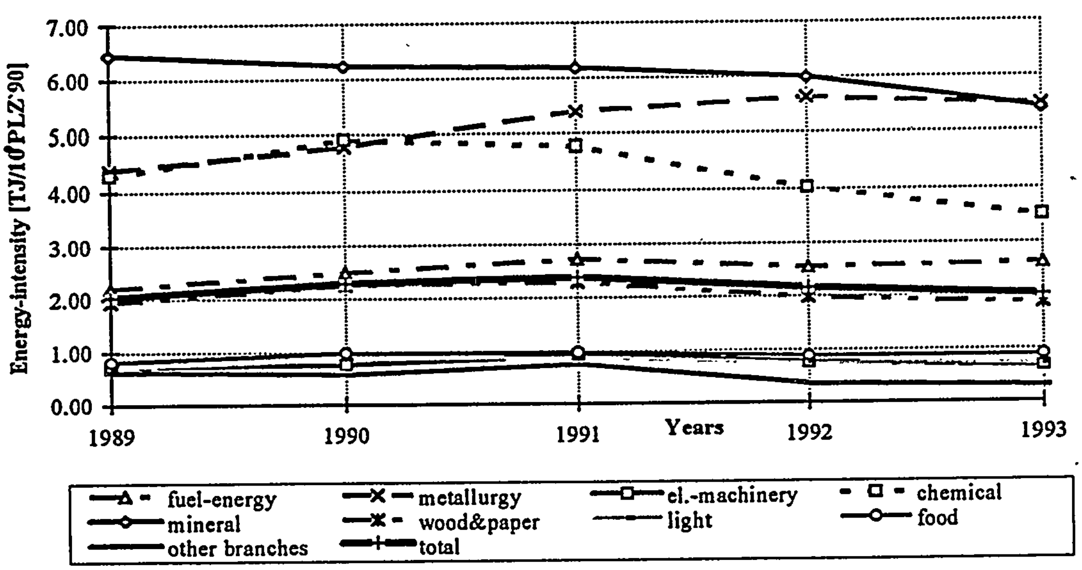


Fig.9.2.5. Share of industrial branches in sold production of industry

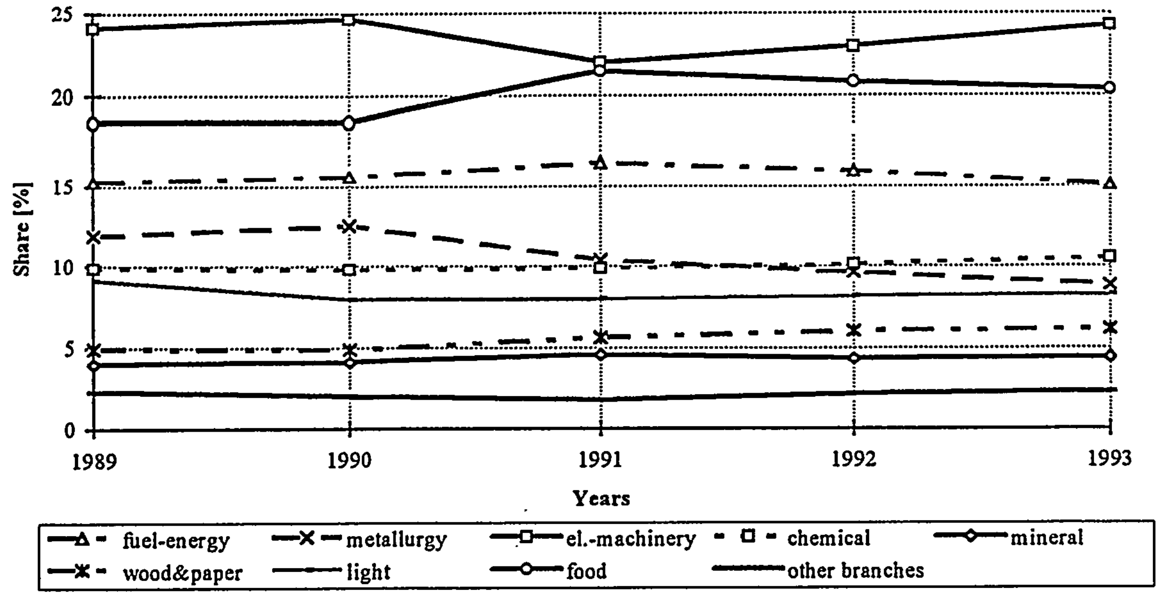


Table 9.2.1. Changes of final energy consumption and CO_2 emission in industry and impact of particular factors on these changes (yearly changes-beginning 1989)

			1990	1991	1992	1993
$\Delta E_{\Delta A}$	Energy consumption change as a result of production value changes	[PJ]	-371	-542	-503	-426
	Energy consumption change as a result of production structure changes	[PJ]	18	3	-16	-30
$\Delta E_{\Delta e}$	Energy consumption change as a result of energy efficiency	[PJ]	129	163	86	17
ΔE	Summary energy consumption change in the production system	[PJ]	-224	-376	-433	-439
E	Summary energy consumption in the production system	[PJ]	1337	1185	1128 .	1123
$\Delta EGC_{\Delta A}$	Change of CO_2 emission as a result of production value changes	[Gg]	-47824	-69858	-64748	-54825
$\Delta EGC_{\Delta u}$	Change of CO_2 emission as a result of production structure changes	[Gg]	-64	942	-1145	-3995
$\Delta EGC_{\Delta e}$	Change of CO_2 emission as a result of energy efficiency changes	[Gg]	18393	24370	14710	6842
$\Delta EGC_{\Delta r}$	Change of CO_2 emission as a result of energy carriers structure changes	[Gg]	665	353	-115	-20
ΔEGC	Summary change of CO_2 emission in the production system	[Gg]	-28831	-44193	-51298	-51997
EGC	Summary CO_2 emission in the production system	[Gg]	172286	156924	149818	149119

NOTE: Final energy consumption in the Polish industry in 1989.: 1561.34 [PJ]

CO_2 emission includes emission from power & heat sector from electricity and heat production consumed by industry.

Summary CO_2 emission in 1989: 201116.4 [Gg]. Production value in fixed prices of 1990.

Fig.9.2.6. Energy - intensity of steel production in European Union countries and in Poland (PL) in 1988

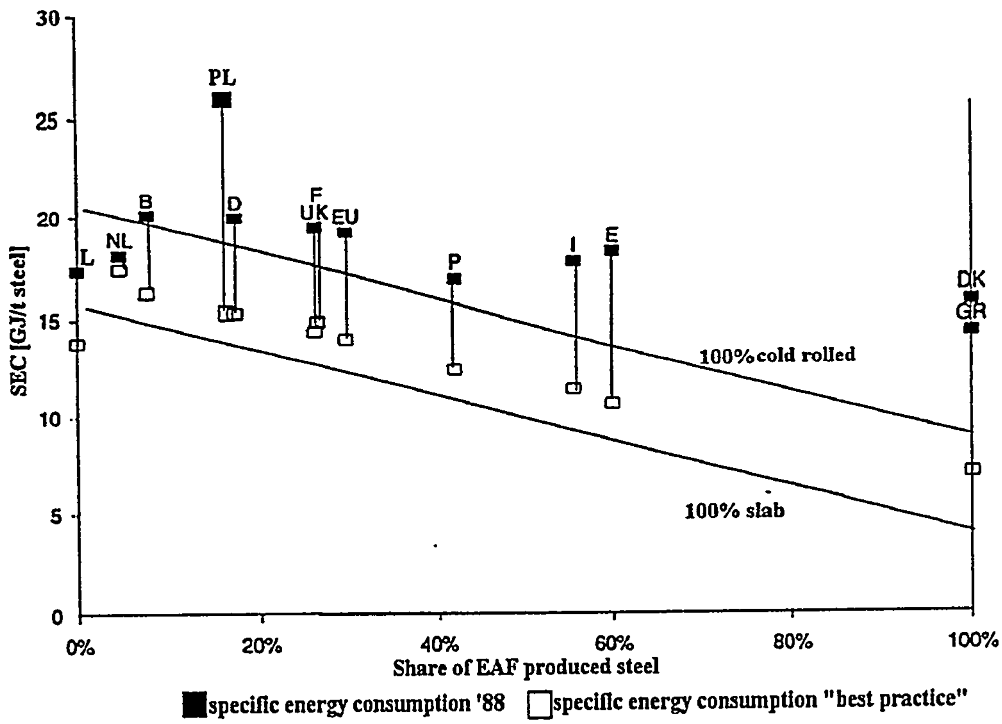


Fig.9.2.7. Energy - intensity of ammonia production in European Union countries and in Poland (PL) in 1988

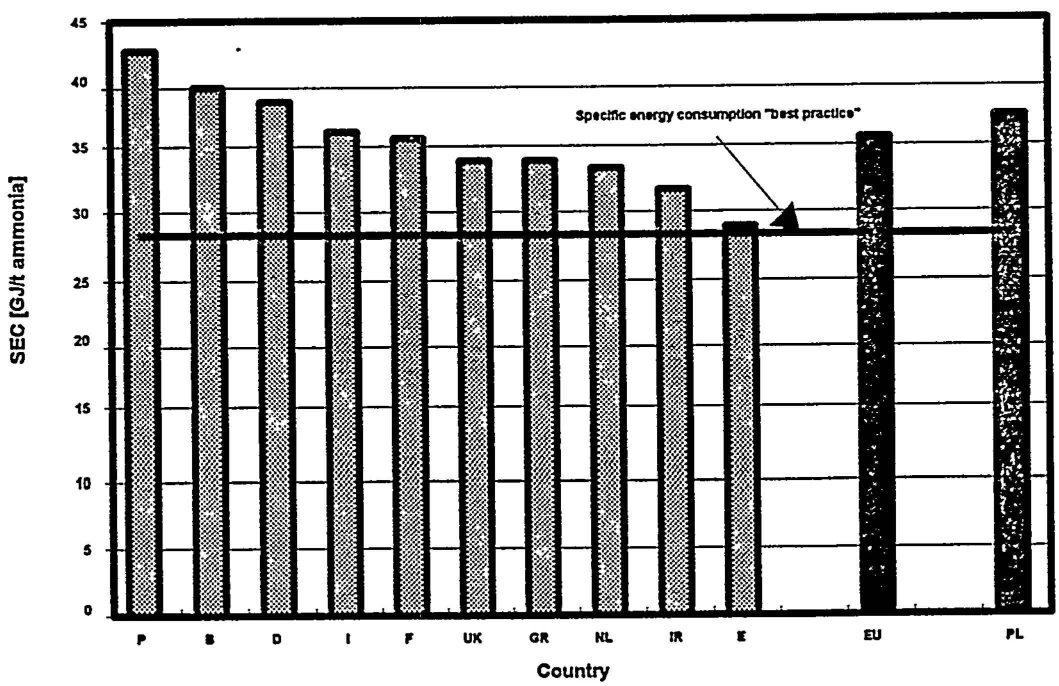


Fig.9.2.8. Energy - intensity of cement production in European Union countries and in Poland (PL) in 1989

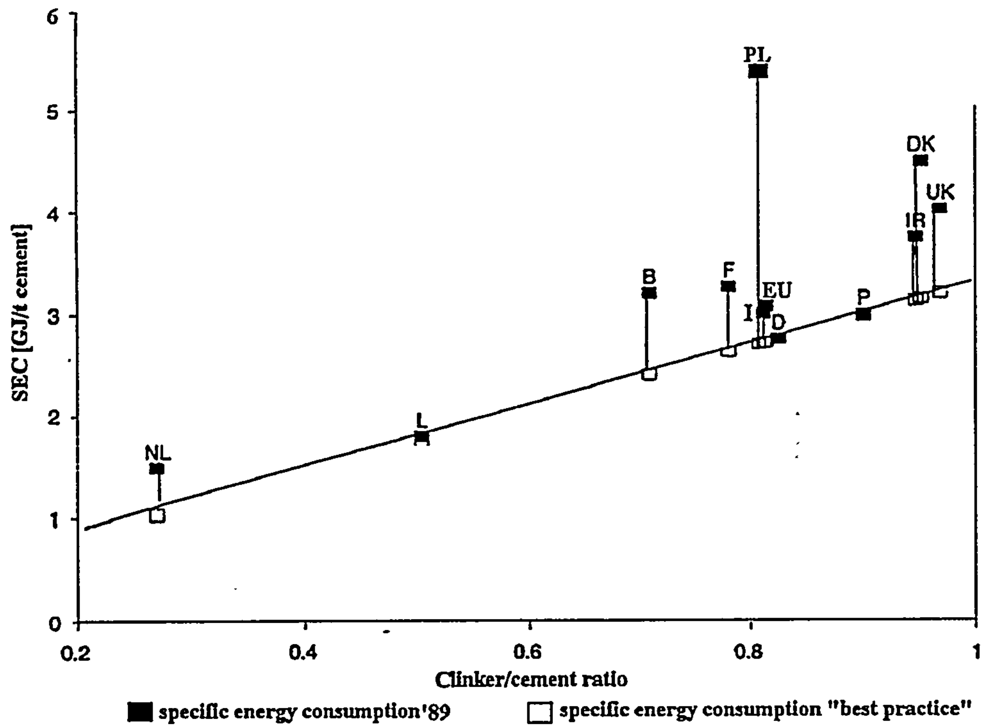


Fig.9.2.9. Energy - intensity of paper production in European Union countries and in Poland (PL) in 1988

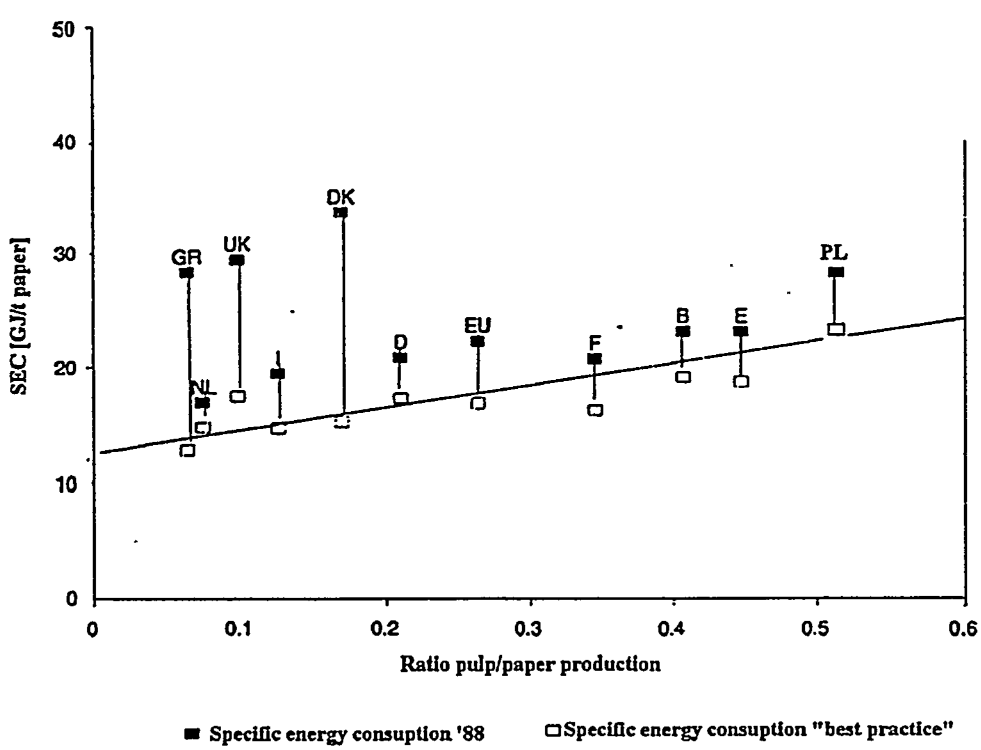


Fig.9.2.10a. Shares of GHG emission according to group of industrial branches in 1993

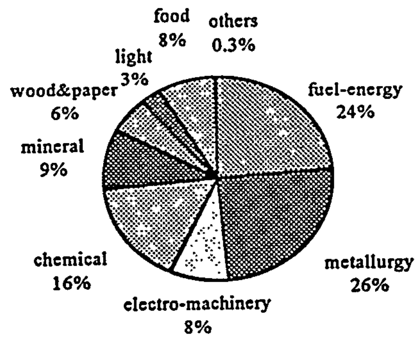


Fig.9.2.10b. Shares of GHG emission from industry in 1993

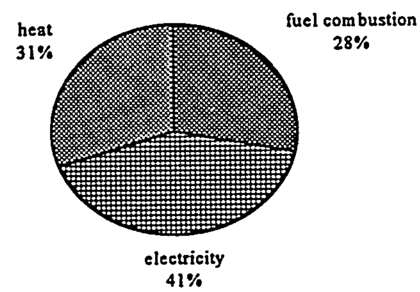
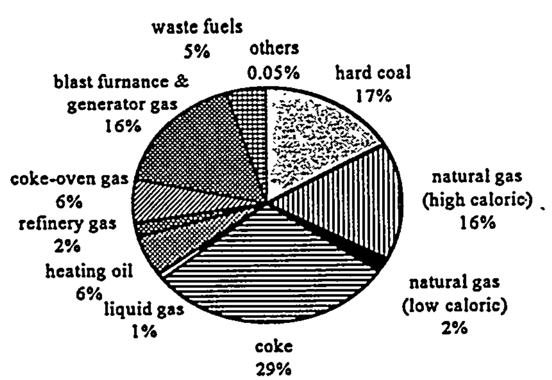


Fig.9.2.10c. Shares of GHG emission from fuel combustion in industry in 1993



Potential of GHG emission mitigation from industry

Incomplete recognition of opprotunities of the GHG emission reduction from industry allows to assess a potential emission reduction at over 100 million tonnes in 2030. Out of this figure 66% falls on energy measures, 28 % on the autonomous measures, and 6 % on measures which reduce GHG emission (Fig. 9.2.11, Tab. 9.2.2).

In the set of energy measures the highest potential annual result can be achieved by the improvement of production management - about 18 million tonnes of CO_2 equivalent, improvement of steam economy - about 14 million tonnes of CO_2 equivalent, utilization of coalbed methane for producing electricity in professional power plants in steam & gas systems (about 10 million tonnes), as well as by improvement of efficiency of energy using machines and devices (about 9 million tonnes), four measures (using of high-efficiency electric motors, electronic drives regulation, modernization of reheaters, heat recovery in waste-heat boilers and evaporated installations) give from 2.3 to 3.5 million tonnes per year, 12 million tonnes in total. Other measures have total potential of GHG emission reduction of about 7.5 million tonnes of CO_2 equivalent (Fig. 9.2.12). These measures can result in GHG emission reduction by about 70 million tonnes.

Because of the lack of needed information it is impossible to analyze the autonomous measures by unified means. Three industries - iron & steel metallurgy, chemical industry as well as refinery & petrochemical industry were considered as separately aggregated measures. On the other hand the analysis of mineral industry and non-ferrous metallurgy was made according to production technologies.

In the set of these measures the highest annual potential refers to modernization of raw material part of iron & steel metallurgy - about 11 million tonnes of CO_2 equivalent, followed by modernization of chemical industry - just under 10 million tonnes, as well as to technological modernization of refinery & petrochemical industry - about 8.5 million tonnes. Technologies considered in mineral industry have the GHG emission mitigation potential on the level of about 1.2 million tonnes, in non-ferrous metallurgy about 100 thousand tonnes. Total potential of GHG emission mitigation from industry from autonomous measures is evaluated at about 30.5 million tonnes of CO_2 equivalent (Fig. 9.2.13).

In the set of measures whose aim is the GHG emission reduction exclusively, there are two measures - replacement of hard coal steam boilers (capacity <20 tonnes/hour) in heat & power generating industrial plants by gas boilers, as well as production of electricity and heat in industrial power plants in co-generation systems with increased use of natural gas. Total yearly potential of these measures is estimated at over 6 million tonnes of CO_2 equivalent.

In the above analysis of the potential of GHG emission reduction only one criterion was taken into account - the size of GHG emission reduction potential.

Specification of GHG emission potential in industry, by the types of measures is presented in Tab. 9.2.2.

Present structure of GHG emission from industry

In 1993 the Polish industry emitted together with emission from power industry (electricity and heat used in industry) over 157 million tonnes of GHG (CO_2 equivalent). From this quantity about 24 % falls on each - fuel & power industry and metallurgy, about 16 % on chemical industry, 8 - 9 % on mineral industry, electro-machinery and food industries, about 6 % on wood & paper industry, about 3 % on light industry and 0.3 % on other branches.

Emission structure regarding the carriers of directly used energy is as follows: 41 % falls on the emission in power industry (professional and industrial) from electricity used in industry and about 30 % on the heat energy used, while over 28 % of GHG's originates from fuel combustion. In the structure of emission from fuel combustion (excluding gasolines and diesel fuels) the largest share falls on the emission from coke combustion - about 30 %, about 17 % from hard coal and the same percent from blast-furnace gas, 16 % from pipeline (high BTU) natural gas, about 6 % from coke-oven gas combustion and the equal amount from heating oil combustion, 5 % from waste fuels combustion. In 1993 industry emitted about 45 million tonnes of GHG (CO_2 equivalent) from fuels combustion (Fig. 9.2.10).

Fig.9.2.11. Potential of GHG emission mitigation from industry in 2030

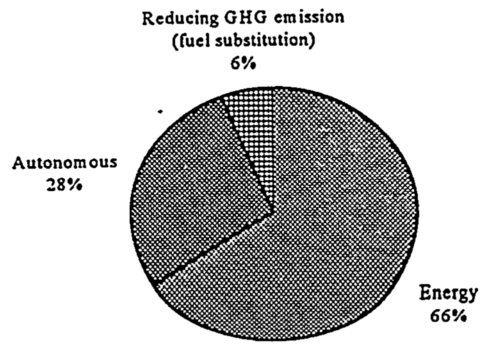


Fig.9.2.12. Potential of GHG emission mitigation from industry - energy measures - in 2030

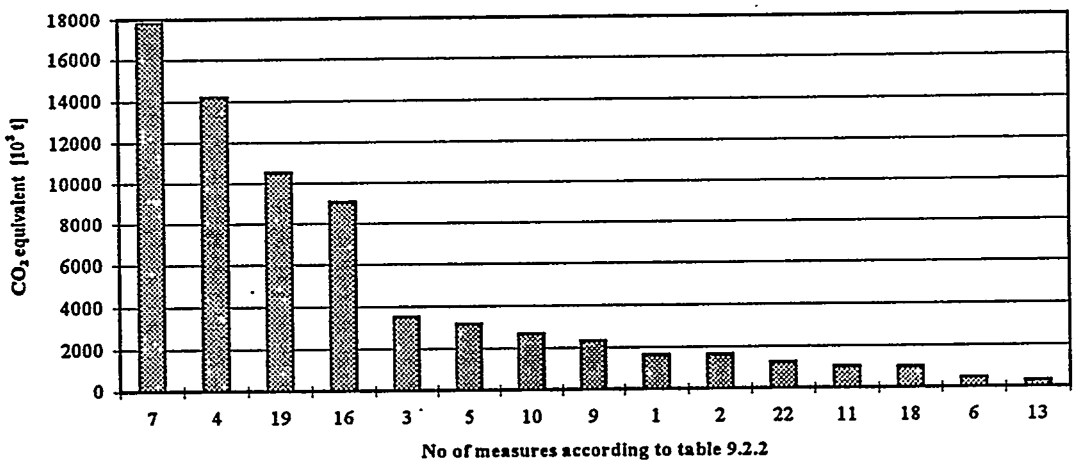


Fig.9.2.13. Potential of GHG emission mitigation from industry - autonomous & reducing GHG measures - in 2030

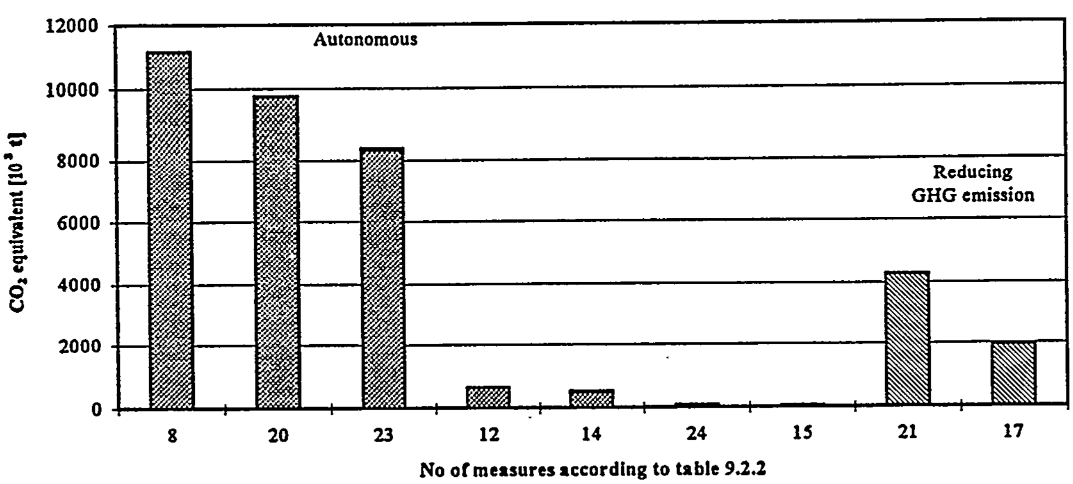


Table 9.2.2.GHG emission mitigation from industry according to groups of measures, specific investment cost (SIC) and intern return rate (IRR)

No of measures	Energy measures - en	Emission mitigation in years [Gg]				SIC [USD/t]	IRR [%]
		2000	2010	2020	2030		
1	High-efficiency lighting	273	1468	1631	1631	-92.03	*
2	Monitoring of production processes	182	1468	1631	1631	-89.48	123
3	High-efficiency electric motors	427	3194	3549	3549	-85.35	109
4	Improvement of steam economy	855	9565	14167	14167	-83.82	66
5	Electronic control of electric motors	72	2862	3181	3181	-81.22	77
6	Blast furnance gas pressure turbines	431	431	431	431	-77.89	59
7	Improvement of energy management in industry	8030	11146	14859	17833	-76.93	56
9	Heating processes - heat recovery in the recuperators	2333	2333	2333	2333	-55.53	72
10	Modernization of heating furnaces	1535	2683	2683	2683	-47.67	42
11	Heating processes - heat recovery in the boilers and evaporated instalations	1036	1036	1036	1036	-44.71	36
13	Utilization of chemical energy of basic oxygen furnace gas	316	316	316	316	-41.06	153
16	Improvement of efficiency of energy using machines & divices	9058	9058	9058	9058	-36.43	53
18	Generation of electricity in industrial combined cycle power plants	866	999	999	999	33.15	*
19	Generation of electricity from colbed methane in power plants - combined cycle	3514	10543	10543	10543	55.33	*
22	Dry coke quenching installation	908	1258	1258	1258	199.16	*
	Subtotal	29837	58361	67675	70650		
	Autonomous measures - au						
8	Modernization of raw - material part of iron & steel metallurgy	11134	11134	11134	11134	-70.96	42
12	Enlargement of cement production by dry method using	640	640	640	640	-43.21	*
14	Enlargement of lime production in Maerz furnaces	125	313	408	533	-40.49	146
15	Implementation of modern zinc electrolyze	32	32	32	32	-38.02	18
20	Technological modernization of chemical industry	4947	6472	8350	9764	56.36	*
23	Technological modernization of refinery & petrochemical industry	2858	5109	6408	8313	224.77	*
24	Alumina electrolyze by using of agglomerated anodes	72	72	72	72	227.57	*
	Subtotal	19808	23773	27044	30488		
	GHG emission mitigation measures (by fuel subtitution) - ec						
17	Replacement of coal, steam boilers (capacity < 20 t/h) by gas boilers in industrial power plants	701	1952	1952	1952	7.31	*
21	Co-generation of elecricity and heat in industrial power plants by enlarged using of natural gas	1595	4262	4262	4262	198.71	*
	Subtotal	2295	6214	6214	6214		
	TOTAL	51940	88348	100933	107352		

9.2.2. Reference scenario

Methodology of strategy assumptions construction

Construction of assumptions of GHG emission mitigation strategy is based on the following basic elements:

1. Calculation of base scenario (base-line or business as usual), which points out what would occur, if historic and natural development trends continue automatically. This scenario is also named a "non-intervention" scenario, i.e. that in the future GHG emission will be changed without special activities of the adopted GHG emission mitigation policy.

2. Choice of an aim - the level of GHG emission mitigation, counted against the base scenario for the following media in the time horizon to 2030. Choice of aim is a political decision which is connected with:

   - Poland's obligations which can originate from signing of international agreements regarding GHG emission mitigation within UN Framework Climate Change Convention (FCCC),

   - comparison of profitability of industry options to other economic sectors options and choice of mitigation objective for as a whole according to the rule of best benefit and implementation possibilities,

   - presentation of Poland's share in the reduction of world climate change threat as an active action for the world community.

   Ordering of the options according to decreasing economic profitability and increasing effect of GHG emission reduction (Fig. 9.2.14 to 9.2.17) gives possibility for a choice of the objective.

3. Conditions evaluation and choice of instruments for fulfillment of the objective. The choice of instruments be guided by the following criteria:

   - Polish government on behalf of the Polish State is responsible for fulfillment of the objectives resulting from signed international agreements,

   - thus the planned strategy will be a long-term activity of the governments,

   - economic system of Poland will be developed towards market economy, therefore choice of influencing instruments for independent enterprises in industry will be adequate to possibilities of the state interventionism on the market,

   - GHG emission reduction strategy should be integrated with environmental industrial and energy policy of the state and create synergy of instruments of these policies.

Summarizing, construction of assumptions of GHG emission reduction strategy is placed within the framework of the following scheme:
- where are we?
- in what direction are we heading?
- in what manner do we want to achieve the goal, we head towards?

Base scenario

Scenarios of GHG emission reduction can be considered against the frozen and base scenarios. The frozen scenario is a scenario of economic growth with frozen production structure and energy-intensity from the year preceding change of social and economic system (1988). The base scenario is the economic growth scenario with assumed changes of production structure in industrial branches and frozen energy-intensity (1988). We will use this scenario to compare the GHG emission reduction scenarios.

In the transition period (after 1989) calculations of base scenario based on continuation of the old economic system trends - centrally planned economy - do not seem to be reasonable (Fig. 9.2.18 and 9.2.19). On the other hand taking the base scenario as a scenario of adaptation of the Polish industry towards rationalized economy demand for industrial products and services as well as towards world's competition of open national economy could produce the false picture of Poland's effort and its contribution to the reduction of the GHG emission and perceiving it as something that will take place inherently (without effort) (base scenario rule).

Fig.9.2.14. Measures of GHG emission mitigation according to levelized net marginal costs

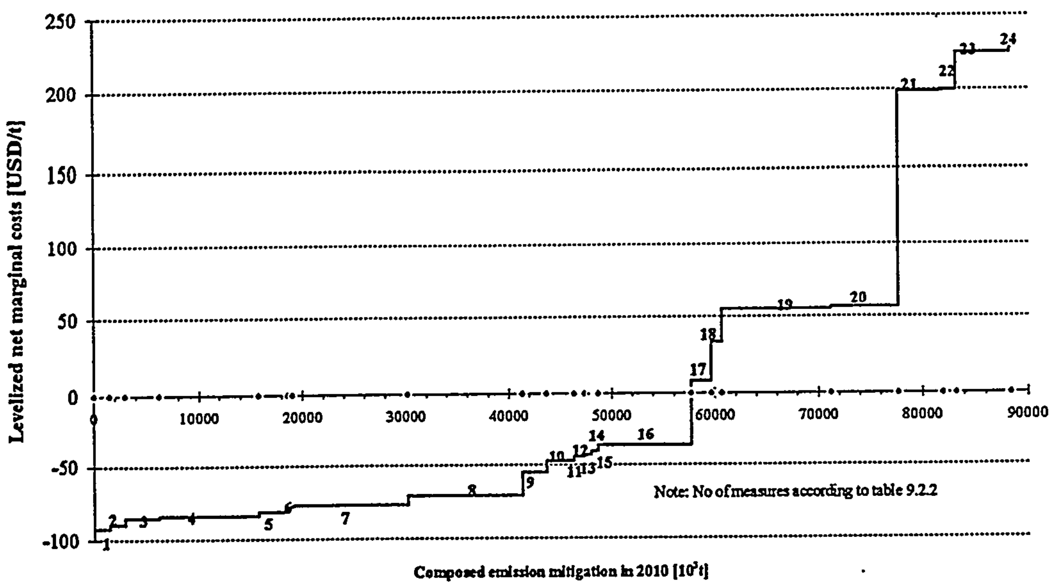


Fig.9.2.15 Energy measures of GHG emission mitigation

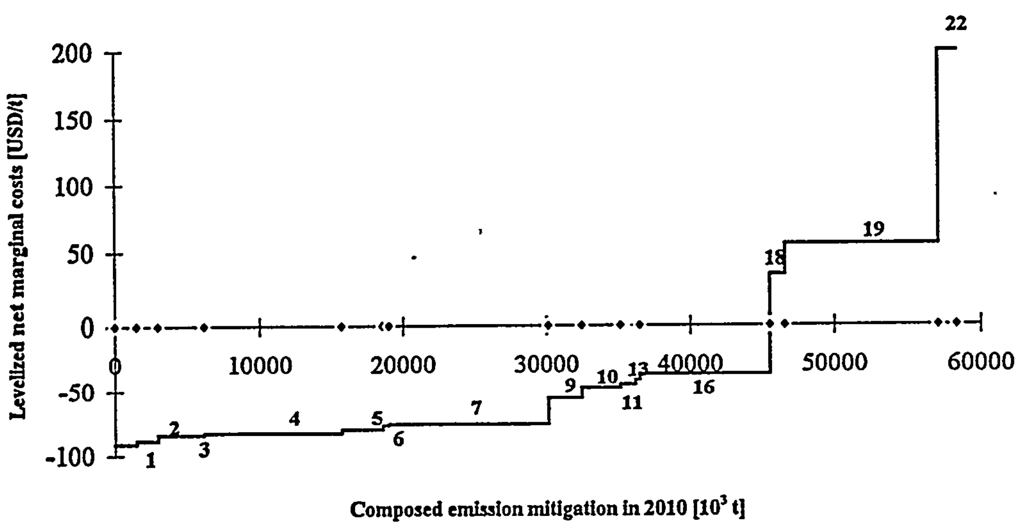


Fig.9.2.16. Autonomous measures of GHG emission mitigation

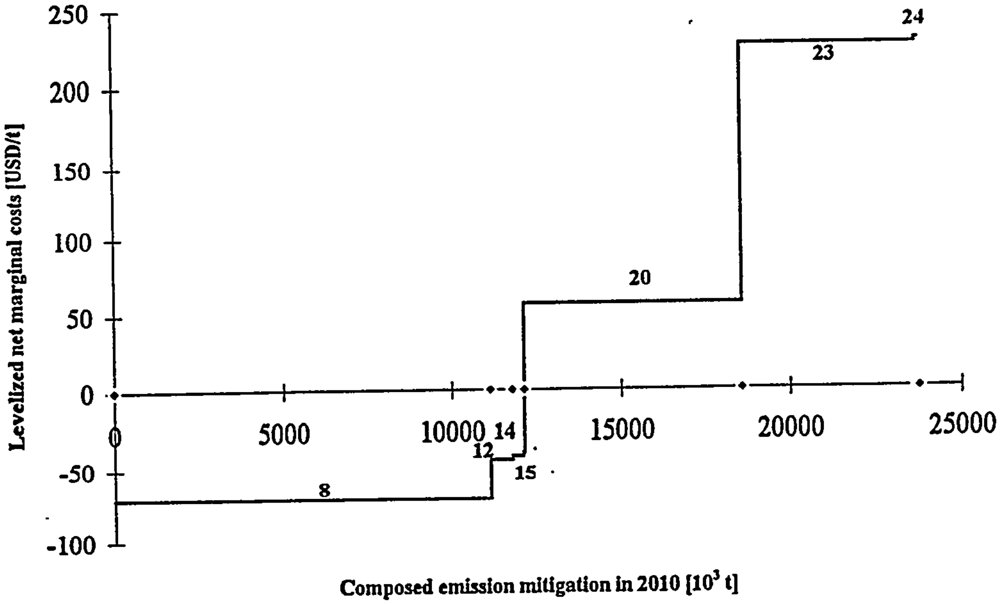


Fig.9.2.17. Measures of GHG emission mitigation by increasing of natural gas consumption

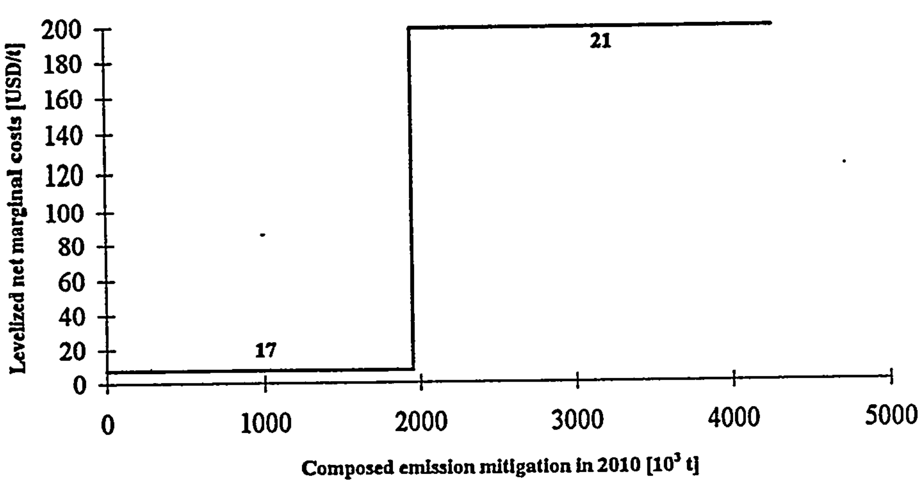


Fig.9.2.18. Final energy consumption in industry for different scenarios in 1988 - 2030

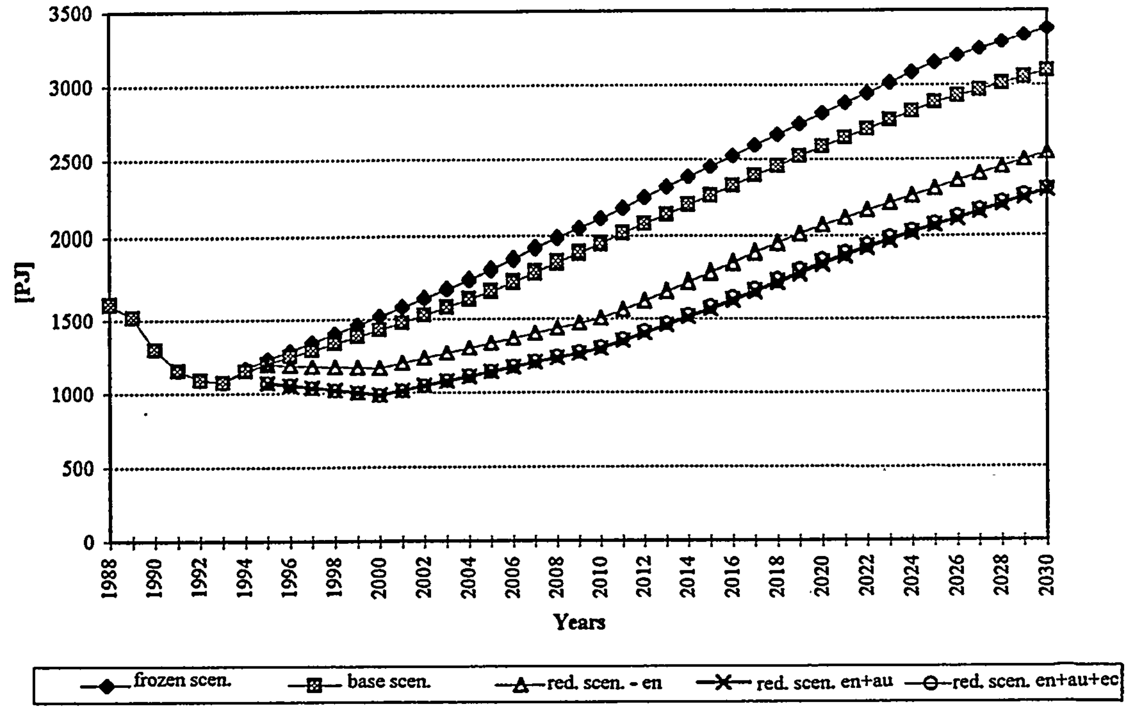
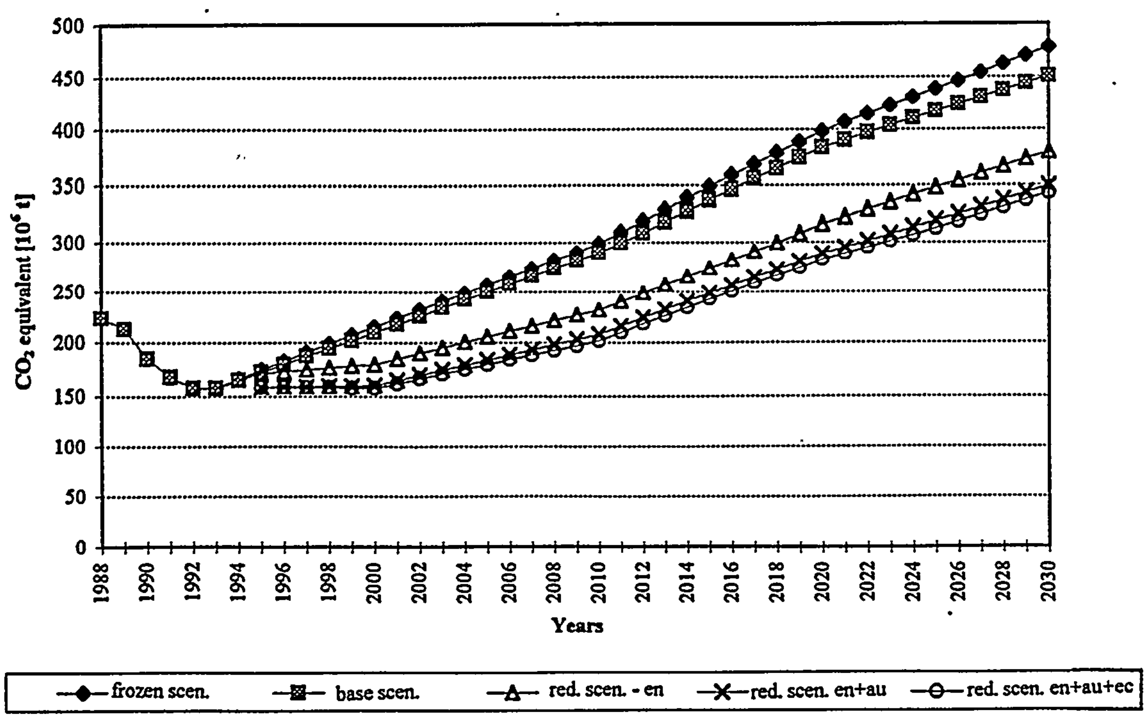


Fig.9.2.19. GHG emission from industry for different scenarios in 1988 - 2030



Reconstruction of Polish industry and first of all its energy-intensive branches, will require large support of the Polish government industrial policy. For that reason it is proposed to include options of technological reconstruction of energy-intensive industrial branches (metallurgy, chemical industry, mineral industry) into the GHG emission mitigation scenario. These options could take part in international bidding on GHG emission mitigation, especially when rule of a joint investment based on the least cost planning (joint implementation) will be developed.

GHG mitigation scenarios

GHG emission mitigation scenarios on the level 10%, 30%, 50% were assumed, counted against a base scenario. Achievement of the given mitigation scenario will be a set of technological options sorted. for example, from the least to the greatest unit (marginal) investment cost which allows to achieve the given level of GHG mitigation.

After analysis all of twenty four measures, the GHG emission reduction in 2000 was estimated at 50 million tonnes of CO_2 equivalent, which, against the base scenario is about 25 %; in 2010 at 90 million tonnes, i.e. about 30 %; in 2020 at 100 million tonnes, i.e. about 25 % and in 2030 at 107 million tonnes, i.e. about 24 %. As already mentioned in previous chapters, the above presented measures do not contain all opportunities of GHG emission reduction from industry. Further reduction of this one by 10 % would be possible by implementation of the best available technologies.

9.2.3. GHG abatement scenarios

Scope of choice of GHG emission mitigation aim

The choice of GHG emission mitigation aim in industry results from the final choice of the aim for national economy. It shows to what extent the results of GHG emission mitigation through implementation of technological options in industry are economically competitive, more effective and more credible in execution than options from other sectors of Poland's economy. It will be presented in the model-study for the whole economy.

Industrial study can be considered as autonomous, giving both strategy assumptions for industry and information for the strategy for Poland [Krawczyński F., 1994; Międzynarodowa, 1995; Założenia, 1995]. Scope of the aim choice is a derivative of the results of GHG emission mitigation and of the forecast execution of technological options:

a. *In a group of technologies to increasie energy efficiency (energy measures).*

This group represents 15 quasi-technologies [Demand, 1993, Guidance, 1994, Michalik J., 1992] in the entire industry (Tab. 9.2.2). 12 out of them are profitable, i.e. their implementation gives profit, in other words, gives negative investment cost (cost of GHG emission mitigation (Fig. 9.2.15). Fig. 9.2.15 and Tab. 9.2.2 show that it is possible to assume the GHG emission reduction aim to be 28 to 35 million tonnes in 2010. This amounts 56 to 70 % of described and evaluated options in this group. Taking into account this level of aim seems to be safe and realistic, because:

- about 30 % (according to energy consumption) of technologies which are not taken into account should give additional result of energy consumption and GHG emission reduction,
- gradual introduction of higher fees and penalties for the use of environment (carbon tax related to CO_2 emissions) should further increase profitability of energy measures and consequently stimulate greater reduction of GHG emission.

b. *In a group of technological reconstruction options regarding the energy-intensive branches of industry (autonomous measures).*

All options in this group of measures are or should be economically profitable, giving inherently lower unit costs, either due to the drop of energy costs or due to addtional production quantity or quality. Specification of unit GHG emission mitigation costs (LNMC) was presented in Fig. 9.2.14 and description of technological options of industry reconstruction in Tab. 9.2.2. In these options, in which the unit costs are positive (increased costs), results from increase of production quantity and quality are underestimated [Analiza, 1990, Ciecieręga R., 1995, Kirszensztein J., 1994].

The biggest share in GHG emission reduction from industry belong to the following technologies of industry reconstruction (Fig. 9.2.13):

- modernization of raw-material part of iron & steel metallurgy,
- technological modernization of chemical industry,
- technological modernization of refinery & petrochemical industry,
- modernization of mineral industry,
- modernization of non-ferrous metallurgy.

Total GHG emission mitigation in 2010 received as a result of implementation of the above mentioned activities will be 24 million tonnes of CO_2 equivalent, i.e. of about 30 % of total GHG emission reduction from industry. The increased effects of GHG emission reduction as a result of technological reconstruction of industry is shown in Fig. 9.2.16.

The greatest dynamic of GHG emission reduction (Fig. 9.2.20) occurs in the period of 1995-2005, so in accordance with the assumed dynamics of reconstruction of energy-intensive industrial branches. About the year 2000 it is possible to reach the competitiveness of these industrial branches on internal and foreign markets.

The reconstruction of Poland's industry brings about changes in the existing development trends at each particular branch of industry. The GHG emission reduction is a result of the implementation of autonomous measures influencing a of the existing structure of industry. Consequently this effect can be included in the choice of the level of GHG emission reduction.

c. *In a group of technologies of substitution of hydrocarbon fuels with lower emission factor for coal fuels (measures aimed GHG emission mitigation).*

This group is represented by two technologies. The first of them gives an insignificant, the second a significant increase of the unit investment cost (Fig. 9.2.17, Tab. 9.2.2). One can expect that GHG emission reduction by about 2 million tonnes of CO_2 equivalent can take place by the year 2010 from implementing the first technology, i.e. as a result of replacement of coal steam boilers in industrial heat and power generating plants by gas boilers, stimulated by environmental policy (which allows for emission standards and fees for the use of environment) and by energy policy (management of larger quantities of natural gas from import). Thus for this group the aim can be GHG emission reduction by 6 million tonnes in 2010.

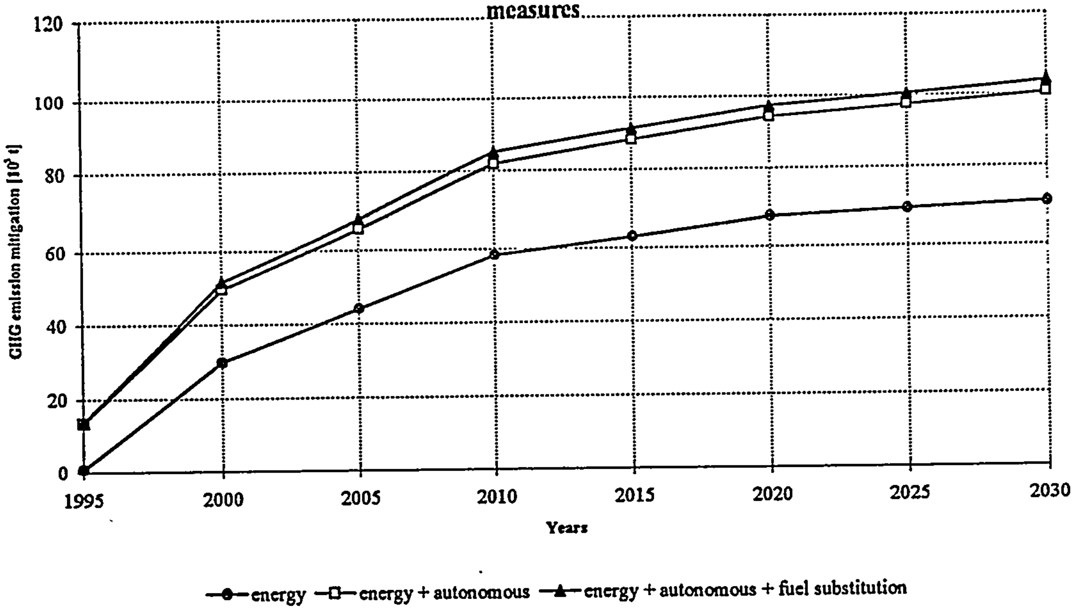
To sum up, aim of GHG emission mitigation in 2010 can fluctuate around the following values:

a.	from the group of energy technologies	28 , 35 million tonnes
b.	from autonomous technologies group (industry reconstruction)	24 million tonnes
c.	from the group of fuel substitution technologies	6 million tonnes
	Total	58 , 65 million tonnes

It constitutes 37 - 41 % of GHG emission reduction regarding the emission level from 1993 or 20 - 22.5 % of GHG emission reduction regarding the base scenario emission level in 2010 (Fig. 9.2.19).

For 2030 it is proposed to assume the GHG emission reduction aim as the sum of all described and evaluated in this report technologies, e.i. about 100 million tonnes. It is assumed that these technologieswhich are not commercialized yet and will not be till 2010, after this period will be profitable. As a result of there will be the GHG emission reduction by 22 % compared to the emissions from the base scenario in 2010 (Fig. 9.2.19).

Fig.9.2.20. GHG emission mitigation from industry in 1995 - 2030 according to group of measures



General assumptions of the strategy of GHG emission reduction from industry

Untill 2005

Untill 2005, in a short-term period, the so called "first wave" technologies will be implemented, i.e. such technologies that are already economically justifiable but at present are not yet fully widespread on the market. It is mainly related to the Polish industry reconstruction aiming at its adaptation to the competition on foreign and internal markets.

The main expression of state intervention on the market should be the industrial policy and ownership-organizational transformations. In the nearest years, i.e. in the period 1995 - 1997 the integrated energy and environmental policy should be created which will produce an additional incentive for faster penetration of the efficient and the environmentally friendly (including climate protection) technologies on the market, especially the energy and substitution of energy carriers technologies.

The ownership-organizational transformations and further bringing of energy carriers prices to a more realistic level should promote better use of potential of no- and low investment measures connected with the so called good energy management and economy. This can provide the additional reduction of energy consumption (GHG emission mitigation) by about 5 - 8% in the entire industry. Consequently by as much can increase the effect of technological changes on GHG emission described in this report.

Within 2005 - 2020 period

In 2005 - 2020, i.e. in the period of middle-term horizon of technological changes, those technologies will be implemented which actually are technically viable but up to date can be not feasible economically. At the beginning of this period also the final effects of implementation of the so called "first wave" - technologies will take place, especially energy technologies. This, because of finalizing of the process of energy carriers prices reflecting the costs (regarding the long-term marginal costs of development) in 2000 - 2005. The Polish industry will begin to integrate with European Union structures, therefore the more rapid transfer of modern technologies to Poland will be possible. It is foreseen that the global climate protection policy will develop along with legal obligations of particular countries in framework of signed conventions. In this environment the natural environmental protection policy and its instruments such as: "carbon tax" [Chandler, 1990, Energy, 1993], international emission trade and common investment ("joint-implementation") policy will have stronger influence. The period till 2005 Poland can utilize to create the analysis an decision making bases to prepare itself for creating GHG emission mitigation policy and to contribute considerably into global climate protection policy. This can have a great importance in both availability and attractiveness of capital investment in Poland, therefore in a faster development of Polish industry.

After 2020

After 2020, i.e. in long-term time horizon, technologies of so called "third wave" will be implemented which at present are not viable in practice and efficient in full production scale and are in a research and development phase. Results of these technologies as well as to large extent of the "second wave" technologies are not included in this report, therefore the real forecast of GHG emission reduction can be greater.

The basis of the Polish industry strategy should be the early participation (as possible immediately) in common international institution (OECD, IEA) which coordinate and co-finance research and development, at least regarding the access to information concerning the advanced technologies and create country centers of information and advising.

9.2.4. GHG abatement costs

Methodology of evaluation of technological option of GHG emission mitigation

Methodology to evaluate the technology option is based on unit costs of GHG emission reduction [Worrell E., 1992]. The basis for costs calculating is the *Calculation Sheet* prepared by the Coordination Team in order to bring about the unification of costs accounting within the whole Country Study.

The unit, marginal, discounted cost of GHG emission mitigation cost LNMC is the average levelized cost in all life cycle of technology, which was calculated as follows:

$$LNMC = \frac{LNC \text{ - total net mitigation cost}}{RED \text{ - reduced emission amount}} \qquad 1$$

where:

LNC - total net GHG emission mitigation cost is the sum of changes of introduced and replaced technologies costs:

(1) DI - change/difference of investment cost,
(2) DKZ - change/difference of variable costs (excluding fuels and energy costs),
(3) DKP - change/difference of fuels and energy costs,
(4) DWP - change of production value, e.g. lost production value

The interpretation of specific cost is as follows:

- sign "-" means that option is profitable from a investor's point of view,
- sign "+" means that option is unprofitable from an investor's point of view,
- the higher the absolute value of costs with sign "-", the more profitable the technological option is,
- the higher the absolute value of costs with sign "+", the less profitable the technological option is.

For profitable options the additional evaluation criterion is an Internal Rate of Return (IRR).

Investment outlays

Execution of GHG emission mitigation measures in industry needs considerable investment outlays (Tab. 9.2.3). In the period 1995 - 2030 about 95 billion USD in total should be allocated for this purpose. This amount can be split as:

- energy measures - about 14 %,
- autonomous measures - 78 %,
- fuel substitution - 8 %.

In particular periods repartition of investment costs is as follows:

1995 - 1999	- 16.0 %
2000 - 2009	- 28.5 %
2010 - 2019	- 24.0 %
2020 - 2030	- 31.5 %.

List of specific investment outlays regarding the GHG reduction for particular measures is given in Tab. 9.2.2 as well as illustrated in Fig. 9.2.14 to 9.2.17.

Table 9.2.3 Investment cost for GHG emission mitigation in industry in 1995 -2030

No of measures	Group of measures	Investment cost in years [10^3 USD]				
	Energy measures - en	1995-1999	2000-2009	2010-2019	2020-2029	2030
1	High-efficiency lighting	22209	52982	8394		
2	Monitoring of production processes	17040	66799	11602		
3	High-efficiency electric motors	103197	831984	152216		
4	Improvement of steam economy	115384	1081885	714407		
5	Electronic control of electric motors	9335	438960	71071		
6	Blast furnance gas pressure turbines	61250				
7	Improvement of energy management in industry	983671				
9	Heating processes - heat recovery in the recuperators	159705	53235			
10	Modernization of heating furnaces	179638	73373			
11	Heating processes - heat recovery in the boilers and evaporated instalations	145593	62397			
13	Utilization of chemical energy of basic oxygen furnace gas	6632				
16	Improvement of efficiency of energy using machines & divices	738644	246215			
18	Generation of electricity in industrial combined cycle power plants	325000	50000			
19	Generation of electricity from colbed methane in power plants - combined cycle	1302180	2604360			
22	Dry coke quenching installation	2125000	820000			
	Subtotal	**6294478**	**6382191**	**957690**		
	Autonomous measures - au					
8	Modernization of raw - material part of iron & steel metallurgy	1526620				
12	Enlargement of cement production by dry method using	4410	216300			
14	Enlargement of lime production in Maerz furnaces	12100	18700	40300		22000
15	Implementation of modern zinc electrolyze		18900			
20	Technological modernization of chemical industry	2000000	6300000	9000000	12000000	
23	Technological modernization of refinery & petrochemical industry	3000000	9300000	12500000	18000000	
24	Alumina electrolyze by using of agglomerated anodes		240000			
	Subtotal	**6543130**	**16093900**	**21540300**	**30000000**	**22000**
	GHG emission mitigation measures (by fuel subtitution) - ec					
17	Replacement of coal, steam boilers (capacity < 20 t/h) by gas boilers in industrial power plants	67180	105200			
21	Co-generation of elecricity and heat in industrial power plants by enlarged using of natural gas	2700000	4515000			
	Subtotal	**2767180**	**4620200**			
	TOTAL	**15604788**	**27096291**	**22497990**	**30000000**	**22000**

9.2.5. Policy measures activating abatemnet options

A. Structural changes and technological reconstruction of industry

Causative forces	Programmatic activity	Instruments	Influence period
1. Adaptation to international competition and gaining competitiveness on internal and foreign markets.	1.Macroeconomic market reforms	1. Organizational and ownership changes forcing greater economy efficiency and development capacity (demonopolization, commercialization and privatization etc.). 2. Setting prices of energy carriers at the real level regarding the marginal costs of energy sector development	successively till 2000 1995 - 1997
2.Needs of reconstruction and modernization of production potential 3. Adaptation of production capacity towards the rationalized market demand. 4. Necessity of employment rationalization in heavy industry for less capital-intensive medium and small enterprise sector.	2. Industrial policy	**1. Planning:** 1.1.Updating, approval and implementation of the following reconstruction programs: - metallurgy, - fuel & energy sector, - heavy chemical synthesis. **2. Financial:** 2.1. Creation of state financial guaranty system supporting reconstructing programs for heavy industry. 2.2. Stimulation of establishing of consortiums of banks for financing of reconstruction. 2.3. Construction of investment tax credit system according to state strategy of industry reconstruction. 2.4. Creating of conditions promoting small and middle enterprises development. Review, amendment and use of law, especially civil and commercial law, in context influencing the establishment and operation of small and medium enterprises as well as regarding coherence with European Union regulations. 2.5. Stimulating of development of non energy-intensity and modern industry sectors, so called "high chance sectors". **3. Information:** 3.1. Elaborating and implementation of monitoring system of structural changes and technological industry reconstruction (including impact on energy consumption changes and pollutions emission). 3.2. Defining of research & development works directed towards modern, environmentally friendly, as well as material- and energy-saving production technologies and ensuring their financing. 3.3. Including of country research & development base into process of organizational and ownership changes in industry.	1995 - 1997 till 2000 till 2002 till 2002 1996 - 2005 1995 - 1997 till 2010 till 2010 1995 1996 1996

B. Technologies of energy efficiency increase (quasi-technologies - cross-branches technologies)

Causative forces	Programmatic activity	Instruments	Influence period
1. Market mechanisms forcing competition and decrease of production costs. 2. Increasing profitability of measures regarding the energy efficiency and at the same time making energy prices real. 3. Legal, economic and information stimulating of measures regarding the energy efficiency for breaking of market defects, so called investment disequilibrium of investment supply and demand side of energy. 4. Importance of natural resources, incl. energy exploitation efficiency for improvement of environmental condition.	1. Energy policy	**1. Legal** 1.1. Creating of new energy law which would regulate: - opportunity and investment profitability for producers and grid distributors of energy carriers for energy efficiency by energy users, - construction of principles of prices and tariffs for these energy carriers which stimulate energy efficiency, - defining of standards and implementation of requirements of energy efficiency of devices offered on the market.	1995
		2. Financial 2.1. Implementation of accelerated amortization system for devices with high energy efficiency. Implementation of amortization duty of such devices into amortization act in the period till 4 years for enabling - in a consequence - an earlier use of profit.	since 1997
		2.2. Stimulating innovative financing form of measures, including pilotage additional capitalizing (under commercial law) by state agencies of self-financing firms based on dividing of profit from energy cost-saving (firms of ESCO type).	1996 - 1997
		2.3. Including into investment tax credit system preferences regarding the devices with high energy efficiency.	since 1997
		2.4. Implementation into criteria of additional financing environmentally friendly heat sources in industry by Environmental Protection Funds (National, Voivodship), principles of sustainable investing both on the supply and demand side (IRP, LCP).	since 1996
		3. Information: 3.1. Funding of auditing of energy efficiency increase in small and medium industrial enterprises.	since 1998
		3.2. Elaboration and implementation of voluntary agreement system between energy suppliers and industrial enterprises on a long-term increase of energy efficiency and GHG emission reduction.	since 1998
		3.3. Institutionalizing and financing of professional data bases as well as guidance regarding energy-saving and environmentally friendly technologies, connected with international OECD/IEA systems as: CADET, GREENTIE, EPA etc.	since 1996

C. Technologies of substitution of hydrocarbon fuels with lower emission factor for coal fuels and renewables energy carriers

Causative forces	Programmatic activity	Instruments	Influenc period
1. Necessity of adaptation to the domestic and, in the near future, international standards of permissible emission of pollutants. 2. Growing economic competition and requirements for the comfort of use of environmentally friendly energy carriers (natural gas, liquid fuels). 3. Necessity of using enlarged (150-200% as compared to actual consumption) natural gas supplies by new pipeline from Russia as well as domestic potential including coalbed methane.	1. Environmental policy	**1. Legal:** 1.1. Standards of permissible pollutions emission into air: - national, - international (European Union) 1.2. Implementation of so called pollutions emission trade taking into account energy sources integrated planning principles, i.e. engagement of a polluter (energy source) in the reduction of energy consumption by energy users. 1.3. Implementation of standards regarding the energy pollutions emission for smaller heat production units. **2. Financial** 2.1. Adaptation of payment system for the use of environment to marginal costs of pollutions mitigation. 2.2. Progressive (educational) and later a significant increase of charges for CO_2 emission (so called "carbon tax"). 2.3. Tax credits (VAT, income taxes) for elimination of non-efficiency and polluting small furnaces and boilers and replacement of it by gas- and liquid fuels-fired ones. 2.4. Elaborating of new principles of using of National Fund of Environment Protection and Water Management NFOS (Narodowy Fundusz Ochrony Srodowiska i Gospodarki Wodnej) resources to enable energy producers to finance environmental protection investments directly from fees for the economic use of environment as well as participation of NFOS as a joint-venture shareholder.	 till 2000 since 2000 since 1998 1998 till 2000 reasonable; after 2000 significant 1997 - 2005 1995
	2. Energy policy	**1. Legal:** 1.1. Use of regulation system of new energy law for pro-ecological and pro-efficiency behaviours of energy utilities including gas utilities. (Act from ... 1995 "Energy law" - Art. 17, 18, 21, 25, 28 and 29).	since 1996
	3. Integrated energy and ecological policy	1. Coordination of energy and environmental policy instruments according to the least costs principle of energy sector and maximizing of results of environmental pollution emission mitigation.	1996 - 1997

9.2.6. Conclusions

1. The Polish industry in the period between 1950-1989 was characterized by near fourty-years long tendency of decreasing energy-intensity and pollution emission as well as sold production of industry. In the period of 1970 - 1994 energy-intensity of sold production dropped by 53 % (in fixed prices 1990) [Roczniki, 1970-1994]. Nevertheless both economic and technological progress in developed countries were faster. As a result of this, the economic potential of energy efficiency increase in particular branches of industry amounts to 20 - 55%. At the same time directly in final energy carriers consumption or indirectly by producing electricity and heat, dominates coal with high GHG emission factor. Because of that, Poland is one of the countries with highest level of GHG emission per unit of added value of industrial production.

2. In the transition period from centrally planned to market economy of 1989 - 1993, the Polish industry reduced its final energy consumption from 1561 PJ/year in 1989 to 1123 PJ/year in 1993, i.e. by 28 %. This drop is mostly due to the reduction of sold production by 27 % and, to a much less extent, is the result of change of industrial branches structure (2 % contribution). At the same time there was disadvantageous increase of energy consumption by 1 % as a consequence of decrease in effective use of energy (Tab. 9.2.1, Fig. 9.2.21) [Gospodarka, 1970-1993, Pasierb S., 1995]. At the same time in the period of 1989 - 1993 the decrease of GHG emission (CO_2 equivalent) occured in the industry, in this case from about 201 million tonnes in 1989 (counted together with emission from electricity and heat generation) to about 149 million tonnes in 1993, i.e. by about 26 % (Tab. 9.2.1, Fig. 9.2.22).

   This drop (in the amount of 26 %) of GHG emission from industry can be attributed to:

   - decrease by 27.3 % as a result of sold production drop,
   - decrease by 2.0 % as a result of industrial branches structure change,
   - increase by 3.4 % as a result of worsening of effective use of energy,
   - small decrease as a result of energy carriers structure change [Pasierb, 1990].

   Only the recent years, i.e. from 1992 to 1994 brought the improvement of effective use of energy in industry. It began the positive trend of energy consumption in industry, with the increased value of the sold production. By maintaining this trend, the Polish industry would have the chance to return to the sold production level of 1989 with reduced by 23 % final energy consumption.

3. The opportunities to reduce energy consumption and GHG emission from industry are a result of both industrial branches structure change to less energy-intensive and implementation of technologies with better energy utilization and more friendly for the environment (lower emission of pollutants, including GHG) technologies. In the report it was evaluated e.g. for 2010 the opportunity of GHG emission reduction by about 88 million tonnes, i.e. by about 40 %, compared to 1988 level and about 30 % regarding the base scenario, compared to GHG emission in 2010.

   GHG emission reduction in 2010 can happen as a result of:

   - reduction by about 58 million tonnes as a result of energy efficiency increase in universal, cross-branches technologies, so called energy technologies,

   - decrease by about 24 million tonnes as a result of technological reconstruction of production in energy-intensive industrial branches,

   - decrease by about 6 million tonnes as a result of energy carriers structure change in industry, in other words of growing share of hydrocarbon fuels, especially natural gas.

   Additionally, comparing the base scenario to a frozen scenario, further GHG emission reduction by about 9 million tonnes can take place as a result of shifting from energy intensive production to less energy intensive technologies.

4. Most of the evaluated technologies, i.e. about 67 %, is characterized by negative investment cost of GHG emission mitigation, i.e. their implementation is feasible from economic point of view. On the other hand this part of production technology which is a result of reconstruction of industry brings about the so called autonomous effect of energy consumption reduction and GHG emission reduction. The criterion of undertaking the decisions regarding their implementation is not only energy cost but mainly a capability of

outliving and adaptation for foreign market competition. The aim choice was proposed within these criteria. i.e. GHG emission reduction level in 2010, which oscillate around 58 - 65 million tonnes. It is 37 - 41 % of GHG emission reduction level of the 1993 or 20 - 22,5 % in regard to the base scenario in 2010. The choice of this aim in industry which could be the subject of Poland's obligations in the framework of international conventions seems to be a level of reasonable political risk, because in industry the effect of GHG emission mitigation is underestimated. This underestimation is a result of about 30 % of technologies in industry were not the subject of this analysis as well as because of that in the analysis it is not taken into account the impact of implementation no- and low investment measures which are a result of better management and energy economy.

5. Achieving the GHG emission reduction by about 20 % by the year 2005 (regarding the base scenario) would stimulate the instruments of the state industrial policy towards reconstruction of the Polish industry [Ocena, 1995]. It will have impact on both the industrial branches structure changes increasing the share of less energy-intensive industrial branches and on the technological reconstruction of most energy-intensive branches. The period till 2000 should be used for preparation of energy and environmental policy instruments which will increase energy efficiency and energy carriers substitution towards enlarged share of natural gas. Integration of energy and ecological policy and their instruments can create a good initial position for defining and implementation of GHG emission mitigation strategy. In this way, at the beginning of the next century Poland can present to international community both already achieved results regarding the GHG emission mitigation and can offer a set of prepared measures referring to climate protection in a framework economic and politic cooperation. After 2005 the force of influencing the instruments of implementation of GHG emission mitigation strategy should be predominated by developed instruments of integrated energy and environmental policy. Part of them can be adapted within framework of international cooperation regarding the climate protection.

6. Going out from technology positions, so called "first wave" technologies (currently viable technically, commercialized and profitable for implementation) it is possible to construct the scenarios of GHG emission reduction in industry only by 30 % as compared to base scenario. It seems however that it is not possible to construct the scenarios for GHG emission reduction by 50 %. In the time horizon till 2030 it can be changed by faster economic progress of so called "second wave" technologies (actually feasible but yet not profitable) or deeper changes of industry structure for modern, non-energy-intensive industrial branches and to some degree, further increase of natural gas consumption.

7. Taking into account the necessity of industrial reconstruction and its adaptation towards the requirements of international competition, the Polish industry has a chance of significant reduction of energy consumption and GHG emission to some extent as an autonomous effect. This feature of the Polish industry development, can supply Poland with a number of economic and political arguments on international forum as criteria favorable to political and economic integration of Poland with OECD-countries. Therefore preparation and implementation of GHG emission mitigation strategy, including also the one in industry, in framework of integrated energy and economic policy as well as active participation in international institutions of climate protection can bring a number of profits to Poland, mainly because of:

   - joint investment, so called "joint implementation", in Poland,
   - receiving more favorable climate on international financial market (World Bank, European Bank of Investment - EIB, European Bank of Reconstruction and Development - EBRD, financial corporations) for financing of the Polish industry reconstruction.

Fig.9.2.21. Final energy consumption change in industry in 1993 (regarding to 1989)

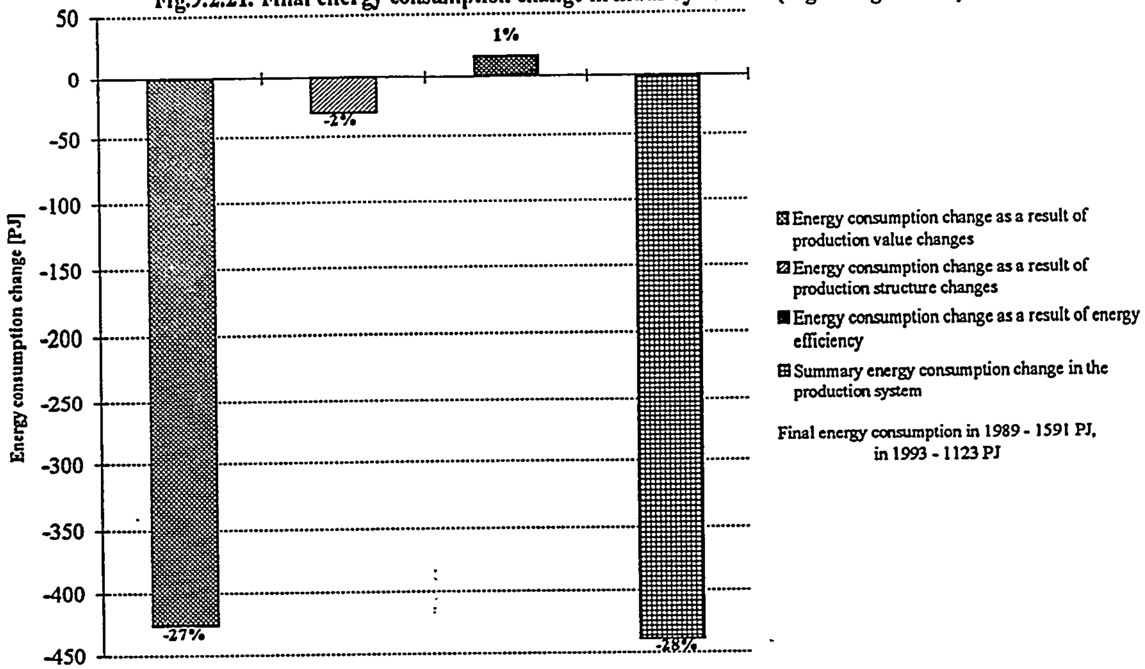
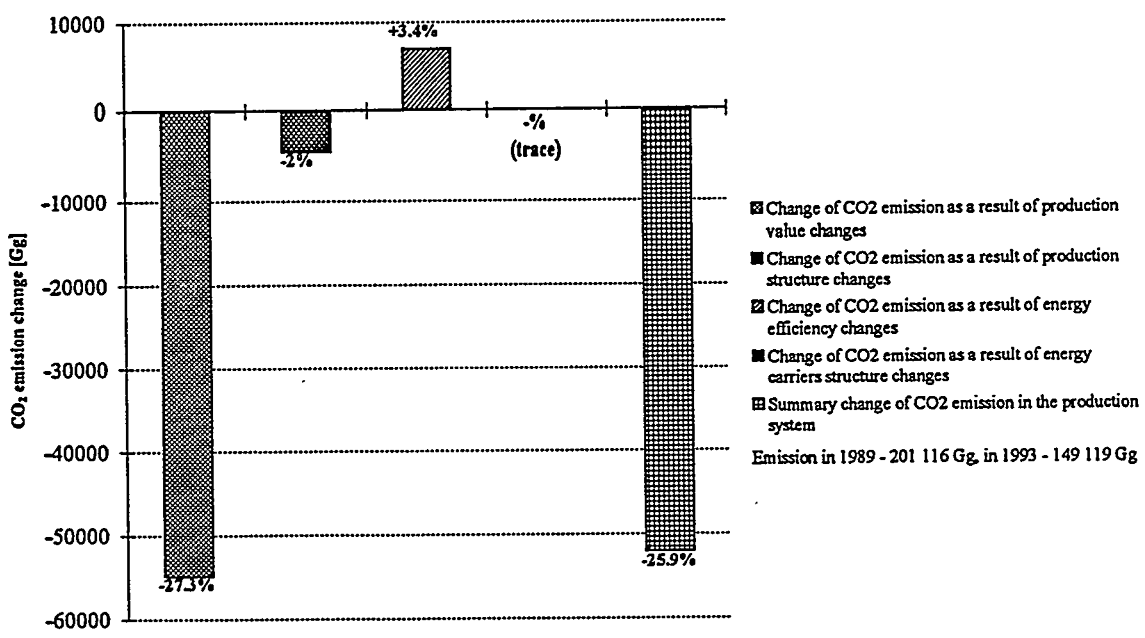


Fig.9.2.22. CO_2 emission change in 1993 (regarding to 1989)



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9.3. Municipal Sector

Methodological Assumptions

An emission of greenhouse gases which results from the use of energy in municipal sector has been estimated on the basis of a consumption of different energy carriers and applied technologies of energy conversion to cover identified needs in the sector. In particular stages of the project the following problems were considered:

- basic, identifiable aims of energy use and the final energy demand,
- current standards of energy receivers and their possible changes,
- applied and possible technologies of energy use,
- possibilities for changes of standards and methods of energy use resulting the GHG emission,
- proposed strategies for the emission reduction.

The current and predicted consumption of the final energy was estimated using the „bottom-up" approach on the basis of the energy demand and applied technologies of conversion and supply. A complete verification of the obtained results with the "top-down" approach is not possible because of differences between assumed scope of analysis and the division of the national economy on sectors and branches in Polish statistical descriptions. The „bottom-up" approach was applied also for studies on GHG emission from landfills.

The following aims of energy use in households were considered:

m.1 room heating
m.2 warm sanitary water heating
m.3 room (space) lighting
m.4 cooking
m.5 food cooling
m.6 audio-visual equipment power supply
m.7 appliances and others power supply

inside non-residential buildings in the municipal sector:

n.1 space heating
n.3 space lighting

outside:

d.3 street lighting and external lighting of buildings.

It was impossible to even roughly identify energy consumption for other purposes because of their variety, especially the variety of the electricity use for non-residential needs. An attempt was made to estimate the total energy consumption to fulfil those needs. It was also assumed that indicative demand for the warm sanitary water in households, estimated for the whole population with a use of factors of specific water consumption including the warm sanitary water consumption outside the households.

The energy consumption for the particular identified needs was estimated using specific demand factors and accessible statistical data:

- demographic statistics,
- data on residential buildings, applied space heating systems, equipment in warm tap water and gas plumbery,
- data on the increases of cubature of non-residential buildings,
- data on the consumption of particular energy carriers in households,
- other data on detailed problems.

The results of the National Census from 1988, the additional estimates for 1992 and other selected data for the years 1945-1988 were analysed. Values of factors of specific demand were accepted on the basis of:

- technical data of devices, materials and objects,
- design recommendations in use,
- Polish Standards,
- literature data,
- results of inquiry research,

- or experts opinions.

A prediction of changes in energy use are based on accessible prognostic reports and experts opinions.

Remarks on the procedure of the reduction scenarios elaboration

Scenarios of reduction of greenhouse gases emission were elaborated with assumptions on implementation of particular option of the GHG emission reduction and foreseen changes of standards resulting in the increase or decrease of energy consumption. Time and rate of implementation of a particular option were assumed subjectively without a deeper analysis of development limitations in other economy sectors.

9.3.1. Sector description

The objective of the project was to determine possible strategies of the reduction of the GHG emission resulting from energy use in households and other stationary objects - non-residential buildings (except for industrial or agricultural ones) - in commercial sector and public utility services. Other non-energy sources of GHG emission, such as landfills, were also considered.

Information about housing resources in Poland is given in table 9.3.1.

Table 9.3.1. Dwellings

year	data source	number of dwellings [million]	usable area [million m^2]
1988	National Census	10,7	633
1992	published statistical data	11,3	676
1995	estimates	11,5	692

Equipment of the dwellings is differentiated. According to the estimations for 1992 about 60% of the dwellings in towns and cities was supplied with heat from municipal heating systems of local boiler-houses. The most of dwellings in the villages (57%) was heated with solid fuel fired stoves, and about 31% was equipped with internal central heating system (CH systems) with solid fuel fired boilers. 5 - 8% (energy rate) of fuel fired in these stoves and boilers was wood. More than 82% of the dwellings in towns and only 52% in the rural areas had warm sanitary water plumbery. Network gas was supplied to more than 3/4 of the dwellings in towns and only 10% in villages. In rural areas more than 60% of dwellings were not supplied with any gas. Since 1988 to 1992 a number of LPG receivers rapidly increased. Decline of consumption of natural gas in industry made it possible to increase consumption of gas in households, particularly in rural areas where the number of network gas receivers doubled in 1988-1992.

An average demand for space heating is relatively high in Poland. It is said that the demand is almost two times higher than, for example, in Sweden. This situation is a consequence of several factors, such as bad thermal insulation of external walls and roofs, too high heat transmission through windows, bad quality of windows frames, no control of ventilation, inefficiency of control valves in internal central heating systems, a lack of automatic control devices in CH systems, lump-sum accounting in network heat supply not related to a real current energy consumption. The maximum thermal power demand for space heating in multiapartment houses is 21 - 28,5 W/m^3, while in one -family houses 31 W/m^3 to over 40 W/m^3.

The energy demand for warm sanitary water heating depends on the water supply or heating system, the kind of energy carrier in use, rules of accounting for the carrier (or the warm water) supply, and addopted standards of living. Selected factors of warm sanitary water consumption are given in table 9.3.2 after [Mańkowski, 1981].

Table 9.3.2. Selected factors of warm sanitary water consumption

	dwelling category	warm water consumption [l/ca•day]
[Chybowski, 1973]	a dwelling with a bath, a wash-hand basin and a sink	75
	a dwelling with a shower, a wash-hand basin and a sink	50
[Górecki, Krzyżyński, 1969]	a dwelling with a bath, a wash-hand basin and a sink	120
[Recknagel, 1976]	in cities	60 - 80
	in smaller towns	40 - 60

Basing on analyses of the energy carriers consumption for the warm water generation it was accepted that the average consumption of the warm water in the dwellings which are supplied with the water generated outside the dwelling is about 80 l/ca•day, where the water is heated in geysers or boilers supplied with gas network 60-65 l/ca•day, with electric heaters 55 l/ca•day, with LPG 50 l/ca•day, with solid fuels 40 l/ca•day. It was accepted as well that in the dwellings with no plumbery or devices for the warm water preparation or supply, the water for sanitary needs is heated first of all on kitchen stoves (solid fuel fired) or with electricity in the amount 10 l/ca•day.

Applied methods of cooking depends also on the dwelling equipment in energy systems. An estimated structure of cooking methods in 1992 is given in table 9.3.3.

Table 9.3.3. Structure of applied cooking methods in 1992

	towns/cities	villages
coal fired stoves	8 %	58 %
gas range - LPG	11,5 %	22 %
gas range - network gas	75,5 %	11 %
electric	5 %	8 %
microwave	≈ 0 % [1)]	≈ 0 %

[1)] in 1993 in use in 3-4% dwellings in towns

The state of lighting in dwellings is characterized by an factor of power of lighting sources for a unit of useable area of the dwelling. According to experts opinion it is 20 W/m^2 in Poland in recent years. The inquiry researches indicated that rates of light sources of particular electric power in the their total number is the following: 23,9 % up to 40 W, 39,7 % of 60 W, 20,0 % of 75 W, 15,7% of 100 W, and 0,7 % of higher power.

The equipment of households in electric devices and appliances is given in table 9.3.4. The data were collated on the basis of the surveys of the Main Statistical Office (GUS) and Polish Foundation for Energy Efficiency (FEWE). The summary of the GUS research results were published in [GUS, 1995].

Table 9.3.4. Appliances and audio-visual devices in households

	an average for a household
washing machines and spin-driers	1,29
in this: impeller-type washing machines	0,77 [1)]
authomatic washing machines	0,51 [1)]
refrigerators and freezers	1,27
in this: refrigerators	0,99 [1)]
freezers	0,28 [1)]
TV-sets	1,29
radio	1,14
video-tape recorder/player	0,48
vacuum cleaners	1,02
computers	0,10

[1)] according to FEWE

The consumption of the energy carriers in households in 1992, according to GUS data, are given in table 9.3.5. According to the analysis of energy consumption for different purposes one can suppose that the real consumption of electricity in dwellings in rural areas was about 2 TWh higher than reported in official statistical descriptions, being about 11 TWh. The consumption of solid fuels in households was also higher than reported for the rural areas, and a part of this consumption was included in the fuel use reported for the agriculture production. Consumption of electricity in households has been growing. In the period between 1989-1992 the rise was about 2 TWh yearly.

Table 9.3.5. Consumption of energy carriers in households in 1992

carrier	unit	consumption
electricity	TWh	23,4 [1)]
coal and derived solid fuels	PJ	584
thermal energy from municipal heating systems and local boiler-houses	PJ	292,5
network gas	PJ	160
LPG	PJ	6,6
other fuels, incl. timber	PJ	34

1) In this about 5 TWh in private farms for living needs; together for villages, according to GUS, 9 TWh - source: "Sprawozdawczość o odbiorcach i zużyciu energii elektrycznej według podziału administracyjnego"

Average efficiencies of energy generating devices and efficiencies of use are given in table 9.3.6.

Table 9.3.6. Efficiencies of generation, transmission and use in selected devices and systems [Cherubin, 1995]

device, system, process	average energy efficiency [%]
Cogenerating Heat and Power (CHP) plants - professional (power industry)	82
industrial CHP plants - network heat generation	67-77
municipal heating stations	67
heat transmission and distribution in heating networks	85,5
small boilers in CHS	
- fired with solid fuels	45-55
- fired with gas fuels	80 - 85
- fired with oil fuels	80 - 85
gas water heaters	65 - 70
electric volume type water heaters	85 -90
solid fuel fired stoves	35 - 45
gas fired stoves	75 - 80
electric heaters - space heating	100
solid fuel fired kitchen stoves	25 - 35
gas cookers	65 - 70
electric cooking devices	80 - 85

A number, a cubature, and a technical condition of non-residential buildings is not known exactly. A growth of the are and the cubature of these buildings in different branches of the national economy has been reported since the 50's. The volume of these buildings was estimated in the project, based on the data on the cubature growth, demographic statistics, data on residential buildings development, and changes of standards. The rough results are given in table 9.3.7. The data on the cubature and the area growth in a particular category of the non-residential buildings were used also, as for housing, for defining their structure of construction technologies.

Table 9.3.7 Estimated cubature of non-residential buildings

	volume [mln m^3]
railway and/or bus stations	5
garages and depots	4
buildings for communication	42
shops, warehouses, services - commercial sector	181
buildings for municipal offices and services	81
buildings for science and technology (universities, institutes, etc.)	8
schools, nurseries, kindergartens, etc.	321
buildings for culture and art	16
buildings for health and social care	154
building for sport and recreation	30
other	38
TOTAL	880

The energy demand for space heating in these groups of buildings varies. The average peak thermal power demand for space heating equal to 27,4 W/m^3 was adopted after the analysis made for Warsaw and some other cities. This demand is about 8% higher than the average peak demand in residential buildings in the analyzed urban complexes.

Electricity consumption for lighting of non-residential space (apart of industry and agriculture) was estimated as 5,3 TWh in 1993 (it was over 6,7 TWh in residential buildings).

It is difficult to estimate the energy consumption in the considered groups of non-residential buildings as this consumption is only a part of reported by GUS energy use in particular economy sectors. The estimation was calculated based on the subtraction of the energy consumption for the residential needs from the energy consumption of so called "other" consumers in 1992. Comparison of these numbers with the energy demand only for space heating indicates that the consumption in the considered buildings is much higher.

Table 9.3.8. Energy carriers consumption in non-residential buildings in 1992 - estimation based on GUS statistical data

energy carrier	unit	consumption
electricity	TWh	9,6
coal and derived solid fuels	PJ	61,4
thermal energy from municipal heating systems and local boiler-houses	PJ	56,3
network gas	PJ	167
LPG	PJ	NA
other fuels, incl. timber	PJ	NA

The energy consumption for street lighting was 1,44 TWh in 1992 and is declining.

The emission of methane from landfills was estimated as 1,6 billion m^3 per anum according to the report of greenhouse gases emission from landfills. Unless a part of the methane emission is utilized the emission is not likely to change in the nearest 15 years because with the growth of the volume of waste, organic matter contents will decline [Maksymowicz, 1995], [Opęchowski, 1994].

9.3.2. Basic scenario of energy use and GHG's emission changes

The major assumptions adopted for the basic scenario of energy use and greenhouse gases emission in municipal sector are following.

According to the expert's report [Żarski, 1995] which is convergent with governmental prognoses, a development of residential buildings construction will be such that numbers of new dwellings constructed yearly will be as follows:

100 - 120 ths.	in the period 1995 -2000
200 ths.	in the period 2001 -2010
250 ths.	in the period 2011 -2020
300 ths.	in the period 2021 -2030.

In the same time the following numbers of old dwellings will be abandoned:

180 ths. (average 30 ths. yearly)	in the period 1995 -2000
600 ths. (average 60 ths. yearly)	in the period 2001 -2010
650 ths. (average 65 ths.yearly)	in the period 2011 -2020
700 ths. (average 70 ths.yearly)	in the period 2021 -2030.

In the condudted analyses it was assumed that the most numerous group of liqudated dwellings will be the oldest and the worst equipped in sanitary plumbery and heating systems.

A successive gasification of the country will take place. During the considered period network gas will be supplied to 30% of village dwellings and to 90% of dwellings in towns.

The dwellings equipment in warm sanitary water plumbery will be systematically improving. The ratio of the dwellings without warm tap water systems will decline to 45% in 2000, 30% in 2010 r., 15% in 2020 r. and 5% in 2030 in rural areas, and to 16% in 2000, 9% in 2010, 5% in 2020 and 3% in 2030 in towns and cities. As the result, the demand for energy for heating of sanitary water will grow. The demand for electricity will undergo a particular growth.

An increase of number of energy consuming devices in households and/or longer periods of their use (i.e. TV-sets, computers, dish-washers) were foreseen.

Changes of the cubature of non-residential buildings will be less dynamic as for the residential ones. It was assumed that total cubature of these buildings will increase to 990 million m^3 in 2000, 1097 million m^3 in 2010, 1233 million m^3 in 2020 and 1415 million m^3 in 2030.

New building will fulfill the current standards of thermal insulation.

The electricity consumption for street lighting is to be decreased to a half from 1992 to 1997 as the street lighting is currently being intensively modernized by local communities[Bąk, Gabryjelski, 1995].

The foreseen changes of use of the energy and of GHG emission are given in the following tables.

The predicted changes of the thermal power demand for space heating in residential buildings are illustrated in figure 9.3.1 and given in table 9.3.9. It was estimated that the power demand will grow from 90 GW in 1995 to almost 150 GW in 2030. The ratio of municipal heating systems and local boiler-houses will significantly increase from 30% in 1995 to over 41% in 2030. The ratio of individual CH systems with gas fired boilers will also increase significantly from 12% to 25%. The demand for stove heating will decline from about 32 GW (of final power) to 20 GW. The demand for energy carriers given in table 9.3.10 will change adequately to changes of final energy demand, generation efficiency, and times of use of maximum load.

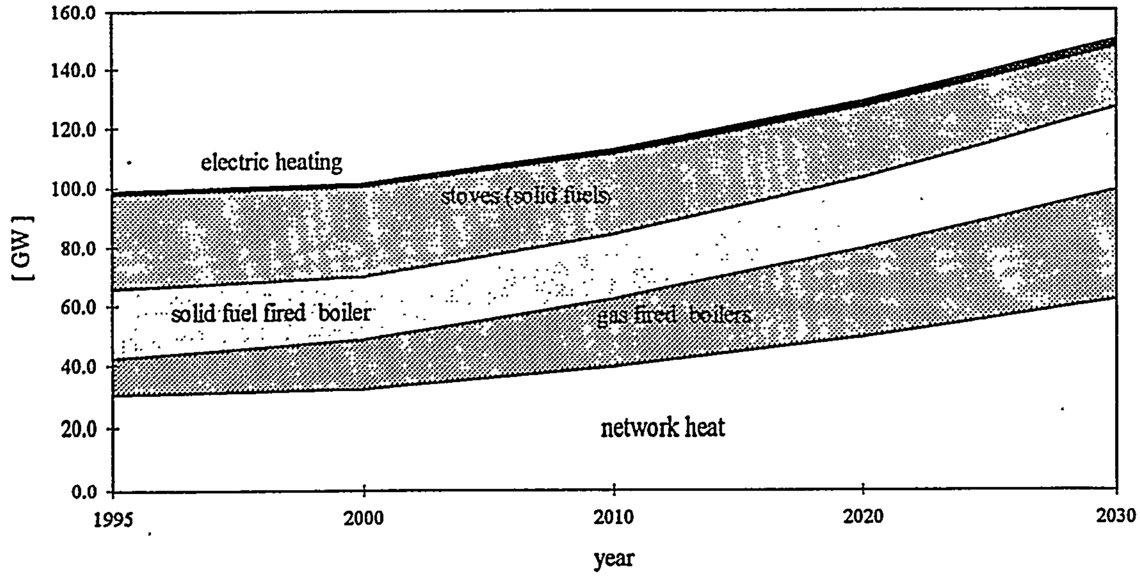

Fig.9.3.1. Final power demand for space heating in dwellings

Table 9.3.9. A structure of supply with final energy for space heating in residential buildings

system		1995	2000	2010	2020	2030
network heat - municipal	thermal power demand	30,4%	31,2%	34,7%	38,2%	41,3%
heating systems and local boiler houses	annual energy demand	36,2%	36,6%	39,4%	42,2%	44,7%
individual CH systems	thermal power demand	12,4%	16,4%	20,3%	23,3%	25,1%
- gas fired boilers	annual energy demand	14,1%	18,5%	22,4%	25,4%	27,1%
individual CH systems	thermal power demand	23,5%	20,8%	19,6%	18,6%	18,3%
- solid fuel fired boilers	annual energy demand	21,2%	18,5%	17,1%	16,0%	15,6%
stoves	thermal power demand	32,7%	30,4%	24,1%	18,4%	13,7%
	annual energy demand	27,4%	25,2%	19,7%	14,8%	10,9%
electric heaters	thermal power demand	1,1%	1,1%	1,3%	1,5%	1,7%
	annual energy demand	1,1%	1,2%	1,3%	1,5%	1,7%
TOTAL	thermal power demand	100,0%	100,0%	100,0%	100,0%	100,0%
	annual energy demand	100,0%	100,0%	100,0%	100,0%	100,0%

Table 9.3.10. Structure of demand for energy carrier for space heating in residential buildings

carrier	year	1995	2000	2010	2020	2030
network heat *** from a source	[PJ]	251,3	258,9	304,0	363,6	444,8
	ratio	27,9%	28,7%	32,0%	35,4%	38,5%
network gas	[PJ]	100,2	134,3	175,4	221,7	273,2
	ratio	11,1%	14,9%	18,5%	21,6%	23,7%
coal / coke	[PJ]	521,1	481,7	442,3	412,4	405,4
	ratio	57,8%	53,3%	46,6%	40,2%	35,1%
electricity	[PJ]	6,5	7,1	9,2	11,9	15,2
	ratio	0,7%	0,8%	1,0%	1,2%	1,3%
other fuels	[PJ]	22,8	21,3	19,2	17,5	16,6
	ratio	2,5%	2,4%	2,0%	1,7%	1,4%
TOTAL	[PJ]	902,0	903,3	950,0	1027,0	1155,1
	ratio	100,0%	100,0%	100,0%	100,0%	100,0%

Changes of the demand for thermal power and energy for space heating in non-residential buildings are given in tables 9.3.11., 9.3.12. and presented in figure 9.3.2. The foreseen increase of the final power demand is 54% in the considered period.

Table 9.3.11 Power and energy demand for space heating in non-residential buildings

year	1995	2000	2010	2020	2030
power demand [GW]	25,1	27,1	30,0	33,7	38,7
annual energy demand [PJ]	171,6	185,3	205,3	230,8	264,8

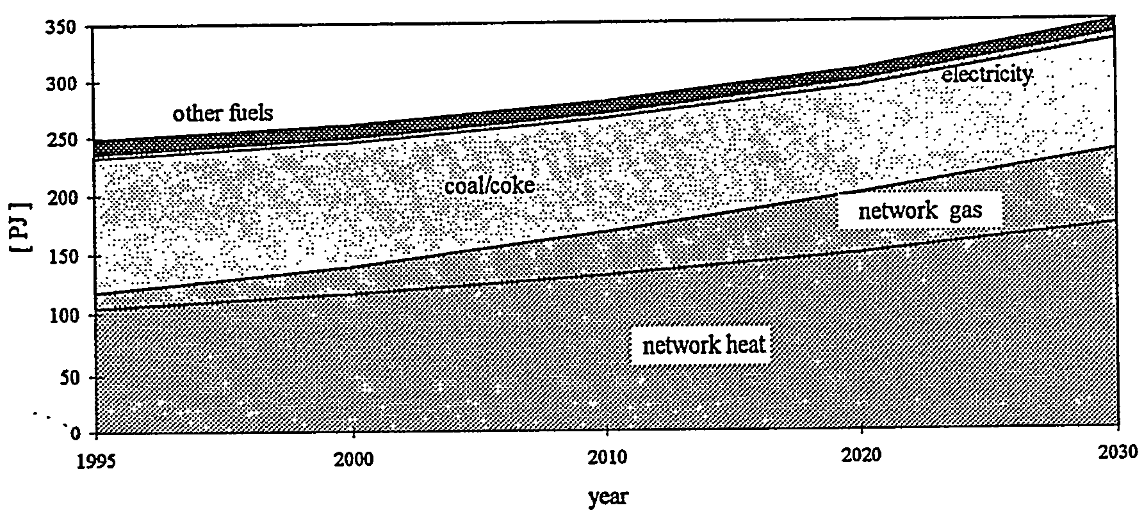

Fig.9.3.2.Estimation of energy carrier demand for space heating in non-residential buildings

Table 9.3.12. An estimation of demand of energy carriers for space heating in non-residential buildings

carrier	year	1995	2000	2010	2020	2030
network heat *** from a source	[PJ]	105	116	131	149	173
	ratio	42,1%	44,5%	46,7%	48.3%	49,5%
network gas	[PJ]	13	23	37	51	63
	ratio	5,2%	8,8%	13,2%	16,6%	18,1%
coal / coke	[PJ]	115	107	98	93	97
	ratio	46,3%	40,8%	34,8%	30,2%	27,7%
electricity	[PJ]	3	4	4	5	6
	ratio	1,3%	1,4%	1,5%	1,6%	1,7%
other fuels	[PJ]	13	12	11	10	11
	ratio	5,1%	4,5%	3,9%	3,4%	3,1%
TOTAL	[PJ]	248	261	281	308	349
	ratio	100,0%	100,0%	100,0%	100,0%	100,0%

The prognosis of changes of demand for power and energy in warm sanitary water and applied supply systems are given in the table 9.3.13. and illustrated in the figure 9.3.3. This demand will increase more than the population as standards for sanitary water use will be higher, particularly in rural areas. This will imply increased demand for electricity especially to the year 2020. The predicted consumption of energy carriers is given in the table 9.3.14.

Table 9.3.13. The demand of final power and energy for warm sanitary water generation

system	demand	1995	2000	2010	2020	2030
net work heat - municipal	power [GW]	2	3	3	4	4
heating systems and local boiler houses	energy [PJ]	65,42	66,48	80,69	96,50	110,79
water geysers	power [GW]	14	16	19	22	25
supplied with network gas	energy [PJ]	30,98	38,56	46,08	52,10	55,48
volume heaters	power [GW]	0,04	0,06	0,07	0,09	0,10
in systems with gas fired boilers	energy [PJ]	0,99	1,47	1,95	2,38	2,69
volume heaters	power [GW]	1,2	1,2	1,1	1,0	1,0
in systems with solid fuels fired boilers	energy [PJ]	31,78	30,36	28,49	26,78	26,54
electric heaters	power [GW]	2,5	3,9	4,6	4,6	4,2
volume and flow kind	energy [PJ]	20,7	32,4	38,5	38,9	33,6
water geysers	power [GW]	2	5	7	7	6
supplied with LPG	energy [PJ]	1,5	3,3	4,2	4,4	3,9
heaters in systems	power [GW]	0,10	0,09	0,09	0,11	0,12
supplied with other fuels	energy [PJ]	2,6	2,4	2,3	2,9	3,2
supplementary methods of water heating	power [GW]	0,15	0,09	0,05	0,03	0,03
for sanitary needs - electricity	energy [PJ]	0,89	0,56	0,28	0,12	0,09
supplementary methods of water heating	power [GW]	2,6	1,7	1,0	0,6	0,5
for sanitary needs - coal / coke	energy [PJ]	16,0	10,1	5,0	2,1	1,6
supplementary methods of water heating	power [GW]	0,15	0,09	0,05	0,03	0,03
for sanitary needs - other fuels	energy [PJ]	0,9	0,6	0,3	0,1	0,1
TOTAL	power [GW]	25	31	36	39	42
	energy [PJ]	172	186	208	226	238

Table 9.3.14. Demand for energy carriers for warm water generation

carrier	year	1995	2000	2010	2020	2030
network heat *** from a source	[PJ]	77,0	78,2	94,9	113.5	130,3
	ratio	32,5%	31,2%	34,7%	38.8%	42.4%
network gas	[PJ]	45,5	56,9	68,2	77,3	82,5
	ratio	19,2%	22,7%	25,0%	26,4%	26,8%
coal / coke	[PJ]	83,2	69,1	56,0	47,3	46,1
	ratio	35,1%	27,5%	20,5%	16,2%	15,0%
electricity	[PJ]	23,6	36,1	42,2	42,2	36,3
	ratio	10,0%	14,4%	15,5%	14,4%	11,8%
LPG	[PJ]	2,1	4,8	6,1	6,3	5,6
	ratio	0,9%	1,9%	2,2%	2,1%	1,8%
other fuels	[PJ]	5,7	5,9	5,8	6,1	6,6
	ratio	2,4%	2,3%	2,1%	2,1%	2,1%
TOTAL	[PJ]	237,1	250,9	273,2	292,8	307,5
	ratio	100,0%	100,0%	100,0%	100,0%	100,0%

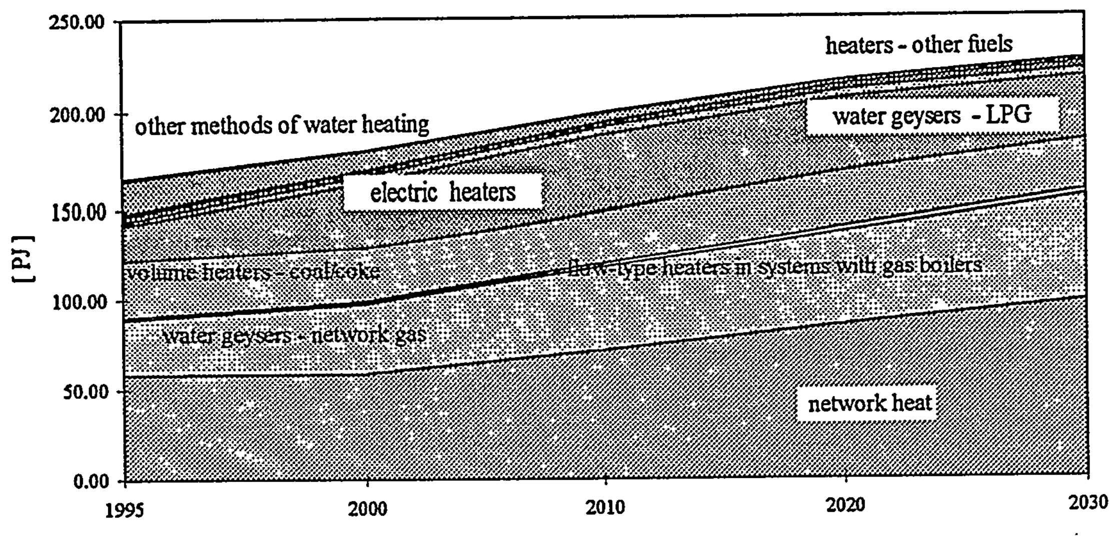

Fig.9.3.3.Final energy demand for warm tap water

The energy demand for cooking will not change too much. The final energy demand will change proportionally to the population increase. These changes are illustrated in figure 9.3.4. The consumption of energy carriers for cooking is given in table 9.3.14. and in figure 9.3.5. The total consumption of usable energy will remaine almost unchanged as average efficiency of energy carriers use will increase. The ratio of network gas will increase which will result from the assumed gasification of the country. Kitchen stoves fired with solid fuels will be in less use.

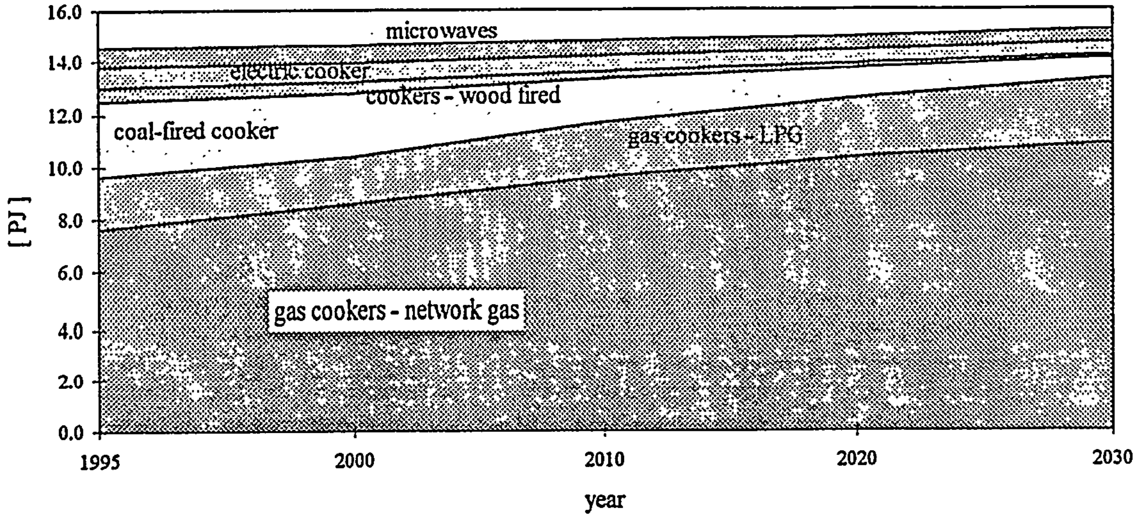

Fig.9.3.4.Final energy demand for cooking

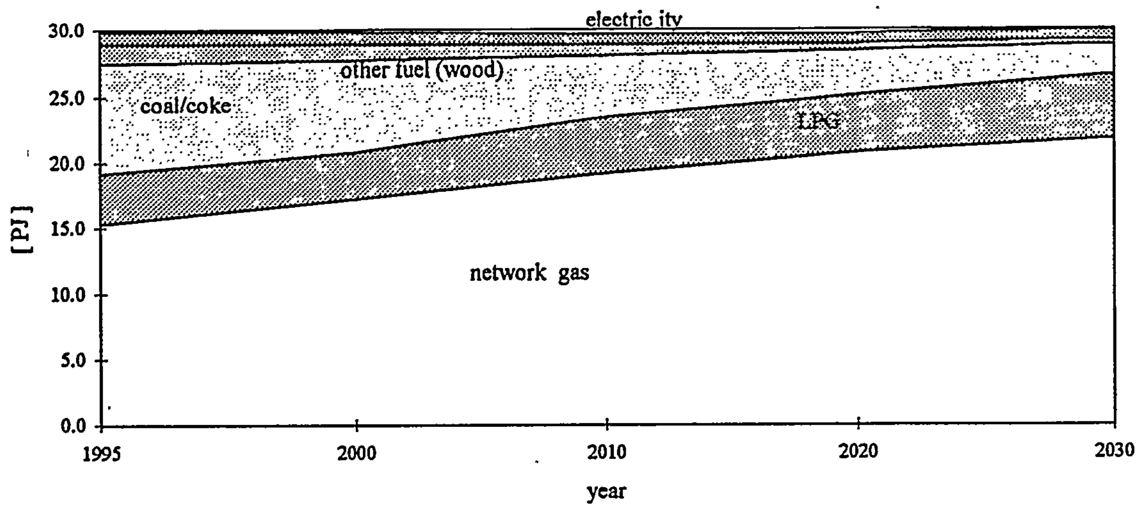

Fig.9.3.5. Energy carriers demand for cooking in households

Table 9.3.15. A demand for energy carriers for cooking

carrier	year	1995	2000	2010	2020	2030
network gas	[PJ]	15,2	17,2	19,2	20,7	21,7
	ratio	50,9%	57,6%	64,6%	69,7%	72,6%
LPG	[PJ]	4,0	3,6	4,2	4,5	4,8
	ratio	13,4%	12,1%	14,3%	15,0%	16,2%
coal / coke	[PJ]	8,2	6,9	4,6	3,2	2,2
	ratio	27,5%	23,1%	15,5%	10,7%	7,3%
other fuels (wood)	[PJ]	1,4	1,2	0,8	0,6	0,4
	ratio	4,8%	4,1%	2,7%	1,9%	1,3%
electricity	[PJ]	1,0	1,0	0,9	0,8	0,8
	ratio	3,4%	3,2%	2,9%	2,7%	2,6%
TOTAL	[PJ]	29,9	29,8	29,7	29,7	30,0
	ratio	100,0%	100,0%	100,0%	100,0%	100,0%

The elaborated prognosis assumed that the electricity consumption per capita in the households will increase significantly (about 70%) and reach about 58 TWh in 2030 what is illustrated in figure 9.3.6. The foreseen changes of consumption of electricity for other purposes apart space heating, warm sanitary water generation and cooking, are given in tables 9.3.16-18. The prognosis of changes of the electricity demand for lighting dwellings, non-residential buildings and streets are given in table 9.3.19. An essential increase of CFLs use was assumed.

Table 9.3.16. Demand for electric energy and power for refrigerators and freezers supply

		1995	2000	2010	2020	2030
	year	1995	2000	2010	2020	2030
electrical energy consumption	[TWh]	9,7	10,0	10,9	12,3	14.2
	[PJ]	34,8	35,8	39,4	44,4	51.2
estimation of maximum power of devices in use	peak [GW]	2,4	2,5	2,7	3,1	3,6

Table 9.3.17. Demand for electricity for audio-visual devices supply [TWh]

	1995	2000	2010	2020	2030
TV-sets	2,61	3,84	6,58	7,75	8,85
radios and connected	0,28	0,32	0,33	0,37	0,41
personal computers	0,19	0,46	0,74	1,15	1,73
video tape recorder/player	0,14	0,20	0,31	0,38	0,46
TOTAL	3,2	4,8	8,0	9,6	11,4
estimated peak power demand [GW] *	1,5	1,8	2,1	2,6	3,2

*with simultaneity factor 0.5

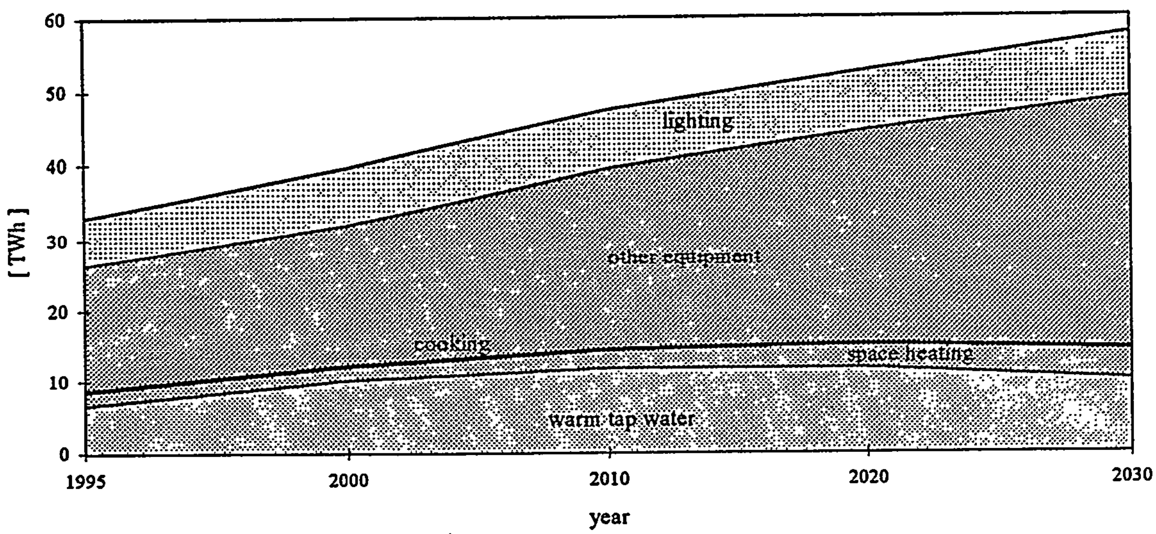

Fig.9.3.6. Electricity consumption in households

Table 9.3.18. Demand for electricity for other appliances supply [TWh]

	1995	2000	2010	2020	2030
washing devices	1,96	1,81	1,41	0,95	0,73
automatic washing machines	1,43	1,71	2,17	2,80	3,63
vacuum cleaners	0,18	0,24	0,37	0,72	1,06
irons and others	0,96	0,97	1,06	1,19	1,37
dish-washers	0,07	0,20	0,74	1,25	1,73
others	0,11	0,12	0,13	0,15	0,17
TOTAL	4,7	5,1	5,9	7,1	8,7
estimated peak power demand [GW] *	4,1	4,4	4,8	5,5	6,4

*with simultaneity factor 0.1

Table 9.3.19. Demand of electricity for lighting

	year	1995	2000	2010	2020	2030
dwellings lighting	[TWh]	6,96	7,48	7,99	8,40	8,82
lighting at non-residential buildings	[TWh]	6,36	8,44	9,02	7,23	5,92
street lighting	[TWh]	0,87	0,68	0,73	0,76	0,77

The foreseen energy consumption in the residential sector and for the identified needs in non-residential facilities are given in tables 9.3.20 - 9.3.21.

Table 9.3.20. Consumption of energy carriers in households - basic variant

carrier		1995	2000	2010	2020	2030
network heat *** from a source	[PJ]	328,3	337,1	398,9	477,1	575,2
network gas	[PJ]	160,9	208,4	262,8	319,8	377,5
coal / coke	[PJ]	612,5	557,7	502,8	462,9	453,6
electricity	[TWh]	*33,2*	*39,6*	*47,3*	*52,7*	*57,7*
	[PJ]	119,6	142,5	170,2	189,7	207,8
LPG	[PJ]	6,1	8,4	10,3	10,7	10,5
other fuels	[PJ]	30,0	28,3	25,8	24,1	23,5
TOTAL	[PJ]	1257,4	1282,3	1370,9	1484,4	1648,1

Table 9.3.21 Consumption of energy carriers for identified needs in non-residential objects

carrier	year	1995	2000	2010	2020	2030
network heat *** from a source	[PJ]	104,5	116,2	131,0	148,8	172,9
network gas	[PJ]	12,9	22,9	37,0	51,1	63,1
coal / coke	[PJ]	115,0	106,5	97,5	93,1	96,7
electricity	*[TWh]*	*8,1*	*10,1*	*10,9*	*9,4*	*8,3*
	[PJ]	2,3	2,8	3,0	2,6	2,3
LPG	[PJ]	NA	NA	NA	NA	NA
other fuels	[PJ]	12,8	11,8	10,8	10,3	10,7
TOTAL	[PJ]	247,5	260,3	279,4	306,0	345,8

The estimation of the GHG emission is given in table 9.3.22. According to the adopted basic scenario the emission increases about 37% in the case of CO_2, 45% in the case of NO_x, and about 28% in the case of CH_4 since 1995 to 2030. It is impossible to estimate N_2O emission as the most of specific emission factors for N_2O are unknown.

Table 9.3.22 Greenhouse gases emissions according to the basic scenario

	1995	2000	2010	2020	2030
CO_2 [mio t]	162.2	169.0	183.99	200.4	222.92
NO_x [k t]	154.7	151.7	155.9	165.0	182.1
CH_4 [k t]	3.29	3.42	3.61	3.89	4.33

9.3.3. Options of reduction of GHG's emission

Options of reduction of the energy consumption and the GHG emission which were considered are listed below:

in terms of space heating m.1 and n.1:

- improvement of thermal insulation of external walls and roofs,
- reduction of heat losses trough the replacement of windows,
- ventilation control and windows sealing up,
- application of automatic control equipment in CH systems,
- introduction of an accounting system for heating based on physical measurements of consumed energy,
- application of more efficient boilers and control of transmission and distribution losses of network heat,
- substitution of energy carriers (coal fired in stoves - with timber, coal burned in boilers in individual CH systems - with network gas, coal burned in network heat sources - with geothermal energy, application of heat pumps in place of conventional electric heating systems)

in terms of supply with warm sanitary water m.2:

- introduction of an accounting system based on physical measurements of consumed energy (warm water),
- substitution of energy carriers, application of renewable energy sources (coal used for sanitary water heating - with solar energy)

in terms of space lighting and street lighting m.3, n.3 and d.3:

- application of energy saving light sources and changes of lighting standards,

in terms of food cooling in households m.5:

- improvement of efficiency of refrigerators and freezers,

in terms of supply for audio-visual devices and other household appliances m.6 and m.7

- reduction of receivers energy consumption,

The changes which have already been taking place and are forced by current economic conditions or adopted standards of living were not included as options of the emission reduction. These changes are embodied in the basic scenario of development of energy use in the sector. The examples of such changes are the modernization of street lighting and the extension of gas network which have been done with various intensity in different regions of Poland.

An estimate of possible reduction of GHG emission from landfills was done in the expert's report. It was stated that it is possible to utilize to 70% of the emitted gas.

9.3.4. Selected scenario of reduction of GHG emission

The result of progressive implementation of projects assisting in the emission reduction is illustrated in the next figures. It is possible to limit the particular energy carrier consumption for residential space heating from 19% to over 30% (on average by 29%), and to limit the particular energy carrier consumption for non-residential space heating from 6% to 28% (on average 17,6%). These changes are illustrated in figure 9.3.7-9.3.10.

An improvement of efficiency of devices for warm sanitary water supply can help reduce demand for energy carriers by 6%. Particularly large savings can results from a improvement of operation of municipal heating systems. However, according to the reduction scenario the demand for energy carriers for sanitary water heating will be 25% higher in 2030 than in 1992.

As illustrated in the figure 9.3.11 it will be possible to reduce annual demand for electricity for supply of appliances in households by about 4,9 TWh.

Wider use of energy saving light-sources than assumed in the basic scenario, allows for a significant decline of electricity consumption for lighting. In accordance with the considered reduction scenarios the demand for energy for lighting is to be reduced by several percents to 2030. This is illustrated in figures 9.3.12-9.3.14.

The final result of implementation of the chosen reduction scenario is the GHG emission limit to 2030 in relation to 1995: to about 109% in the case of CO_2, and to about 92% in the case of CH_4. The predicted reduced GHG emissions and emission in basic scenarios are presented in figures 9.3.15-9.3.17.

The scenario of changes of capital costs which are necessary for implementation of the assumed emission reduction projects is illustrated in figure 9.3.18.

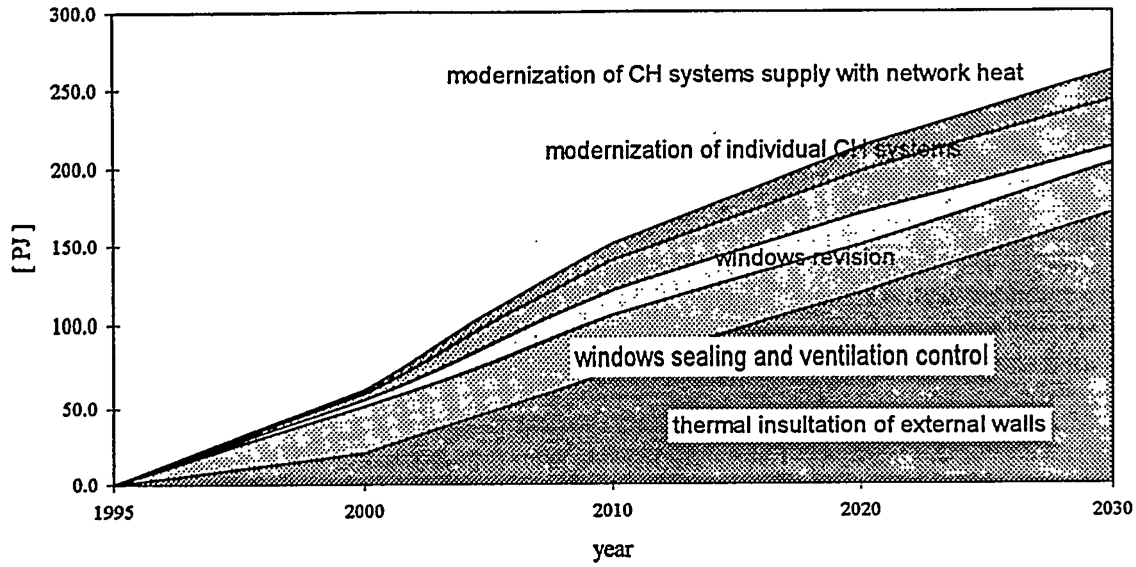

Fig.9.3.7.Reducction of final energy demand for space heating in residential buildings

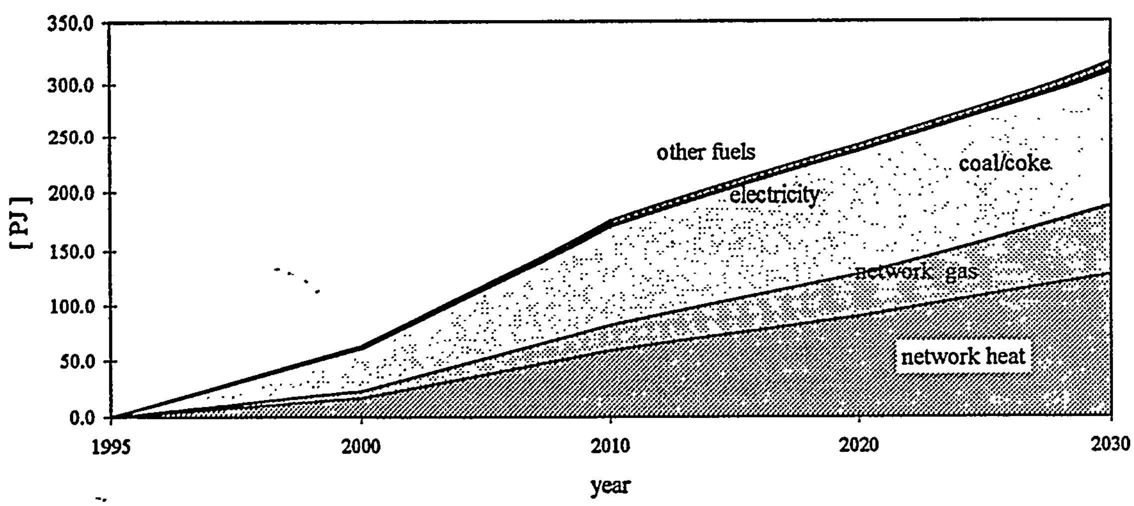

Fig.9.3.8.Reduction of energy carriers demand for space heating in residential buildings (assumed improvment of usable energy processing)

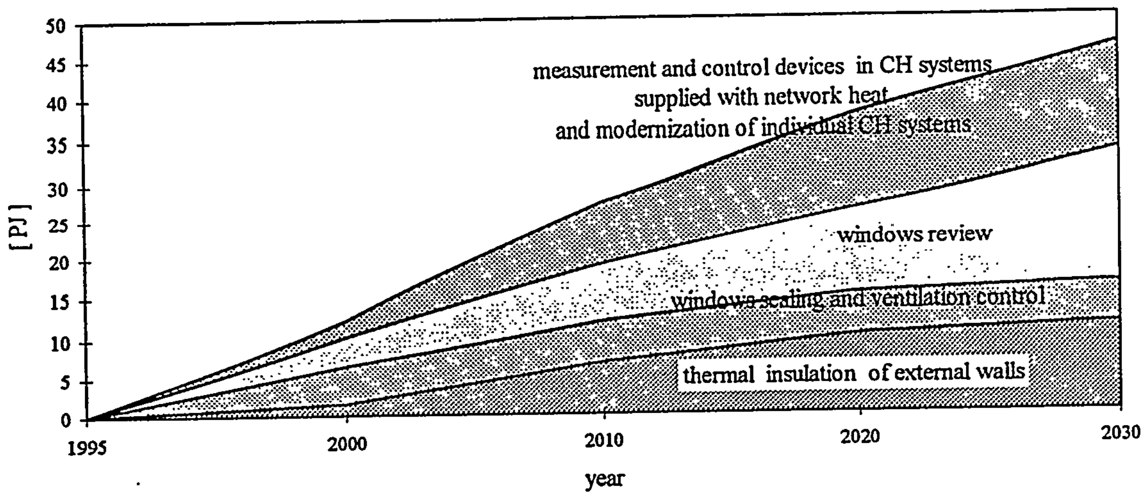

Fig.9.3.9.Reduction of final energy demand for space heating in non-residential buildings

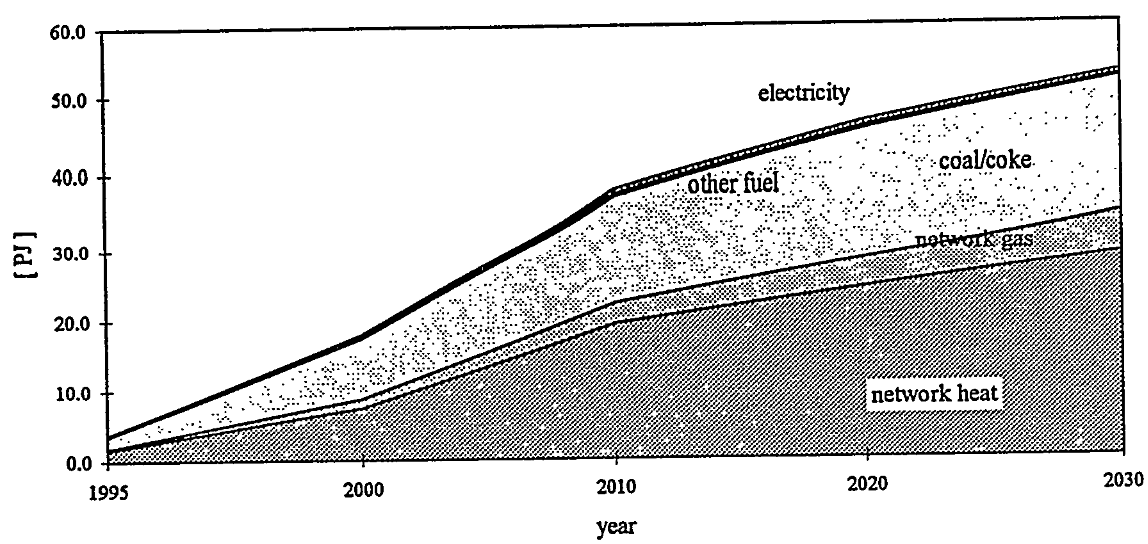

Fig.9.3.10. Reduction of energy carriers demand for space heating in non-residential buildings (assumed improvment of usable energy processing)

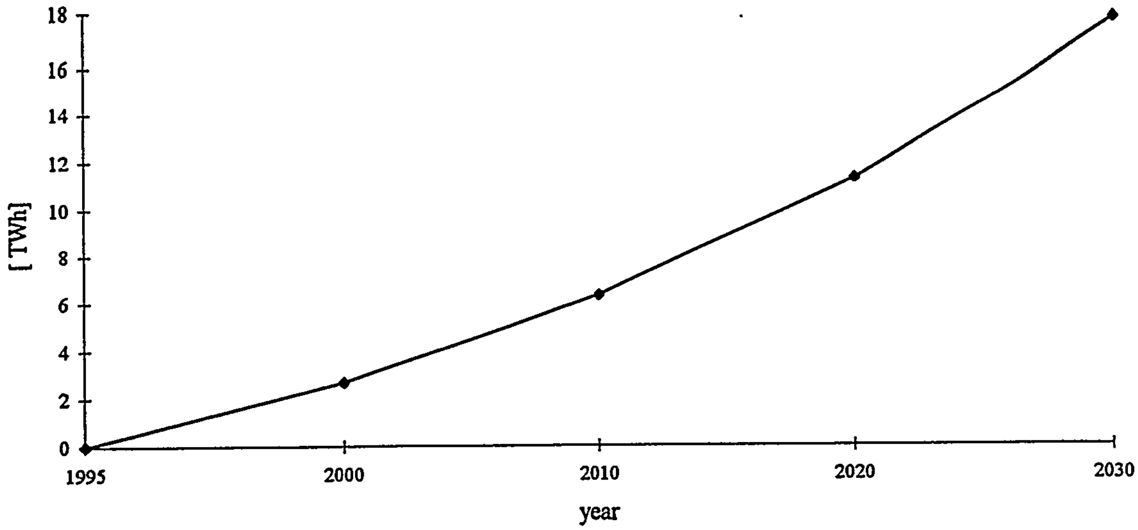

Fig.9.3.11.Potential reduction of electricity consumption after implementation less energy-consuming refrigerators, appliances and audio-visual devices

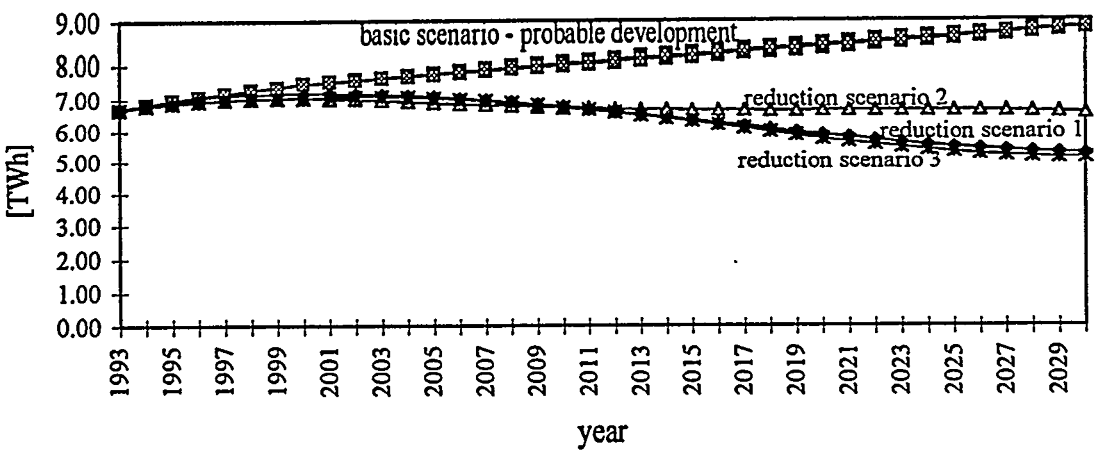

Fig.9.3.12. Foreseen changes of electricity demand for lighting in households

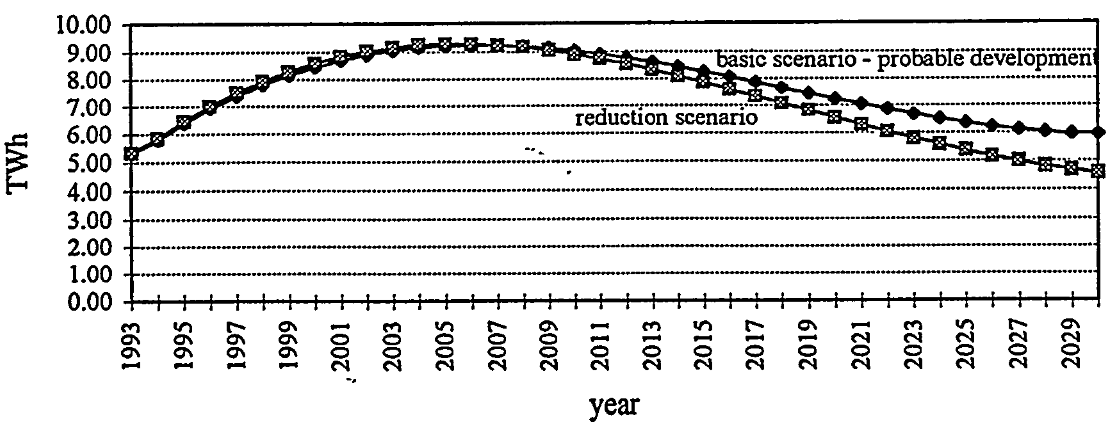

Fig.9.3.13.Probable changes of electricity demand for lighting in non-residential buildings

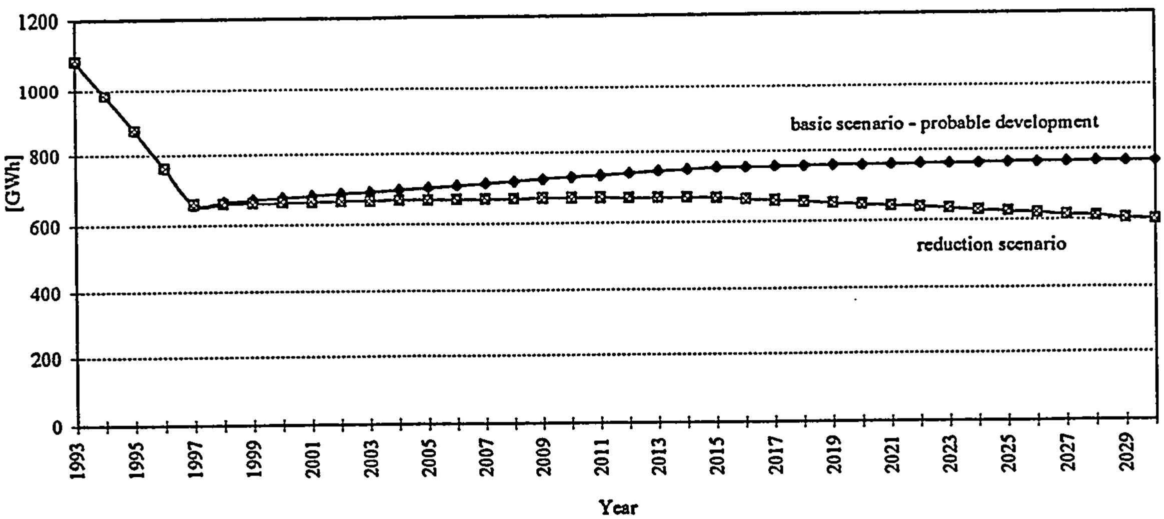

Fig.9.3.14. Foreseen changes of electricity demand for street lighting

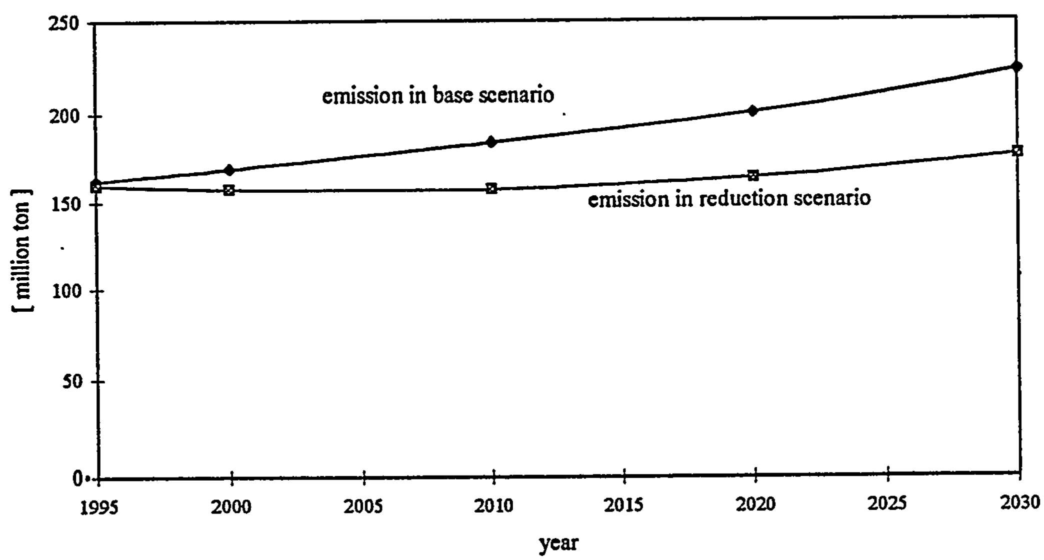

Fig.9.3.15.Emission of CO2 according to the base- and the reduction-scenario

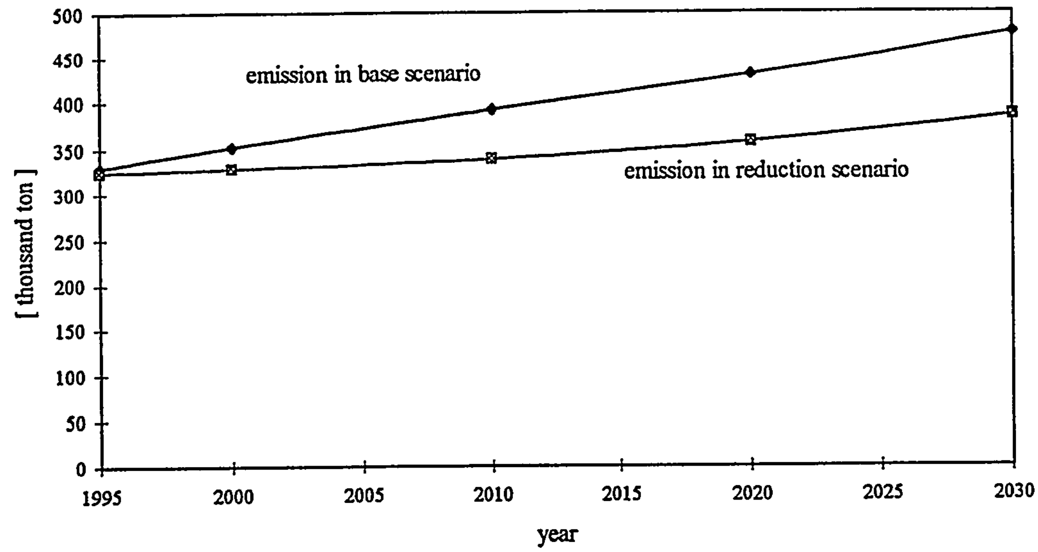

Fig.9.3.16.Emission of NOx according to the base- and the reduction-scenario

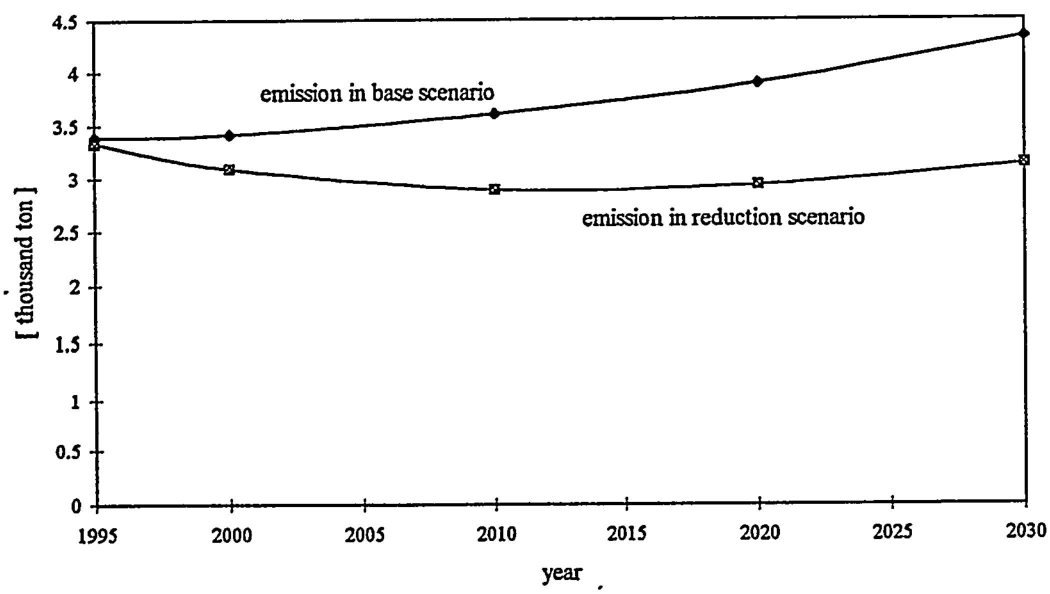

Fig.9.3.17.Emission of CH4 according to the base- and the reduction-scenario

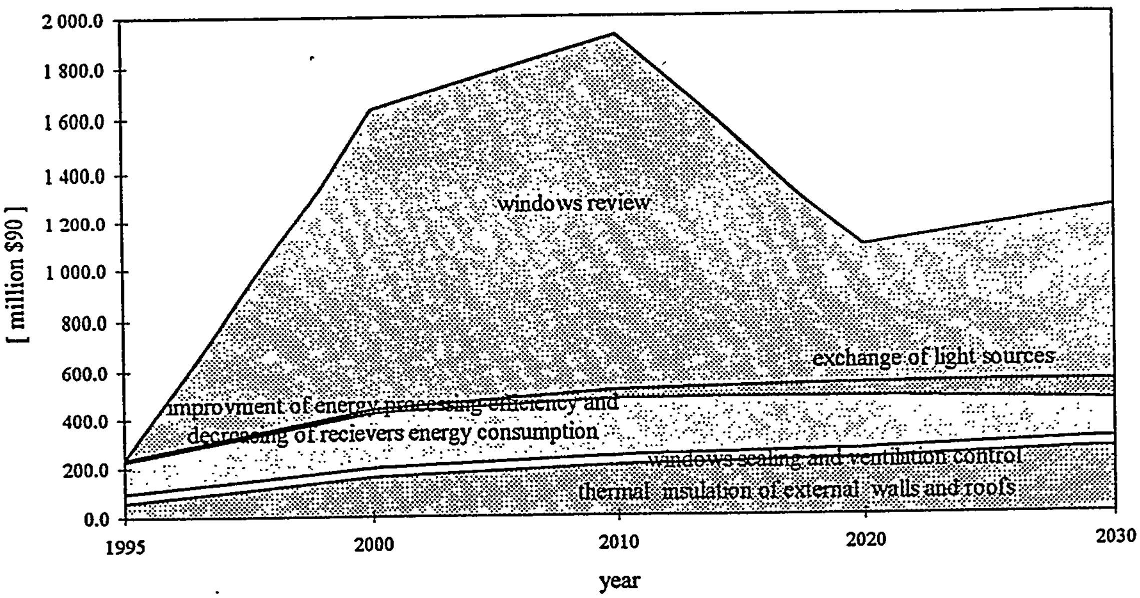

Fig.9.3.18. Capital costs reduction

9.3.5 Conclusions

The economy development and combined changes of standards of living cause significant increase of final energy demand for different living needs and other purposes in the municipal sector. If no wider program of modernization of systems of energy use is undertaken, the annual emission of GHG will rise between 1995 and 2030 by about 40% in CO_2 and about 28% in CH_4.

It is possible to implement such changes in methods of meeting the energy needs that the GHG emission will be stabilized roughly at the 1995 emission level and reduced by over 20% in relation to 2030 emission foreseen in the basic scenario.

In the set of considered options the lowest unit costs of GHG emission reduction characterize programs of modernization of heating systems:

- application of automatic control systems, so called "weather control systems, and temperature controller in CH systems,
- substitution of gas fired and solid fuel fired boilers being in operation with more efficient ones,
- improvement of energy transmission efficiency in heat network,
- assembling of network heating systems and internal CH systems with measurement and control devices which are necessary for accounting ssytems based on consumed energy according to measurements, not on the lump sum as it is now.

The program of windows sealing in residential and non-residential buildings is relatively easy to implement and important for the GHG emission reduction.

Potentially significant possibilities of reduction of the energy demand and related GHG emission result from possible improvement of the building thermal insulation, especially of residential buildings. Today most of these projects is however economically not profitable and need high capital investments. Similar situation applies in the case of option of windows replacement and energy carriers substitution.

If the GHG emission reduction program is to be accomplished it will be necessary to find financial sources for this purpose, to change some legal regulations and to undertake some organizational activities. In particular the following problems should be considered:

- changes of standards for devices and other objects - energy receivers resulting in a decrease of energy demand, i.e. bringing down permissible levels of heat transmission factors through the walls and windows, heat losses per building cubature, to close or limit the market for energy consuming devices.
- taxes for use of less pure fuels (coal, heavy oils, etc.) and promotion of gas system and nuclear energy development,
- breaking social fears of consequences of nuclear power industry development and accomplishing a wide program of scientific research projects on the use of nuclear energy in electricity systems and heating systems (also in the industry),
- support of a development of small electric power sources (electrical or thermal) - subsidies, taxes reduction, etc. and legal preferences for operation of these sources in a national electrical system and local electrical or heating subsystems,
- legal regulations allowing investing in modernization of energy management by the "third party", allowing in some cases to account investment costs as operational costs, also costs of investments made for the energy receivers (some solutions are proposed in the new "Energy Act"),
- tax reductions for purchase of less energy consuming devices if these substitute the older ones,
- supplementing the primary and secondary school curriculum with subjects on the use and protection of the environment , promotion of behavior and formation of sound habits for energy savings and rational use of environment,
- publicity and educational actions directed on the adult, promoting the necessity of environmental protection, and energy and materials savings (i.e. recycling),
- reorganization of public services to ensure proper implementation of foreseen legal changes, educational programs and efficient use of results of social behavior changes.

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9.4. Transport

9.4.1. Sector description

Transport demands resulting from economic policies

Transport in Poland has to be considered within a broader framework of political and economic legacies of the old system of central planning. Transport policies were to the large extent determined by the structure of demand which was a consequence of economic and spatial policies. Rapid urbanization and industrialization, nationalization of the means of production, overemphasizing the heavy industry and power sectors at the expense of consumer goods and services, excessive concentration and specialization of production in combination with general failure of central planning, ineffective management and distribution systems as well as lack of market mechanism led to a very high demand for freight transport, with bulky raw materials, heavy industry products, and agricultural products being the prevailing cargo categories. International freight transport was mostly held between the COMECON countries whereas international passenger traffic was limited by regulations. which have briefly been characterized in preceding paragraphs.

Railways

Railways dominate the transport sector in Poland. In the peak period (1980), 68 per cent of ton kilometers and 47 per cent of passenger kilometers were served by rail. The Polish railway network consists of 24,313 km lines under operation (94 % - standard gauge) of which almost 50 % are electrified. However, only 17 % of line length is adjusted to speeds more than 120 km/h, and only 10 % is equipped with modern traffic control devices. The density of railway lines (7.7 km/100 km^2) and the share of electrified lines are among highest in the world. At the end of 1991, almost 47 per cent of the total length of the network was electrified. Main problems encompass: the technical condition of tracks; the out of date traffic control system; the obsolete and underdeveloped communication system; low quality of rolling stock and low operational efficiency. As a result, the quality of service and economic efficiency are very low. Generally, railways are not competitive in terms of speed and convenience.

Road transport

In the forties and fifties, road transport was considered of secondary importance, and private motorization, undesirable. Gradually, the policy of the government was changing, in response to the revealed preferences of the population. In spite of a relatively low income level, since 1970's the number of private automobiles was rapidly increasing and the rate of car ownership per GDP unit, per capita became much higher than in more developed countries. Automobiles, goods vehicles and buses were predominantly made in COMECON countries; they were environment unfriendly and inefficient with regard to fuel consumption.

The situation has radically changed in the period of transition. There is a very rapid growth in the number of road vehicles and the increasing portion of them come from OECD countries.

The Polish road network consists of more than 350,000 km of roads, of which 2/3 are paved and 55 % are equipped in modern pavements. Urban roads which constitute 1/6 of the network are paved in 80 % (equipped in modern pavements in 70 %). Rural roads which constitute the remaining 5/6 of the network are paved in 64 % and equipped in modern pavements in more than 50 %. 95 % of the network are two-lane roads.

While the density of intercity roads in Poland is not much lower than in high-income countries, these networks have several shortcomings. Motorways and expressways constitute only a very small proportion of roads; most roads, including international roads, do not have access control and are used by mixed traffic - long- and short-distance motor traffic and slow traffic (tractors, bicycles, pedestrians). Standard of many sections of main roads is lower than in the Western European countries. Major roads go through built-up areas, and some through city and town centers.

Sea transport and ports

For decades, sea transport played an important role, serving international freight transport. The structure of production, i.e. a very high proportion of heavy industry, required ports and fleet for bulky cargo. Generally, most port infrastructure, facilities and equipment were developed mainly for this kind of cargo. Capacities to serve general cargo and containers are very limited. The most important shortcoming is that, as with other modes of transport, maritime transport suffers because of poor transport logistics.

Generally, under the old regime, maritime transport was in an advantageous position. From the beginning of economic reforms, however, it is losing that position, because of the competition from railways and, most of all, from the road transport.

Inland water transport

In Poland, inland water transport plays a marginal role, in spite of the country generally flat surface, extensive river network and high volumes of bulky goods transported. In 1990, the inland water transport served only 0.3 per cent of all traffic (tonkm). Although the length of officially navigable waterways is equal to 4000 km, only 1700 km are regularly used.

Air transport

Not surprisingly, as a result of low level of income, air transport is used much less than in Western Europe. International travel prevails, with about 2.1 million passengers per year, of which 95 % are served by the Warsaw airport. Domestic air transport serves 1,664 km of air lines. In 1994, it carried 241,000 passengers and 2,376 tons of cargo which is and will probably stay marginal when compared to rail and road transport.

In comparison to the number of passengers, the number of airports both international and domestic is adequate. However, most airports and air traffic control systems are out-of-date and require upgrading. Until very recently, the aircraft fleet was, with few exceptions, Soviet built planes with high fuel consumption which caused environmental pollution, unacceptable in West European and US airspace. In the recent years, almost the whole fleet of the Polish Airlines was replaced with modern Western planes.

Domestic air transport serves 1.664 km of lines. In 1994, it carried 241.000 passangers and the cargo of 2.376 tons. It is likely to stay of marginal importance, as compared to rail and road transport.

Pipelines

Pipelines in Poland were built to serve primarily crude oil imports from the former USSR. There are almost 2,300 km pipelines for crude oil and petroleum products. They carried 34 M tons in 1994. A network of gas pipelines from Russia is expanding.

Inter-modal/combined transport

In contrast to what could be expected in countries with centrally-planned economies, freight transport was not organized as a chain-of-services Each mode was organized as a public monopoly, with extreme vertical integration. Under these conditions, combined transport was not very developed. Containers were used, but there was a lack of terminals with efficient handling equipment. Very few controlled links were in operation as regards combined transport. Generally, the potential of relatively dense railway network was not used for combined transport.

Urban transport

In Poland as in other countries of the region, urban transport policy was oriented towards public transport. Fares were kept low, and heavy subsidies were accepted. Capital investment, including purchasing of vehicles, was financed from the central budget and, in many cases, operating expenses were covered from the same source. Priority was given to serving commuter traffic, since production was considered the main objective. Generally, all cities were served by extensive, multi-modal mass transport systems. While the quality of service was not very high, the density of network and frequencies were generally good. Clearly, this policy, combined with low car ownership ratio, meant that, for a long time, a very high proportion of vehicle transport (85 - 95 per cent) was public.

Taking into consideration that oil had to be imported, there was a policy of promoting electric means of transport. In theory, development of urban transport was planned in coordination with urban development plans. In practice, the plans were only partially implemented.

The present state as the legacy of an old political system

The present state of the transportation systems in Poland can be attributed to some features of the previous political system. In the specific conditions of the past 40 - 45 years, the development and operation of the transport systems was determined by the following practices:

- prioritizing the large-scale infrastructure projects over the upgrading, maintenance and operation of the existing facilities. Emphasis was put on quantitative enlargement of civil engineering infrastructure rather than on enhancing the quality of the system;
- overoptimistic economic forecasts and hopes that, in the next planning period, much greater resources will be available for capital investment than in the past period;
- underestimation of construction and operating costs combined with overoptimistic economic forecasts leading to slow project implementation, freezing of financial resources, and overall inefficiencies;
- underdeveloped economic and financial studies; alternatives were seldom analyzed and prices were determined administratively (which caused distortion) and capital funds had no time value assigned to.

Economic reforms and their impact on transport sector

At the beginning of the transition period, the Gross Domestic Product has declined, however, after a period of stabilization, it started rapidly growing. The political and economic transformation has already triggered demand for transport. The following changes can be observed:

- changing volumes of passenger and goods transport as a result of growing GNP, the growth of motorization and changing travel behavior; there are almost 11 million vehicles registered in Poland, including more than 7 million passenger cars; the car ownership has been growing rapidly reaching recently the level of 185 cars per 1,000 inhabitants and more than 300 in the largest cities; the fleet structure has been changing and the share of modern, more fuel efficient and environment friendly vehicles raising; starting July 1995, all newly registered gasoline vehicles must be equipped with catalysts;
- shift of demand from heavy capital goods industries to lighter consumer goods industries and services; from low quality services (with little emphasis on the time, punctuality and reliability of transport) to high quality services; and from international traffic among the former COMECON countries to traffic between countries of Central and Eastern Europe and the EC/EFTA countries.

The changing structure of production and the nature of personal needs of travelers have lead to an increasing role of the road transport in serving national and international traffic. Theoretically, low income per capita should depress the demand for high quality passenger services; in practice, however, there will be a strong tendency to own and use personal cars. Strong competition of the road against the rail transport has lately been observed as a new phenomenon These trends might be slowed down by governmental intervention, but such an intervention seems to be very unlikely in the nearest future..

In the new situation, the most difficult decision to be made by the governments is how to divide resources between:

- various competing means of transport;
- maintenance, renovation (upgrading) of existing infrastructure and new capital investment;
- replacement and expansion of vehicle (maritime) fleets and infrastructure;
- investing in the upgrading/development of international transport corridors and the domestic networks and facilities.

High priority has been assigned to programs and projects aiming at upgrading and developing the transport systems and integrating them with the systems of the Western Europe. This is to be achieved through *(inter alia)* the following actions:

- adjusting the railway lines of major international importance (4.9 thousand kilometers of main lines) to the requirements of the European Agreement on Main International Railways Lines (AGC) and the European Agreement on Important International Combined Transport Lines and Related Installations (AGTC);

- upgrading and expanding road networks according to the European Agreement on Main International Traffic Arteries (AGR), including the Trans-European Motorway (TEM) project; programs for the modernization and development of the main network have been prepared, including plans for the development of motorways (2600 km) ; 45 thousand kilometers of national and regional roads are to be upgraded to allow loads of up to 10 ton per axle; however, in the transition period the budgetary resources allocated to the road sector have been drastically reduced; and in consequence, the present rate of the network modernization and development is much slower than the rate of increase of the vehicle fleet and traffic volumes;

- development of facilities for combined transport; while there are good reasons for promoting combined traffic, it cannot be expected that it will play a more important role, because haul distances in Europe are not long
- upgrading and constructing specialized sea port facilities; while Polish ports have some excess capacity, they are not well prepared for the present and future trends and types of cargo; The principal investment projects are aimed at extending the capacity of handling liquid fuel as well as containers, railway cars and road transport vehicles;
- upgrading and development of border crossing facilities, communication and information systems, etc.

General trends

Generally, after a period of extensive quantitative development, the Polish transport system has been undergoing structural transformations. The main reason being the transition to market economy with all the consequences. The most visible features of the present state of the transport system are the following:

- a reduction of the amount of goods carried (by about 50 per cent within 15 years - to 1,343 M tons a year);
- rapid increase of international traffic (by road, rail, and air, less by sea);
- a shift from rail to road in both passenger and goods transport; the tonnage of goods carried by rail transport decreased by 55 % within the past 15 years; the decrease of the number of passengers is similar; however, a slow increase of the tonnage carried has been observed since 1992 (reaching 215 M tons in 1994) while the reduction in the number of passengers has continued (almost 495 M passengers traveled by rail in 1994);
- a shift from collective to individual means of passenger transport in urban areas; there are more than 25,000 km bus routes and almost 1.000 km tram routes in Poland. they are served by 13,000 buses (with 72 % in operation), more than 4.100 tram cars (63 % in operation), and 250 trolley-buses (2/3 in operation) which carry 5.980 M passengers a year; a constant reduction of the number of public transport passengers carried has been observed within last years; increase in car ownership is considered as the main reason; however, services rendered by small private operators (which constitute a meaningful share of the market in some towns) stay out of statistics.
- slow but continuous modernization of road and railway infrastructure and railway rolling stock;
- rapid growth of motorization causing fast increase of road traffic volumes; slow changes in vehicle fleet towards more energy -efficient and environment friendly vehicles;
- modest role of modes other than road and rail in domestic transport.

9.4.2. Modeling Methodology

To assess the GHG emissions from the transport sector and to enable evaluation of mitigation strategies, a set of models have been built. The following points are the brief characteristics.

<u>A model for calculation of transport demand and emissions</u>

The methodology for forecasting the demand for transport has been chosen taking into consideration:

- availability of input traffic data;
- level of detail of the data describing interdependence between the level of the traffic and the emission.

Generally, the emission rates were prepared in relation to vehicle-kilometers or passenger-kilometers, according to the means of transport, characteristics (including structure) of the fleet and operating speed. This required rather detailed traffic forecast, which is specific for the methods of end-use modeling. Estimation of the following was necessary:

- the efficiency of each type of energy using device;
- average use per customer per energy-using device;
- the number of specific devices within each end-use.

Traffic forecasting methods used in the study required the following data:

- development of motorization and number of vehicles;
- transport intensity expressed in the number of trips per capita and the number of tons per capita;
- energy usage rates and emission rates.

To calculate the first two, extrapolation and elasticity models were used to describe interrelationships between economic characteristics and transport demand, as well as correlation between the variables describing the transport itself. The computational model was built as to facilitate its use for testing different scenarios of transport policy by introducing changes in elasticity models. To verify the model, the results of model applications were compared with the earlier traffic forecasts for the year 2010 such as prepared by JICA [1992], the Foreign Advisory Unit in the Ministry of Transport and Maritime Economy[1994] and the most recent forecasts contained in the "Transport Policy" prepared at the Ministry [1995].

<u>Traffic forecasting model</u>

Traffic forecasting model was based on the "top-down" method: starting with very general relationships between macroeconomic assumptions and transport demand, then more detailed modal split, down to vehicle fleet structure which was necessary to take into account varying emission rates for different classes of vehicles and operational conditions.

Traffic forecasts were prepared for passenger traffic and cargo transport. Passenger traffic was divided into urban and nonurban traffic. For urban traffic the following transport modes were used:

- passenger car;
- bus;
- tramway.

For nonurban traffic the following transport modes were considered:

- passenger car;
- train;
- bus;
- air transport;
- inland water transport;
- sea transport.

Cargo traffic was calculated for the whole country, and the following means of transport were considered:

- train;
- truck;
- air transport;
- inland water transport;
- sea transport.

For passenger cars and trucks traffic three classes of operating speed were used:

- up to 20 km/h;
- from 20 to 60 km/h;
- over 60 km/h.

In the model, percentages of vehicle-kilometers driven with given speed were assumed on the basis of results of various studies.

In addition, trucks were divided into three load categories:

- up to 3,5 tons;
- from 3,5 to 6,0 tons;
- over 6,0 tons.

Base year and time horizon

According to general assumptions, forecast period covers the period up to the year 2030. Resulting emissions were to be calculated for each year within the period. Base year data are available for 1994. Because of the availability of the input data for the future years, it was decided that the forecast will be calculated for 5-year periods and the results for the years in-between were interpolated. Traffic forecast was calculated for the years: 1995 - 2000 - 2005 - 2010 - 2015 - 2020 - 2025 - 2030.

Macroeconomic and motorization forecast

Data on *economic development* used in the whole GHG Country Study were adopted in the transport forecasts. GDP is the main variable on which other model elements are based. It influences the mobility of people expressed by the number of trips per capita, as well as car ownership and car usage, and the number of tons of goods which should be transported.

The remaining variables concern *demography and the urban development*: number of inhabitants and the level of urbanization were adopted from the recent demographic forecasts and national spatial development plans.

The car ownership forecast covers the number of passenger cars, trucks and buses. To calculate the number of passenger cars the elasticity model was used which described the relationship between the increase of car ownership rate and the GDP. Additionally, to verify the model, the relationship between the GDP increase and car ownership rates in the period 1980-1993 was used.

The relationship between GDP and car ownership can be used as a part of transport policy. The number of trucks and buses were calculated according to the average level of motorization which can be found in the developed countries in Europe.

The input macroeconomic data for the reference scenario and the results of the car ownership forecast are presented in table 9.4.1. In the scenario, the continuation of the present trends and the lack of mitigation activities have been assumed.

Table 9.4.1 Macroeconomic data and motorization - reference scenario

MACROECONOMIC DATA		1990	1991	1992	1993	1994	1995	2000	2005	2010	2015	2020	2025	2030
GNP	%	0.0	-7.0	2.6	3.8	4.0	4.5	4.5	4.4	4.3	4.2	4.0	3.6	3.6
Population	million	38.2	38.3	38.4	38.5	38.5	38.6	39.1	39.6	40.0	40.3	40.7	41.1	41.5
Employment	million	16.3	15.3	14.7	14.3	14.5	14.7	15.1	15.3	15.5	15.8	16.1	16.3	16.5
Unemployed	%	6.3	11.8	13.6	16.4	16.0	15.6	13.8	13.9	13.2	12.1	11.0	9.9	9.5
Passenger vehicles	v/thous. people	138	160	169	+176	186	196	242	291	338	386	427	464	504
Trucks	v/thous. people	27	30	32	32	34	34	39	43	45	47	48	48	47
Buses	v/thous. people	2.4	2.3	2.2	2.2	2.2	2.3	2.5	2.7	2.9	3.2	3.5	3.8	4.1
Urban population	%	61.8	62.0	62.2	62.3	62.5	62.6	63.4	64.2	65.0	65.8	66.6	67.4	68.2
Urban population	million	23.6	23.7	23.9	24.0	24.1	24.2	24.8	25.4	26.0	26.5	27.1	27.7	28.3
Passenger vehicles	million	5.26	6.11	6.50	6.77	7.15	7.57	9.46	11.53	13.51	15.55	17.38	19.06	20.91
Trucks	million	1.04	1.15	1.21	1.24	1.31	1.31	1.53	1.71	1.81	1.89	1.95	1.96	1.96
Buses	million	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.11	0.12	0.13	0.14	0.16	0.17

Passenger traffic forecast

The passenger traffic forecast was based on the assumption that the number of trips per capita increases according to the increase of income which implies the increase of the number of cars, the quantity of free time and the portion of income which can be spent for traveling. So the relationship between GDP and mobility was made use of. The model was verified by comparing mobility factors calculated for year 2010 to the existing mobility factors from developed European countries.

The urban passenger traffic forecast was calculated for the urban population. Utilizing traffic survey results from different cities, the existing mobility rates for non-pedestrian traffic were calculated. Data on mobility rates observed in the cities of the OECD European countries indicate the level of mobility to be expected in Polish cities in the future.

In the *modal split* model it was assumed that the percentage of trips by car will increase according to the increase of the number of cars. Limitations in car usage in the cities, parking policy, etc. implies that this relationship is nonlinear. It can be used as a tool in transport policy. Modal split for public transport was done by estimating the percentage of bus and tramway passengers. The existing level was assumed but it can be changed in establishing transport policy.

Nonurban passenger traffic was calculated for the whole country. Mobility factors for those trips were estimated according to the existing data from other studies, including forecasts adopted for the national "Transport Policy". Results from other developed countries were used as well. Similarly to urban traffic, more and more trips are made by car. It cannot be limited by administrative methods like in the cities, and the share of trips made by cars is more directly related to the increase in the number of cars and economic potential of car owners.

Cargo traffic forecast

The cargo traffic forecast was based on the amount of cargo transported per capita. The starting point was the present level. The increase of transport intensity rates was related to the increase of GDP, but not as linear dependence, as it is assumed that the future production will be less transport intensive. As control data, the level of transport intensity observed in developed European countries, were used.

In the *modal split model* the tendency to use road transport rather than any other was taken into consideration. As a starting point the existing division between railways and road transport was assumed. The future share of road transport was calculated from the number of vehicles and average capacity resulting from vehicle fleet structure. The share of air and water transport, compared to land transport is very small and has been estimated as similar to the existing level. The results of cargo traffic forecast for the reference scenario are presented in tables 4 (tons) and 5 (ton - kilometers).

Computer program

To carry out computations, a computer program was built. It is based on Lotus 1-2-3 worksheet. It has a special menu which makes the use of the program very easy. The worksheet consists of over 40 tables and 50 charts representing input and output data. It is divided into three parts: traffic forecasting, energy consumption calculation and emission calculation.

The input data contain:

- macroeconomic data;
- average trip length;
- mobility;
- elasticity models;
- modal split in numbers and percentage;
- vehicle fleet structure;
- speed structure;
- fuel and energy consumption ratio;
- emission factors.

The output tables give the overview of all intermediate results and final results. In this the main results concerning traffic forecast are presented: number of passengers, passenger kilometers, tons and ton kilometers. The results of emission calculation are presented in the main part of the report.

Output and intermediate tables are the following:

- motorization forecast;
- passenger transport in passengers and passenger kilometers;
- cargo transport in tons and ton kilometers;
- consumption of energy and fuels;
- GHG emissions in tons.

Methodology for the estimation of greenhouse gas emissions from the transport sector

The GHG emissions have been calculated taking into consideration transport volumes (passenger-kilometers and ton-kilometers), and emission rates per one unit of transport volume. These rates have been determined on the basis of the research and forecasts of the Transport Economics Research Center and Automotive research Institute in Warsaw and have been expressed in MJ per vehicle-kilometer and MJ per ton-kilometer for the following transport modes:

Passenger transport:
- rail transport, including steam, diesel, and electric traction;
- public interurban road transport;
- public urban transport;
- passenger cars and motorcycles;
- air transport;
- inland waterway transport.

Freight transport:
- rail transport, including steam, diesel, and electric traction;
- road transport, including professional and individual carriers;
- air transport;
- inland waterway transport.

Following requirements of the methodology adopted for the whole country study, energy consumption by the sea transport and related emissions have been calculated from the total volumes of fuels sold in the Polish ports to all operators.

To calculate GHG emission from the operation of the above transport subsectors, the following approach has been applied:

- for traction using liquid and solid fuels - emission coefficients expressed in grams per GJ of energy contained in fuel have been used;

- for electric traction - starting with rates of direct energy consumption (per pas-km and ton-km) the total energy consumption was calculated (multiplier 2.94); emissions were calculated using emission coefficients for electricity production by professional power plants in Poland..

Direct operational emission in road transport has been determined in accordance with the research by S. Radzimirski's team [1994] with some modifications:

- categories of vehicles has been adopted as recommended by IPCC;

- GHG emission coefficients expressed in grams per 1 kilogram of fuel or grams per 1 GJ of energy contained in fuel applicable in 1992, have been extended for all time periods in Reference Scenario (1985-2030);

- annual number of kilometers per vehicle has been changed on the basis of an analysis made by the authors; moreover, S. Radzimirski's data relate to the year 1992 only, whereas needed were data referring to the whole period 1985 - 2030. Therefore, appropriate adjustments have been made.

Results of the research mentioned above as well as other reference data allowed to establish a relationship between fuel consumption, the resulting emissions and average travel speed. That relationship has been used to determine the GHG emissions expressed in grams per vehicle-km in the period from 1985 to 2030, for the following vehicle types :
- passenger cars;
- vans;
- light freight vehicles (capacity from 3.5 to 6 tons);
- heavy freight vehicles (capacity over 6 tons);
- buses;
- motorcycles;
- mopeds.

Use of energy by tractors and other equipment has not been included because it has been taken into consideration in other sectors.

For each time period from 1990 to 2030, the composition of the fleet of vehicles has been forecasted. The most probable technological progress in vehicles construction and the resulting changes in energy consumption and the unitary emissions have been taken into account, including rising proportion of less polluting vehicles (with catalysts, diesel engines, and electricity-driven ones). All the probable changes have been adopted for the Reference Scenario. Rates of GHG emissions in grams per vehicle-km or t-km have been calculated as weighed emissions for specific vehicle types for 1985, 1995, 2010, and 2030 time periods.

Emissions related to the maintenance of the transport subsectors have been calculated as if these emissions had come from the electric energy used by the transport sector.

Due to lack of data on the relationship between energy consumption/ emissions and average speed for transport modes other than road, emissions rates (expressed in grams per vehicle-km or ton-km) for those modes have been estimated for average operating conditions.

Taking into consideration the methodology adopted in the country study, the following compounds have been taken into account:

- CO_2P;
- CO_2R;
- CH_4;
- N_2O.

Detailed calculations of emission rates (expressed in grams per vehicle-km or ton-km) for all transport modes listed in point above for the 1985 - 2030 period, have been executed.

In order to evaluate complex influence of greenhouse gases at the atmosphere, CO_2 equivalent has been used with the following conversion rates

- CO_2R - 1.0;
- CH_4 - 24.5;
- N_2O - 320.0.

The model enables two options of calculation:

Alternative 1. Calculation of the use of energy and emissions, taking into account both direct transport operation and other transport activities (operation and maintenance of facilities).

Alternative 2. Calculation of the use of energy and emissions, taking into account only direct transport operation.

While, because of the methodology adopted for the whole country study, **alternative 2** had to be used as a basic one, in the authors' opinion **alternative 1** would be more relevant. Alternative 1 provides more information on emissions from the transport sector as it presumes the use of energy (and relating emissions) for other purposes, such as operating terminals, maintenance etc.

The final results contain the total consumption of electric energy and liquid fuels. According to the methodology used in the country study, for the electric energy only direct use has been quoted.

The above described method enabled to calculate the total energy consumption and the GHG emissions from the area of Poland generated by the transport sector for the Reference Scenario and other emission abatement scenarios for the whole period 1990 - 2030. This allowed to examine the effectiveness of various policies aimed at the reduction of emissions.

Compared to earlier works on GHG emissions by the transport sector in Poland, the methodology proposed in this study reflects some additional factors such as speed distribution for road transport and additional emissions caused by energy consumption for other purposes than vehicles propulsion.

9.4.3. Reference Scenario

Reference (or Baseline) Scenario has been elaborated under an assumption that the present trends will continue and, consequently, the transport sector will develop without interventions aimed at the reduction of the GHG emissions.. Main features of the Reference Scenario refer to:

- transport demand - the most probable trends are assumed; forecasts are based on the most recent official forecast up to the year 2010 with extrapolation up to 2030;
- transport technology - moderate improvements in vehicle technologies and switch to fuels with lower emissions are assumed;
- traffic conditions - as at present (no additional congestion, speed distribution as at present).

Transport volumes and resulting emissions have been calculated using models and computer program described in point 9.4.2. Passenger traffic forecasts for the Reference Scenario are presented in tables 9.4.2 (numbers of passenger trips) and 9.4.3 (number of ton-kilometers). The results of international comparisons are presented in figures 9.4.1 to 9.4.6. Freight transport forecasts are contained in tables 9.4.4 (tons) and 9.4.5. (ton-kilometers).

Energy and fuel consumption resulting from forecasts of freight and passenger transport demand for the Reference Scenario over time are shown in table 9.4.6, and emissions in table 9.4.7, and in figures 9.4.7 and 9.4.8. As could have been expected, emissions calculated with the use of alternative 1 are much higher than for alternative 2. Nevertheless, taking into consideration requirements of the methodology adopted for the whole country study, further analysis was carried out with the use of alternative 2 only, as a calculation method.

Table 9.4.7 indicates that, for all alternatives, after a period of rapid growth of emissions in 1990's, rather moderate growth of the GHG emissions can be expected and, beyond the year 2020, stabilization of emissions level is being envisaged.

Tab. 9.4.2. Passenger traffic forecasts (million of passengers per year) - reference scenario

		1990	1991	1992	1993	1994	1995	2000	2005	2010	2015	2020	2025	2030
NONURBAN														
Public transport - total	million	2881	2364	2065	1925	1954	1964	2319	2652	2965	3252	3547	3699	3753
Railway	million	790	652	549	541	550	493	735	920	1048	1109	1213	1287	1349
Nonurban buses	million	2085	1709	1513	1381	1402	1469	1581	1727	1910	2135	2325	2402	2392
Air	million	1.7	1.2	1.3	1.4	1.5	1.2	2.0	2.9	3.9	5.1	6.4	7.6	8.9
Inland shipping	million	3.8	1.0	0.7	0.6	0.6	0.4	0.5	0.6	0.7	0.7	0.8	0.8	0.9
Sea	million	0.6	0.6	0.7	0.6	0.6	0.8	1.0	1.2	1.3	1.5	1.6	1.7	1.8
Passenger vehicles	million	1301	1626	1848	2043	2101	2156	2623	3121	3585	4043	4431	4762	5117
Total	million	4182	3991	3913	3967	4055	4121	4942	5773	6549	7295	7978	8461	8870
URBAN														
Public transport - total	million	4688	4875	5427	5962	5980	5447	5772	6296	6816	7584	8271	8843	9449
Urban buses	million	3394	3530	3929	4317	4362	3973	4210	4592	4972	5532	6033	6450	6893
Railway	million	1294	1345	1498	1645	1618	1474	1562	1703	1844	2052	2238	2393	2557
Passenger vehicles	million	5312	6596	7515	8451	8614	9115	11353	13741	15942	18074	19805	21286	22875
Total	million	10000	11471	12942	14413	14594	14562	17125	20036	22759	25658	28076	30129	32325
TOTAL	million	14182	15462	16855	18380	18648	18683	22067	25809	29308	32953	36054	38589	41194

Fig. 9.4.1 TOTAL TRANSPORT

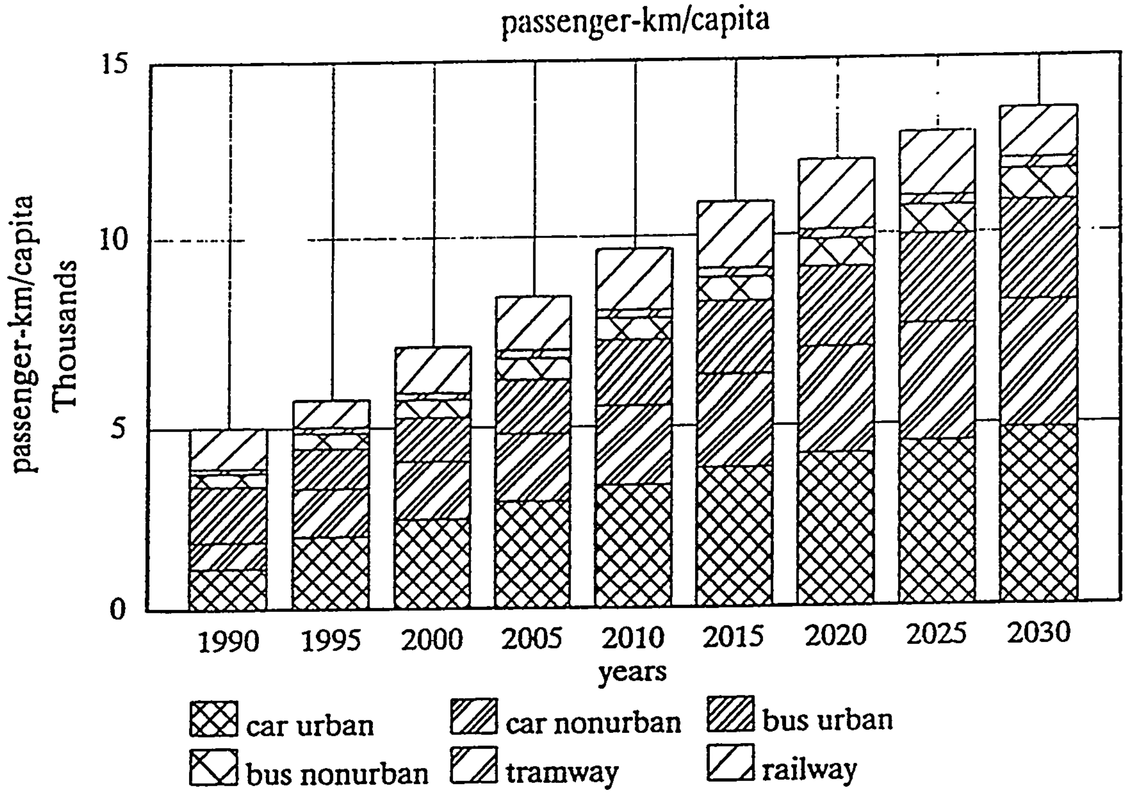
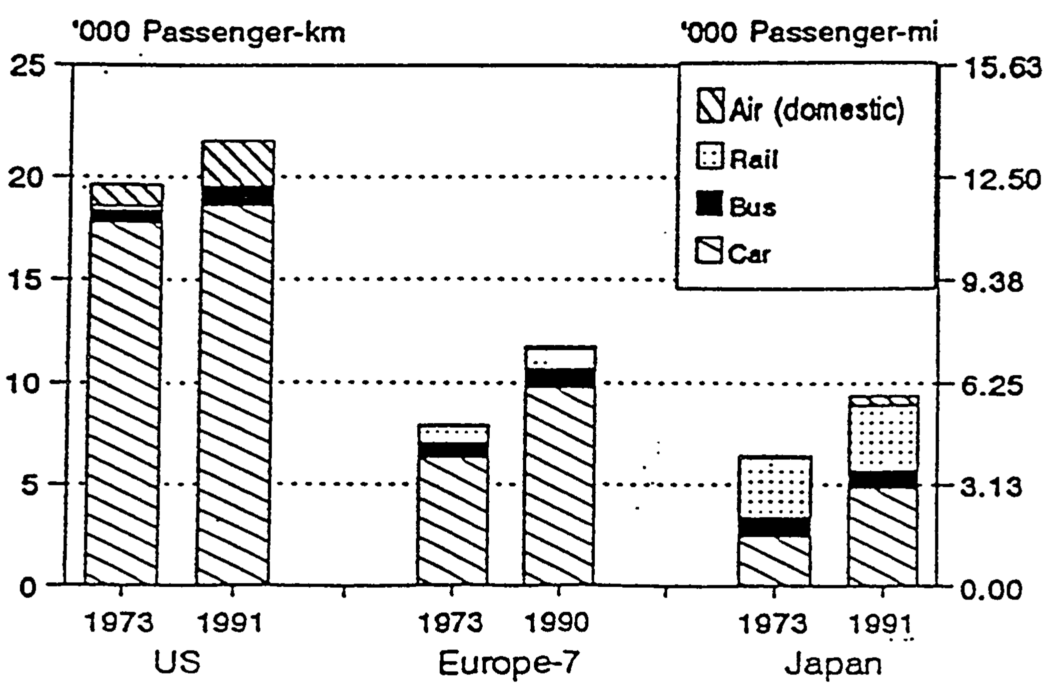


Fig 9.4.2 Per Capita Travel By Mode



Source: Sch... [1994]

Fig. 9.4.3

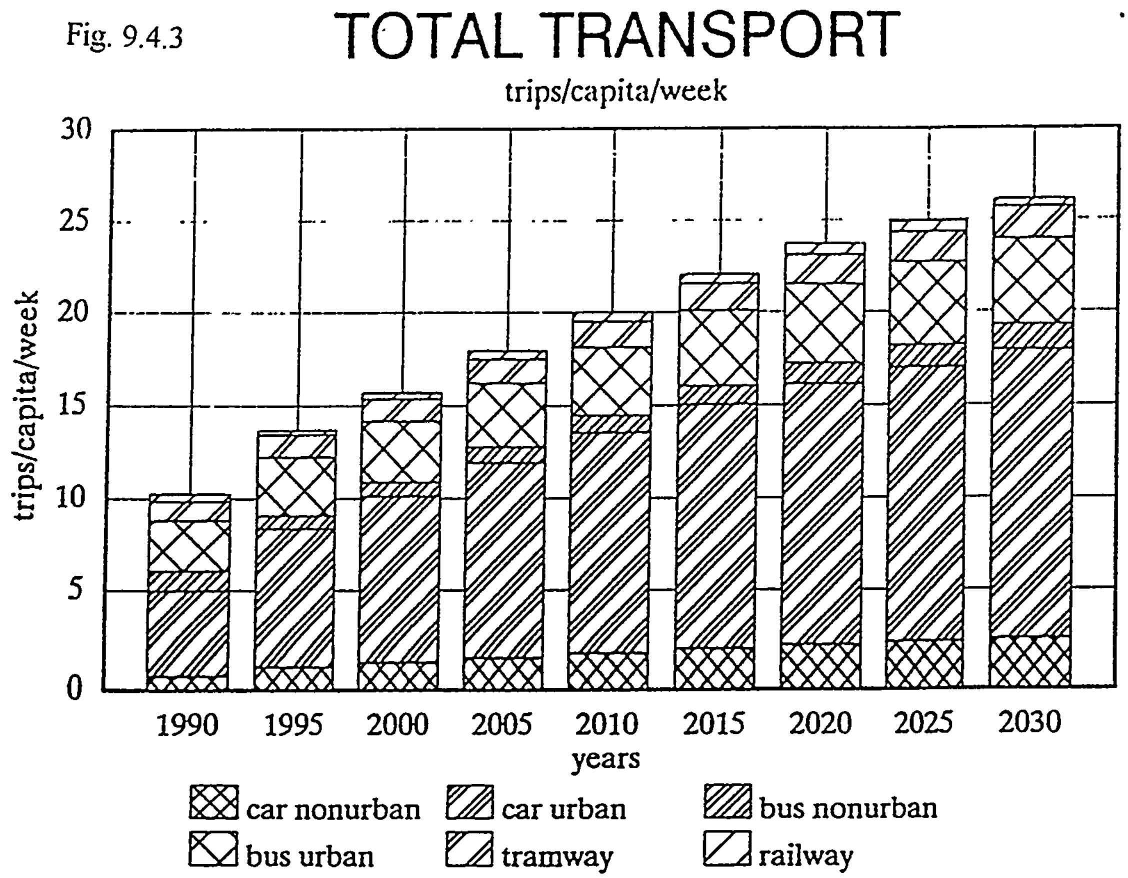
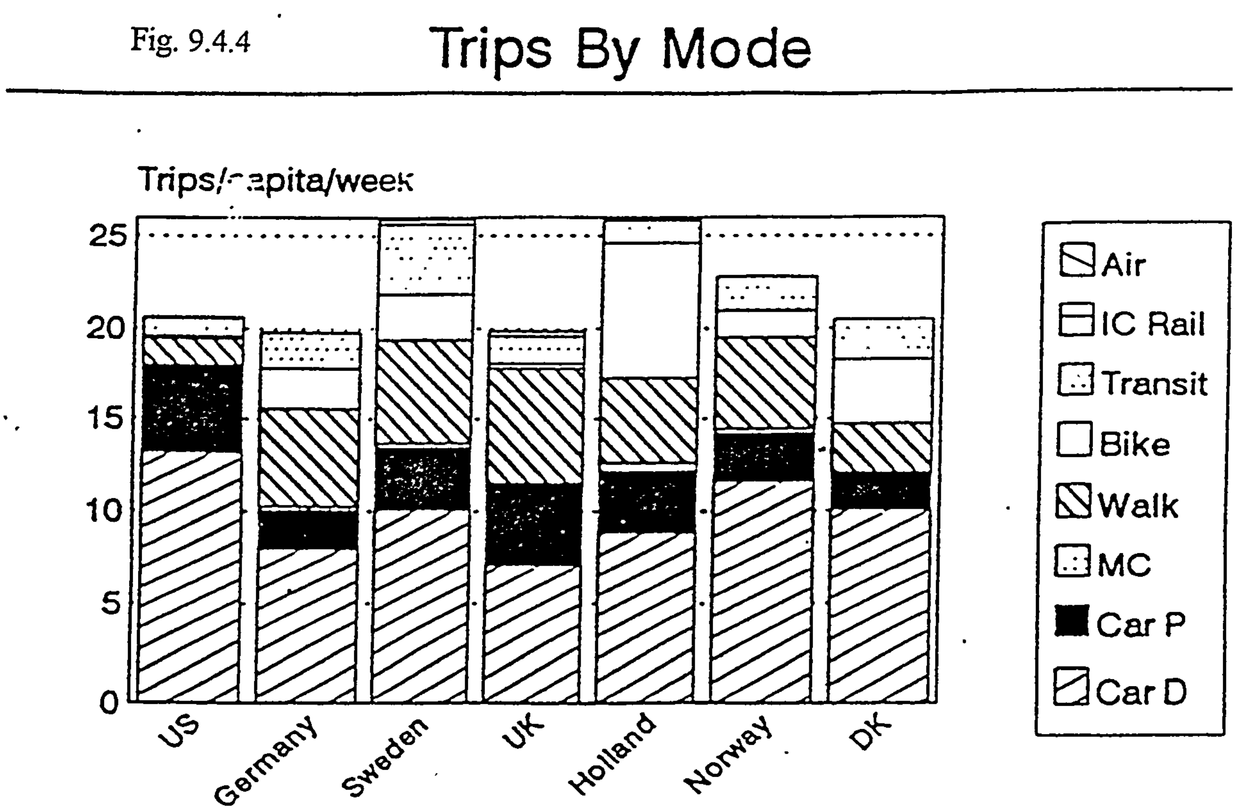


Fig. 9.4.4



Transit includes buses+subways and other modes of Public Transport

Source: Schipper [1994]

Fig. 9.4.5

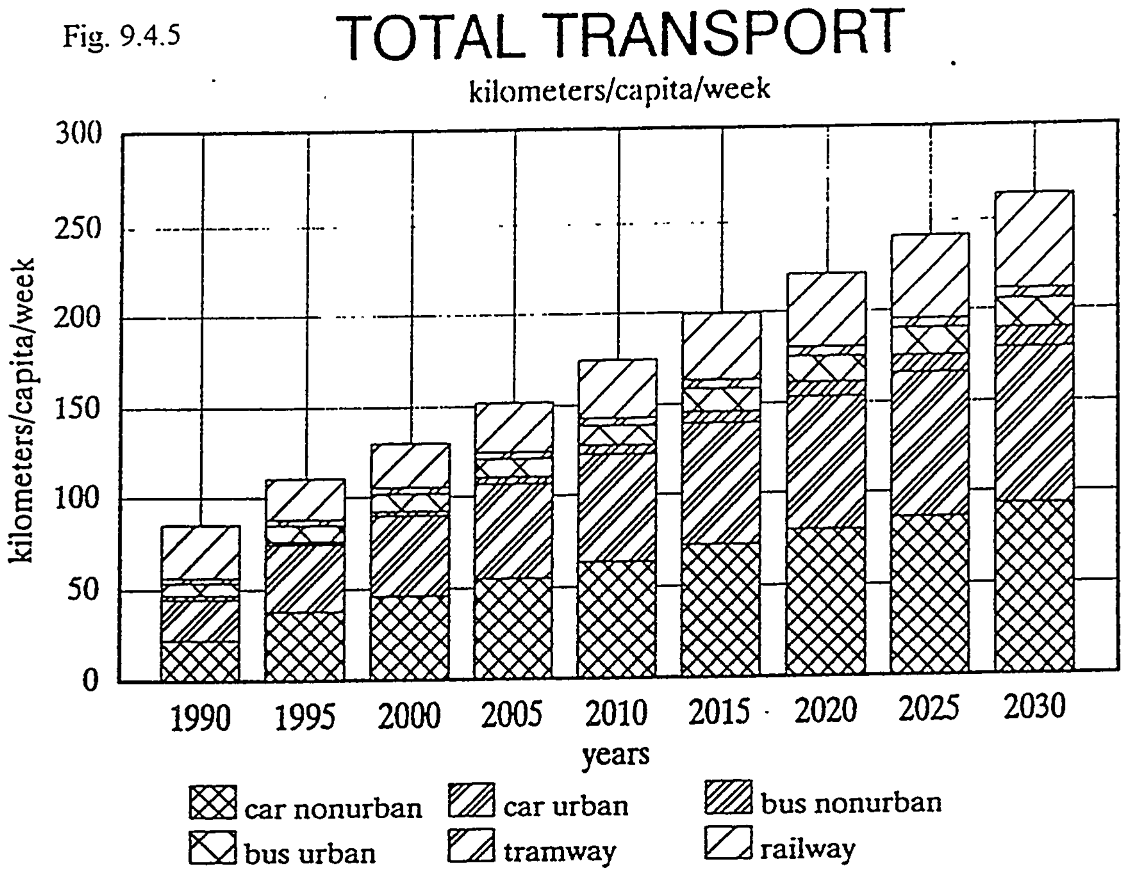
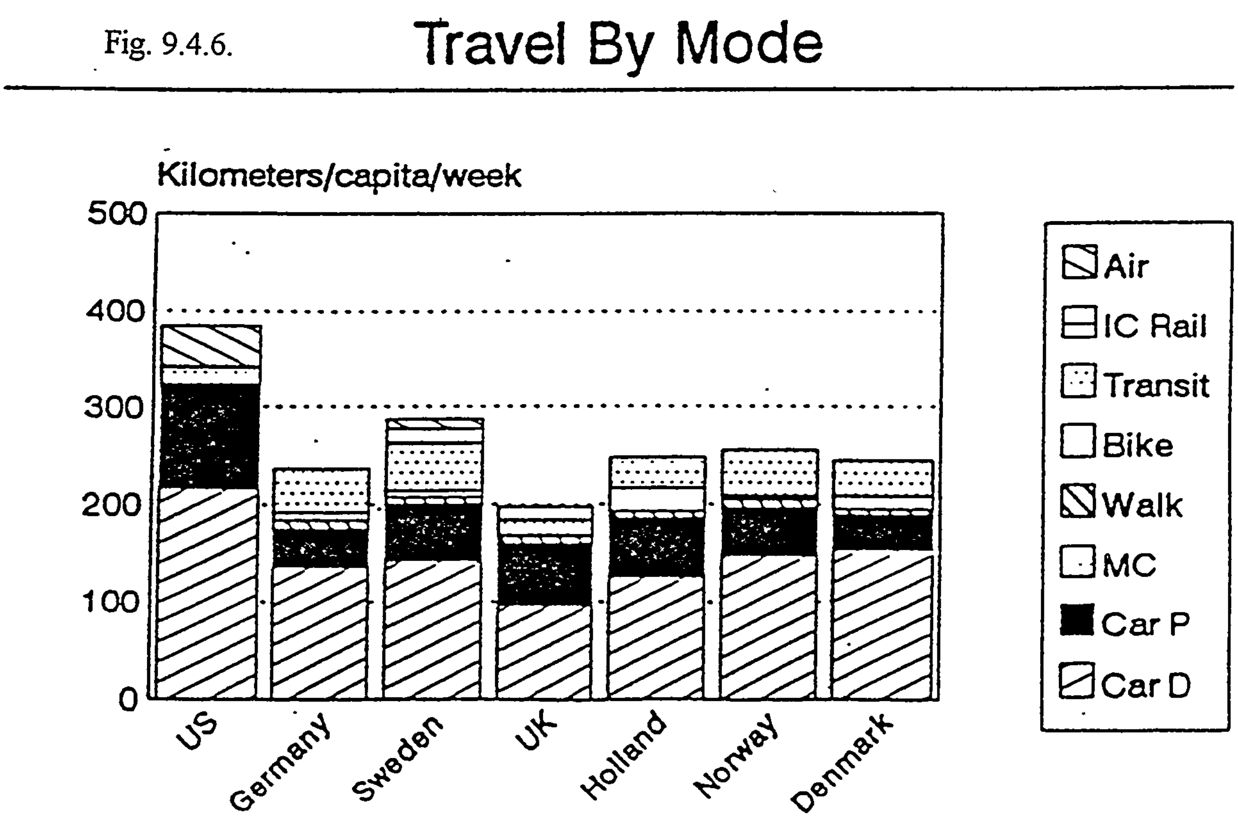


Fig. 9.4.6.



Source: Schipper [1994]

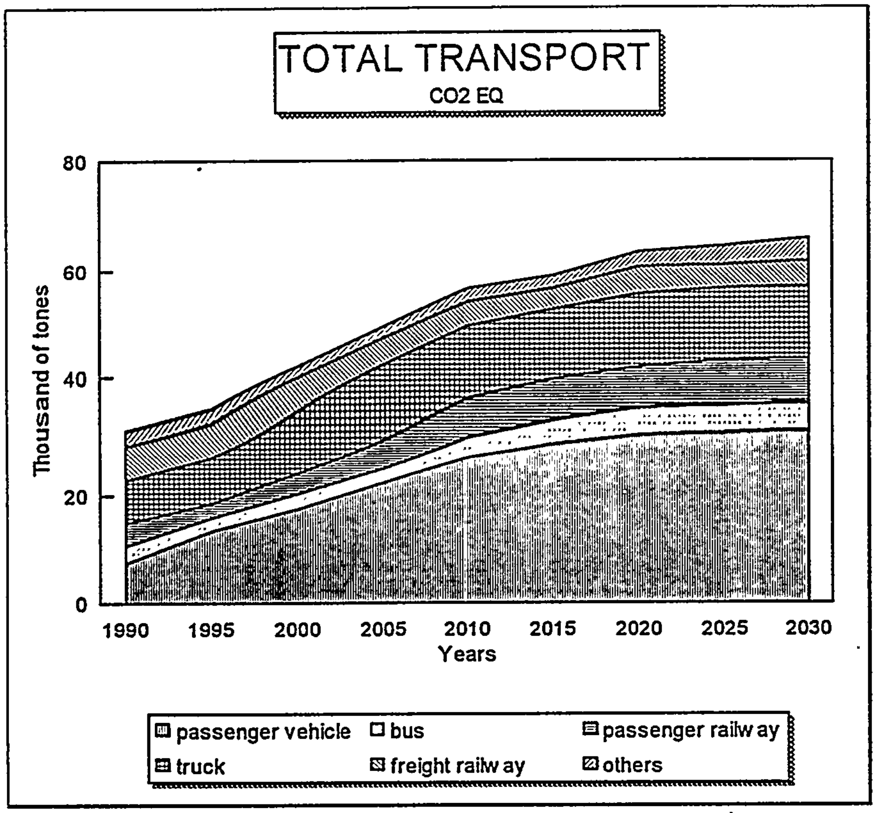


Fig. 9.4.7 Summarised emissions (CO2 EQ) for alternative 1

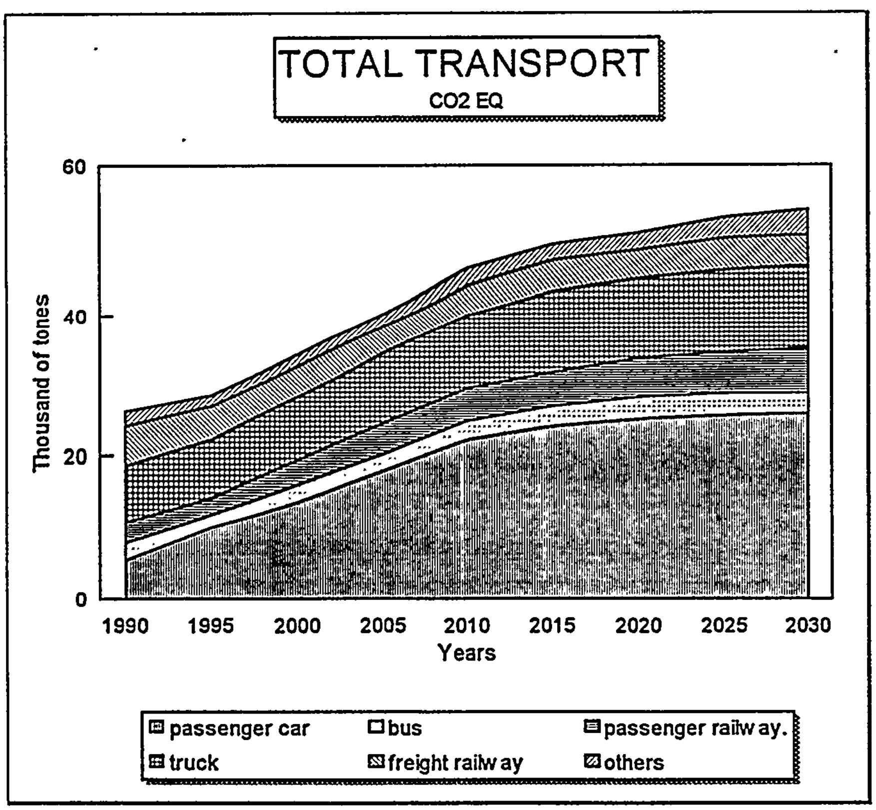


Fig. 9.4.8 Summarised emissions (CO2 EQ) for alternative 2

Tab. 9.4.3. Forecast of passenger traffic (in billion passenger-kilometres) - reference scenario

		1990	1991	1992	1993	1994	1995	2000	2005	2010	2015	2020	2025	2030
NONURBAN														
Public transport-total	billion	106.9	87.4	76.4	72.6	76.5	77.3	100.1	122.0	142.7	161.0	181.6	196.4	207.4
Railway	billion	45.1	37.2	31.4	30.9	32.0	29.3	44.4	56.6	65.6	70.1	77.4	82.9	87.7
Nonurban bus	billion	57.1	46.8	41.5	37.8	40.5	44.5	50.2	57.4	66.3	76.9	86.8	92.9	95.7
Air	billion	4.4	3.1	3.4	3.6	3.9	3.2	5.2	7.6	10.3	13.5	16.8	20.1	23.5
Inland shipping	billion	0.028	0.021	0.015	0.013	0.014	0.010	0.012	0.017	0.020	0.023	0.026	0.029	0.031
Sea	billion	0.200	0.179	0.209	0.179	0.179	0.302	0.329	0.394	0.442	0.479	0.508	0.523	0.531
Passenger vehicles	billion	43.3	54.5	62.8	71.5	73.7	75.9	93.6	113.3	132.3	151.6	168.8	184.3	201.1
Total	billion	150.2	141.9	139.3	144.1	150.3	153.2	193.8	235.3	275.0	312.6	350.4	380.7	408.5
URBAN														
Public transport - total	billion	18.8	19.9	22.6	25.3	25.9	24.1	26.0	28.9	31.8	36.0	40.0	43.5	47.2
Buses	billion	13.6	14.4	16.4	18.3	18.9	17.5	18.9	21.0	23.2	26.3	29.2	31.7	34.5
Railway and Tram	billion	5.2	5.5	6.2	7.0	7.0	6.5	7.0	7.8	8.6	9.7	10.8	11.8	12.8
Passenger vehicles	billion	26.6	33.5	38.8	44.4	45.9	49.4	62.4	76.7	90.3	103.9	115.5	125.9	137.3
Total	billion	45.3	53.4	61.4	69.7	71.9	73.4	88.4	105.6	122.1	139.9	155.5	169.4	184.5
TOTAL	billion	195.5	195.3	200.7	213.8	222.1	226.7	282.2	340.8	397.1	452.6	505.9	550.1	593.0

Tab. 9.4.4. Forecasts of freight transport (in million tons per year) - reference scenario

	1990	1991	1992	1993	1994	1995	2000	2005	2010	2015	2020	2025	2030
Railway	281,7	227,8	201,7	214,2	221,0	245,7	219,6	205,4	197,2	201,7	204,8	188,1	189,7
Trucks	1292,3	1188,7	1121,7	1071,2	1107,6	1091,7	1367,3	1628,5	1837,7	2038,9	2225,3	2251,7	2371,4
Inland Shipping	9,8	7,8	7,9	8,7	9,0	8,4	10,0	11,5	12,8	13,8	14,7	15,4	16,2
Sea	28,5	27,6	26,9	23,9	23,8	25,2	29,9	34,6	38,4	41,3	44,2	46,3	48,6
Pipelines	33,0	26,4	30,2	31,2	32,4	30,8	36,6	42,3	46,9	50,5	54,0	56,6	59,4
Total	1645,3	1478,3	1388,4	1349,2	1393,8	1401,9	1663,5	1922,3	2133,0	2296,7	2455,1	2574,2	2698,8
Number of tones/inhabitant	43,1	38,6	36,2	35,0	36,2	36,3	42,5	48,5	53,3	57,0	60,3	62,6	65,0

Tab. 9.4.5. Forecasts of freight transport (in billion ton-kilometres per year) - reference scenario

	1990	1991	1992	1993	1994	1995	2000	2005	2010	2015	2020	2025	2030
Railway	83,5	65,1	57,8	64,4	66,6	74,2	67,0	63,2	61,3	63,2	64,6	59,8	60,7
Trucks	40,3	39,6	42,0	40,7	42,6	42,5	56,5	71,3	85,5	96,6	107,4	110,6	118,6
Air	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Inland Shipping	1,0	0,7	0,7	0,7	0,7	0,7	0,8	0,9	0,9	1,0	1,1	1,2	1,3
Sea	207,4	202,3	193,1	155,1	154,1	163,1	191,6	219,2	240,8	258,6	275,6	288,1	301,2
Total	332,2	307,7	293,6	260,9	264,1	280,4	315,8	354,7	388,6	419,4	448,7	459,7	481,7

Tab. 9.4.6. Consumption of energy and liquid fuels - reference scenario

ELECTRIC ENERGY CONSUMPTION [PJ]

Year	1990	1995	2000	2005	2010	2015	2020	2025	2030
Freight Railway	13,78	11,68	10,55	9,96	9,66	7,51	10,18	9,42	9,56
Passenger Railway	9,47	6,14	9,32	11,88	13,78	14,72	16,26	17,40	18,41
Tram	1,09	1,37	1,48	1,64	1,81	2,05	2,27	2,47	2,68
Total	24,34	19,19	21,34	23,48	25,25	24,28	28,71	29,29	30,66

LIQUID FUEL CONSUMPTION [PJ]

Year	1990	1995	2000	2005	2010	2015	2020	2025	2030
PASSENGER TRAFFIC									
Railway	13,3	8,8	13,3	17,0	19,7	21,0	23,2	24,9	26,3
Passenger vehicles	130,7	228,0	280,9	340,1	398,5	425,5	437,9	439,0	436,5
Bus	21,2	16,8	18,7	20,4	22,4	24,8	26,7	27,4	27,3
Air	13,2	7,9	10,8	15,3	20,6	26,8	33,5	40,1	46,8
Total	178,5	261,4	323,7	392,8	461,1	498,1	521,3	531,3	536,9
FREIGHT TRAFFIC									
Railway	15,0	13,7	12,6	11,9	11,5	8,9	12,1	11,2	11,4
Trucks	114,9	103,6	136,1	154,8	174,3	183,5	194,3	195,0	197,7
Inland Shipping	0,8	0,5	0,5	0,5	0,4	0,5	0,5	0,5	0,6
Sea	3,9	3,9	3,9	3,9	3,9	3,9	3,9	3,9	3,9
Total	134,6	121,7	153,0	171,0	190,2	196,8	210,8	210,6	213,6
TOTAL	313,1	383,1	476,7	563,8	651,3	694,9	732,2	741,9	750,5

Table 9.4.7. Total emissions (thousand tons) - reference scenario

CO_2 EQ	1990	1995	2000	2005	2010	2015	2020	2025	2030
alternative 1	32050	35064	42043	49526	56410	58851	63401	64449	65719
alternative 2	26065	28498	34177	40222	45828	49046	50624	52726	53778

9.4.4. GHG abatement scenarios

The GHG abatement scenarios have been built with regard to five categories of actions.

1. Reduction of transport demand:
- exogenous factors: economic and population growth, urbanization, national industrial policy, transport demand reducing changes in people's behavior (telework, teleshopping), etc.;
- endogenous factors resulting in mobility changes: spatial structures, motorization growth, costs for users, etc.

Potential policy measures include: land use/transport planning, controlling motorization growth, fiscal measures discouraging excessive use of transport means with high emission rates.

2. Encouraging modal shift to environment friendly means of transport through measures such as:
- promotion of non-mechanized transport (walking, bicycle) and mass transport, as well as railways and water transport;
- increase of the attractiveness of mass transport;
- fiscal measures (taxation, toll roads, road/parking pricing, congestion pricing, etc.);
- traffic restraints (pedestrian zones, limited access zones).

3. Improvement in vehicle technology: more efficient engines, reduced weight, drag and rolling resistance, reduced emission rates.

4. Shift to fuel systems with lower emissions: from petroleum to natural gas, methanol, ethanol, biofuels etc. Effects of shifting to electricity depend on the source of energy (coal, gas, oil, hydro etc.) and the efficiency of electric energy production and distribution. Attention: some fuel switching may reduce direct emissions from vehicle tail pipes but overall effect can be negative if emissions in the phase of energy production are included into calculations.

   Policy measures include: governmental industrial and fiscal policies and regulations.

5. Improvements in transport operation: better traffic management (coordinated signal control, reduction of bottlenecks), smoothing traffic flows, etc.

Taking into consideration limited possibilities to examine all combinations of possible options and capabilities of the models applied the following approach has been adopted:

a) a number of elementary strategies have been tested (for the method of calculation defined in alternative 2):

- **strategy U** - transport-efficient urban structures resulting in reduced average trip lengths (by 5 % for trucks and buses and by 10 % for cars, as assumed);
- **strategy T** - reduced transport intensity at the national economy (reduced freight transport demand - by about 0.5 % of the number of tons carried per inhabitant as related to GNP);
- **strategy M** - reduced personal mobility (reduced number of trips by about 1 % as related to GNP);
- **strategy A** - slower growth (reduced car ownership by 1 % as related to GNP);
- **strategy P** - maintaining the role of public transport, railways and water transport (the share of these modes of transport similar to that in 1995);
- **strategy V** - improved vehicles and shift to better fuel (reduced emission from cars and trucks by 10 %);
- **strategy B** - better use of transport means (increase of occupancy rates by 10 %);
- **strategy O** - improvement of road traffic conditions (a 5% increase of the share of average speed, ranging from 80 to 110 km/h, both for trucks and cars).

Results of the assessment of the GHG emissions for elementary strategies are summarized in table 9.4.8. It is visible that in a short- and medium-term perspective the effectiveness of all strategies in terms of GHG emission reduction is similar. However, when long range effects are considered, the following strategies seem to be the most promising:

- B - better use of transport means;
- V - improved transport technology (improve vehicles, switch to better fuels);
- M - aimed at the reduction of the demand for personal travel.

Table 9.4.8. Total emissions for elementary stratergies (thousand ton per year)

CO_2 EQ	1990	1995	2000	2005	2010	2015	2020	2025	2030
reference scenario	26065	28498	34177	40222	45828	49046	50624	52726	53778
strategy A	26065	28498	33840	39825	45375	48561	50118	52199	52096
strategy B	26065	28498	34177	39946	45152	46682	49962	49694	49756
strategy M	26065	28498	33962	39714	44954	47996	49344	51226	50894
strategy O	26065	28498	34177	40222	45828	47901	51598	51724	52170
strategy P	26065	28498	34177	40222	45828	49046	50624	52726	52622
strategy T	26065	28498	34017	39851	45209	48052	49554	51874	52441
strategy U	26065	28498	34177	38896	44237	47329	48845	50916	51956
strategy V	26065	28498	33375	38243	42307	45252	46708	48755	49797

b) at the second step, the following 4 combined (multi-element) strategies, composed of elementary strategies, have been identified and tested:

- strategy I = U + M + A + P + B (sustainable development of urban structures);
- strategy II = T + P + B (increased transport efficiency of national economy);
- strategy III = V + B + O (improvement in transport technology and operation);
- strategy IV = all elementary strategies together.

Results of the analysis have been summarized in tables 9.4.9 - 9.4.11 and presented in figures 9.4.9 through 9.4.11. Table 9.4.10 and figure 9.4.11 indicate that strategy IV, combining all elementary strategies, can bring about the reduction of the GHG emissions in 2030 by about 21 % in comparison to the reference scenario. All other combinations lead to the reduction of GHG emissions from 4 to 13%. A conclusion which can be drawn from these simulations is that influencing personal mobility seem to be more effective than influencing freight transport. Table 9.4.11 contains summary data on the use of electric energy and liquid fuels for all combined strategies. All these results relate to the basic macroeconomic scenario.

Table 9.4.9. Transport demand forecasts for combined strategies

Passenger transport

billion-pass-km	1990	1991	1992	1993	1994	1995	2000	2005	2010	2015	2020	2025	2030
reference scenario	195,5	195,3	200,7	213,8	222,1	226,7	282,2	340,8	397,1	452,6	505,9	550,1	593,0
strategy I	195,5	195,3	200,7	213,8	221,6	226,7	264,7	316,2	364,4	412,8	458,5	495,3	530,4
strategy II	195,5	195,3	200,7	213,8	222,1	226,7	282,2	340,8	397,1	452,6	505,9	550,1	593,0
strategy III	195,5	195,3	200,7	213,8	222,1	226,7	282,2	340,8	397,1	452,6	505,9	550,1	593,0
strategy IV	195,5	195,3	200,7	213,8	221,6	225,6	263,7	313,0	367,1	415,4	461,2	498,0	533,3

Freight transport

billion-t-km	1990	1991	1992	1993	1994	1995	2000	2005	2010	2015	2020	2025	2030
reference scenario	332,2	307,7	293,6	260,9	264,1	280,4	315,8	354,7	388,6	419,4	448,7	470,1	491,6
strategy I	332,2	307,7	293,6	260,9	264,1	280,4	309,9	347,6	380,4	410,4	424,4	455,4	477,0
strategy II	332,2	307,7	293,6	260,9	264,1	280,4	312,4	346,8	375,5	401,3	428,1	434,4	462,3
strategy III	332,2	307,7	293,6	260,9	264,1	280,4	315,8	354,7	388,6	401,5	446,1	459,7	485,9
strategy IV	332,2	307,7	293,6	260,9	264,1	280,4	306,5	339,8	367,5	392,7	402,3	435,0	448,3

Table 9.4.10. Total emissions for combined strategies (thousand ton per year)

CO_2 EQ	1990	1995	2000	2005	2010	2015	2020	2025	2030
reference scenario	26065	28498	34177	40222	45828	49046	50624	52726	53778
strategy I	26065	28498	31288	36412	41027	42515	45785	46348	47120
strategy II	26065	28498	32730	38208	43193	45869	48443	48839	50361
strategy III	26065	28498	32159	36771	40596	42147	45594	46359	47625
strategy IV	26065	28498	30402	34223	37406	39457	40340	42222	42476

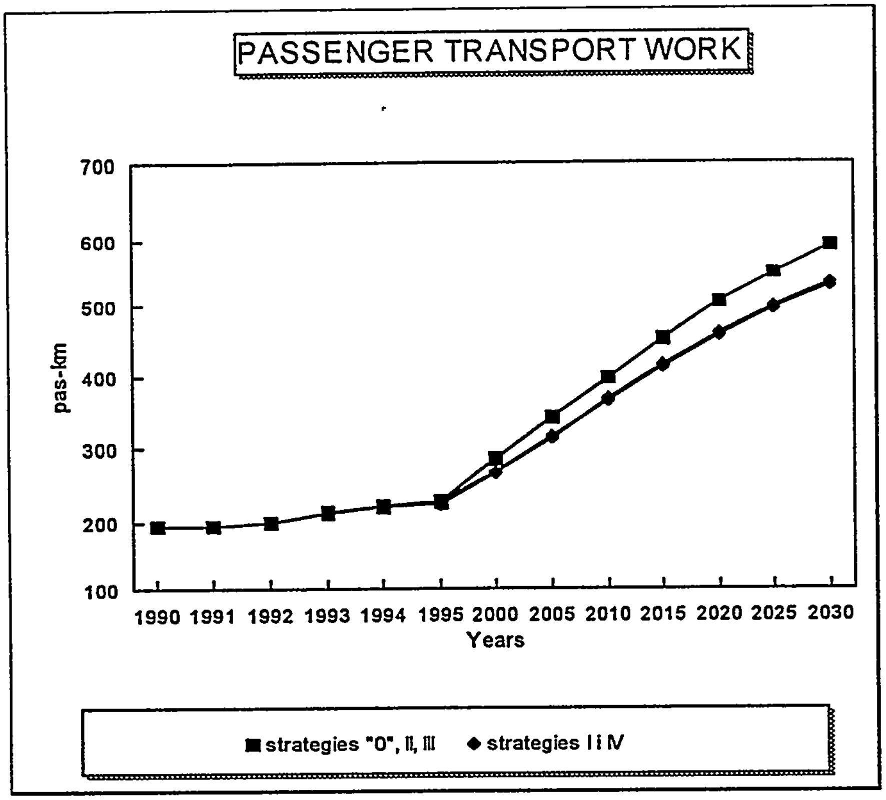


Fig. 9.4.9 Passenger transport work - base macroeconomic scenario

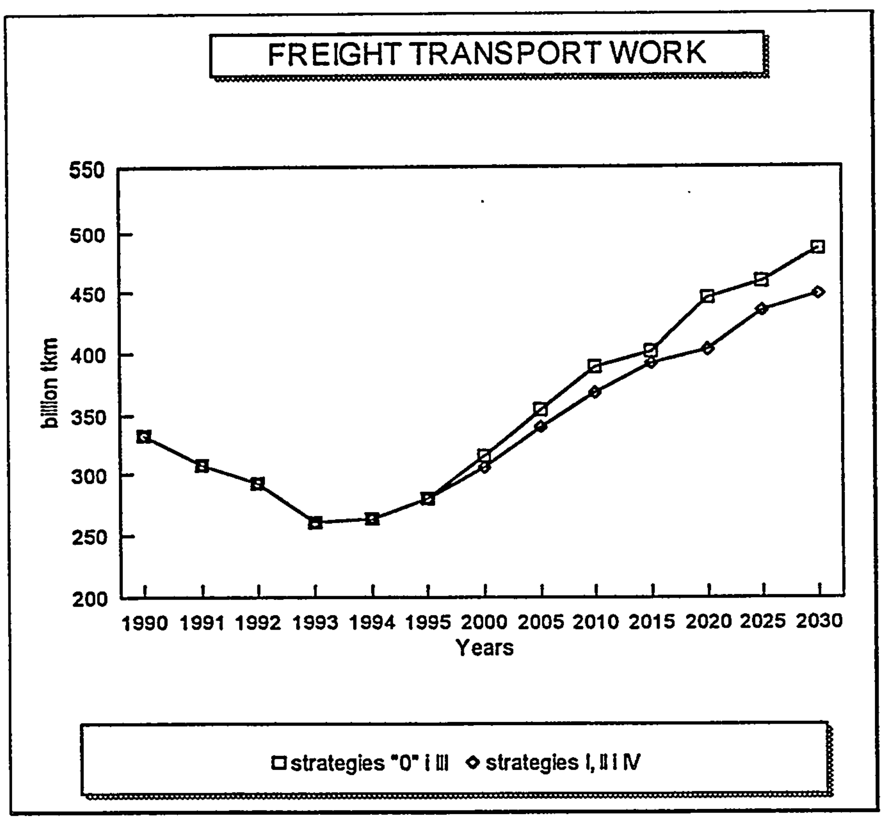


Fig. 9.4.10 Freight transport work - base macroeconomic scenario

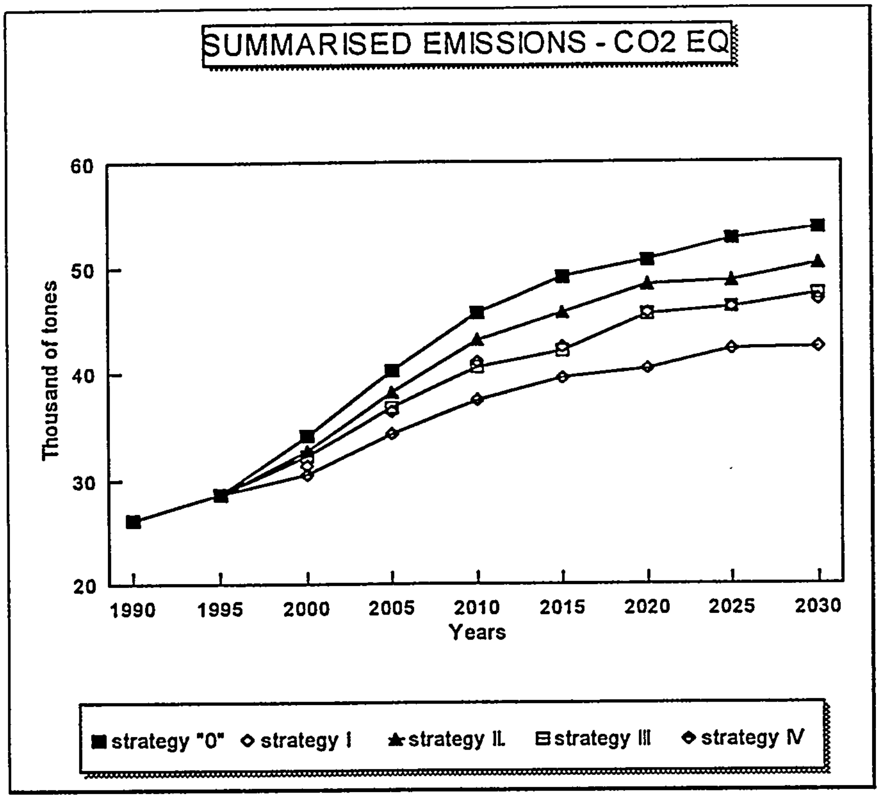


Fig. 9.4.11 Summarised emissions for combined strategies composed of elementary strategies - CO2 EQ - base macroeconomic scenario.

In addition, the impact of different scenarios of the economic development on the transport demand, energy consumption and GHG emissions was tested. The results of simulations for strategy of stagnation and strategy of chance are presented in tables 9.4.12 through 9.4.15 and in figures 9.4.12 and 9.4.13.

Table 9.4.11. Consumption of energy and liquid fuels for combined strategies

Electric energy consumption [PJ/year]

Strategy	1990	1995	2000	2005	2010	2015	2020	2025	2030
reference scenario	24,34	19,19	21,34	23,48	25,25	24,28	28,71	29,29	30,66
strategy I	24,34	19,19	20,51	21,78	22,47	23,63	23,51	26,17	27,22
strategy II	24,34	19,19	20,96	22,59	23,76	25,12	24,77	28,38	29,08
strategy III	24,34	19,19	21,34	23,48	25,25	24,28	28,71	29,29	31,34
strategy IV	24,34	19,19	20,49	21,77	22,50	23,73	25,40	25,12	27,55

Liquid fuel consuption [PJ/year]

Strategy	1990	1995	2000	2005	2010	2015	2020	2025	2030
reference scenario	313,1	383,1	476,7	563,8	651,3	694,9	732,2	741,9	750,5
strategy I	313,1	383,1	446,9	527,3	607,7	647,4	681,1	688,8	695,3
strategy II	313,1	383,1	476,3	562,8	636,1	676,4	698,1	709,7	707,2
strategy III	313,1	383,1	476,7	563,8	621,7	652,8	676,0	670,8	662,8
strategy IV	313,1	382,9	444,0	520,1	555,0	585,7	606,5	602,4	601,1

Table 9.4.12. Total emissions for various macroeconomic scenarios and reference transport scenario (thousand tons per year)

CO_2 EQ	1990	1995	2000	2005	2010	2015	2020	2025	2030
BASE alternative	26065	28498	34177	40222	45828	49046	50624	52726	53778
STAGNATION alternative	26065	28899	35214	41005	45984	46667	46105	44364	47120
CHANCE alternative	26065	28899	40298	50961	63378	70050	75963	80688	84016

Table 9.4.13. Total emissions for various macroeconomic scenarios and transport scenario IV - maximum reduction of emissions (thousand tons per year)

CO_2 EQ	1990	1995	2000	2005	2010	2015	2020	2025	2030
BASE alternative	26065	28498	30402	34223	37406	39457	40340	42222	42476
STAGNATION alternative	26065	28899	31332	34891	37522	37746	36955	34852	33317
CHANCE alternative	26065	28899	35923	43555	52087	58625	61979	67395	69251

Table 9.4.14. Consumption of energy and liquid fuels for various macroeconomic scenarios and reference transport scenario (thousand tons per year)

Electric energy consumption [PJ/year]									
Year	1990	1995	2000	2005	2010	2015	2020	2025	2030
BASE alternative	24,34	19,19	21,34	23,48	25,25	24,28	28,71	29,29	30,66
STAGNATION alternative	24,34	19,47	22,2	24,02	25,17	25,38	25,47	24,93	24,15
CHANCE alternative	24,34	19,47	27,24	33,36	40,92	42,45	45,04	47,89	51,14
Liquid fuel consumption [PJ/year]									
Year	1990	1995	2000	2005	2010	2015	2020	2025	2030
BASE alternative	313,10	383,10	476,70	563,80	651,30	694,90	732,20	741,90	750,50
STAGNATION alternative	313,10	388,60	490,60	574,60	654,10	668,10	652,50	621,40	581,80
CHANCE alternative	313,10	388,60	555,70	703,20	881,80	996,30	1085,50	1152,50	1191,20

Table 9.4.15. Consumption of energy and liquid fuels various macroeconomic scenarios and transport scenario IV - maximum reduction of emissions (thousand tons per year)

Electric energy consumption [PJ/year]									
Year	1990	1995	2000	2005	2010	2015	2020	2025	2030
BASE alternative .	24,34	19,19	20,49	21,77	22,50	23,73	25,40	25,12	27,55
STAGNATION alternative	24,34	19,47	21,32	22,27	22,41	22,52	22,52	20,79	21,10
CHANCE alternative	24,34	19,47	26,23	31,19	37,16	37,25	46,35	48,27	53,48
Liquid fuel consumption [PJ/year]									
Year	1990	1995	2000	2005	2010	2015	2020	2025	2030
BASE alternative	313,10	382,90	444,00	520,10	555,00	585,70	606,50	602,40	601,10
STAGNATION alternative	313,10	388,30	457,00	530,10	557,40	560,70	539,40	503,90	465,50
CHANCE alternative	313,10	388,30	517,70	649,20	752,30	848,10	895,10	940,40	948,70

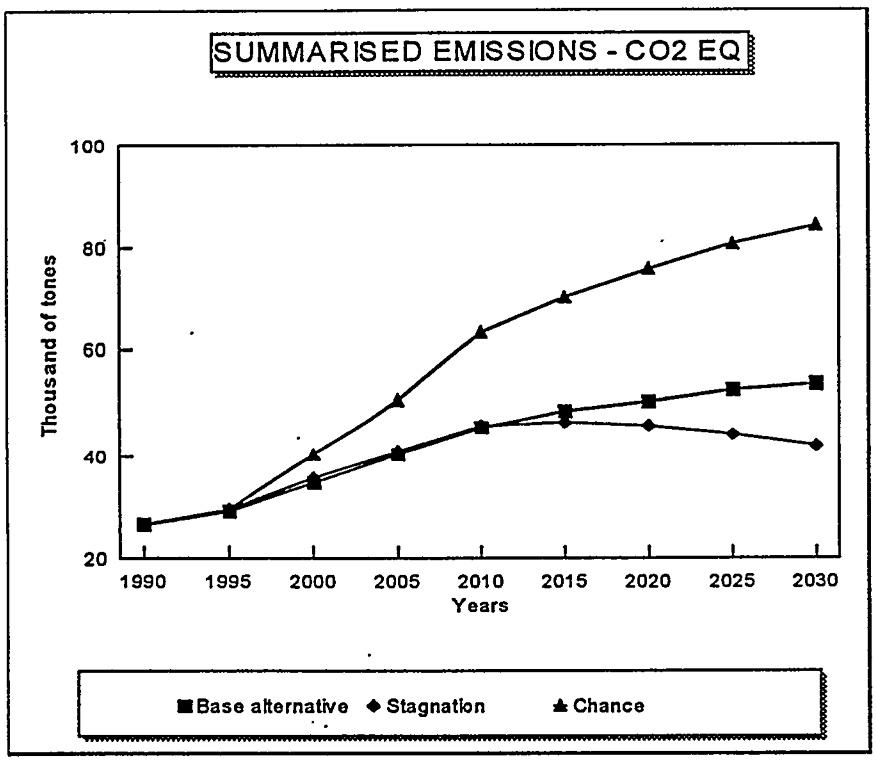


Fig. 9.4.12 Summarised emissions - CO2 EQ -without reduction (according to sceanrio 0)

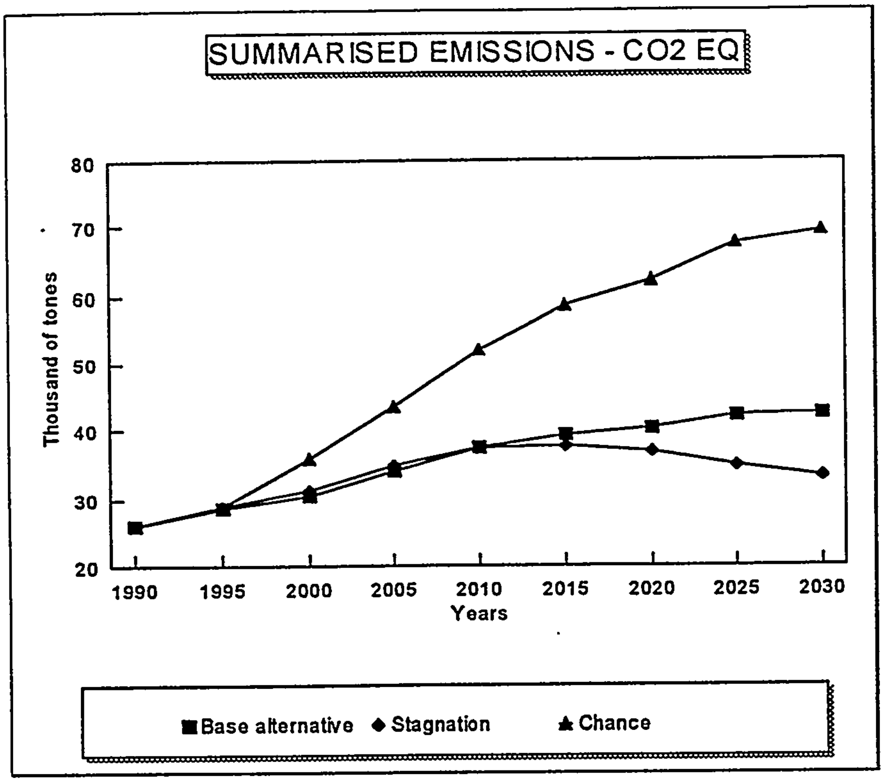


Fig. 9.4.13 Summarised emissions - CO2 EQ - with reduction (according to scenario IV)

9.4.5. GHG abatement costs

Unfortunately, attempts to determine the costs for each strategy quantitatively have not been successful. Interrelationships between various factors are so complex that further studies and macroeconomic modeling, which could not have been covered within this study, would be needed. It is known from the literature (see, e.g. OECD, 1993) that even for the most direct strategies, such as fuel switching in cars, the cost-effectiveness for GHG emission is very difficult to calculate. The cost -effectiveness of other ways of reducing emissions, such as restructuring urban areas or reducing transport-intensity of the national economy, is much more difficult to measure.

9.4.6. Policy Measures Activating Abatement Options

Review of the results of various studies (OECD, IPCC, ECMT, etc.) made it possible to identify a range of policy instruments which seems to be applicable in Polish conditions. They are listed in table 9.4.16 with brief explanations. Some of these instruments serve a single objective, however, often, a given measure can contribute to several objectives at the same time. For this reason, table 9.4.17 has been built to show interrelations between measures and policies. Based on the results of the analysis presented in point 9.4.4, the most effective strategies have been printed in bold.

Table 9.4.17 can easily be transformed into table 9.4.18 showing the impact of various measures on combined policies.

Table 9.4.18 makes it clear that the most effective measures are those relating to the development of motorization, utilization of cars and the promotion of public transport. The table contains two additional pieces of information as well. Firstly, the probability of application in a short-, medium-, and long-term has been indicated using letters *S*, *M* and *L*. Secondly, measures which are most effective were printed in bold.

Taking into account the present preferences of the population it is not realistic to propose immediate introduction of fiscal measures such as increased fuel tax/duty and general road pricing as well as vehicle energy consumption standards and restrictive parking standards. These measures should be, however, considered as the most important in the medium- and long-term policies.

In the short-term, vehicle emission standards and promotion of public transport (fare policies and priority in traffic) deserve special attention.

Table 9.4.16. Policy measures

Policy measure		Comments
Urban planning	N/L	Avoid urban sprawl
Mixed use of land	N/L	Avoid single-purpose zones
Density standards	N/L	Minimum density standards
Promoting city-center development	N/L	Promote concentration of economic activities in the central area served by public transport
Promoting transport-effective development of national economy	N	National industrial and spatial development policies
Development of telecom./telematics	N	Investment in telecommunications, service delivery systems, etc.
Vehicle purchase tax/annual license fee	N/L	Discourage car ownership, encourage purchase of energy-efficient, low-emission vehicles
Fuel (carbon) tax/duty	N/I	
Parking charges	N/L	Discourage the use of personal car; encourage high occupancy
Road pricing	N/L	Internalization of external costs
Modernization/development of railways	N/I	
Public transport fares (subsidy policy)	N/L	Low fares encourage the use of public transport
Public transport and HOV priorities in traffic	L	Encourage shift towards modes with lower emissions
Parking standards	N/L	Limit supply of parking spaces, encourage a shift towards public transport and better use of private cars
Car-free zones	L	Encourage shift towards public transport and non-motorized means of transport
Promoting bicycles	L	Provide cycle lanes and paths
Vehicle energy consumption standards	N/I	
Vehicle emission standards		
Lowering road traffic speed limits and enforcement of the related regulations	N/L	Lower speed limits on rural roads leading to lower speed dispersion, fuel consumption and emissions
Promoting transport logistics	N	Improve system efficiency

Notes: N- national; L - local; I - international;
HOV - high occupancy vehicles, e.g., car with more than 2 persons.

Table 9.4.17. Policy instruments for elementary strategies

	Policy measure	Strategy							
		U	T	M	A	P	V	B	O
1	Urban planning	+		+	+	+		+	
2	Mixed use of land	+	+	+	+	+		+	
3	Density standards	+	+	+	+	+		+	
4	Promoting city-center development	+		+	+	++		+	
5	Promoting transport-effective development of national economy		+						
6	Development of telecom./telematics			+	+				
7	Vehicle purchase tax/annual license fee				++	+			
8	Fuel (carbon) tax/duty		+			+	++	+	
9	Parking charges			+	+	++		+	
10	Road pricing		+	+	+	++		+	
11	Modernization/development of railways					+			
12	Public transport fares (subsidy policy)				+	+			
13	Public transport and HOV priorities in traffic					++		+	
14	Parking standards			+	+	+			
15	Car-free zones	+		+	+	++			
16	Promoting bicycles	+			+	+			
17	Vehicle energy consumption standards						+		
18	Vehicle emission standards						+		
19	Lowering speed limits and enforcement								++
20	Promoting transport logistics							+	

Table 9.4.18. Policy instruments for combined strategies and their applicability in Polish conditions

	Policy measure	Strategy			
		I	II	III	IV
1	Urban planning	L			L
2	Mixed use of land	ML			ML
3	Density standards	ML			ML
4	Promoting city-center development	ML			ML
5	Promoting transport-effective development of national economy		SML		SML
6	Development of telecom./telematics	ML	ML		ML
7	Vehicle purchase tax/annual license fee	ML	ML		ML
8	Fuel (carbon) tax/duty	ML	ML	ML	ML
9	Parking charges	SML		SML	SML
10	Road pricing	ML	ML	ML	ML
11	Modernization/development of railways	SML	SML		SML
12	Public transport fares (subsidy policy)	SML			SML
13	Public transport and HOV priorities in traffic	SML		SML	SML
14	Parking standards	ML			ML
15	Car-free zones	ML			ML
16	Promoting bicycles	SML			SML
17	Vehicle energy consumption standards			ML	ML
18	Vehicle emission standards			SML	SML
19	Lowering speed limits and enforcement			SML	SML
20	Promoting transport logistics		SML	SML	SML

S - measure applicable in the short-term;
M - measure applicable in the medium-term;
L - measure applicable in the long-term.

9.4.7. Conclusions

1. In the reference scenario, based on the most probable trends assumption, if there is no intervention aiming at the reduction of GHG emissions, the total emissions from the transport sector will be growing up to the years 2020 - 2025, and then will stabilize at the level of about 190 % per cent of the present emissions (in 1995).

2. Analysis of various elementary strategies has led to the conclusion, that the most effective would be: (i) reducing personal mobility; (ii) technological progress in the construction of road vehicles leading to better fuel efficiency and switch to better fuels; and (iii) better use of transport means, first of all through increasing occupancy rates. Each of these strategies would allow for the reduction of the emissions by about 5 to 10 %, in relation to the reference scenario.

3. Combination of strategies (strategies I, II and III) can reduce the GHG emissions 8 - 15 % below the level expected in the reference scenario. In the best scenario IV, in the long-term, total emissions from the transport sector would be lower by 21 %, as compared to the case in the reference scenario and would stabilize at the level of about 150 % of the present emission level.

4. Analysis of economic growth scenarios (strategies of *stagnation* and of *chance*) has led to the conclusion that the accelerated economic growth - without mitigation interventions - could bring about the growth of the GHG emissions in the year 2030, to the level of 290% of the present emissions. With the most effective mitigation strategy (strategy IV) this value would be reduced to about 235 % of the present emissions.

5. The most effective policy measures are fiscal measures, such as: increased fuel tax/duty and general road/parking pricing; and restrictive measures, such as: energy intensity standards or restrictive parking standards. However, it is very unlikely that these measures will be acceptable in the nearest future. They should be considered as the most important in the medium- and long-term policies.

6. In the short-term, vehicle emission standards and promotion of public transport (fare policies and priority in traffic) deserve special attention.

7. The results of the studies completed should be treated as preliminary since various elements of the transport/emission model built in the course of the study, require further research.

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9.5 Agriculture

9.5.1 Introduction

In the agricultural sector there are real possibilities for a direct or indirect reduction of GHG emission as a result of some changes in crop and livestock production, as well as a change in use of this production.

The options chosen as feasible were those in which the GHG emission abatement results from:

- production of renewable energy sources in agriculture (options: "rape", "triticale", and "miscanthus")
- long-term atmospheric CO_2 retention in timber produced through afforestation of fallow and arable land (option "forest")
- reduced animal protein with increased plant protein consumption (option "pulses")
- increase of cattle milk efficiency (option "milk")
- reduction of nitrogen fertilizers as well as pesticides production and use (option "symbiotic bacteria", "free-living bacteria" fixing atmospheric nitrogen, and option "colorado beetle").

The above listed options do not exhaust all possibilities of GHG emission reduction in agriculture. The choice of options was done on the basis of already tested and partially used technologies (afforestation of set aside and arable land, inoculation of seeds and soil by atmospheric nitrogen-fixing bacteria, increase of milk efficiency of cattle, etc.) and on the basis of extensive literature and experiences of many developed countries of the world in introduction of new technologies in the production of renewable energy sources, such as diesel oil from rape, ethanol from triticale and solid fuel from miscanthus [Chartier et al. 1995, Dressler and Herzog 1994, Wickens et al. 1989, Janick and Simon 1993, Parry et al. 1988, Rozenzweig and Hiller 1993].

Each of the options was considered in each of four climatic scenarios and ranked according to climate changes and atmospheric CO_2 concentration changes, as well as possibilities of adapting of specific options to those changes [Nalborczyk et al. 1995b]. The base options, not considering climate changes by the year 2030 were used as a reference.

For example, as a result of ranking based on the analysis of capabilities of adaptation of rape to climate change, the relation of GHG emission reduction in 2030 in the case of implemented option "rape" to the reduction which does not take into account any climate changes (assumed as 1) will be 2.5 in warm and humid climate, 3.2 in humid and hot climate, 0.65 in dry and warm climate, and 0.74 in dry and hot climate. Within each of the four climatic scenarios, various participation of each option were found as a result of the ranking based on the vulnerability of each option to climate change and possibility of their implementation when the available area of land under cultivation is defined and different for each scenario. For example, for the humid and hot climate scenario, the ratio of GHG emission reduction in 2030 to the emission reduction with climate change not involved (assumed as 1) is: for the option "rape" 3.2, "triticale" 2.5, "miscanthus" 20, "free-living bacteria" 2.0, "symbiotic bacteria" 1.2,"pulses" 1.5, "milk" 1, "forest" 1.4, "colorado beetle" 1.9.

The complete data on the share of GHG emission reduction of each option in various climatic options and various options in each climatic scenario is shown in Table 9.5.1. Ranking data presented in the table result from rigidly assumed changes of temperature, precipitation, and atmospheric CO_2 concentration till the year 2030 for the scenarios, as well as from technological and economic capabilities of their implementation at present. They might be subject to change parallel with a change of climatic scenarios and changes in technology and costs of implementation of individual options.

9.5.2. Methodology

In accordance with the adopted criterion [Gaj 1995 a, b] that the choice of individual option or a set of options is based on the economic analysis of costs, covering necessary input and expected outputs, 9 previously identified options of CO_2 emission abatement in Polish agriculture by the year 2030 were ranked [Nalborczyk et al. 1995a]. The ranking was based on the following economic criteria: expected reduction of GHG emission expressed as CO_2 equivalent, levelized global costs of this reduction, and levelized marginal costs. Calculations refer to the year 2030.

Materials concerning the base version of the set of options were elaborated, as well as 4 different variant of those 9 options resulting from potential modifications forced by expected climate changes in Poland [Nalborczyk et al. 1995b]. Shares of individual options in different climatic scenarios were calculated taking into account factors that either favor or reduce implementation possibilities of each option. Expected changes of mean annual temperature, precipitation, atmospheric CO_2 concentration and their influence on plant growth and development, as well as an area of land withdrawn from cultivation because of production surplus specific for each scenario, were adopted as most objective factors.

Within each scenario, participation of various options was defined on the basis of most probable possibilities of introduction of new crops into the existing rotation systems, species of plants grown and demand for nitrogen fertilizers and pesticides, possibilities of crop utilization, and production costs.

This ranking was supplemented by a diagram showing the changes in the GHG emission reduction in time until the year 2030, related to implementation of a system of options and individual options. Basic data concerning CO_2 emission reduction were acquired based on calculations of CO_2 emission reduction estimate, done in FEWE (Polish Foundation for Energy Efficiency) spreadsheet.

Economic conditions for CO_2 emission abatement in the base option were analyzed in detail, including also, as an additional element, differential investment costs and differential consumption of energy carriers-sources of GHG emission. Differential costs and consumption were taken from spreadsheets option FEWE through subtracting a technology that is replaced from the values that characterize the technology being introduced. The sign (-) next to the so calculated difference should describe the supremacy of new technology over the old one.

The most important energy carrier in the analyzed options was diesel oil (thousands liters) - necessary for cultivating relevant areas of arable land and greenland, followed by electric power (MWh), and - in three of the options - high-methane contents natural gas, as well as - in the option "miscanthus" implemented in 49 heat generation plants - coal, electric power for the industry (thousands tones). In relation to the so outlined energy consumption structure, calculation of a differentiated fuel consumption brought about cases (options "colorado beetle", "symbiotic bacteria" and "free-living bacteria") where one of the technologies (introduced or replaced) did not involve the same fuels, and thus the difference was limited to "0 or 1" analytic issue.

In the economic calculation started with levelized (i.e. assuming lack of non-uniform distribution of activities in time) global cost of CO_2 emission reduction in implementation of a given option in USD (year 1990). However, a better measurement of costs of CO_2 emission abatement is a marginal cost or a unit cost, i.e. the value showing what amount in USD (90) the Polish society is willing to pay for an additional tone of reduced CO_2 and other GHG emission. Marginal costs are understood as a ratio (in USD 90) of increase of emission reduction costs to the increase of emission in a given option of a set of reduction options. Those costs were calculated on the basis of the a.m. spreadsheet for estimating effects of the emission abatement in a given option.

Use of marginal costs of specific reduction options ranked according to a declining profit ratio, allowed to estimate marginal costs of the entire complex of 9 options. Resulting from this exercise, cost curves in the function of GHG emission reduction as CO_2 equivalent were analyzed both in the base option and in climatic variants. It was also assumed that, apart from the option "rape", the marginal costs of individual options do not change under the influence of climatic conditions. Only in the case of a complicated option "rape", where, apart from the crop there is an additional element of the rape oil used as bio-fuel, it was necessary to commission additional expert estimates concerning growth of unit costs of implementation of this option in individual climatic variants.

Ranking of 9, not colliding with each other, options of CO_2 emission reduction according to marginal costs is only possible for a given year and with defined price conditions (Morthost 1993), therefore using a fuel price prognosis the ranking could only be done for one final year of the option operation - 2030. Thus the approach was adopted known in the literature as primary and hierarchy-oriented while the historical approach was abandoned as it requires simulation models used in energy sector which are not yet adapted to the analytical needs in agricultural sector.

An attempt was made in the study not to break a consistent structure of 9 reduction options but only to show the role of subsequent options in this hierarchy. It should however be remembered that all options jointly add to a significant CO_2 emission reduction in the agricultural sector. Such approach is compatible with the assumption of system option evaluation. It is difficult to select more preferred options on the basis of their exclusive operation, especially because summed results might be subject to changes depending on the climate for Polish agriculture.

Only the higher probability pointed out by the group of experts might indicate that the complex of 9 options will be implemented in the conditions of an extreme climate (i.e. dry and hot or humid and hot)> Therefore, the main goal of this study will rather be to define possibilities for the extension of the complex of 9 options over additional area of fallow land, which was not previously managed [Nalbörczyk et al. 1995b], than to select preferred options from the set.

9.5.3 Differential fuel consumption

Diesel oil

Differential diesel oil consumption can increase, decrease or gain minus values (i.e. the new option introduced requires lower oil consumption that the replaced option), depending on implemented option. Growth of oil consumption is typical for options "miscanthus" and "rape".

In both cases this is a linear growth in accordance with crop production area increase and is related mainly to agronomic measures from sowing to harvesting, reaching in 2030 about 5.8×10^3 t for the option "miscanthus" and about 2.6×10^3 t for the option "rape". Taking into account the global biomass production for those plants and its utilization as a source of renewable energy we should expect much higher values of energy produced (diesel oil from rape and solid fuel from miscanthus) ratio to the energy incorporated in about 8.4×10^3 t of used diesel oil.

In the case of option "forest" consumption of diesel oil decreases (from 1400 t in 1996 to 450 t in 2030). This results from high fuel cost related to direct afforestation of set aside land under cultivation and a declining use of fuel for silvicultural measures in young plantations. It should be expected that after the year 2030, when the plantations will approach their harvesting age the use of diesel oil will again grow. Related to this, increased CO_2 emission will however be manifold smaller than the retention of CO_2 in the growing mass of timber.

Linear growth of negative values of differential diesel oil consumption is visible in the options: "pulses", "triticale" and "milk". Both, size and reasons of this growth are different. For the option "pulses" the value grows from -4.25×10^3 in 1996 to -22.4×10^3 in 2030 as a result of replacement of energy-intensive production of animal protein by much less energy-intensive production of plant protein. For the option "triticale" the differential diesel oil consumption changes from -0.5×10^3 to -17.5×10^3 as a result of growing production of triticale instead of more energy-intensive potato production.

The option "milk" which involves an increase of milk efficiency from a cow, together with reduced fodder consumption will enable a reduction of diesel oil consumption from 0.08×10^3 t in 1996 to 2.8×10^3 t in 2030. In the option "colorado beetle" a gradual introduction of field production of new varieties of potato, genetically resistant to this insect pest is projected. This will allow to eliminate spraying of plantation with insecticides by the year 2004 and save about 6×10^3 t of diesel oil, not including the abolition of a very high energy-intensive insecticide production.

Electric power

Differential electric power consumption in the case of plant biomass production for energy generation purposes (rape, triticale, miscanthus) shows a linear growth until 2030 along with the assumed linear growth of their production area. This growth enable systematic withdrawal of land from traditional crop (for food and fodder) production, resulting from surplus of their production and still growing demand for renewable energy sources.

The consequence of the above changes is a growing reduction of GHG emission (mainly CO_2 emission) manifold higher than their emission being a result of a total electric power consumption used for their production in 2030 which is 6.68×10^3 MWh. This consumption is lowest for the production of triticale, higher for rape, and highest for the production of miscanthus, respectively: 1.05, 2.10, and 3.53×10^3 MWh. Depending on the crop, electric power is used in technological processes involved in preparation of material for seeding, cultivation, harvesting, drying and storing of yield. A similar structure of differential electric power consumption is shown by the option "colorado beetle", however the growth of energy consumption end at the moment when new resistant varieties of potato are introduced for production in 2004. The maximal differential electric power consumption in this year is forecast at 6.4×10^3 MWh.

Differential electric power consumption related to implementation of the options "milk" and "pulses" until 2030 shows also a linear run of negative values. These values are respectively -14.0 and 9.14 x 10^3 MWh. In the option "pulses" they result from the replacement of high energy-intensive animal protein production with plant protein production, while in the option "milk" from the raised milk efficiency of cows and more efficient fodder consumption (both volume and intensive fodder).

The options "symbiotic bacteria" and "free-living bacteria" show a completely different from the above character of differential electric power consumption. The options involve growing biological fixing of nitrogen by soil microorganisms along with declining use of industrially manufactured nitrogen fertilizers. For both options there are negative values of differential electric power consumption, which is related to a reduction of fertilizing with nitrogen. Maximum levels of energy consumption: -28.2 x 10^3 MWh (free-living) and -58.5 x 10^3 MWh (symbiotic) are recorded at the beginning of implementation of those options (till 2004) which results from construction in this period of industrial laboratories for the production of inoculums and their relatively easy implementation in field production.

Gas

Methane natural gas is not a direct source of energy for basic production processes in agriculture. From the 9 proposed options of the GHG emission reduction, only 3 use gas as a source of direct or substituted energy. The option "colorado beetle" in the initial period of implementation (by 2004) will consume a relatively low amount of gas , 200 x 10^3 for the purposes related to laboratory and greenhouse production of more resistant seed-potatoes.

Two options involving increase of atmospheric nitrogen fixing in soil consume small amounts of gas for the laboratory production of nitrogen-fixing microorganisms, while creating significant opportunities for its savings, resulting from reduced use of fertilizers manufactured in nitrogen plants. With a short period of implementation of those options and increased use of symbiotic nitrogen-fixing bacteria, in three stages (related to the construction of four industrial laboratories producing inoculums) gas consumption could be reduced by about 30 x 10^6 m^3 as early as in 2004. Even earlier (using the existing laboratory base), large scale inoculum of free-living nitrogen-fixing bacteria production could be commenced, which should allow for the reduction of gas consumption in fertilizer production by 14.85 x 10^6 m^3.

Coal

Out of all the proposed options, only the option "miscanthus" can add to a relatively large savings in coal consumption. These savings result from a possibility of utilization of a renewable fuel, i.e. biomass of the plant *Miscanthus gigantheus*, instead of coal that serves as an energy source in local municipal and industrial heat generation plants. Assuming that by 2030 at least one, 5 MWh heat generation plant using miscanthus is operational in each province, there is a possibility to reduce differential coal consumption in this period by 225 x 10^3 t.

9.5.4 Differential capital costs

Depending on the option implemented, differential capital costs until 2030 might grow, decline or take up negative values (i.e. when the new, introduced option requires lower capital costs that the replaced one), or even, in the case of the option "rape" a differential capital cost might equal 0.

Growing costs are recorded in the option "forests", however it should be borne in mind that the land afforested is a fallow land, where literary no activity takes place. In this case preparation of planting and subsequent cultivation of plantations bring about high capital cost at the level from about 28 million USD (90) to 55 million USD (90) in 2030. Those figures could however be much lower if afforestation is done on the land directly withdrawn from agricultural production (e.g. potato or rye) instead of fallow land. Nevertheless, even so high capital cost are profitable from the point of view of high potential of long-term sequestration of carbon in the option "forest". The planted forest can only be felled after 40 years.

Diminishing positive differential capital costs at similar level as in the above option, are typical for the biotechnological options "free-living bacteria" and "symbiotic bacteria". At the very beginning of implementation of both these options only small capital investments for construction and start-up of industrial laboratories to produce inoculums are necessary. This stage involves about 4.5 million USD. When this is done, capital costs necessary for maintaining the project become so low, that practically it can be assumed that the technology introduced is at least at the same level of costs as the replaced one.

In the case of the option "miscanthus" the analysis of changes of differential capital costs shows that in the start-up period some funds are required for adaptation of heat generating plants equipment for combustion of miscanthus biomass, as well as for covering the costs related to the production of seed material and establishment of plantations. All those investments lead to the situation when for 15 years the option in a progressive self-financing mode. The tendency to approach more and more negative i.e. beneficial differential costs is disrupted every 15 years when it is necessary to renew plantations.

For the biotechnological option "colorado beetle" differential capital cost run irregularly. In the start-up period it is necessary to invest about 1 million USD for the construction of relevant biotechnological laboratories and propagation of seedling material. The material thus produced just after a year can bring profit of 2 million USD as compared to seed-potatoes of traditional varieties. Gross of the option implementation period does not require any larger input than a traditional technology, but about the year 2016 some major modernization of biotechnological laboratories will be necessary, which can be spread in time. There might also be some costs related to the production of better quality and more efficient varieties of potato, which will have to be introduced in practice.

Differential capital costs related to implementation of the option "milk" and "pulses" can be regarded as solutions which provide growing investment saving against traditional technologies practically right from the start. In both cases this results from growing benefits of elimination of many energy-intensive stages of milk or meat production technology. Those options lead to significant savings in 2030 of 35 (the option "milk") or 140 (the option "pulses") million USD.

The highest negative values of differential capital costs, i.e. 320 million USD, can be achieved as a result of implementation of the option "triticale". This is a consequence of, *inter alia,* introduction of triticale production instead of more energy-intensive and more expensive potato crops.

9.5.5. Reference scenario

In the basic selection of the set of 9 options to reduce GHG emission, the highest reduction can be obtained through the option "rape" (Fig. 9.5.1). It reaches in 2030 the level of about 2.8 million t (the option "rape") and 1.5 million t (the option "pulses"). Other options bring much lower abatement of GHG emission. Three options ("pulses", "miscanthus" and "forest") increase the possibilities for reduction with time, while the three biotechnological options ("colorado beetle", "symbiotic bacteria", and "free-living bacteria"), after the completion of laboratories and implementation of inoculums or transgenic plants, i.e. since 2004, provide stable annual GHG emission reduction.

Relatively small GHG emission reduction gained through the option "forest" (0.68 million t) becomes more valuable when one takes into account that to a large extent, this is also a long-term retention of sequestrated CO_2, for nearly 40 years. Obviously, gaining so high benefits requires large costs, which is clear (Tab. 9.5.1) both from levelized global costs and marginal costs. Highest benefits in terms of global costs can be achieved through implementation of the option "triticale" (85 million USD) and "pulses" (41 million USD) but other, less profitable options are also not to be missed - those with negative levelized costs, and even the option "rape" with just positive implementation costs.

Those options, as it is visible in Tab. 9.5.1 which shows the marginal costs of the configuration of 9 options in the function of GHG emission reduction, with less beneficial unit costs than "triticale" (0.005 million t of emission reduction), and "pulses" (about 0.73 million t of emission reduction) bring the reduction at the level of 0.46 million t (the option "miscanthus") or 2.8 million t (the option "rape"). The options that would seem not worth of attention: "milk", "colorado beetle", "symbiotic bacteria" and "free-living bacteria" (in the marginal costs "up to -450 USD" group), implemented jointly will bring the emission abatement of 0.28+0.18+0.10=0.56 million t, while the option "triticale" for comparison brings 0.05 million t. Therefore those options are important components of the set of options, whose implementation will bring in the year 2030 nearly 5.24 million t (as CO_2 equivalent) of GHG emission reduction in Polish agriculture.

Fig. 9.5.1. CO2 reduction emission (t) during 1996-2030 in Polish agriculture due to the use of the set of 9 options (basic version)

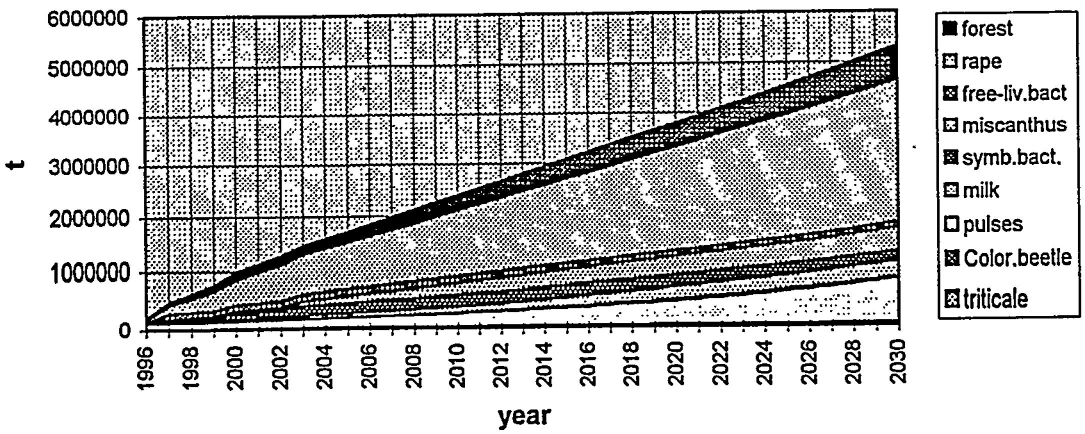
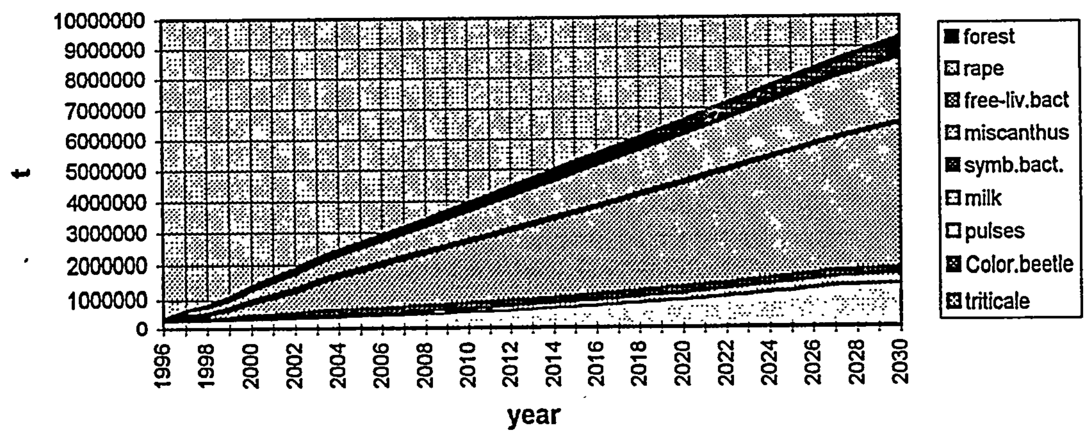


Fig. 9.5.2. CO2 emission reduction (t) till 2030 in Polish agriculture due to the use of the set of 9 options (dry and warm scenario)



Tab. 9.5.1 Costs (in USD) and CO_2 emission reduction (in Mt) in the year 2030 for climatic scenarios

Basic options	Reference scenario	Scenario I	Scenario II	Scenario III	Scenario IV
Rape					
Levelized costs	2 355 009	2 355 010	2 355 009	5 887 523	7 065 027
Marginal costs	6.6	10.1	8.9	6.6	6.1
Emission reduction	2.82	1.85	2.09	7.06	9.06
Ethanol/triticale					
Levelized costs	-8.5E+07	-6.8E+07	-6.8E+0.7	-1.7E+08	-2.1E+07
Marginal costs	-13059.8	-13059.8	-13059.8	-13059.8	-13059.8
Emission reduction	0.51	0.04	0.04	0.1	0.13
Miscanthus					
Levelized costs	-2 902 593	-2 902 593	-2.9E+07	-2.9E+07	-5.8E+07
Marginal costs	-59.5	-59.5	-59.5	-59.5	-59.5
Emission reduction	0.46	0.46	4.61	4.61	9.23
Free-living bact.					
Levelized costs	-2 024 183	-2 024 183	-2 024 183	-2 429 020	-4 048 366
Marginal costs	-49.4	-49.4	-49.4	-49.4	-49.4
Emission reduction	0.1	0.1	0.1	0.12	0.2
Symbiotic bact.					
Levelized costs	-3 992 511	-3 992 551	-3 992 511	-3 992 511	-4 791 013
Marginal costs	-70.6	-70.6	-70.6	-70.6	-70.6
Emission reduction	0.18	0.18	0.18	0.18	0.21
Pulses					
Levelized costs	-4.1E+07	-1.0E+08	-8.2E+07	-6.2E+07	-6.2E+07
Marginal costs	-386.9	-386.9	-386.9	-386.9	-386.9
Emission reduction	0.74	1.84	1.47	1.10	1.10
Milk					
Levelized costs	-1.2E+07	-1.2E+07	-1.2E+07	-1.2E+07	-1.2E+07
Marginal costs	-337.2	-337.2	-337.2	-337.2	-337.2
Emission reduction	0.28	0.28	0.28	0.28	0.28
Forest					
Levelized costs	23 318 832	23 318 832	23 318 832	27 982 598	32 646 365
Marginal costs	275.6	275.6	275.6	275.6	275.6
Emission reduction	0.68	0.68	0.68	0.81	0.95
colorado beetle					
Levelized costs	-8 950 713	-1.8E+07	-1.8E+07	-1.5E+07	-1.6E+07
Marginal costs	-3009.8	-3009.8	-3009.8	-3009.8	-3009.8
Emission reduction	0.01	0.02	0.02	0.02	0.02

9.5.6 Ranking of options according to climate scenarios

The climate that will accompany Polish agriculture till the year 2030 will have an impact on GHG emission reduction, however will not affect the unit costs. Except for the option "rape", marginal costs will be the same. but smaller reductions of emission will be possible. Depending on the climatic alternative, global reduction of GHG emission as CO_2 equivalent is at the level from 5.25 million t (dry and warm climate, scenario I fig. 9.5.2), through 8.31 million t (dry and hot climate, fig. 9.5.3, humid and warm climate - scenario II and III, fig. 9.5.4)) up to about 21 million t (humid and hot climate - scenario IV, fig. 9.5.5).

The analysis of levelized global costs related to implementation of options for the reduction of CO_2 emission indicates that the options "rape" and "forest" require relatively high input, while the rest of options give opportunity for gaining profit. Climatic impacts change the ranking to some extent placing preferences mostly on the options "pulses" (in dry climate) or "triticale" (in humid climate). In humid and dry climates the ranking position of the option "miscanthus" changes while the other options remain at unchanged positions. Maximal costs of implementation (about -100 million USD) in a dry climate are much lower that in a humid one (-170 to -210 million USD) and result from physiological properties of plants dictating smaller or larger area of the crop production.

Marginal cost analysis shows that apart from the option "triticale", which gives an opportunity to earn about 13 000 USD per 1 tone of reduced emission (the reduction itself is at a rather moderate level), in the combination of options a significant role is played by the remaining, less profitable options (with unit costs starting at 0 to -400 USD), which ensure a substantial proportion of reduction (e.g. the options "rape", "miscanthus" in humid climates, or "pulses" in dry climates). Relatively low emission reduction takes place in the case of the option "forest" which seems to incur very large costs. However in this option we shall gain also a retention and sequestration of the absorbed CO_2 for 40 year period (up to the forest felling age).

In all options of Polish agriculture development in changing climatic conditions, serious changes in crop and livestock production should be expected. Those changes will concern the area and structure of field crop production, efficiency and fidelity of crop, and structure and number of livestock. They were described in detail in the scenarios of the development of Polish agriculture by the year 2030 with climate changes and GHG emission taken into account [Nalborczyk et al. 1995b]. Nine options were identified in those scenarios assuming reduction of GHG emission and atmospheric CO_2 retention. Alike crop and livestock production, implementation of those options will depend on climate changes. Considering influence of changeable soil and atmospheric humidity conditions, increased mean annual temperature and CO_2 concentration in the atmosphere - the options can be implemented according to the following variants.

Warm and dry climate with small increase of CO_2 concentration in the atmosphere (Scenario I)

In these climatic conditions a basic factor limiting the crop and livestock production efficiency will be a growing water deficiency. This will cause decrease of yield of all crop out of one hectare, and a necessity to utilize virtually entire area of arable land. Only 0.5 million ha of fallow land is foreseen, which does not create such conditions for production of plants for energy production purposes as in both variants of humid climate. A shrink of land under production of triticale for ethanol by 0.2 million ha should be expected. Because of reduction of meat production and consumption caused by the lack of fodder, a growth of pulses production and consumption is inevitable (by about 0.5 million ha) which should have a positive impact on methane emission reduction. In those difficult climatic conditions implementation of basic GHG emission reduction options by the agricultural sector is still expected. Implementation of this variant will in 2030 bring the GHG emission abatement of 5.2 million t.

Hot and dry climate with high increase of CO_2 concentration in the atmosphere (Scenario II)

In this climate, the most difficult conditions for crop and livestock production will occur. Soil drought should be expected on extensive areas of light soils and it will be necessary to apply irrigation, mainly in vegetable and fruit plantations. Alike the previous variant, basic production of plants for energy purposes will be maintained with the decrease of area under triticale for ethanol by 0.2 million ha, and the increase of pulse production area (as a substitute of animal protein) by 0.23 million ha. Very good temperature condition for the growth of miscanthus on the areas of high soil humidity (or where irrigation is applied) will cause that production of this plant will be profitable either for energy purposes or as a raw material for building/construction and paper manufacturing. Likely growth of the production area of miscanthus will reach about 0.14 million ha. Extension of plant production area for energy purposes will be impossible since the entire agricultural land will be taken up by the plant production for food and fodder. Implementation of the variant will in 2030 bring the GHG emission reduction of 9.3 million t.

Fig. 9.5.3. CO2 emission reduction (t) till 2030 in Polish agriculture due to the use of the set of 9 options (dry and hot scenario)

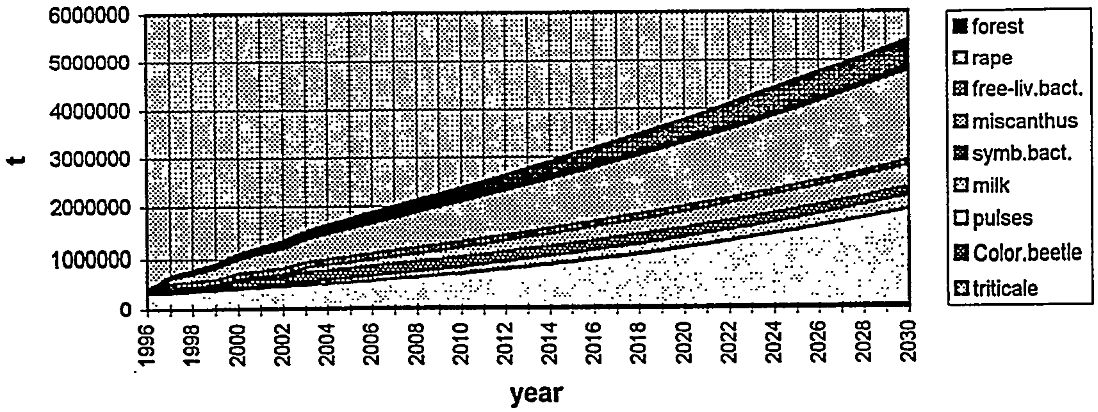


Fig. 9.5.4. CO2 emission reduction (t) till 2030 in Polish agriculture due to the use of the set of 9 options (humid and warm scenario)

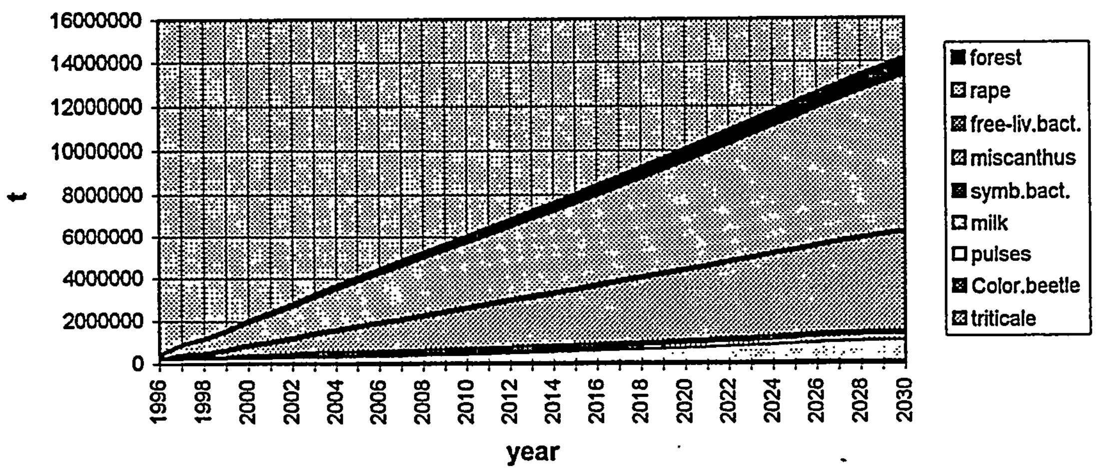
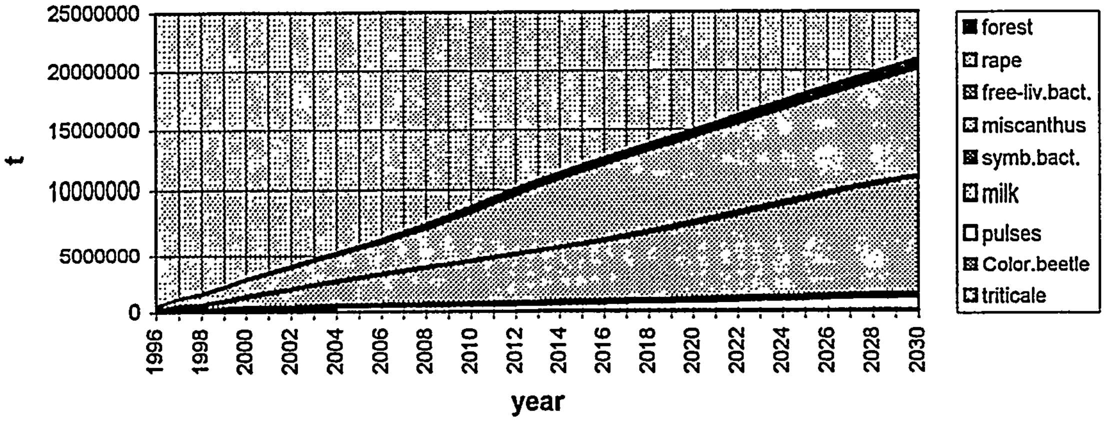


Fig. 9.5.5. CO2 emission reduction (t) till 2030 in Polish agriculture due to the use of the set of 9 options (humid and hot scenario)



Warm and humid climate with small increase of CO_2 concentration in the atmosphere (Scenario III)

In these climatic conditions, which favor the growth of plant and livestock production, production surplus will occur resulting in withdrawal of about 4 million ha of arable land from production. This will allow for a significant ultimate (by the year 2030) increase of rape production for diesel oil (1.05 million ha), triticale production for ethanol (0.98 million ha) and miscanthus production for fuel or a raw material for building/construction and paper production (0.144 million ha). Growth of pulses production is also foreseen (0.117 million ha) which will enable a reduction of meat consumption as well as an abatement of methane emission related to livestock production. In this climatic variant afforestation of additional 0.2 million ha will be possible (on the top of the planned for 2030 afforestation growth by 1 million ha), which will have an impact on CO_2 retention growth. Activity of free-living nitrogen-fixing bacteria will increase, which should lower the nitrogen fertilizers consumption, whose production involves high GHG emission. Implementation of this variant will in 2030 bring the emission reduction of 14.2 million t.

Hot and humid climate with high increase of CO_2 concentration in the atmosphere (Scenario IV)

Alike the previous scenario, climatic conditions will favour crop and livestock production and a high unit yield will cause withdrawal from production of about 4.5 million ha of arable land. This will enable further growth of rape production for diesel oil (1.4 million ha) and triticale production for ethanol (1.48 million ha). Particularly beneficial conditions will take place for the production of miscanthus. It is planned to expand production of this new plant over the area of 0.3 million ha. If the production for energy purposes is highly profitable there might be a decrease of production of rape for oil or even triticale for ethanol, which will be replaced by miscanthus. High increase of activity of nitrogen-fixing free-living and symbiotic bacteria is expected in the climatic conditions of this variant, which will lead to the reduction of nitrogen fertilizers consumption. Alike the previous variant, increase of pulses production is expected (0.117 million t) allowing for the reduction of meat consumption and livestock production, as well as related methane emission. A possibility of additional afforestation (by 0.4 million ha) will also occur which will result in additional atmospheric CO_2 retention. Implementation of the variant will result in GHG emission reduction of 21.0 million t.

Implementation of the proposed options for GHG emission abatement in Polish agriculture until 2030 will bring, depending on a climatic variant, an increase of reduction of 0.01 million t (scenario I) to 15.7 million t (scenario IV) as compared to the base option.

In all variants assuming the rise of mean annual temperatures, GHG emission in agriculture will decline as a result of lower energy consumption for existential purposes (heating of apartments and service buildings) and for heating of greenhouses and glasshouses. Estimate calculations of GHG emission reduction from those sources require separate studies.

9.5.7 Technological, legal and economic conditions of GHG emission abatement in agriculture

Scope and speed of implementation of tasks aimed at GHG emission reduction will to a large extent depend on many factors, of which the most important include:

- social awareness of producers and agricultural administration as to the necessity of implementation of technologies for GHG emission reduction in agriculture;
- changes in the structure of farms and character of their production (larger farms specialized in plant production will implement GHG emission reduction technologies quicker than small farms with no defined specialization):
- fiscal policy that prefers producers implementing options of GHG emission reduction;
- financial assistance from various sources (state budget, private sector, foundations, international aid, etc.) for agricultural producers implementing GHG emission reduction technologies, in the form of: subventions, soft loans, tax exemptions and easements, etc.;
- extension of industrial plants that use agricultural products as renewable energy sources and renewable raw materials for various industry sectors (refineries for rape oil processing into diesel oil, heating rooms fired with miscanthus biomass, biodegradable packaging manufacturers, etc.)

Breaking technological and economic barriers incurred in implementation of GHG emission reduction options has to accompanied by formal and legal activities allowing for:

- identification of standards of permissible levels of GHG emission in agriculture;
- introduction of transgenic varieties of potato, resistant to colorado beetle and other transgenic plants resistant to biological and environmental stress to the food market;
- obtaining a license (national and EU) for production of environmentally save food by producers that implement GHG emission reduction options through a change in fertilization from mineral to biological nitrogen fixing and abandoning pesticide use;
- application of legal regulations for international transfer of GHG emission reduction technologies.

Progress in implementation of all options aimed at GHG emission reduction in Polish agriculture will depend on a coordinated action of technological, economic, social, formal and legal (legislative) factors. Such coordination should be centralized in the Ministry of Food and Agriculture or in the Ministry of Environmental Protection, Natural Resources and Forestry.

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9.6 Renewable energy

9.6.1 Introduction

In Poland climatic and water conditions as well as the lay of the land are not creating especially favourable circumstances for renewable energy utilization. Nevertheless, in some regions of our country there are chances for utilization of renewable energy sources, and consequently, for GHGs emission reduction. The following renewable energy sources may be used in practice:

- solar energy,
- wind energy,
- geothermal energy,
- hydroenergy (rivers),
- energy from biomass conversion, namely:
    * wood chips from forest and energy plantations,
    * straw for combustion in heating plants,
    * ethyl spirit as addition to gasoline,
    * vegetable oil as a substitute of mineral oil,
    * biogas formed within methane fermentation of manure.

Energetic potential of all the above-mentioned renewable energy sources was calculated and the identification of areas on which there are technical and economic basis for their utilization was done.

Annual possibilities of solar energy utilization equal 950-1090 kWh/m^2 (referring to horizontal surfaces with irradiance of 100 W/m^2 and more). The most favourable conditions are in coastal zone. The smallest influx of solar energy is observed in the south of Poland.

In case of wind energy, similarly as in case of solar energy, the biggest potential is in coastal zone and in the north-eastern Poland. Mazovian Plain, Middle Beskid, Żywiec Beskid as well as the eastern part of Sandomierz Valley with average annual wind velocity not exceeding 4 m/s were recognized as regions with middle wind conditions. In other regions this velocity is lower.

Geothermal waters occur in different regions of the country. In the southern Poland the best hydrothermal conditions are in Podhale Basin (high Artesian pressure, output ca. 60 m^3/h, water temperature at outflow 70-85°C). Convenient conditions occur also in some regions of Polish Lowlands, where several geothermal basins and subbasins were discovered. The narrow zone stretching from Szczecin to Łódź with area ca.67 tys.km^2 as well as Grudziądz-Warsaw region with area ca.70 tys. km^2 should be distinguished. Total geothermal waters potential in Poland is relatively large, but because of high mineralization, high salinity, low output and great depths not all of it can be used for energy purposes.

Hydropower resources in Poland are relatively small and have severe restrictions, resulting from national water deficiency (especially in law water state periods). The most important from water use for energy purposes point of view are rivers of Vistula and Odra Basins and rivers of Baltic Przymorze district. Total country technical hydropower resources equal 13650 GWh/per annum. The largest part of national resources (ca. 68%) is situated in Vistula Basin region, half of which is from the lower part of the Vistula.

Biomass, in aspect of its utilization for energy purposes has the biggest share in renewable energy. Wood chips resources are almost in all regions of the country. Forests are the biggest source of wood, it was estimated that 52000 m^3 of chips per year can be obtained additionally for energy purposes, next 11100 m^3 can be generated from industrial wood wastes, 10000 m^3 - from orchards and 2650 m^3 from afforestation. Altogether ca. 75750 m^3 of wood fuels can be used per year.

For combustion, especially in local heating plants straw can be utilized. Annual straw production in Poland equals 28000-29000 tons. Of that only about 30% can be used for energy purposes, because significant quantities of straw are used for other purposes in agriculture and besides it.

Alcohol received from agricultural products can be added up to 5% to gasoline (according to actual Polish standard). Polish agriculture is able to deliver raw materials for increasing alcohol production by approx. 250 mln l and more for energy purposes. Alcohol is produced from potatoes and cereals. Before utilization as additive to gasoline alcohol should be dehydrated.

Vegetable oil can be utilized in compression-ignition engines instead of actually commonly used universal oil. In Poland rape oil is the best for that purpose, because of rape traditional cultivations and acreage. Esterified rape oil can be used as a substitute of diesel oil, what gives the biggest ecologic effects, or in different ratio mixtures with diesel oil.

Husbandry animals in the village are kept on a litter or without it. In both cases large quantities of manure are produced, which must be managed in rational way in aspect of the environment protection. Methane fermentation of manure allows for reduction of unpleasant odour, improvement of fertilizer properties and production of combustible gas, which can be used for heating purposes in farms and farmers houses. Actual manure production equals 50 million m^3. Results of investigations showed, that from $1m^3$ of manure about 20 m^3 of biogas can be produced, what is equivalent to 46 MJ of energy. For insurance of proper conditions for methane fermentation manure or liquid wastes should be heated, which consumes about 40% of energy.

All the above-mentioned sources of renewable energy were described in details in reports from stages of SE-7 realization. In II, III and V parts energetic potential and its distribution in the country were given [Tymiński et al., 1994a; 1994b; 1995b].

9.6.2. Reference scenario

In Poland the biggest possibilities of renewable energy utilization are in agriculture, except for geothermal energy used for municipal heating and ethyl alcohol added to gasoline used commonly in cars. The rural area, including agriculture, in comparison with urban area has smaller energy consumption, also a number of agricultural production technologies is outworn because of energy shortage or relatively high prices of traditional energy carriers. On the other hand, space conditions and relatively low powers of energy devices used in agriculture are favourable for utilization of renewable energy sources. For these reasons energetic requirements of the village and agricultural production are forming the reference scenario.

In national energetic balance a share of fuels and energy consumed in agriculture and small enterprises of food processing is not exceeding 7-10 % of energy consumed in the whole national economy. On the other hand, direct consumption of fuel and energy in agricultural production equals about 3%, only contribution of diesel fuel is significant - 20%. In Table 9.6.1 the consumption of direct energy carriers (in PJ) in Polish agriculture, according to IBMER forecast [Tymiński et al., 1995d] is given.

Analysis of numerical data of the above forecast is showing an increase in demand for diesel oil, electric energy and gaseous fuels.

Table 9.6.1. Consumption of direct energy carriers in Polish agriculture in PJ, [Wójcicki Z., 1993], own calculations

Type of energy carrier	Consumption of energy carriers, PJ per annum					
	1993	2000	2005	2010	2020	2030
Solid fuels	207,0	194,2	185,0	175,8	157,4	138,9
Liquid fuels	79,4	91,2	99,6	107,8	124,6	141,2
Gaseous fuels	24,8	34,1	40,7	47,3	60,4	73,4
Electric energy	25,1	33,2	39,0	44,9	56,6	68,6
Total	336,3	352,7	364,3	375,9	399,0	422,1

In presented forecasts a supply of energy from renewable sources is not included in the consumption structure, so these data may form general reference scenario for further analysis.

The assumptions given above and energetic forecasts concerning quantity and structure of energetic requirements of agriculture are presented in graphical form on fig.9.6.1.

The above-mentioned forecasts are assuming linear change of energetic requirements and linear changes of energy carriers consumption structure.

Energetic requirements of agriculture (fig.9.6.2) are estimated for two main sectors: agricultural production and municipal requirements. In production sector two main directions of energy consumption can be distinguished: on plant production and on animal production. In plant production energy is consumed for drying and drying up agricultural products, vegetable production under coverings as well as for drive of machines, devices and transport.

In animal production energy is consumed for heating of water for technologic purposes, lighting and heating of husbandry buildings, drive of machines, devices and transport. In municipal sector energy is consumed for space heating, water heating, lighting, preparation of meals, for drive of every day equipment and for transport.

The following are energy carriers which are consumed in particular production processes:
- electric energy,
- solid fossil fuels: coal, coke and others,
- diesel oil, gasoline, heating oil,
- natural gas and propane-butane.

Actual and foreseen structure of energy carriers consumption in particular processes of agricultural production and in municipal sector in agriculture are presented below.

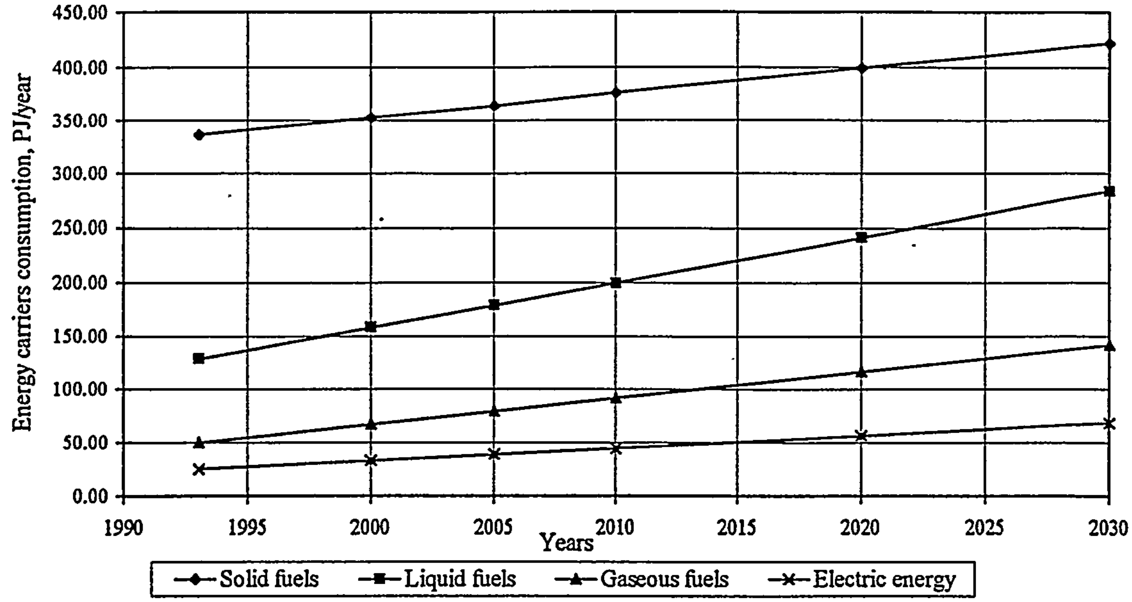

Fig. 9.6.1. Forecast of structure and consumption of energy carriers in agriculture in years 1993 - 2030 (reference scenario)

Plant production

- Agricultural drying

Annually, about 30 PJ of thermal energy (contained in fuel) is consumed for agricultural products drying in Poland, it means more than 10% of energy requirements of agriculture. Structures of energy carriers consumption for option „agricultural drying" in 1993 and 2030 are given in Table 9.6.2. In 2030 utilization of solar energy will cover 44,3% of requirements and wood utilization - 13%.

Annually, energy consumption for drying purposes equals 30 PJ, which is not showing real energy requirements in that sector of agricultural production. In fact, because of insufficient equipment of agriculture with drying devices and high prices of traditional energy carriers part of agricultural products which could be artificially dried up, is in practice naturally dried on the field or only ventilated with not heated air on simple flat dryers.

It was assumed, that drying base should assure drying of 40% of collected cereals mass, 50% of mass of green crops for hay and 100% of special plants (oil plants, leguminous crops, tobacco, herbs, vegetable seeds and onion). The remaining part of crop will be naturally dried or on conventional dryers. Additionally, it was assumed, that grain, leguminous crops, oil plants, tobacco, herbs, seeds of vegetables and vegetables will be artificially dried directly after harvest, whereas green crops for hay will be artificially dried up after initial natural drying on field.

In Table 9.6.2 actual structure of energy carriers consumption for option „agricultural drying" in 1993 as well as structure assumed for 2030 are given.

- Production of vegetables under coverings

According to GUS year-book [1994] actual production of vegetables under coverings is realised on the following surface:

- in plastic tunnels 16781 x103 m^2,
- in greenhouses 14720 x 103 m^2.

Table 9.6.2. Structure of energy carriers consumption for option „agricultural drying" in 1993 and 2030

Energy carriers	Consumption structure, %		Carrier consumption in PJ	
	1993	2030	1993	2030
Coal	70	15,7	21,0	5,0
Natural gas	10	17,5	3,0	5,6
Heating oil	10	9,1	3,0	2,9
Wood	10	13,4	3,0	4,3
Solar energy	0	44,3	0	14,2
Total	100,0	100,0	30,0	32,0

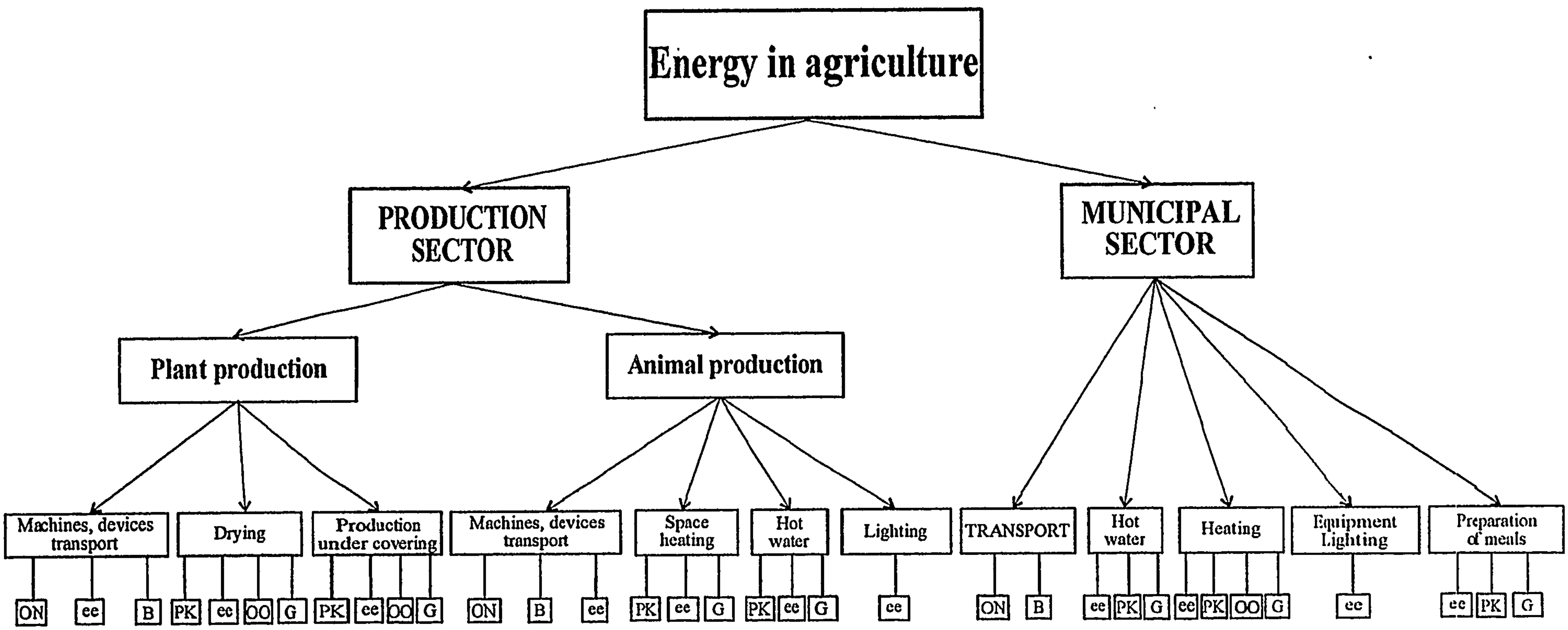

Fig 9.6.2. Energetic demands in agriculture and commonly used energy carriers
Designation: ee - electric energy; PK - solid fossil fuels; OO - heating oil; ON - diesel oil; B - gasoline; G - propane-butane gas.

Energetic requirements for heating plastic tunnels and greenhouses in Polish climatic conditions can be calculated on the basis of assumption, that for heating $1m^2$ of plastic tunnels surface, about 700 MJ of energy is required, and for heating $1m^2$ of greenhouse ca.1800 MJ of energy per season is needed [Grochowski et al., 1990]. On the basis of the above assumption energy requirements for plastic tunnels and greenhouses in energy units were calculated. For heating the above-given plastic tunnels surface 11,7 PJ are required, and 27,3 PJ for greenhouse heating. Total energy requirements for production of vegetables under covering equal ca.39,0 PJ. In 2030 an increase of production in plastic tunnels and greenhouses is assumed connected with increase of cultivation area up to 21000 x 103 m^2 of plastic tunnels and 18000 x 103 m^2 of greenhouses. Simultaneously reduction of unit energy requirements to ca.1600 MJ per $1m^2$ of greenhouse surface is foreseen.

Table 9.6.3. Structure and consumption of energy carriers for option „vegetable production under covering" in 1993 and 2030

Energy carriers	Consumption structure, %		Consumption, PJ	
	1993	2030	1993	2030
Coal	75,0	50,8	29,2	22,3
Heating oil	5,0	10,0	2,0	4,3
Natural oil	10,0	24,0	3,9	10,4
Wood	10,0	8,4	3,9	3,8
Geothermal heating stations	-	6,8	-	3,0
Total	100,0	100,0	39,0	43,8

In 2030 total energy demand for plastic tunnels and greenhouses heating will equal 43,8 PJ (in plastic tunnels - 14,6 PJ, in greenhouses - 29,2 PJ). Structure of energy carriers consumption in production of vegetables under coverings in 1993 as well as structure assumed for 2030 are given in Table 9.6.3.

Animal production

In animal production hot water should fulfil following temperature requirements:

- in dairy cattle breeding average temperature of water should be 45°C,
- in swinery breeding water temperature should be 30-40°C.

In animal production following average coefficients are taken for hot water demand calculation:

- in dairy cattle breeding 15 1/24 h per one stand,
- in swinery breeding 10 1/24 h per one head.

Taking into account actual state of animal production equalling: 8221 x 103 of cattle and 22086 x 103 of pigs demand of energy required for covering actual annual requirements was calculated.

Cattle

15kg x 362 days x 8221000 x 4,19 kJ/kg x K x (45 - 10 K) = 6,6 PJ

Swinery

10kg x 365 days x 22086000 x 4,19 kJ/kg x K x (30 - 10 K) = 6,8 PJ

Actual energetic requirements of animal production for water heating equal 13,4 PJ. Taken into account also energy needed for heating of husbandry buildings equal, according to expert opinions, 20% of energy demand connected with water heating in animal production (i.e. 2,7 PJ) total requirements equal 16,1PJ.

In 2030 according to expert opinions an increase of animal production by 20% is foreseen, what respectively increases up to 16,1 PJ demands of energy, needed for water heating. Similarly, increase by 20% of energy demands connected with building heating was assumed, what gives total energy demands in 2030 equal 19,3 PJ. Actual structure of energy carriers consumption is presented in Table 9.6.7, and structure foreseen for 2030 is given in Table 9.6.8.

Municipal sector

- Hot water

Standards of hot water consumption are different for particular groups of consumers. For further analysis model assuming consumption of 60 l of water heated from 10° C to 45°C per day per person was taken.

Both, the proposed quantity and temperature are lower than data in technological recommendations but in authors' opinion in longer prospects such values are the most probable. With 60 l of water heated from 10° C to 45° C annual direct energy requirements1) for preparation of hot water for one person equal:

60 kg x 365 days x (45 - 10)K x 4,19 kJ/kg x K = 3,212 GJ = 892 kWh

Assuming, that actually about 14717 x 103 inhabitants is living in rural areas, theoretical quantity of energy for water heating contained in hot water equals 47,2 PJ. With an assumption that in perspective actual number of inhabitants living in rural area will not change, it was estimated that energy requirements calculated in useful hot water in 2030 will reach theoretical level i.e. 47,2, because of increase of unit of hot water consumption.

In Table 9.6.4 actual and foreseen structure of consumed energy are given. Taking into account the above-mentioned structure and efficiency of water heating with utilization of different fuels, average efficiency of water heating was estimated at 66,6% in 1993 and 77% in 2030. With these assumptions requirements of energy (fuels) for water heating in 1993 should equal 47,2/0,66 = 70,9 PJ, and assumed for 2030 energy consumption will equal 47,2/0,77 = 61,3 PJ. Energy consumption in 1993 was corrected by factor equal 0,6 connected with difference between actually recommended hot water use - 60 l/day, and practice. For that reason estimation of energy demands for water heating in agriculture in 1993 equals 0,6 x 70,9 = 42,5 PJ. Detailed results are given in Table 9.6.4.

Table 9.6.4. Structure of energy carriers consumption in 1993 and 2030 for option „heating of water"

Energy carriers	Consumption structure,%		Consumption, PJ	
	1993	2030	1993	2030
Coal	74,1	29,3	31,5	18,0
Heating oil	-	0,5	-	0,3
Natural gas and propane-butane	4,2	16,0	1,8	9,8
Electric energy	14,0	23,8	6,0	14,6
(in that from hydropower stations)				
District heat	4,3	5,0	1,8	3,0
Solar energy from water collectors	-	25,4	-	15,6
Other fuels (biomass, heating oil)	3,4	-	1,4	-
Total	100,0	100,0	42,5	61,3

- Space heating

In 1992 useful surface of houses in rural areas equalled 266370 x 103 m^2 [Tymiński et al., 1995b]. Assuming that unit energy demand for space heating in houses equals 400 MJ/m^2 of useful surface there is required 106,6 PJ of net thermal energy for heating of the above-mentioned surface. Actually not all rooms in rural district are heated or are not adequately heated. For that reason actual net consumption of thermal energy for space heating is estimated at 86,3 PJ, it means 80% of theoretical energy consumption. Taking into account that average efficiency of energy production and utilization for heating purposes in rural buildings equals 50% it was estimated that actual fuel consumption for heating purposes equals 172,6 PJ.

It was foreseen that in 2030 demands for thermal energy for space heating will be equal 90% of actual theoretical requirements for net thermal energy i.e. 96,2 PJ. It is connected with assumed improvement of thermal insulation of buildings what will result in reduction of energy demands for space heating by 50% in 2030. Useful surface which was taken to calculations of thermal energy concerns houses in rural areas. Population living in these areas may be working in other sectors than agriculture. Structure of energy carriers consumption in 1993 as well as structure with use of renewable sources assumed for 2030 is given in Table 9.6.5.

[1] Efficiency of reference electric heating of water was assumed 100%.

Table 9.6.5. Structure of energy carriers consumption for option „space heating" in 1993 and forecast for 2030

Energy carrier	Consumption structure,%		Consumption, PJ	
	1993	2030	1993	2030
Coal	80,0	36,1	138,2	34,7
Heating oil	2,0	7,6	3,6	7,3
Natural gas	10,0	20,0	17,4	19,2
Electric energy	2,0	10,0	3,6	9,6
Wood	4,0	11,1	6,2	10,7
Straw	-	3,3	-	3,2
Energy from auton. wind power stations	-	-	-	0,1
Geothermal heating	-	1,9	-	1,8
District heating (coal)	2.0	10.0	3.6	9.6
Total	100.0	100.0	172.6	96.2

- Preparation of meals

According to authors' own calculations consumption of energy for meals preparation equals 15,0 PJ. It is assumed that energy consumption in 2030 for meals preparation will be at the same level. Development of agrotourism will be one of the main reasons of that state.

Structure of energy carriers consumption for meal preparation in 1993 is given in Table 9.6.7, structure assumed for 2030 is given in Table 9.6.8.

Specification of energy requirements of agriculture in 1993 as well as those assumed for 2030 are given in Table 9.6.6. A structure of energy carriers consumption in particular agricultural processes and a structure of energy carriers consumption in municipal sector in 1993 and 2030 are given in Tables 9.6.7 and 9.6.8; in intermediate years 2000, 2005, 2010 and 2020 - in tables 9.6.9 - 9.6.12.

Changes of energy requirements and energy carriers structure for accomplishment of basic production processes in agriculture, it means production of vegetables under coverings and in drying as well as in fulfilling of energetic requirements of municipal sector (space heating and water heating) till 2030 are presented on figures 9.6.3-9.6.6. Linear changes are assumed of energy requirements and energy carriers structure. On figures 9.6.7-9.6.9 are presented changes of energy carriers structure in agriculture in years 1993-2030 with included renewable energy sources and a division on municipal demands and agricultural production demands.

In 1993 energetic requirements were equal 422,2 PJ per year. In expert opinion it will stabilize on the level 419,0 PJ per year in 2030.

It is assumed that renewable energy form biomass (wood and straw) combustion, solar energy from air collectors, electric energy from autonomous wind power stations and grid connected ones, hydro energy, biogas and rape biofuel will be consumed in 100% in agricultural sector. Energy produced from renewable sources will not cover demands in particular directions of agricultural use. On the other hand only 12 % of geothermal energy (i.e.4,8 PJ) will be consumed in agriculture in 2030. It is connected with localization of these sources and easier exploitation in municipal sector. It is foreseen that 88% of geothermal energy (i.e.35,2 PJ) will be used in municipal sector. Moreover consumption of 35% of produced ethanol is assumed in agriculture in 2030, what is equivalent to 5,9 PJ. The remaining part of ethanol will be used in transport sector. It is connected with ratio of vehicles used in agriculture (gasoline ones) to vehicles used in other sectors, which equals 1/3. Only part of thermal energy from water collectors i.e.15,6 PJ will be used directly in agriculture. Remaining potential of water solar collectors in 2030 i.e. 27-15,6=11,4 PJ will be used in processes of hot water preparation in urban areas.

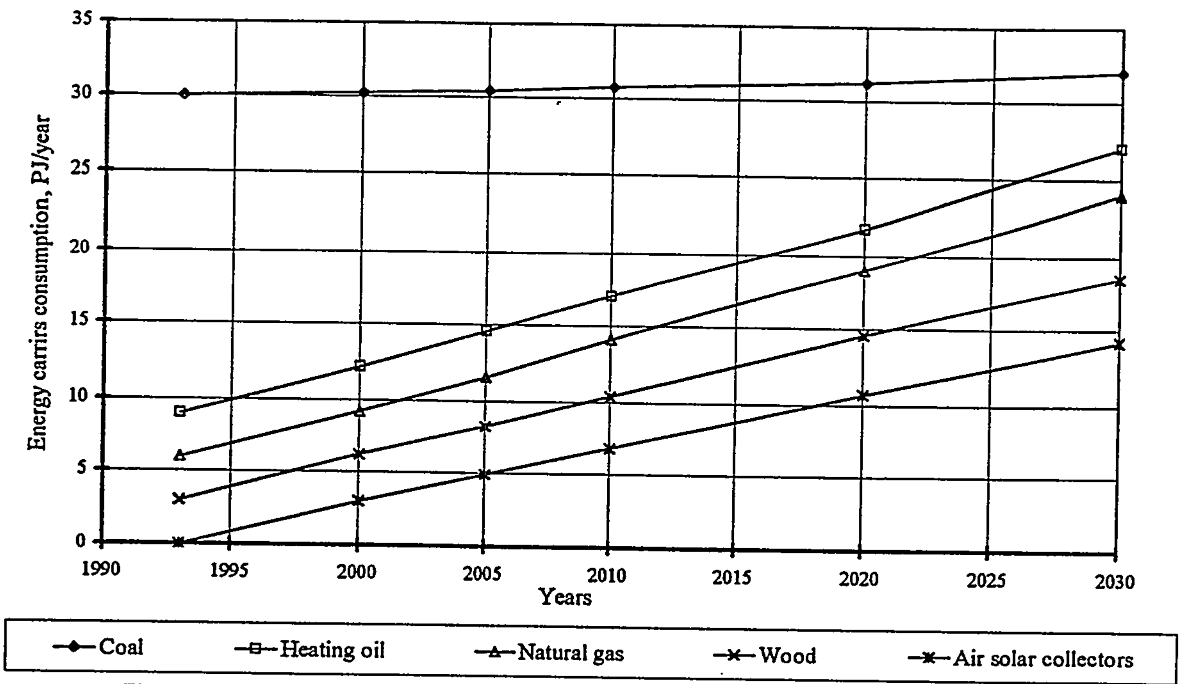

Fig. 9.6 3. Forecast of energy demands changes and structure of energy consumption in drying in years 1993 - 2030

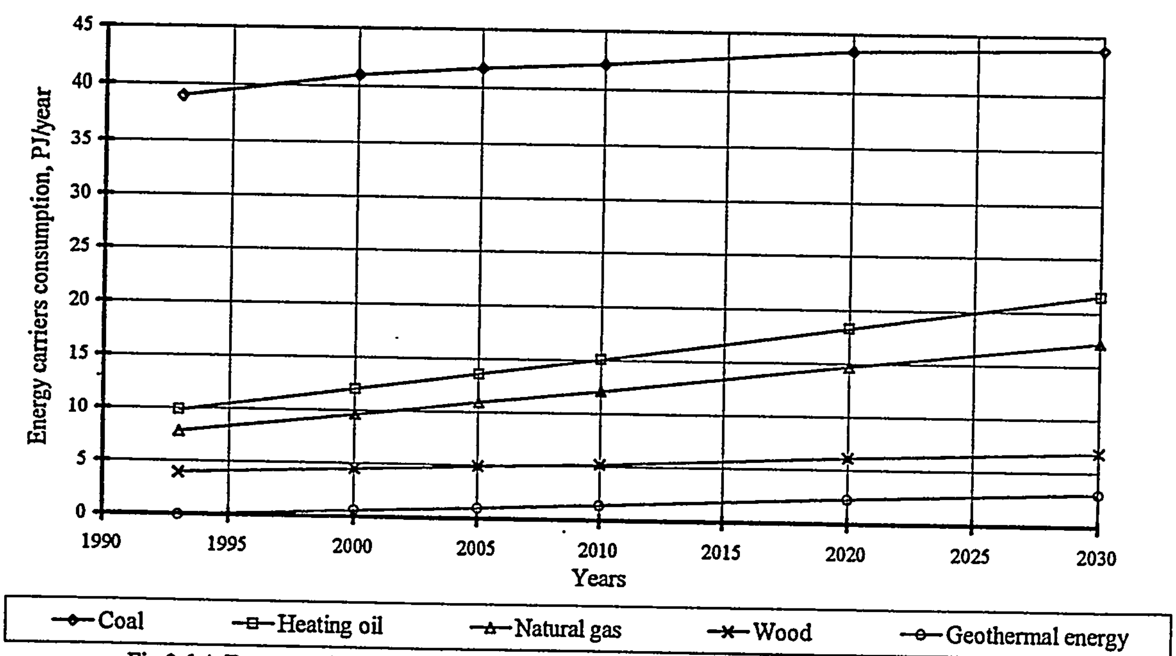

Fig 9.6.4. Forecast of structure and consumption of energy carriers in production under coverings in years 1993 - 2030

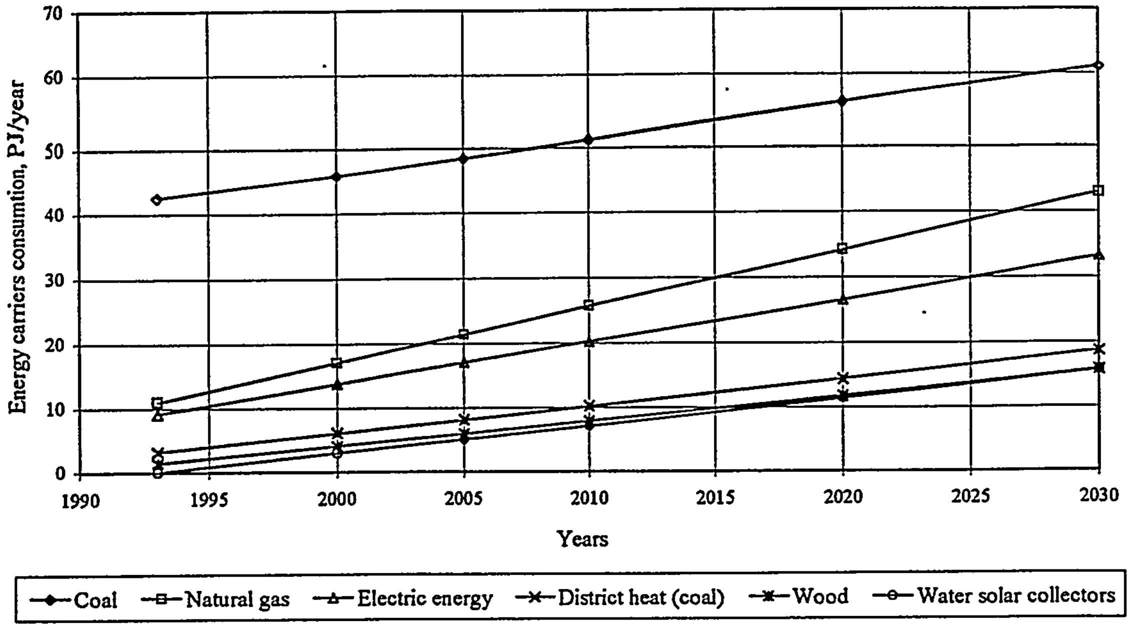

Fig. 9.6.5. Forecast of energy demands changes and structure of energy consumption in water heating in municipal sector in years 1993 - 2030

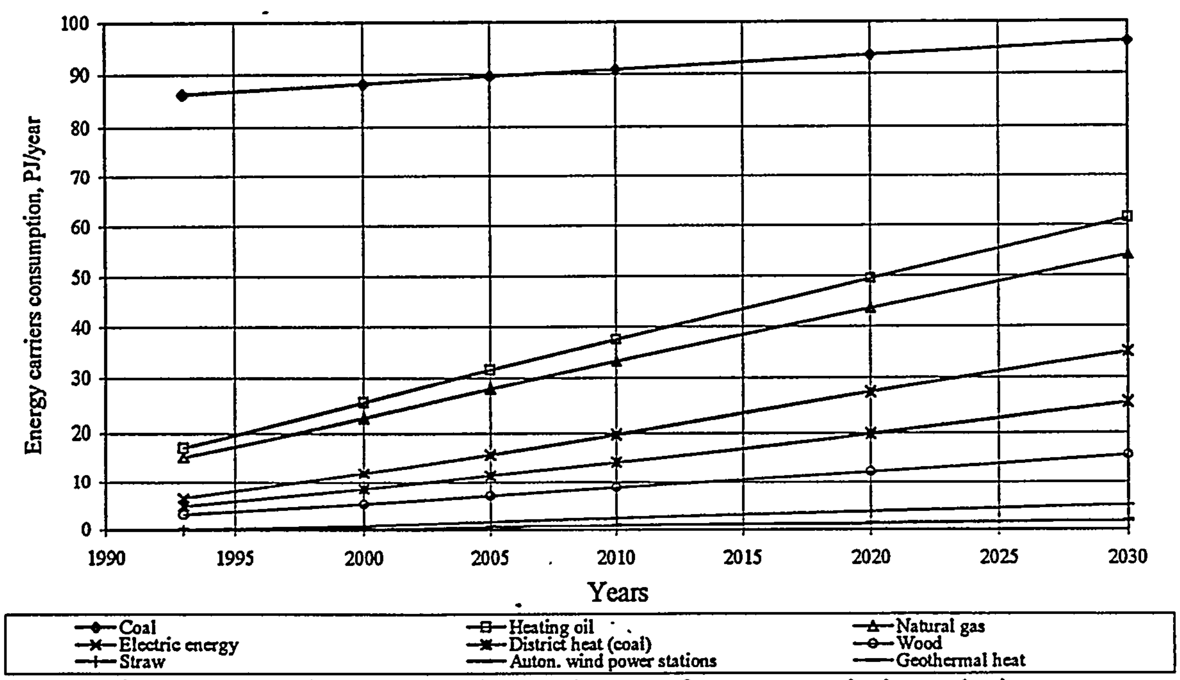

Fig. 9.6.6. Forecast of energy demands changes and structure of energy consumption in space heating in agriculture in years 1993 - 2030

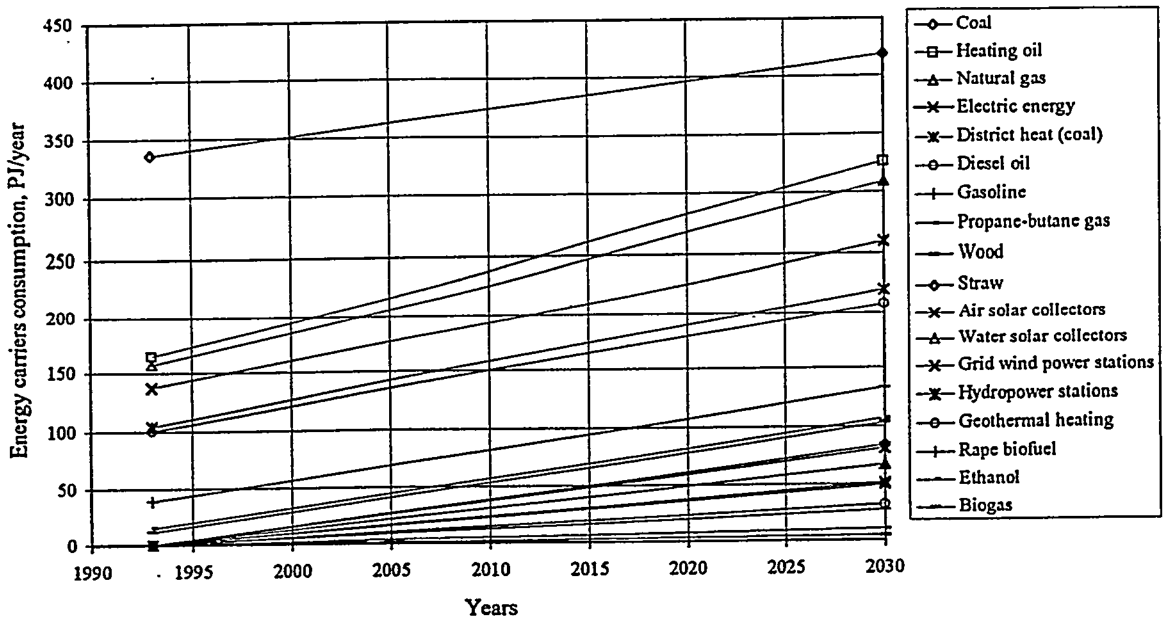

Fig. 9.6.7. Structure of energy carriers consumption in agriculture in years 1993 - 2030

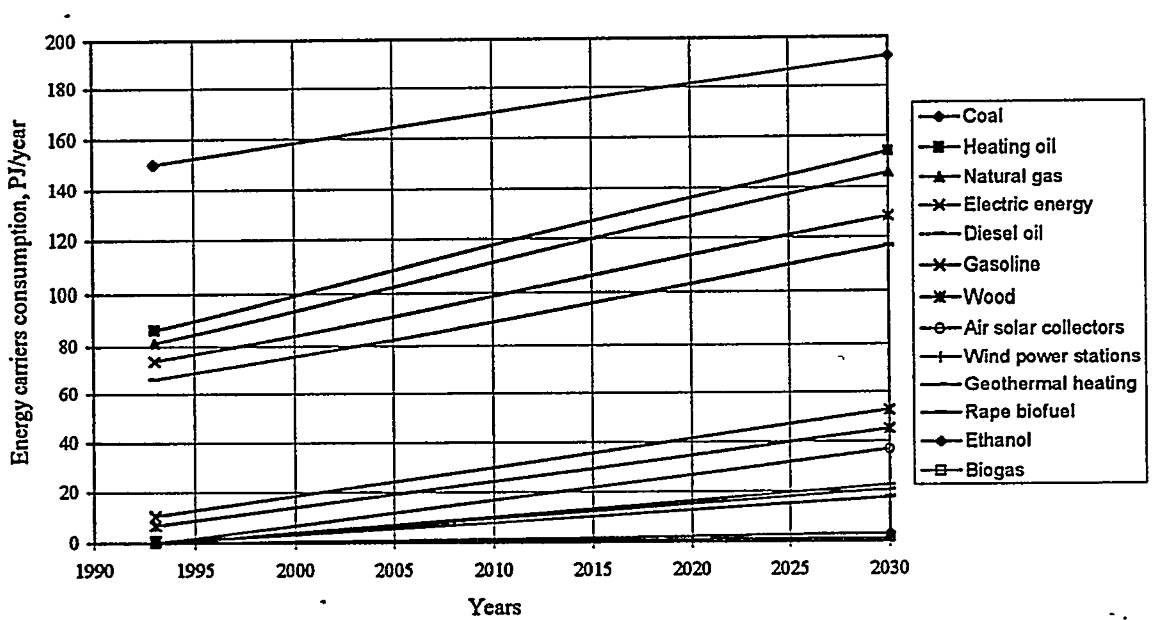

Fig. 9.6.8. Forecast of consumption and energy carriers structure in agricultural production sector in years 1993 - 2030

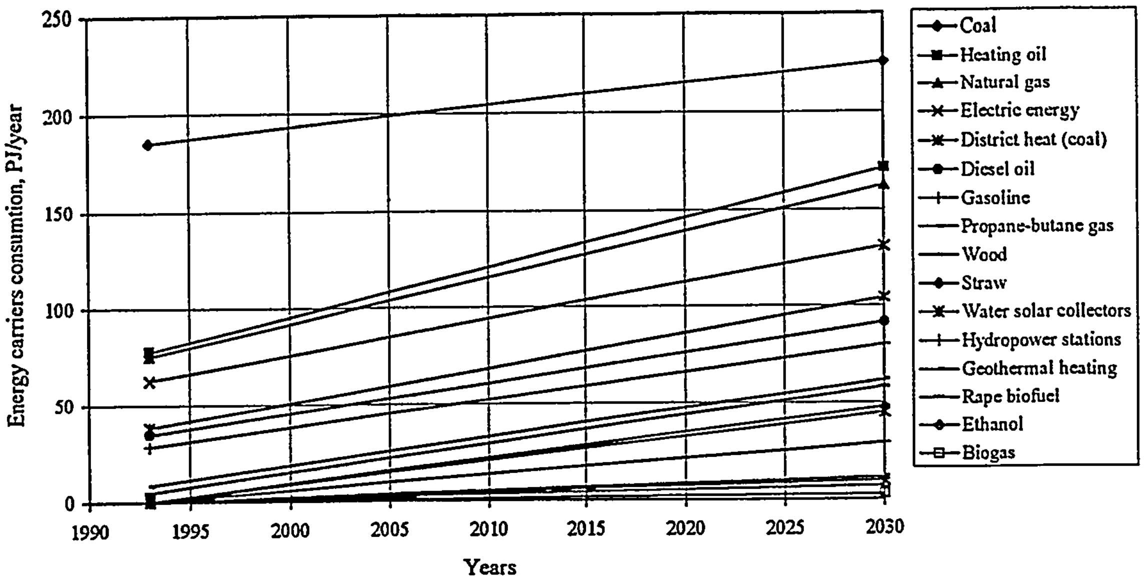

Fig 9.6.9. Forecast of consumption and energy carriers structure in municipal sector of agriculture in years 1993 - 2030

Table 9.6.6. Energy requirements of agriculture

No.	Specification	Energy quantity, PJ/year	
		1993	2030
	Production		
1	Drying	30,0	32,0
2	Production under coverings	39,0	43,8
3	Hot water in animal production	13,4	16,1
4	Heating of husbandry buildings	2,7	3,2
5	Equipment and lighting in animal production	6,2	9,5
6	Transport		
	- diesel oil	55,6	78,6
	- gasoline	3,7	9,4
	Total production	150,6	192,6
	Municipal sector		
1	Hot water	42,5	61,3
2	Space heating	172,6	96,2
3	Preparation of meals	15,0	15,0
4	Household equipment and lighting	15,4	17,8
5	Transport		
	- diesel oil	6,4	13,6
	- gasoline	20,1	22,5
	Total municipal sector	272,0	226,4
	Total agriculture	422,6	419,0

It means that from total potential of renewable energy sources realized in 2030, which equals 161,0 PJ in agriculture will be consumed 103,4 PJ and only 57,6 PJ elsewhere, of which 46,6 PJ will be consumed in municipal sector (solar energy and geothermal one) and 11,0 PJ in transport (ethanol). So, renewable energies will cover 103,4/419,0 = 24,5% of total energy demands in agriculture. Contribution of renewable energies in covering municipal requirements in 2030 will equal 58,6 PJ, which is 25,9% of total energy demands in municipal sector in agriculture, in production sector 44,8 PJ will be consumed, i.e. about 43,1% of energetic potential of renewable energy sources. So, contribution of energy from renewable sources in agricultural production will equal 44,8/195,7 = 22,9%.

Table 9.6.7. Structure of energy carriers use in 1993 in agriculture

N	Energy carriers	Agricultural production																Municipal sector														Total
		Drying		Production under coverings		Hot water in animal production		Heating of husbandry buildings		Equipment and lighting in animal production		Transport in agricultural production				Hot water in municipal sector		Space heating		Preparation of meals		Household equipment and lighting		Transport in municipal sector				
												diesel oil		gasoline										diesel oil		gasoline		
		%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	PJ
1.	Coal	70,0	21,0	75,0	29,2	85,0	11,4	90,0	2,4							74,1	31,5	80,0	138,2	48,0	7,3							241,0
2.	Heating oil	10,0	3,0	5,0	2,0			1,0	0,03									2,0	3,6	5,0	0,6							9,23
3.	Natural gas	10,0	3,0	10,0	3,9	3,0	0,4	8,0	0,24							4,2	1,8	10,0	17,4	13,0	2,0							28,74
4.	Electric energy					12,0	1,6	1,0	0,03	100,0	6,2					14,0	6,0	2,0	3,6	10,0	1,5	100,0	15,4					34,33
5.	District heat (coal)															4,3	1,8	2,0	3,6									5,4
6.	Diesel oil											100,0	55,6											100,0	6,4			62,0
7.	Gasoline													100	3,7											100,0	20,1	23,8
8.	Propane-butane gas																			24,0	3,6							3,6
9.	Wood	10,0	3,0	10,0	3,9											3,4	1,4	4,0	6,2									14,5
	Total	100,0	30,0	100,0	39,0	100,0	13,4	100,0	2,7	100,0	6,2	100,0	55,6	100,0	3,7	100,0	42,5	100,0	172,6	100,0	15,0	100,0	15,4	100,0	6,4	100,0	20,1	422,6
		Total production = 150,6 PJ														Total municipal sector = 272 PJ												

Table 9.6.8. Structure of energy carriers consumption in 2030 in agriculture

No	Energy carriers	Agricultural production														Municipal sector														Total
		Drying		Production under coverings		Hot water in animal production		Heating of husbandry buildings		Equipment and lighting in animal production		Transport in agricultural production				Hot water in municipal sector		Space heating		Preparation of meals		Household equipment and lighting		Transport in municipal sector				
												diesel oil		gasoline										diesel oil		gasoline		
		%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	%	PJ	PJ
1.	Coal	15,7	5,0	50,9	22,3	55,3	8,9	70,0	2,2							29,4	18,0	36,1	34,7	14,0	2,1							93,2
2.	Heating oil	9,1	2,9	9,8	4,3	5,6	0,9	3,0	0,1							0,5	0,3	7,6	7,3	8,0	1,2							17,0
3.	Natural gas	17,5	5,6	23,8	10,4	7,4	1,2	22,0	0,7							16,0	9,8	20,0	19,2	20,0	3,0							49,9
4.	Electric energy					22,4	3,6	5,0	0,2	91,0	7,7					23,8	14,6	10,0	9,6	14,7	2,2							37,9
5.	District heat (coal)															4,9	3,0	10,0	9,6									12,6
6.	Diesel oil											81,5	64,1											81,5	11,1			75,2
7.	Gasoline													81,0	7,7											81,0	18,3	26,0
8.	Propane-butane gas																			25,3	3,8							3,8
	Fossil carriers together	42,3	13,5	84,5	37,0	90,7	14,6	100,0	3,2	91,0	7,7	81,5	64,1	81,0	7,7	74,6	45,7	83,6	80,4	82,0	12,3	0	0	81,5	11,1	81,0	18,3	315,6
9.	Wood (new)	13,1	4,3	8,7	3,8													11,1	10,7									18,8
10.	Straw																	3,3	3,2									3,2
11.	Solar en. from air col.	44,3	14,2																									14,2
12.	Solar en. from water c.															25,4	15,6											15,6
13.	Auton.wind stations																		0,1									0,1
14.	Wind power stations									9,0	1,8																	1,8
15.	Hydropower st (new)																					100,0	17,8					17,8
16.	Geothermal heating			6,8	3,0													1,9	1,8									4,8
17.	Rape biofuel											18,5	14,5											18,5	2,5			17,0
18.	Ethanol													19,0	1,7											19,0	4,	5,9
19.	Biogas					9,3	1,5													18,0	2,7							4,2
	Renewable carriers total	57,7	18,5	15,5	6,8	9,3	1,5	0	0	9,0	1,8	18,5	14,5	19,0	1,7	25,4	15,6	16,4	15,8	18,0	2,7	100,0	17,8	18,5	2,5	19,0	4,	103,4
	Total	100,0	32,0	100,0	43,8	100,0	16,1	100,0	3,2	100,0	9,5	100,0	78,6	100,0	9,4	100,0	61,3	100,0	96,2	100,0	15,0	100,0	17,8	100,0	13,6	100,0	22,5	419,0

Total production = 192,6 PJ

Total municipal sector = 226,4 PJ

Table 9.6.9. Structure of energy consumption in agriculture in 2000

	Energy carriers	Energy consumption in sector production, PJ/year	Energy consumption in municipal sector PJ/year	Total energy consumption PJ/year	Total fossil / renewable
Fossil	Coal	59,5	154,0	213,5	389,7
	Heating oil	5,5	5,2	10,7	
	Natural gas	9,5	23,2	32,7	
	Electric energy	8,5	26,6	35,1	
	District heat	0	6,8	6,8	
	Diesel oil	57,0	6,5	63,5	
	Gasoline	4,5	19,6	24,1	
	Propane-butane gas	0	3,3	3,3	
Renewable	Wood	7,1	5,2	12,2	27,3
	Straw	0,0	0,5	0,5	
	Air solar collectors	2,5	0,0	2,5	
	Water solar collectors	0,0	2,6	2,6	
	Wind power stations	0,2	0,0	0,2	
	Hydropower stations	0,0	3,2	3,2	
	Geothermal heating	0,6	0,3	0,9	
	Rape biofuel	2,7	0,5	3,2	
	Ethanol	0,5	0,9	1,4	
	Biogas	0,1	0,5	0,6	
		158,1	258,9	417,0	

Table 9.6.10. Structure of energy consumption in agriculture in 2005

	Energy carriers	Energy consumption in production sector PJ/year	Energy consumption in municipal sector PJ/year	Total energy consumption PJ/year	Total fossil / renewable
Fossil	Coal	56,3	137,0	193,0	322,7
	Heating oil	6,0	5,7	11,7	
	Natural gas	11,0	24,6	35,6	
	Electric energy	9,0	26,5	35,5	
	District heat	0,0	7,8	7,8	
	Diesel oil	58,5	7,8	66,3	
	Gasoline	5,0	19,6	24,6	
	Propane-butane gas	0,0	3,9	3,9	
Renewable	Wood	7,0	6,5	13,5	39,9
	Straw	0,0	1,3	1,3	
	Air solar collectors	4,0	0,0	4,0	
	Water solar collectors	0,0	4,6	4,6	
	Wind power stations	0,5	0,0	0,5	
	Hydropower stations	0,0	5,9	5,9	
	Geothermal heating	1,0	0,3	1,3	
	Rape biofuel	4,5	1,3	5,8	
	Ethanol	0,5	1,0	1,5	
	Biogas	0,6	0,9	1,5	
		163,6	254,7	418,3	

Table 9.6.11. Structure of energy consumption in agriculture in 2010

	Energy carriers	Energy consumption in production sector PJ/year	Energy consumption in municipal sector PJ/year	Total energy consumption PJ/year	Total fossil / renewable
Fossil	Coal	53,0	119,7	172,7	365,3
	Heating oil	6,9	5,9	12,8	
	Natural gas	12,5	25,9	38,4	
	Electric energy	9,5	26,4	35,9	
	District heat	0,0	8,8	8,8	
	Diesel oil	59,5	8,5	68,0	
	Gasoline	5,8	19,0	24,8	
	Propane-butane gas	0,0	3,9	3,9	
Renewable	Wood	7,5	7,2	14,7	53,8
	Straw	0,0	2,1	2,1	
	Air solar collectors	6,5	0,0	6,5	
	Water solar collectors	0,0	6,5	6,5	
	Wind power stations	0,7	0,0	0,7	
	Hydropower stations	0,0	8,1	8,1	
	Geothermal heating	1,5	0,8	2,3	
	Rape biofuel	6,5	1,2	7,7	
	Ethanol	1,0	2,0	3,0	
	Biogas	1,0	1,2	2,2	
		171,9	247,2	419,1	

Table 9.6.12. Structure of energy consumption in agriculture in 2020

	Energy carriers	Energy consumption in production sector PJ/year	Energy consumption in municipal sector PJ/year	Total energy consumption PJ/year	Total fossil / renewable
Fossil	Coal	46,0	87,0	133,0	340,6
	Heating oil	7,5	7,4	14,9	
	Natural gas	15,5	28,6	44,1	
	Electric energy	10,6	26,3	36,9	
	District heating	0,0	10,8	10,8	
	Diesel oil	62,0	9,8	71,8	
	Gasoline	7,0	18,3	25,3	
	Propane-butane gas	0,0	3,8	3,8	
Renewable	Wood	7,8	9,1	16,9	79,1
	Straw	0,0	2,4	2,4	
	Air solar collectors	10,5	0,0	10,5	
	Water solar collectors	0,0	11,4	11,4	
	Wind power stations	1,5	0,0	1,5	
	Hydropower stations	0,0	12,9	12,9	
	Geothermal heating	2,0	1,3	3,3	
	Rape biofuel	11,0	1,8	12,8	
	Ethanol	1,1	3,1	4,2	
	Biogas	1,2	2,0	3,2	
		183,7	236,0	419,7	

9.6.3. Scenario of GHG emission reduction

Change of energetic balance of agriculture by renewable energy utilization will cause, first of all, reduction of coal and diesel oil consumption as well as electric energy delivered from power stations and thermal power stations using fossil fuels. Reduction of these energy carriers consumption will have an effect on GHGs emissions reduction, especially carbon dioxide (CO_2). In perspective till 2030 reduction of GHGs emission, expressed in equivalent quantity of CO_2 per annum, will equal 17282447 tons. Taking into account other renewable energy carriers used besides agriculture such as geothermal energy, used in municipal management for heating of housing estates and factories and ethyl alcohol used as additive to gasoline in 65% besides agriculture, total yearly reduction of GHGs emission expressed in CO_2 equivalent units will equal 22376937 till 2030. More then a half of the reduction (77,2%) is resulting from use of renewable energy in rural districts and in agricultural production.

Energetic potential and energy production from renewable energy sources in particular years were taken according to experts estimation.

Energy production in 2030 is given in Table 9.6.13. In 2030 total economic potential of energy from renewable sources will equal 161,0 PJ.

Table 9.6.13. Production of energy in 2030

Source	Type of energy	Unit	Quantity of energy	PJ/year	Surplus besides agriculture
Hydropower stations:					
- large	electric	MWh/year	3720000	13,4	-
- medium	electric	MWh/year	680000	2,4	-
- small	electric	MWh/year	562560	2,0	-
Wind power stations					
- autonomous	electric	MWh/year	34777	0,1	-
- grid connected	electric	MWh/year	500000	1,8	-
Geothermal heating stations	thermal	GJ/year	40000000	40,0	35,2
Wood combustion	thermal	GJ/year	18865000	18,8	-
Straw combustion	thermal	GJ/year	3250490	3,2	-
Rape biofuel	thermal	GJ/year	17010000	17,0	-
Ethanol	thermal	GJ/year	16925000	16,9	11,0
Water solar collectors	thermal	GJ/year	27000000	27,0	11,4
Biogas combustion	thermal	GJ/year	4188000	4,2	-
Air solar collectors	thermal	GJ/year	14200000	14,2	-
Total				161,0	
Total in agriculture				103,4	

Energy requirements in 2030 in agriculture (Table 9.6.1 and Table 9.6.8) equal 422,1 PJ, whereas assumed potential energy production from renewable energy sources - 161,3 PJ. If all energy from renewable sources was used in agricultural sector, then share of renewable energy in fuel-energetic balance would equal 38,2%. Assuming that in 2030 only 35% of energy from ethanol as a fuel, 12% of geothermal energy and 52% of thermal energy from water solar collectors will be used in agriculture (Table 9.6.8), agricultural energy requirements will be covered in 24,5% by renewable energy.

In Table 9.6.14 coefficients of unit emission of fossil fuels and renewable energy sources taken to calculations are given.

In Tables 9.6.15 - 9.6.20 reductions of CO_2 equivalent emission caused by introduction of renewable energy sources in agriculture, with division into production sector and municipal one, are given. Above forecasts are presented on figures 9.6.10 - 9.6.12.

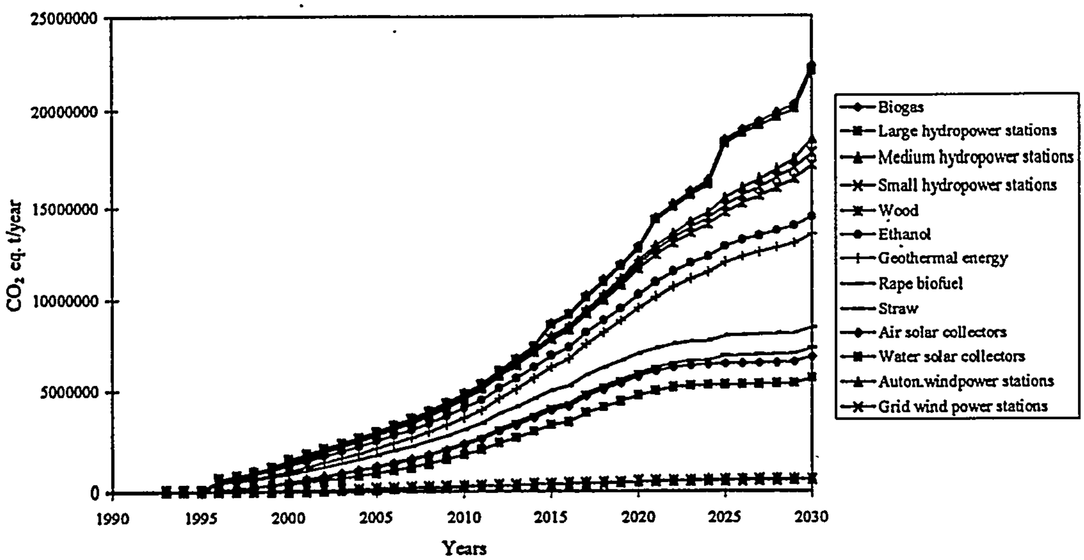

Fig. 9.6.10. Global limitation of CO2 eq. emission caused by introduction of renewable energy sources in years 1993 - 2030

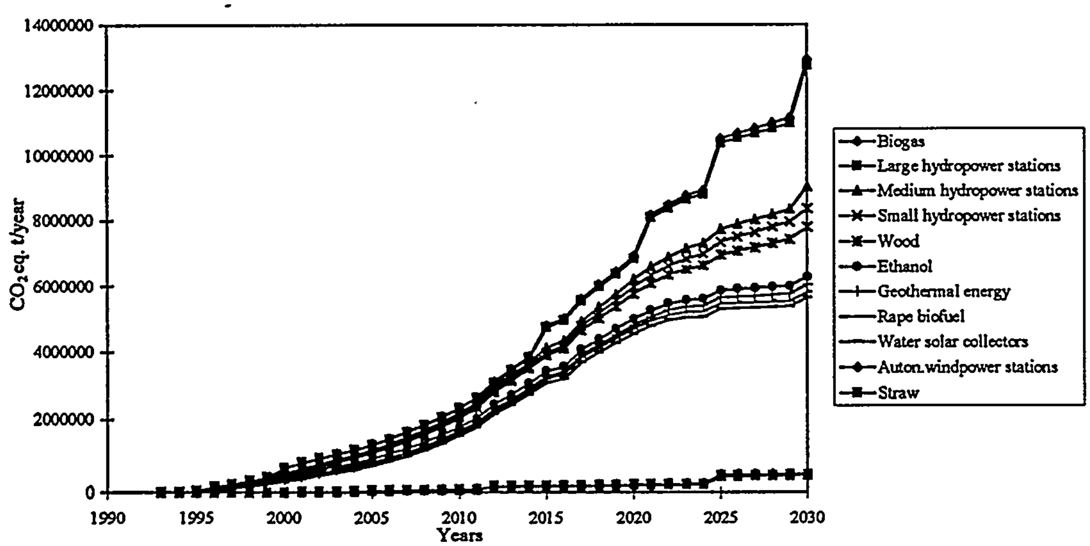

Fig. 9.6.11. Reduction of CO_2 eq. emission in municipal sector of agriculture in years 1993 - 2030

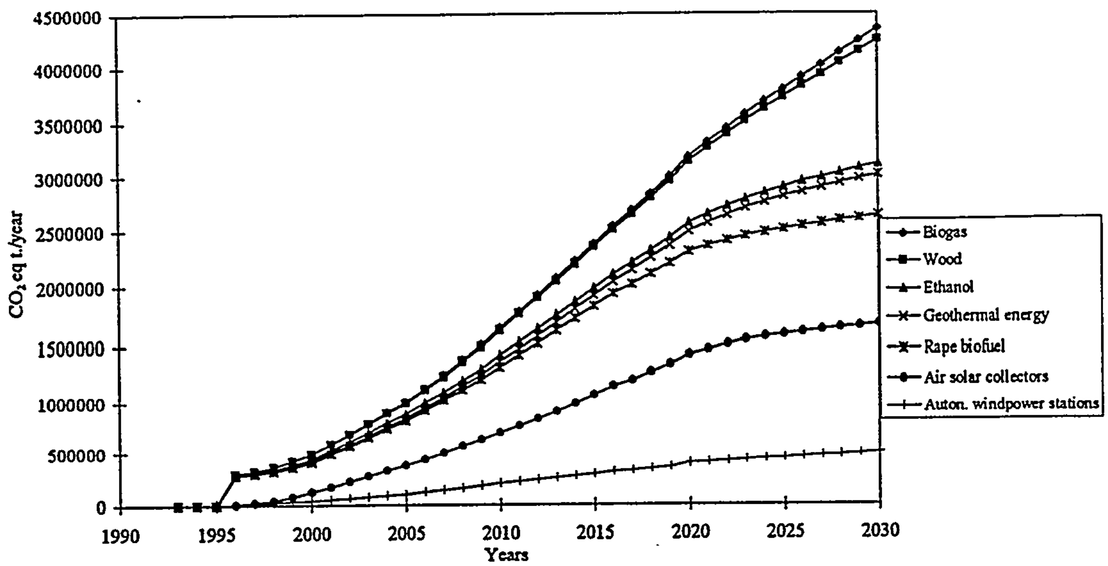

Fig. 9.6.12. Reduction of CO_2 eq. emission in production sector of agriculture in years 1993 - 2030

Table 9.6.14. Coefficients of unit emission from fossil fuels and renewable energy sources

Fuels and energy	Coefficient of GHG emission for use of fuel and energy		
	CO_2 kg/GJ	CH_4 kg/GJ	N_2O kg/GJ
Electric energy for households	295,8	0,0017	0,0412
Coal for power stations	93,82	0,0006	0,0014
Electric energy for industry	295,74	0,0017	0,0041
Heating wood	0	0,015	0
Ethanol	0	0	0
Coal for industry	92,52	0,0022	0,0014
Diesel oil	73,84	0,007	0,004
Straw	0	0,015	-
Coal for households	92,24	0,0024	0,0014
Natural gas for households	55,81	0,0014	0,0001
Gasoline	72,48	0,039	0,002
Light heating oil for households	77,36	0,0029	0,0006

Table 9.6.15. Forecast of CO_2 equivalent reduction caused by introduction of renewable energy sources in 1995

Energy carriers	In production sector t/year	In municipal sector t/year	Total in agriculture t/year	Total t/year
Biogas	0	0	0,00	0
Large hydropower stations	0	1000	1000	1000
Wood	0	0	0,00	0
Ethanol	0	0	0,00	0
Geothermal energy	0	0	0,00	0
Small hydropower stations	0	0	0,00	0
Rape biofuel	0	0	0,00	0
Medium hydropower stations	0	0	0,00	0
Straw	0	0	0,00	0
Air solar collectors	81	0	81,00	81
Water solar collectors	0	19085	19085	19085
Autonomous wind power stations	0	0	0,00	0
Grid connected wind power stations	0	0	0,00	0
Total	81	20085	20166	20166

Table 9.6.16. Forecast of CO_2 equivalent reduction caused by introduction of renewable energy sources in 2000

Energy carriers	In production sector t/year	In municipal sector t/year	Total in agriculture t/year	Total t/year
Biogas	826	1489	2315	2314
Large hydropower stations	0	130067	130067	130067
Wood	48388	63881	112269	112270
Ethanol	26687	66184	92871	266874
Geothermal energy	9460	5676	15136	126138
Small hydropower stations	0	0	0	22969
Rape biofuel	282526	48689	331215	331215
Medium hydropower stations	0	0	0	0
Straw	0	1577	1577	1577
Air solar collectors	81347	0	81347	81347
Water solar collectors	0	286277	286277	286277
Autonomous wind power stations	0	394	394	394
Grid connected wind power stations	40020	0	40020	40021
Total	489254	604234	1093488	1401463

Table 9.6.17. Forecast of CO_2 equivalent reduction caused by introduction of renewable energy sources in 2005

Energy carriers	In production sector t/year	In municipal sector t/year	Total in agriculture t/year	Total t/year
Biogas	6519	11741	18260	18260
Large hydropower stations	0	130067	130067	130067
Wood	107664	0142137	249801	249801
Ethanol	39438	97806	137244	394381
Geothermal energy	25543	15326	40869	340572
Small hydropower stations	0	38539	38539	38539
Rape biofuel	448455	7283	525738	525738
Medium hydropower stations	0	44297	44297	44297
Straw	0	46039	46039	46039
Air solar collectors	276579	0	276579	276579
Water solar collectors	0	667979	667979	667979
Autonomous wind power stations	0	1578	1578	1578
Grid connected wind power stations	100052	0	100052	100052
Total	1004250	1272792	2277042	2833882

Table 9.6.18. Forecast of CO_2 equivalent reduction caused by introduction of renewable energy sources in 2010

Energy carriers	In production sector t/year	In municipal sector t/year	Total in agriculture t/year	Total t/year
Biogas	12211	21994	34205	34206
Large hydropower stations	0	130067	130067	130067
Wood	199905	263911	463816	463816
Ethanol	52189	129428	181617	521887
Geothermal energy	47302	28381	75683	630688
Small hydropower stations	0	54493	54493	52492
Rape biofuel	619385	106740	726125	726126
Medium hydropower stations	0	88595	88595	88595
Straw	0	69867	69867	69867
Air solar collectors	504349	0	504349	504349
Water solar collectors	0	1450468	1450468	1450468
Autonomous wind power stations	0	4119	4119	4119
Grid connected wind power stations	200103	0	200103	200103
Total	1635444	2348063	3983507	4876783

Table 9.6.19. Forecast of CO_2 equivalent reduction caused by introduction of renewable energy sources in 2020

Energy carriers	In production sector t/year	In municipal sector t/year	Total in agriculture t/year	Total t/year
Biogas	41223	74247	115470	115470
Large hydropower stations	0	620320	620320	620320
Wood	574310	758196	1332506	1332505
Ethanol	73123	181346	254469	731235
Geothermal energy	189206	113524	302730	2522754
Small hydropower stations	0	209960	209960	209960
Rape biofuel	891045	153556	1044601	1044602
Medium hydropower stations	0	255941	255941	255941
Straw	0	192254	192254	192254
Air solar collectors	1016834	0	1016834	1016834
Water solar collectors	0	4351405	4351405	4351405
Autonomous wind power stations	0	12884	12884	12884
Grid connected wind power stations	400206	0	400206	400206
Total	3185947	6923633	10109580	12806370

Table 9.6.20. Forecast of CO_2 equivalent reduction caused by introduction of renewable energy sources in 2030

Energy carriers	In production sector t/year	In municipal sector t/year	Total in agriculture t/year	Total t/year
Biogas	103316	186085	289401	289401
Large hydropower stations	0	3721920	3721920	3721920
Wood	1141059	1506410	2647469	2647469
Ethanol	100374	248928	349302	1003743
Geothermal energy	378413	227047	605460	5045508
Small hydropower stations	0	553778	553778	553778
Rape biofuel	977976	168538	1146514	1146514
Medium hydropower stations	0	669385	669385	669385
Straw	0	456063	456063	456064
Air solar collectors	1155123	0	1155123	1155123
Water solar collectors	0	5152979	5152979	5152979
Autonomous wind power stations	0	34795	34795	34795
Grid connected wind power stations	500258	0	500258	500258
Total	4356519	12925928	17282447	22376937

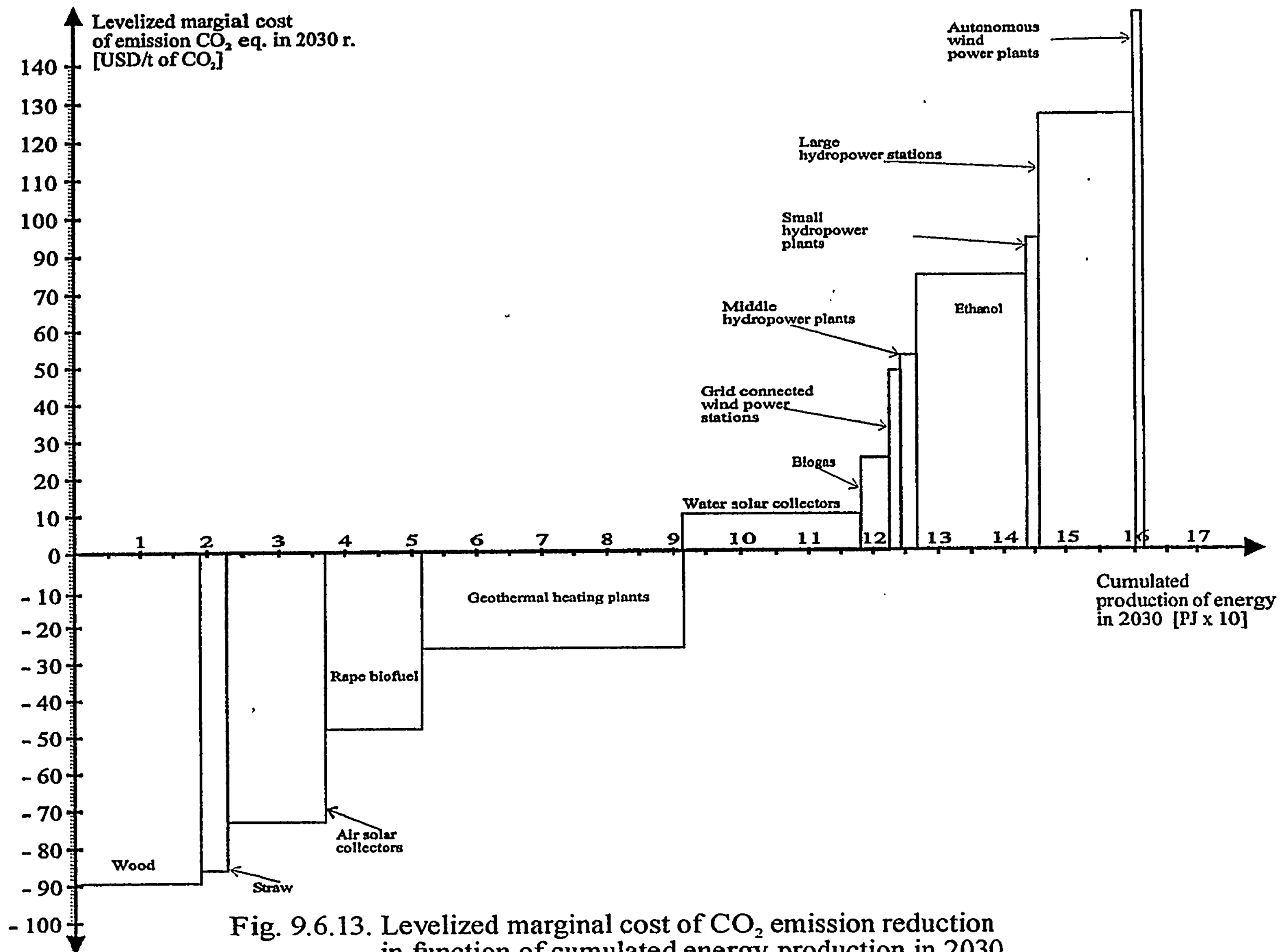

Fig. 9.6.13. Levelized marginal cost of CO_2 emission reduction in function of cumulated energy production in 2030

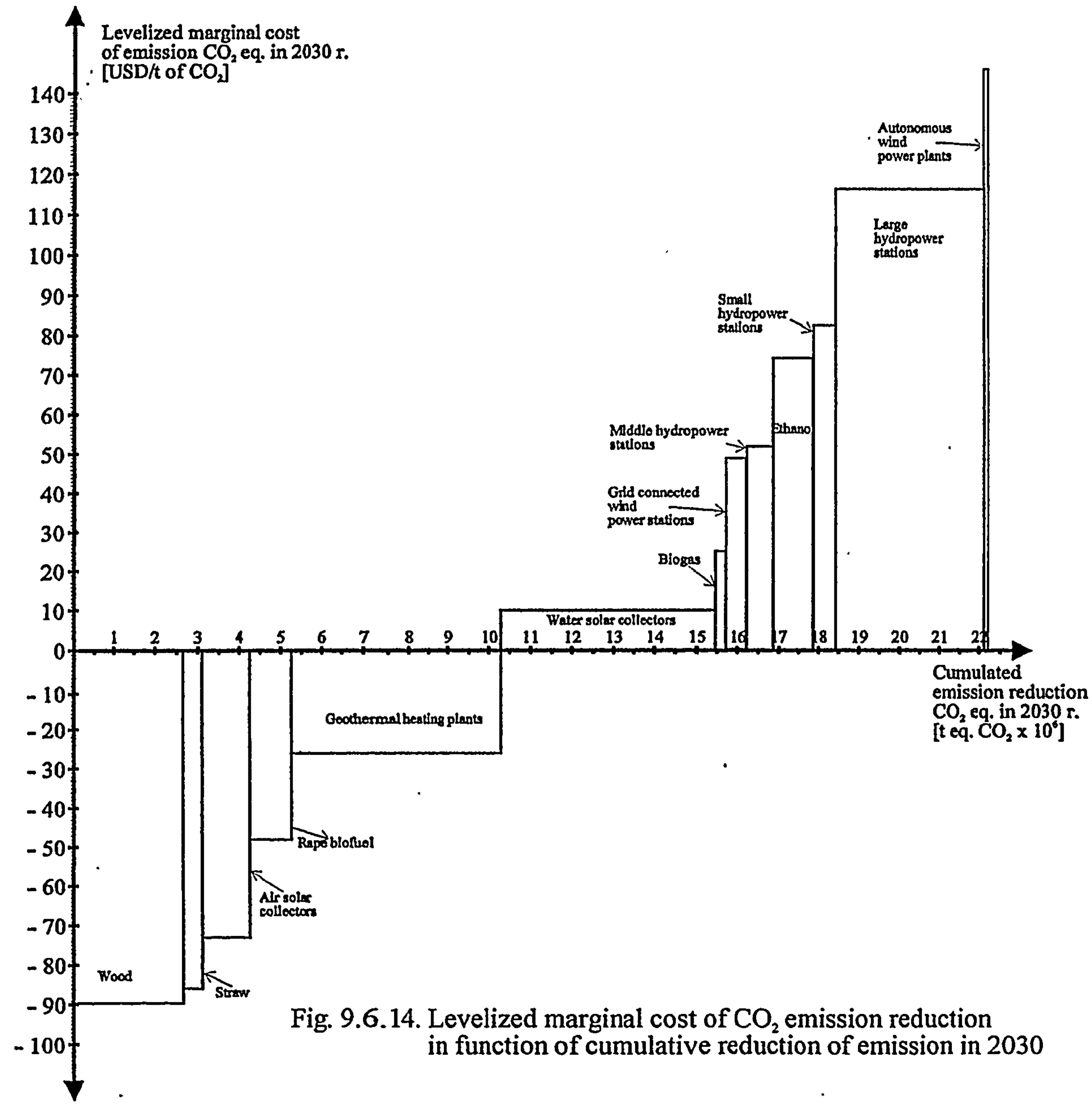

Fig. 9.6.14. Levelized marginal cost of CO_2 emission reduction in function of cumulative reduction of emission in 2030

9.6.4. Costs of GHG emission reduction

GHG reduction costs expressed in CO_2 equivalent were calculated on the basis of methodology worked out by FEWE. Production of energy from renewable sources presented in Table 9.6.15 - 9.6.20 as well as data given by FEWE about prices of fossil fuels, unit GHG emissions in comparison to fuels and energy consumption and discount rate. It was assumed that 1993 value of 1 USD was equal 0.95 zł.

For particular energy sources following parameters for 2030 year were calculated:

- levelled cost of GHG emission reduction,
- levelled marginal cost of GHG emission reduction,
- internal rate of return,
- CO_2 equivalent emission reduction,
- energy production.

On basis of the calculations and values of „warming potential" coefficients adequately equal (according to FEWE recommendations) for CH_4 - 24,5 and for NO_2 - 320 charts presented on figures 9.6.13 and 9.6.14 were done. A dependence of levelled marginal cost of CO_2 equivalent emission reduction in 2030 in function of energy cumulated production in 2030 in PJ (x 10) is shown on fig.9.6.13. Values are set in order from the smallest levelled marginal cost of CO_2 equivalent emission reduction equal for wood - 90 USD/year to the biggest value equal 147 USD/year for autonomous wind power stations.

On fig.9.6.14 a dependence of levelled marginal cost of CO_2 equivalent emission reduction in 2030 in function of cumulated reduction of CO_2 equivalent emission in 2030 is illustrated. This chart is also in ordered form. Levelled marginal cost of CO_2 equivalent emission reduction in 2030 is positive for energy supply from water solar collectors, biogas stations, small, medium and large hydropower stations, autonomous and grid connected wind power stations as well as ethanol, which means that their implementation is not profitable and introduction of additional measures supporting their dissemination and popularization is necessary.

For technologies based on such renewable energy sources as: wood, straw, air solar collectors and liquid biofuels investment costs are returned during their life.

In case of wood it is consistent with accepted assumption, that energetic inputs in combustion of wood are the same as in combustion of fossil fuels. However, some reservation are connected with fact, that technology of rape biofuel production have appeared in that group.

9.6.5. Measures for stimulation of renewable energy utilization and GHG's emission reduction

Computer program OZE EKO [Wiśniewski et al., 1995] was used for generation of economic instruments stimulating renewable energy sources utilization. This program allows economic assessment of investment made in renewable energy sector and identification of barriers in renewable energetics development. Analysis has shown the necessity of introduction of direct financial incentives. Technology of combustion of solid fuels from biomass, mainly wood, in local grid furnaces is the only exception. In that case only gaining money for modernization, further improvement and development of actually used furnaces is needed. For all remaining sources of renewable energy an application of direct economic measures, especially financial incentives in form of subsidies and preferential credits, is necessary.

Scale of necessary financing support, enabling reaching investment profitability in microeconomic sense, is the following:

- wind power stations connected to grid require ca.50% of investment subsidy with tendency to decrease after reaching at least 10 MW of installed power and preferential e.g.10% credit,
- solar systems for hot water preparation require ca. 30% of investment subsidy and credit with no interest,
- agrorefinery for rape methylester production (rape biofuel) without subsidy requires a credit with no interest or ca. 30% of investment subsidy and a credit with interest not exceeding e.g. 10%,
- geothermal heating plants without subsidy require investment credit with interest not exceeding 10%, in case of higher interest e.g. 20% ca.30% of investment subsidy is required,
- air solar collectors without subsidy require a credit with interest to 20%, in case of subsidy in ranges up to 30% of investment credit interest can reach even 40%,
- small hydropower stations without subsidy require financial incentive in form of credit with low interest e.g. 10%;
- in case of autonomous wind power plants, photovoltaic cells and biogas stations required level of subsidy should be in range 90%-50%; direct financial support of investment in those areas is too expensive; the exception - biogas station connected with wastes treatment for compost (additional sale of compost improves investment profitability).

Presented propositions of financial incentives are adequate to price structure of renewable energetics devices and fossil fuels prices occurring in Poland in 1993. As the progress in development of renewable technologies and increase of prices of energy carriers received from fossil fuels arise the level of proposed subsidies will be reduced.

System of fossil fuels taxation (increase of traditional fuel prices) connected with environment contamination, excise and VAT tax will have significant influence on stimulation of renewable energy usage. Energy produced from renewable sources should be tax-free (excise and VAT), till the moment of reaching the significant level of energy production.

Besides economic measures social and political activities will play important role, especially in the area of institutional and information barriers overcoming. In this case the simplest and most effective measure is wide information for society and for potential investors about existing technologies, especially when investments are explicitly profitable.

Lack of progress in dissemination of renewable energy sources usage can be also connected with minimal presence or shortage of adequate equipment on the market. For example at that moment on the market we have scanty supply of boilers for wood and wood refuses, solar collectors for air heating (actually used are built in self-made system) etc. Information and educational programs as well as advertising campaign can be effective method for these equipment popularisation. Difficulties in creation of demand for given technology in this case are connected with shortage of knowledge about the technology and its possibilities.

It is proposed to use following social and political measures:

- full and continuous information and social education (radio, TV, leaflets, brochures) etc.
- development of checked equipment marketing,
- gratuitous assistance by trained staff e.g. ODRs (Centres of Agricultural Advisement), energetic enterprises, agricultural schools, consulting firms,
- link of renewable energy sources utilization programs with energy saving programs, especially in domestic architecture,
- inclusion of private sector (by incentives in tax reduction) into forming the market for renewable energy sources usage,
- introduction to draft of the Energetic Law a recording about non-transferrable law of individual users not carrying on economic activities for use of renewable energy sources for own requirements and possibility of disposing energy surplus produced besides grid. In area of centralized heating systems implementing renewable energy sources it is necessary to introduce duty of energy purchase by distributing firms on priority principles (in the area of electric energy such regulations are existing).
- elaboration and acceptance by Economic Committee attached to the Cabinet far-reaching program of renewable energetics development in Poland with all elements i.e. economic, social and legal measures.

Detailed analysis of economic, social and political measures is given in report from SE7 stage VII realization.

9.6.6. Research needs for further realization of the strategy

Information concerning potential, technologies and state of renewable energy sources utilization presented in succeeding reports from SE7 realization were based on hitherto existing results of investigations, especially those done by IBMER, Geologic Institute and Office of Energetic Study and Designs. Those investigations were mainly concerning energetic and technical problems with turning smaller attention to ecological aspects. The present study is the first attempt to scientific justification of purposefulness of renewable energy sources utilization, not only in aspect of energetic potential increase, but also in aspect of reduction of GHGs emission connected with production and consumption of different energy carriers. As every first attempt it also needs further investigations stating precisely accepted assumptions and obtained results. First of all should be done estimation of GHGs emission reduction, resulting from traditional technologies substitution with those using renewable energy as well as identification of costs connected with that.

On the other hand investigations of particular technologies should take into account requirements of the market and should enable commercialization of development of devices using renewable energy.

The other important problem is testing pilot solutions of renewable energy sources use such as e.g. geothermal heating plants, straw burning heating plants, wind farms etc. In case of wind farms research program requires large investment inputs for establishing of pilot farm (e.g. on the Vistula right riverside in Płock). Such farm can be built with support of foreign capital (e.g. American one) after the example of farms existing in US, Denmark and other countries.

Large projects of renewable energy sources usage are connected with high risk and for that reason research programs should be directed to target grant forming, in which financing sources can be generated from science development funds, private donations or foreign funds. Within those grants implementation of those installations using renewable energy sources which are near the stage of the whole commercialization, should be possible. Grant concerning the establishment of first rape agrorafinery in Poland can be an example (rape biofuel).

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9.7. Strategies of reduction of the carbon dioxide emission in the energy sector

The following chapter is different from the remaining part of the Project in the way it covers the methodology and scope of the work issues. It is, however, consistent with already existing State Energetic Policy, the document drawn up by the Ministry of Industry and Trade, as far as the methodology and scope of work are concerned. This chapter is also a continuation of the above-mentioned document in the aspect of the carbon dioxide emission.

9.7.1. Aim and scope of the work

The main goal of the work under question was to answer the questions: *Is it possible to reduce the emission of carbon dioxide from the energy related sources in Poland until the year 2010, how can it be done in the cheapest way and what additional costs will it cause?*

The prepared strategies consider only technological measures, and not the legal, economical, information and other instruments, which may be used by the Government to enforce the required behaviour of the industrial and individual energy users to achieve assumed goals. This work takes into account the total emission of carbon dioxide from all processes of energy production and use, which, according to the latest data on the emission of the greenhouse gases in Poland [FEWE, 1995] constitutes more than 97% of the total human emission in 1992. Having calculated the possible heating effect, this emission represents over 82% of the so-called global heating potential, as calculated for all the greenhouse gases. Hence, the strategies presented here constitute the important part of the strategy to reduce the emission of all greenhouse gases (GHG) for the whole country.

The scope of the work covers all the most important energy transformation processes of the country, as well as a part of the processes of the final energy consumption. To maintain consistency of the results, the applied methodology takes into account the most important system dependencies, e.g. interconnections between different processes in the chain of energy transformations, competition between various energy carriers, as well as necessity of balancing supply and demand of the energy carriers. Preparation of the strategy of reduction of emission of carbon dioxide requires, in principle, preparation of a complete, suitably oriented strategy of development of the energy system, described as a set of the interconnected processes of energy production and transformation ("supply side") and its consumption ("demand side").

The performed analysis took into account the energy management in all the economy sectors. Its scope is, in part, the same as the area of investigation of other Teams, taking part in the Project. In this work, the partial strategies for different sectors and subsystems were determined by the general objective for the whole country (achieving the assumed reduction of the CO_2 emission at minimum costs). The calculations were performed for the assumptions of the macroeconomic scenario, prepared at the III-rd stage of the project. To maintain consistency of the results with those of other teams, if possible, their numerical results were used as input to the models. However one should not expect complete agreement, between results of this work and other teams, because of different methodology, scale and level of generalization as well as the fact, that some of the teams started their work with considerable delay (e.g. transport).

The assumptions presented in point 9.7.4 concerning energy saving potential and the available range of use of renewable energy sources correspond only to the performed model simulation and do not take into account all the possible situations in given areas. In particular, the given rationalization potentials of energy consumption relate to the evaluated model simulation, rather than, to the issue as a whole. For instance, assumed was a considerable use of energy saved as a result of thermorenovation of buildings, and the amount of transport work occurs in one variant (remarkably preservative one), intensive use of biomass for municipal needs was assumed, with a moderate (considerably feasible) range of obtaining energy from solar collectors.

At the end of the this Chapter, the results obtained from the study under question were compared with similar results for selected European countries.

9.7.2. Energy situation of Poland

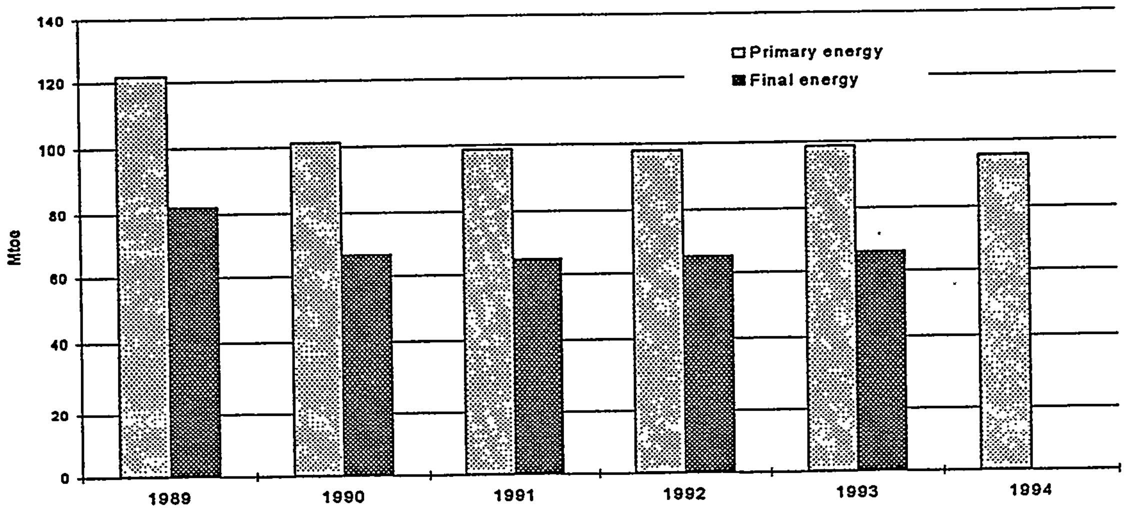
As it follows from the values presented at the beginning, the actions to stabilize or reduce emission of CO_2 will be undertaken mainly within the energy system of the country. Because of many years of communist management the energy system of our country must overcome many problems, very often much more serious than the problem of greenhouse gases. Among the ecological problems one should mention e.g. still very large emission of particulates, sulphur dioxide, nitric oxides, salt carried to the rivers with water from the mines, and still unsolved problem of the solid wastes from mining and power industry. Solving these problems still calls for a lot of effort and money.

To place the further considerations in a more broad system context, short description of the energy situation of Poland and the most important problems of the energy policy of the state [MPiH, 1995] will be presented below. Some indications for the authors of the strategy of the carbon dioxide reduction, following from this situation, will be also presented.

Energy and fuel consumption

Figure 9.7.1 presents the primary and final energy consumption in Poland during the recent years. After 1989 a noticeable decrease of the energy consumption could be seen. As a result of the economic transformations, in 1994 the primary energy consumption decreased by about 27 PJ and the final energy consumption by about 16 PJ, as compared with 1989.

Fig. 9.7.1 Primary and final energy cosumption in Poland by [4,5]



The following figures show the primary energy consumption per unit of the Gross Domestic Product (GDP) (Fig. 9.7.2) and per head of the population (Fig. 9.7.3) in Poland, as compared with the European OECD countries. In spite of considerable decrease of the energy intensity of the GDP in recent years, it is still several times higher than in the European OECD countries.

Fig. 9.7.2 Pimary and final energy cosumption per GDP by [6]

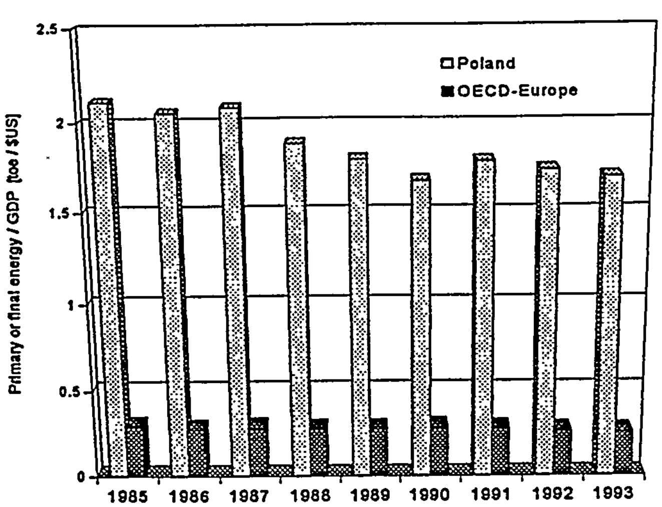
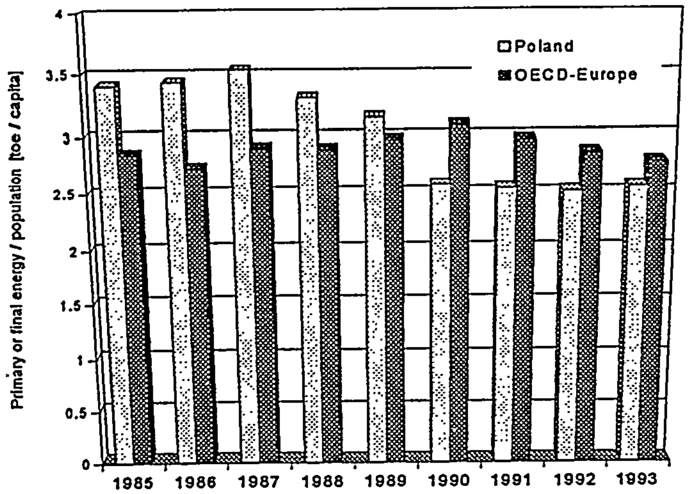


Fig 9.7.3 Pimary and final energy consumption per capita by [6]



The primary energy consumption per capita in Poland is close to that in developed countries, however, the Gross Domestic Product and personal income of the population are much lower. In general, the presented data indicate that in the recent years the energy consumption is permanently decreasing, to large extent due to changes of the economy structure and also improved efficiency of the energy use. It is a positive tendency, and it should be strengthened in the future.

Apart from magnitude of the energy consumption, the structure of the use of the energy carriers (fuels) (Table 9.7.1) is very important from the point of view of the CO_2 emission. As it can be easily noticed, the most important in the energy balance of Poland are solid fuels - hard coal and brown coal. Their share in the primary energy consumption decreased slightly in the recent years, however, it still exceeds 75% of the total consumption. The shares of the other energy carriers changed also very slightly; the share of crude oil increased by 1.2% and natural gas by 0.6%. The changes in the structure of the final energy consumption, as shown in Table 9.7.2, were much more substantial. Hard coal and heat produced in heating plants and supplied through the heating network are dominant. In 1990, appreciable changes in the structure of the energy consumption could be seen - the share of coal decreased by about 8% as compared with the year 1989 and reached the value of 33% of the final energy, while the share of heat increased by about 5% and reached the value of 25% of the final energy. In the subsequent years these changes were reversed to some extent, however, the present share of coal is still about 5% lower than in 1989. Slight, but permanent increase of the share in the final energy consumption can be seen for liquid fuels and electricity.

Table 9.7.1. The structure of primary energy consumption in Poland in 1989-93 (%) [GUS, Gosp.Paliw-Energ]

	1989	1990	1991	1992	1993
Coal	78.2	77.1	78.6	77.2	76.6
Crude oil	12.3	12.6	11.9	13.1	13.5
Natural gas	7.8	8.8	8.1	8.0	8.4
Nuclear energy	-	-	-	-	-
Hydro energy	0.3	0.3	0.1	0.1	0.1
Other fuels	1.3	1.2	1.3	1.5	1.4

Table 9.7.2. The structure of final energy consumption in Poland in 1989-93 (%)

	1989	1990	1991	1992	1993
Solid fuels	41.5	33.0	34.8	35.9	36.2
Liquid fuels	17.0	17.3	17.4	18.5	18.1
Natural gas	10.4	11.9	10.6	10.5	10.8
Electricity	10.1	12.4	11.9	11.3	11.3
Heat	21.0	25.4	25.3	23.7	23.7

Fossil fuels supply structure

The structure of the primary and final energy consumption in Poland depends on the structure of energy production. Coal plays a dominant role in the energy production of the country. In 1993, about 130 million tonnes (3150.3 PJ) of hard coal and 68 million tonnes (583.3 PJ) of brown coal were produced. Export of hard coal in 1993 amounted to about 23 million tonnes, which was about 20% of the whole production.

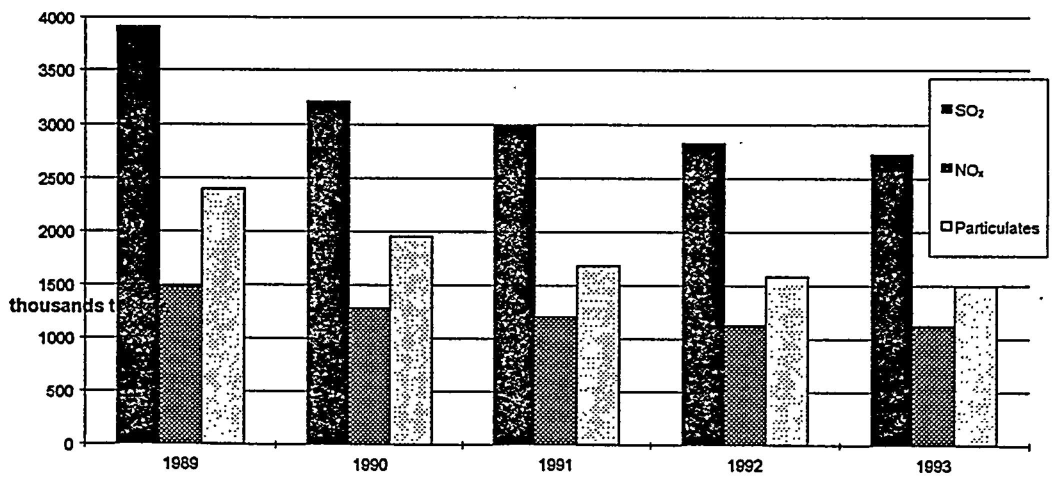
Total production of natural gas in Poland in 1993 equalled about 5 billion cubic meters, which consisted of about 2.1 billion m^3 (70 PJ) of methane and 2.8 billion m^3 (68.3 PJ) of medium BTU gas. Import of natural gas in 1993 equalled 5.5 billion m^3 (198 PJ), which was about 60% of the demand for gas for the whole country.

Crude oil in Poland is produced in negligible amounts. In 1993 it amounted to 235 thousand tonnes (9.8 PJ), while import equalled 13.7 million tonnes (570.4 PJ), which was more than 98% of the demand of the country. Apart from crude oil, appreciable amounts of liquid fuels are imported to Poland. Total import of gasoline, diesel fuel and heavy oil in 1993 equalled about 118 PJ, while export (mainly heavy oil) equalled 43.7PJ.

Emissions of pollutants to the atmosphere

High energy intensity of Polish industry and strong dependence on coal are the main reasons of serious environmental problems. In 1993 the emission of SO_2 equalled about 2.7 million tonnes and emission of particulates about 1.5 million tonnes. As it can be seen in Fig. 9.7.4, emission of particulates and SO_2 has shown tendency to decrease. From 1989 to 1993 the emission of particulates decreased by about 38% and emission of SO_2 by about 30%. Decrease of emission of SO_2 is larger than the corresponding decrease of the primary energy consumption (about 22%), so the decrease of emission is partly caused by technological improvements in production and consumption of energy. In the same period, the emission of NO_x decreased by about 24% and in 1992-93 stayed at the level of about 1.1 million tonnes. However, emissions of all these pollutants are still much higher than the levels approved for the long and medium range goals of the Polish environmental policy, as well as in the international agreements.

Fig 9.7.4 Emissions of particulates, SO_2, NO_x in Polad by [7]



The energy related processes in Poland are responsible for over 97% of emission of carbon dioxide. Depending on the source of information, there are appreciable differences in estimation of the CO_2 emission. According to the yearly GUS [GUS, Ochrona Środowiska] the emission of CO_2 in 1992 equalled 393 million tonnes, while, according to [FEWE, 1995] it equalled 359 million tonnes. Table 9.7.3 shows emission according to GUS.

Table 9.7.3. Emission of CO_2 and primary energy consumption in Poland in 1989-92 according to GUS

	Measure	1989	1990	1991	1992	1993
Emission of CO_2	Million tonnes	488	407	397	393	397
Primary energy consumption	Mtoe	122	101	99	97	95

Emission of CO_2 decreased in the years 1989-93 by about 19%, while the primary energy consumption decreased by about 22%. Emission per capita of the population in Poland is a little smaller than that in Germany and nearly the same as in Great Britain. Emission per unit area in Poland is nearly twice smaller than in Germany, or Great Britain, however, it is larger than in France. Emission of CO_2 per unit of primary energy in Poland is much higher than in the highly developed countries, since coal plays a dominant role in the energy balance of the country.

Energy security of Poland

Energy security of the country depends on providing uninterrupted energy supply in all possible situations. One of the ways of ensuring the energetic security is based on having many independent sources of energy. Poland imports nearly all crude oil and about 60% of the natural gas. Crude oil is imported from different countries - through the pipeline from Russia, by sea from Great Britain, Iran, Norway and others, natural gas, however, comes from only one country - Russia. The latest estimations of the International Energy Agency (IEA) [OECD/IEA, 1995] indicate that the present structure of the sources of the natural gas does not ensure the energy security of Poland, according to the IEA standards. According to opinion of this Agency, without additional sources from other directions, it will be difficult for Poland to increase appreciably the share of gas in the energy balance. This, in turn, may make it difficult to reduce the emission of CO_2 in the future.

Prices and costs of energy

Under the centrally-managed economy in Poland before 1989, the prices of energy were artificially kept at unreasonably low level. The present energy policy aims at reducing the costs of energy for the country on the one side and, on the other side, making the prices of energy real, which could make the mines, power plants etc. economically independent. According to the opinion of the Ministry of Industry and Trade (MPiH) [Duda, 1995], the prices of many energy carriers in Poland are still below the economic level. This applies, in particular, to the prices of natural gas and electricity, which are below the economic level by about 18% and 40% respectively. According to MPiH, further rises of these prices are necessary. On the other hand, however, the share of the energy costs in the household budgets are already very high, which can be seen from Table 9.7.4.

Table 9.7.4. The share of energy costs in total family expenses in Poland and some European countries in 1993 (%) [Duda, 1995]

Belgium	France	Netherlands	Germany	Denmark	Great Britain	Poland
4,4	3,7	4	3,9	3,2	3,5	8,8

Social acceptance

Social acceptance is one of the conditions of a successful energy policy. This acceptance, or lack of it, may concern specific investments, like building a nuclear or hydro power station, but also, higher energy prices, when trying to include in them all the costs of energy production and supply to the users. Even the present energy prices are not accepted by great number of users who are often unable to pay for the used energy. Stealing electricity occurs more often; it is presently estimated to amount to more than 2 TWh per annum. It seems possible, that at so high costs of energy for the final users and planned further rises of the energy prices, it will be very difficult to get the social acceptance for the possible additional costs connected with reduction of emission of the greenhouse gases.

9.7.3. Methodology of the study

Methodology of investigation, applied in the study under question to prepare the strategy of reduction of emission of CO_2 from the sources connected with energy production, is based on scenario approach and a set of mathematical models to investigate the technological, economical and environmental aspects of the development of the energy system, in connection with development of the whole economy. The work was concentrated around the anthropogenic sources of the CO_2 emission from the processes of energy production, transformation and use. The amount of emission in this area depends on the energy demand from the final users and also the fuel and technological structure of the system meeting this demand.

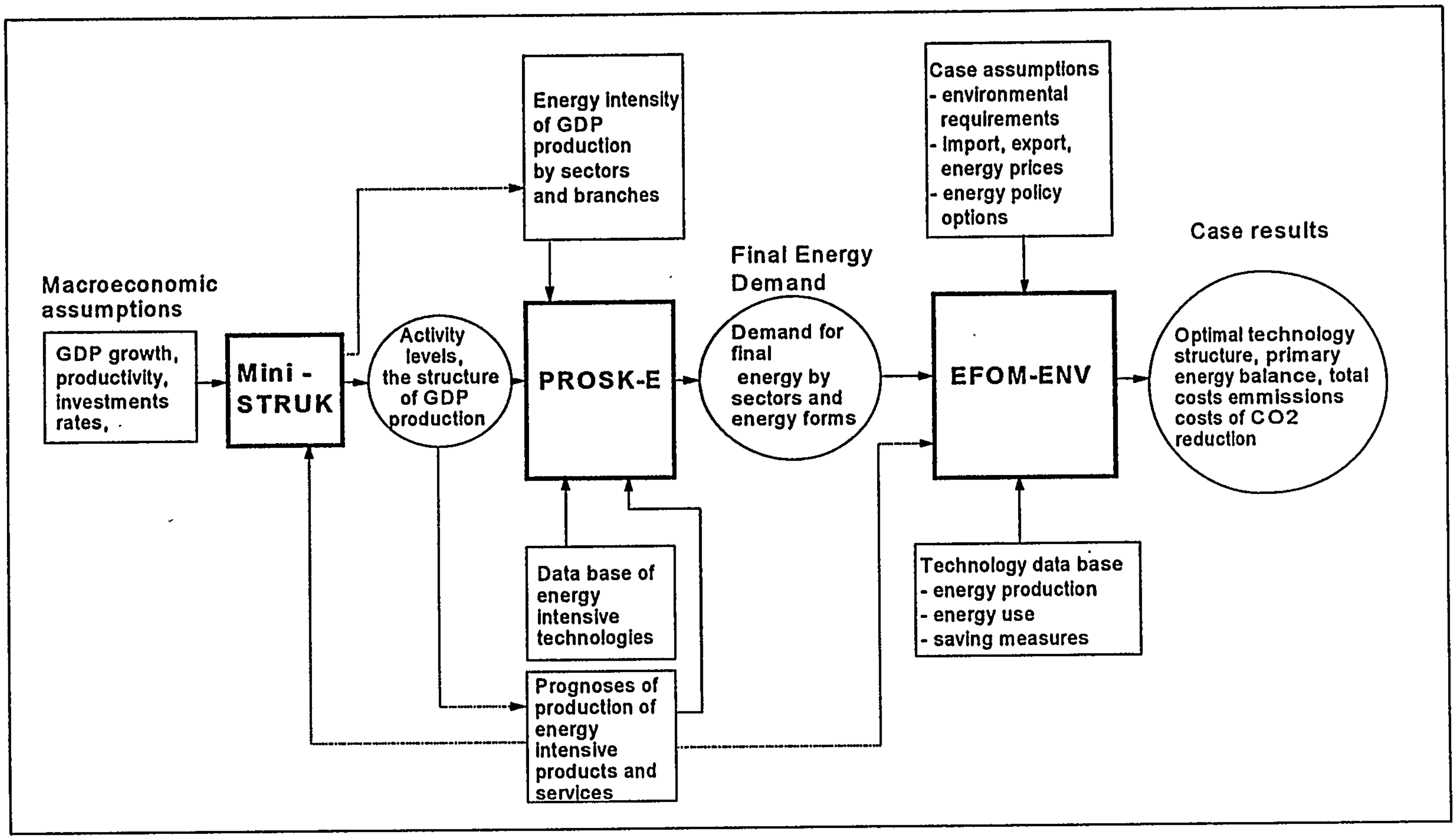


Fig. 9.7.5 Simplified scheme of model configuration used in the present work

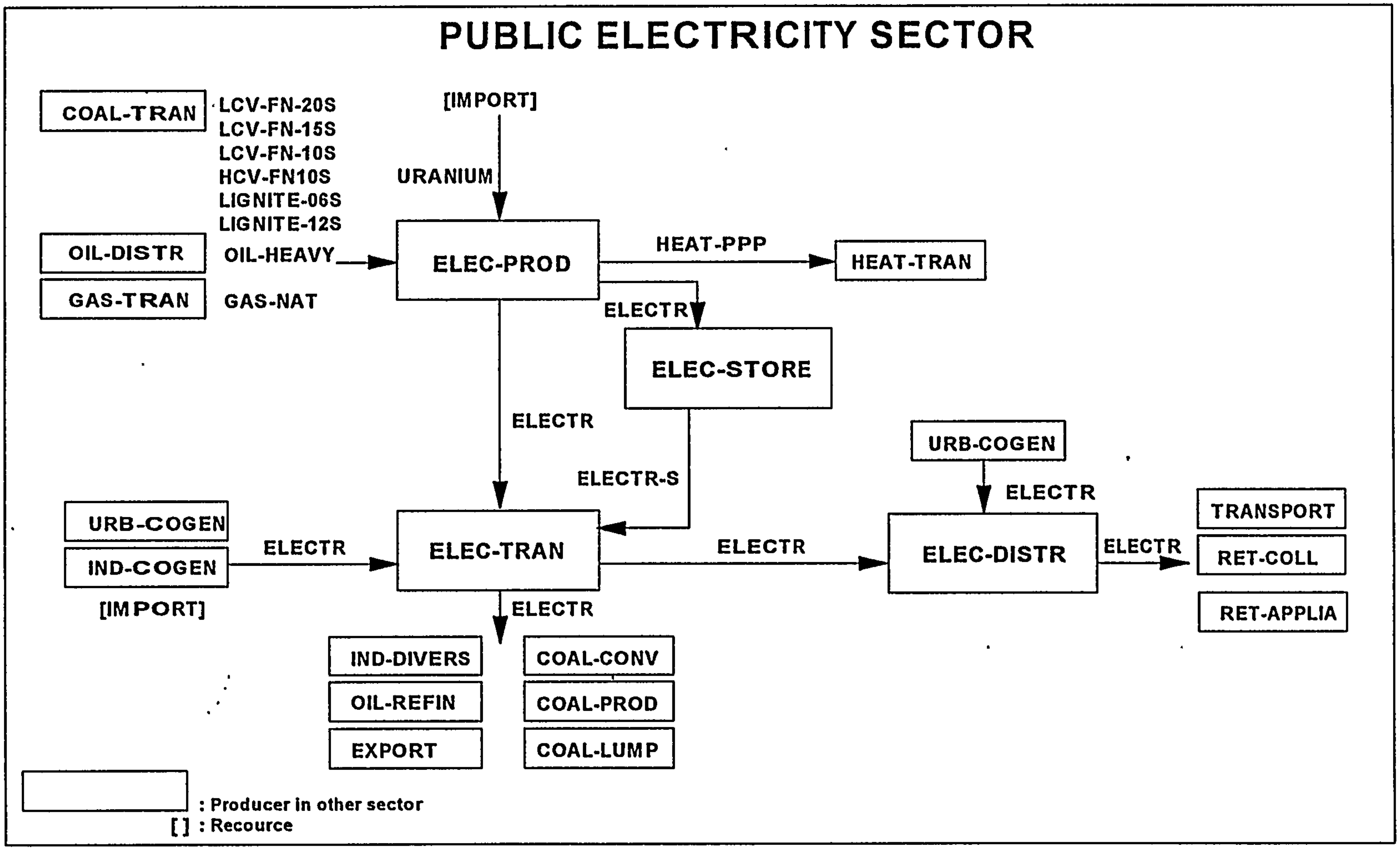


Fig. 9.7.6 An examplary representation of energy flows in electricity subsystem in model EFOM-ENV

The applied set of models consists of three mathematical models composed in such a way, that the output from one of them can be used as input to another. The simplified scheme of calculations, performed with this set, is shown in Fig. 9.7.5.

To define the tasks for the energy system of the country in the future, the scenario method was applied. Scenario is a self-consistent and complete set of forecasts, concerning the energy needs of the country. Mainly extensive quantities, influencing magnitude of the energy demand by the users, are forecast. Scenario combines forecasts on specific, energy-consuming products and services (e.g. production of copper in thousand tonnes, millions of cubic meters of heated cubature) with analyses of macroeconomic and demographic categories (e.g. added value of the electrical industry in billions zlotys, number of people living in rural areas in millions). When preparing the scenario, the models mini-STRUK and PROSK-E are used (compare Fig. 9.7.5). The detailed description of these models can be found in the publications of the ZPE IPPT PAN (e.g. [Cofala et al, 1990]).

The model mini-STRUK takes care of consistency of the macroeconomic and demographic assumption of the scenario. The result of simulation of Gross Domestic Product (GDP) generation and share, performed with this model, creates a framework for other forecasts, more technologically-oriented. Components of the macroeconomic scenario, together with energy intensity coefficients, are used by the model PROSK-E to calculate the final energy demand, or in the model EFOM-ENV they constitute a part of the demand bounds. Demand levels, calculated with the model PROSK-E, are introduced into the optimizing model, which, in turn, finds the solution meeting this demand at minimum costs and given limitations, e.g. defined maximal emission of pollutants.

For the analysis of efficiency of various technological options of the CO_2 reduction, a model of the Polish energy system, prepared with the use of the European package EFOM-ENV, version GAMS [Kruijk, 1994; Roos, 1992] was applied. It is a linear, dynamic optimization model, suitable for investigating the development of energy system of the country in 20-25-year time horizon. The optimization criterion is minimum of the total, discounted costs of meeting the energy demand, with certain conditions assumed, e.g. the admissible level of emission of the pollutants. This model takes into account the processes of production and transformation of energy (at the supply side of the energy system) and also the processes of energy consumption, e.g. production of steel, cement, non-centralized production of heat. The Polish model EFOM-ENV, adjusted to investigation of the CO_2 problem, takes into account about 250 technologies grouped into 7 supply sectors and 5 sectors of energy use. Structure of the energy system is shown in the form of a graph, illustrating energy flows between the producers. Each producer contains at least one technology and represents specific type of energy transformation. Fig. 9.7.6 shows an example of the part of the structure of the energy system for electricity sector.

Description of the system structure is the most important part of the model. The main groups of the input data are: characteristics of the model technologies, useful, or final energy demand, prices of the energy carriers in import and export, discount rate. Another group of the input data consists of quantities representing limitations for development of the energy sector, like political decisions (e.g. concerning the development of the nuclear power plants), admissible values of emission of pollutants, import limitations etc. The results of calculations consist of: the optimized structure of technologies, balances of the primary and final energies, magnitudes of import and export of the energy carriers, magnitudes of emission of particulates, SO_2, NO_X, CO_2, and finally the economical quantities, like capital expenditure, annual costs in all sectors, total discounted costs of meeting the energy demand and marginal costs of reduction of emission of atmospheric pollutants, including CO_2.

9.7.4. Scenario assumptions

Investigation of the energy system in the study under question was based on the assumptions of one scenario of the macroeconomic development of the country and the forecast of the energy needs resulting from it. In all calculations performed, one version forecast of the energy and fuel prices in Polish foreign trade was assumed and the same set of technological options at the supply and demand side of the system was used. In the this Chapter the most important assumptions from the above-mentioned issues are presented.

General assumptions

All the optimization calculations were performed in Polish zloty - of constant purchase power from 1993. To convert to the US dollars the rate of 18145 zloty per dollar was used. The assumed discount rate equalled 12%.

Macroeconomic assumptions

Tables 9.7.5 and 9.7.6 contain the most important macroeconomic assumptions. introduced in the reference scenario.

Table 9.7.5. Assumptions for GDP development [billion zł (93)]

	Measure	1990	1993	2000	2005	2010
Total GDP	1012 zl	1070	1060	1465	1815	2240
Contribution in total GDP						
Industry	%	44.7	37.8	37.6	36.0	34.1
Construction	%	9.7	9.8	6.9	6.7	6.6
Agriculture	%	8.7	7.9	5.5	5.0	4.7
Other sectors	%	36.9	44.5	50.0	52.3	54.6

The values shown in these tables have been aggregated - they follow from more detailed assumptions, or form a basis for their generation. For instance, the added value obtained by the industry consists of the assumptions for its 12 branches, and the assumptions on the annual increase of new flats number in the country constitute the basis for forecasting the heated cubature in six types of building.

Table 9.7.6. Main assumption for evolution of energy intensive categories

	Measure	1995	2000	2005	2010
Population of the country	106	38.7	39.4	39.8	40.0
Rural population	106	14.6	14.5	14.4	14.1
Hot rolled products	Mt	8.8	9.6	9.7	9.8
Production of copper	Kt	410	410	410	420
Production of cement	Mt	13.0	15.5	15.5	16.0
Cultivation area	103 km^2	18.7	18.7	18.6	18.5
Passenger transportation	109 pkm	67.1	69.4	77.2	86.5
Cargo transport (without sea transport)	109 tkm	109.7	114.0	116.7	121.2
City transport	109 vkm	950	1010	1040	1075
Number of private cars	106	7.3	8.7	10.1	11.4
		1991-95	1996-00	2001-05	2006-10
New flats (yearly growth)	103	92.8	140	172	200

The reference scenario is characterized by high dynamics of the economic growth, (average annual GDP growth by about 3.8% over 25 years) and radical change of the economical structure in favour of services. The structure of industry, not shown here, changes in favour of less energy-consuming branches. Increase in production of energy-consuming goods is small (compare Table 9.7.6 - steel and cement). Appreciable increase of efficiency of the energy use follows as a result of general economical processes. At the same time, an appreciable increase of the average standard of living was assumed (compare Table 9.7.6 - passenger transportation, private cars and increase of the number of flats).

Energy demand forecast

In the following table the forecast of the final energy demand for the non-energy sectors is presented for the above-specified macroeconomic assumptions. The values from this table differ in that they are diminished from the total final consumption published by the majority of sources, by the final consumption in the fuel and energy sector (e.g. electricity used in coal mines), and by the direct consumption resulting from the changes in industrial and municipal power plants. These subtracted values constitute part of the energy consumption by the whole energy sector and they are forecast in the optimization model EFOM-ENV together with remaining parts of the energy balance.

Table 9.7.7. Final energy demand in non-energy sectors calculated for the presented macroeconomic assumptions [PJ]

Energy carrier	1993	1995	2000	2005	2010
Steam coal	625	633	617	595	533
Lignite	3	3	0	0	0
Coke	186	189	180	169	155
Medium BTU gas	51	51	42	42	39
Natural gas	290	317	358	388	432
Gasoline	185	238	276	330	366
LPG	7	7	7	7	7
Gasoil	209	235	243	242	245
Oil heavy - low sulphur	0	0	4	16	42
Oil heavy - high sulphur	44	46	50	66	79
Other secondary fuels	41	36	39	44	47
Electricity	310	329	373	429	489
Heat	329	333	348	369	404
Steam	357	379	406	425	433
Other primary fuels	35	40	51	64	76
Total	2671	2836	2992	3186	3349

Energy import and export prices

The energy prices in Polish export and import were assumed according to the price forecast [Chojna, 1993], used earlier when preparing the assumptions for the energy policy of the country [MPiH, 1995]. The anticipated prices of the most important energy carriers are shown in Table 9.7.8. The export prices were defined on the basis of the *fob* prices (price of goods supplied and loaded on the ship), and the import prices, on the basis of the *cif* prices (containing the costs of shipment and insurance) or *franco* border.

Table 9.7.8. Forecast of energy prices in Polish export and import [USD/GJ]

	1991	1995	2000	2005	2010
IMPORT					
Crude oil	3.5	3.1	3.7	4.2	4.7
Natural gas - current contracts	2.9	3.0	3.5	3.8	4.1
Natural gas - new contracts	-	3.6	3.8	4.2	4.5
Natural gas - new contracts (expensive)	-	-	4.5	4.9	5.3
Steam coal	1.65	1.4	1.5	1.6	1.7
Uranium	0.61	0.52	0.55	0.59	0.62
EXPORT					
Steam coal 1%S	1.64	1.44	1.52	1.59	1.68
Steam coal 0.7%S	1.68	1.55	1.63	1.70	1.80
Coke coal	1.79	1.62	1.66	1.70	1.74
Coke	3.15	2.90	3.0	3.05	3.13

In this forecast the mean rate of the price increase in the years 1995 - 2015 equals about 2.5% per annum for crude oil, about 2% for natural gas and about 1.2% for hard coal.

Technological options - supply side

In the model EFOM-ENV, at the supply side, the existing and prospective technologies of production and transformation of the fuels were taken into account. The most important among the considered technological options, leading to decrease the CO_2 emission, are as follows:

- increase of supply of the natural gas for the domestic market,
- modernizing and improving the existing energy transformation technologies,
- using new technologies of production of electricity and heat,
- increased use of renewable energy sources.

Increased supply of the natural gas

More than half (about 59%) of the natural gas used in Poland in 1993 was imported. The maximal production of the natural gas by Polish mines is limited; it can reach about 5 billion cubic meters per annum until 2010 (expressed in methane) [Tokarzewski et al., 1994]. Therefore the natural gas consumption in Poland can be increased only if import can be increased. The whole current import of the natural gas comes from Russia. The existing pipelines allow for supply up to 8 billion cubic meters per annum, which is insufficient to meet the expected increase of the demand in the on-coming years. It is possible, of course, to build new pipelines, it is connected, however, with negotiating new contracts and engaging considerable funds. The most advanced project of this kind, which seems to be closest to realisation, is the transit pipeline which is supposed to supply Western Europe with gas from Northern Siberia. According to the information from PGNiG, from this pipeline Poland may get up to 14 billion cu. meters of gas in 2010. Other sources of gas are also considered. The most promising seem to be supplies from the North Sea (British shelf) and from Norway. In Table 9.7.9 one can find the potential sources of the natural gas for Poland and the maximal possible values of the supply. The values were estimated on the basis of the materials [Tokarzewski et al., 1994; PSE, 1994] and information from PGNiG.

Table 9.7.9. Maximal possible deliveries of natural gas from domestic production and import [109 m^3 /annum]

	2000	2005	2010
Domestic production	5.5	5.3	5.1
Import - existing pipelines, including:	7.5	7.5	7.5
- current contracts	4.7	4.3	1.9
- new contracts	2.8	3.2	5.6
Import - new pipeline from Russia (JAMAL)	5	10	14
Import - new pipeline from North Sea shelf (POLPIPE)	-	3	5
Import from Norway, transit via Germany	1	1.5	2.5
LNG	-	2	3

The model calculations took into account the possibility of importing liquefied natural gas (LNG) e.g. from Algeria, about 2-3 billion cubic meters per annum, beginning in 2005. This would require, however, building a suitable infrastructure of ports and, probably, buying special vessels for shipping this gas. The prices of the imported gas were assumed at different levels, depending on the source of import. It was assumed, that the prices of gas from the present suppliers will be close to the average European prices, new supplies from Russia will be 10% more expensive, and gas from Great Britain, Norway and liquefied natural gas will be 30% more expensive (compare Table 9.7.8).

Table 9.7.9 presents the values of maximal possible import of gas in different price categories. The values in the Table are relatively large, however, it is still not certain whether these supplies can be realized. Since availability of natural gas has a fundamental influence upon the strategies of the CO_2 reduction, two sets of assumptions, corresponding to free and limited accesses to the imported gas were taken for the model calculations. These assumptions will be described in detail at the end of this chapter. The calculations take also into account the cost of transmitting the natural gas, which equals 30USD per thousand cubic meters for the power plants, 50USD per thousand cubic meters for all other big industrial users, including industrial and municipal heating plants. Small users must pay in addition 60USD per thousand cubic meters for distribution of gas (total cost of transmission and distribution to small users then equals 110USD per thousand cubic meters). These costs were kept at constant level during the whole considered period.

Table 9.7.10. Maximal possible deliveries of natural gas by price categories [109 m^3 /a]

	2000	2005	2010
Natural gas - average European prices (current contracts),	4.7	4.3	1.9
Natural gas - higher prices (new contracts from Russia),	7.8	13.2	19.6
Natural gas - expensive (new contracts from North Sea or Algeria)	1	6.5	10.5
Total	13.5	22	32

Modernizing and improving efficiency of existing technologies

Considerable amounts of energy are wasted irreversibly during the transformations of energy, first of all in the process of production of electricity and heat. The majority of presently used equipment in power and heat industry is old. Efficiency of old capital stock is usually considerably lower than that of new one. In many cases modernization of the basic equipment makes it possible to use it longer and to improve the technological parameters of the whole plant. As a rule, the modernization costs are much lower than the costs of building a new plant. In the model calculations the following modernization technologies were taken into account:

- modernization of the system power plants,
- adaptation of the uncompleted combined power and heating plants and public heating plants to combined production of electricity and heat,
- modernization and development of the electricity transmission grid,
- modernization of the municipal heating plants,
- modernization of the heat distribution networks.

Modernization of the system power plants

The range of modernization and the expected improvement of the parameters of the existing system power plants were assumed according to the data, preparation of which was commissioned by the Polish Electricity Network (Polskie Sieci Elektroenergetyczne S.A.) [PSE, 1994] and used in the planning studies in 1994. During calculations with the model EFOM-ENV, the characteristics of the modernization options, considered to be the most favourable for a given group of objects were assumed. As the result of modernization, the efficiency of the power plants increases by 0.1 to 2.9%, depending on the object, and the installed capacity increases too. Table 9.7.11 shows the values, illustrating the described changes in the selected groups of objects.

Table 9.7.11 Expected efficiency and capacity increase in existing power plant as result of their modernization [PSE, 1994]

Power plant (power units)	Gross efficiency [%]			Increase of capacity [MW]
	Before modernization	After modernization	Increase of efficiency	
Połaniec (1-8)	36.9	38.8	1.9	240
Dolna Odra (1-8), Rybnik (1-4)	36.1	38.1	2.0	360
Rybnik (5-9), Łaziska (9-12), Jaworzno III (1-6)	34.8	36.7	1.9	420
Bełchatów (1-12)	36.1	37.8	1.7	240
Pątnów (1-6), Turów (8-10)	35.0	37.9	2.9	300

The capital costs attached to modernization were assumed in accordance with the estimations of the elaboration [PSE, 1994] at 50 - 300 USD/kW, depending on the range of modernization, while the capital expenditure for new power plants estimated to 1000 - 1300 USD/kW.

Development of the existing heating plants and combined power and heating plants.

Possibilities of increasing combined production of electricity and heat in existing public heating and cogeneration plants, were estimated according to the study [Czarkowski et al., 1994], prepared for the PSE S.A. Table 9.7.12 illustrates possibilities of increasing installed capacity in combined systems.

Table 9.7.12. Maximal possible increase of electrical capacity in cogeneration production as a result of expansion of existing heating and cogeneration plants [MW]

Type of enterprise	1995	2000	2005	2010
Installation of new cogeneration BCK unit in existing cogeneration plants	135	395	670	860
Installation of new UCK heating turbine in existing cogeneration plants	135	400	700	860
Installation of new combine cycle gas unit in existing cogeneration plant	-	50	200	200
Installation of new cogeneration unit in existing public heating plants	50	700	1115	1960
Installation of new, small cogeneration unit in existing municipal heating plants	-	-	70	230
Total	320	1545	2755	4110

The capital expenditure connected with the above investments ranges from about 320 USD/kW when replacing the turbine, to 1200 - 1300 USD/kW when building the whole new block in the existing plant (for the sake of comparison - building a new power and heating plant requires about 2000 USD/kW). Described in table 9.7.12 measures aimed at increasing cogeneration production in existing plants were included in the model, where they compete with existing power plants and new cogeneration plants.

Decrease of the losses during transmission of electricity

In 1993 the transmission losses amounted to about 14% of energy introduced to the public power transmission grid. The expected values of losses and costs of transmission for future periods were assumed on the basis of statistics [CIE, 1994] and studies prepared for the Polish Electricity Network (PSE S.A.) [Soliński et al., 1994; Chyrczakowski et al., 1995]. They are shown in Table 9.7.13 for transmission at high, medium and low voltage lines.

Table 9.7.13. Assumed evolution of electricity losses coeficients and costs of electricity during transmission and distribution

	Measure	1993	1995	2000	2005	2010
Transmission losses - high voltage lines	%	4.6	5	4.2	4	4
Transmission losses - medium voltage lines	%	8	8	6.5	5	5
Distribution losses - low voltage lines	%	12.4	9	7.5	6.5	7
Transmission costs - high voltage lines	Zl(93)/kWh	27.1	34	63.8	57.1	52
Transmission costs - medium voltage lines	Zl(93)/kWh	44.9	44	68.3	67.2	65
Distribution costs - low voltage lines	Zl(93)/kWh	200.3	197	307.7	302.6	293

Modernization of heating plants and heat distribution networks

To check the possibilities of improving the work of the existing municipal heating plants and heat distribution networks, an expert opinion was prepared [Mańkowski et al., 1995], which specifies the technological, economical and environmental parameters of the following technologies:

- existing municipal heating plants, fine coal fired, of "large" capacity,
- existing municipal heating plants, fine coal fired, of "small" capacity,
- municipal heating plants, coal fired, modernized including installation of control automatics,
- gas - fired boilers, built in existing heating plants,
- oil - fired boilers, to be used under maximum power requirements, built in existing heating plants,
- systems of combined production of electricity and heat, built in existing, municipal heating plants,
- large municipal heat distribution networks,
- medium and small transmission networks.

The above technologies, after being verified and made consistent, have been included in the model EFOM-ENV. According to the authors of the expert opinion, modernization of the municipal heating plants, including installation of automatics, makes it possible to improve the efficiency by more than 8% (from 66.5% to about 75% for bigger heating plants). It is also possible to decrease the losses of heat from about 10% to about 8% in large heat distribution networks and from 7.5% to about 6.7% in smaller networks.

New energy fossil fuels technologies

Increasing efficiency of technologies, utilizing fossil fuels to produce electricity and heat, is one of the important ways of decreasing emission of CO_2. Apart from modernization of the existing objects, the model calculations took into account new energy technologies with high efficiency of energy transformation, which may be used when more power is needed in the energy system. To prepare the model characteristics of such technologies various sources were used: the publications [PSE, 1994; DOE, 1993; Van Arkel et al., 1993; Hille, 1995], Polish and foreign databases [Bibrowski et al., 1993; Messner et al., 1991] and the expert opinion prepared for ZPE IPPT PAN [Kulicki, 1994]. Table 9.7.14 shows the technologies of production of electricity, accounted for in the calculations with the model EFOM-ENV.

Table 9.7.14. Main parameters of candidate technologies for new public power plants

Technology	Fuel type	Gross Efficiency	Investments	Fixed costs	Variable costs
		%	USD/kW	USD/kW.year	USD/MWh
Conventional power plant with installation of wet desulphurisation	hard coal	39.1	1415	8.0	0.8
	lignite	37.8	1680	9.4	1.4
Peak units	natural gas	30.0	400	4.1	1.0
Combine cycle power plants	natural gas	47.3	650	9.0	1.5
Power plants with fluidized bed combustion	hard coal	38.0	1400	30	1.5
Combine cycle power plants with coal gasification	hard coal	47.0	1590	52	1.9
	lignite	44.0	1780	60	1.9
Nuclear power plants	uranium	33.0	1800	36	2.0

The optimization calculations took also into account technologies corresponding to the new municipal and industrial, combined power and heating plants as well as heating plants. The model embraced technologies, utilizing various fuels: hard coal, natural gas, heavy oil as well as solid and gaseous waste fuels in industrial power plants.

Technologies utilizing renewable energy

Poland has no particularly good conditions to utilize renewable energy. Generally, the high intensity of solar, wind, water or geothermal energy sources occurrence is not a common place. This results in relatively high costs of these kinds of energy. Technological - economical characteristics of the typical technologies utilizing renewable energy were prepared, with the aid of a number of foreign and Polish sources, for optimization purposes. Table 9.7.15 shows the assumed available amounts of energy which can be obtained from the most promising technologies utilizing renewable energy in Poland during the next 20 years. The costs of energy production with technologies utilizing renewable kinds of energy are generally higher than costs of energy produced conventionally (except for air solar collectors and some technologies utilizing biomass).

Table 9.7.15. Assumed limits of energy production from renewable energy sources in Poland

	Energy produced	Unit	2000	2005	2010
Large hydro power plants	electricity	GWh	4400	7100	7100
Small hydro power plants	electricity	GWh	100	250	750
Wind power plants	electricity	GWh	18	70	175
Heating plants - wooden residuals	heat	PJ	2	4	8
Heating plants - straw	heat	PJ	1	3	10
Direct combustion of biomass in rural areas	heat	PJ	46	58	69
Solar water collectors	heat	PJ	0.1	0.3	0.7
Solar air collectors	heat	PJ	1.2	1.7	2.2
Waste incineration	heat	PJ	1	2	5

The data shown here neither present all possibilities of the use of renewable energies, nor give the picture of full technical potential of the mentioned technologies. Still, the assumed values seem rather optimistic and reaching specified limits of renewable energy use should be considered a great success. Some additional explanations and data given below could better illustrate the above-mentioned values.

Large hydro power plants

Maximum use of the existing plants was assumed and, and what is more, the possibility of building 7 hydro power plants at the steps of the so-called Lower Vistula Cascade, with total installed capacity of 1178 MW was allowed (this possibility is equally doubtful as the program for nuclear power industry). Very optimistic value of the coefficient of utilization of the maximum power - equalling 0.5 - was assumed too. This means more than 4000 hours of work with maximum power per annum. According to the available data, in 1993 (extraordinarily "dry" year) the public hydro power plants had total installed capacity of about 700 MW and produced 1446 GWh of electricity in that year.

Small hydro power plants

Following the source [Krzyżanowski, 1991], 200 MW of the maximum possible value of the total installed capacity and 750 GWh of the annual production of electricity was assumed. This corresponds to utilization of all registered water sources. For the sake of comparison it is worth mentioning that the total amount of electricity, sold in 1993 by small, private hydro power stations equalled about 40 GWh.

Wind power plants

It was assumed, optimistically, that until 2015 it will be possible to build wind power plants of total capacity of 200 MW and production of 350 GWh per annum. For comparison - in the most advanced countries from the point of view of wind energy utilization, the production of electricity equalled: about 2500 GWh in California, about 500 GWh in Denmark, 50 GWh in Holland, 35 GWh in Hawaii and 120 GWh in all the remaining countries together. In Poland there are two modern wind power plants with total capacity of about 200 kW and production of 0.4 GWh in 1992. To reach the assumed production of electricity it would be necessary to build about one thousand of such plants.

Utilizing biomass for energy production

The estimations made by different authors. [Tymiński et al., 1994; Kowalik, 1994] show, that the possible use of biomass for energy production in Poland amounts to 110 - 120 PJ per annum, assuming utilization of the waste wood. For the model calculations it was assumed, that the majority of the available biomass (wood, peat, small quantities of straw) will be utilized by the household to heat rooms and prepare food, and the rest will be burnt in the local heating plants. Utilizing biomass is actually the most important way of utilizing the renewable energy in Poland.

Solar energy

When estimating the possibility of developing the water solar collectors it was assumed, that the rate of installing new collectors will be close to that in Germany in the years 1975-1990, i.e. 15-40 thousand square metres per annum [Kalstchmitt et al., 1993]. Until 2015 it would be necessary to install about 770 thousand square metres to obtain the assumed level of production. Acquisition of energy in air collectors was assumed to equal 10% of the total potential, as estimated in the expert opinion [Kowalik et al., 1991].

Waste incineration

According to the elaboration [Kowalik, 1994], the maximal potential of utilization of waste for energy production equals 120 PJ. In the reference scenario it was assumed that up to 10% of this potential would eventually be utilized, which corresponds to the present level of waste utilization in Denmark.

Technological options at the demand side

The following technological options at the demand side were taken into account in the model calculations:

- electricity saving measures,
- thermal insulation of single family buildings,
- technologies of steel production,
- space heating installations in single family houses.

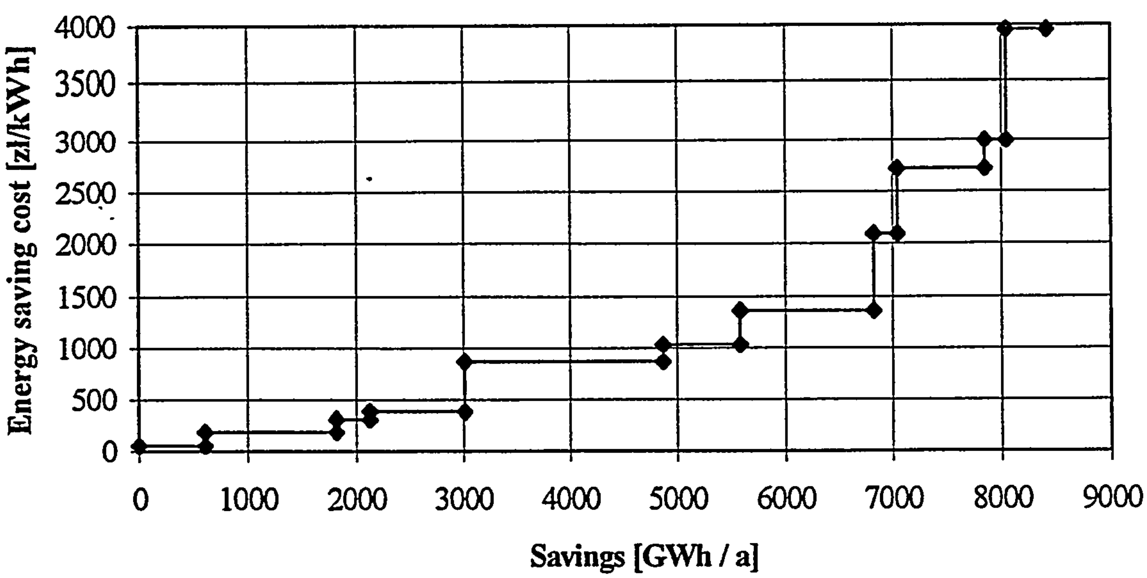
Electricity saving measures

Over 50 technologies of saving electricity were taken into account. Characteristics of these technologies, in particular their costs and potentials, were prepared in the framework of the study made for PSE S.A. [Chyrczakowski et al., 1995]. These technologies, with joint potential about 20 TWh in 2010, represent the most promising actions in the industry, household, trade and services, mining, power industry and transport. Realization of these measures in the range acknowledged by the experts, as independent of any investment encouragement (referred to as minimal), was taken into account in the reference scenario. Taking advantage of further possibilities of saving was made dependent on their profitability with respect to the competing supply options. Table 9.7.16 presents the minimal expected scale (determined) and maximum potential of electricity saving by respective sectors, and Fig.9.7.7 shows the costs and maximal potentials for the saving measures in the industry.

Table 9.7.16. Minimal and maximal electricity savings by sectors [TWh]

Sector	Minimal electricity savings		Maximal electricity savings	
	2000	2010	2000	2010
Electricity industry	0.70	1.58	2.39	3.54
Coal industry	0.41	1.22	1.41	2.27
Non - energy Industry	2.11	4.83	5.31	8.42
Transport	0.02	0.11	0.08	0.31
Household	0.48	0.83	0.78	1.83
Tertiary Sector	0.52	1.27	2.25	4.29
Total	4.24	9.84	12.22	20.66

Fig. 9.7.7 Ordered curve of energy saving costs for industry in 2010



Thermal insulation of the single family buildings

The reference scenario took into account the effects resulting from the assumed range of thermal insulation of the buildings. The values compatible with estimation in the expert opinion [Grochowski, 1994] were into consideration. The estimation assumes thermal insulation of about 90% of the multifamily buildings and about 20% of the single family buildings, mainly in towns. The optimization calculations included options, representing the insulation of additional 30% of individual buildings in towns and 20% in the villages. The technological parameters and costs of these measures were obtained from calculating on the basis of the model of energy system of the building BED-OPT [Chyrczakowski, 1995]. Table 9.7.17 presents costs of energy saving for technologies of thermal insulation taken into account in calculations.

Table 9.7.17 Unit costs and assumed real potential for energy saving due to single family buildings insulation

	Costs of saved heat	Possible savings of heat in 2010
	thousand Zl(93)/GJ	PJ
Insulation of walls, 5cm, plaster	82	11
Insulation of walls, 10cm, plaster	80	13.6
Insulation of roofs, 5cm, plaster	133	1.6
Insulation of roofs, 10cm, plaster	131	2.3
Insulation of cellar ceilings, 5cm, plaster	63	1.9
Insulation of cellar ceilings, 10cm, plaster	77	2.2
Exchange of 2 panel windows by 3 panel windows	648	1.4
Installation of thermostatic valves	133	1.4

Technologies of steel production

To investigate this problem and prepare the model characteristics, two specific studies [Ziębik et al., 1994; Gryza et al., 1995] were commissioned and performed. The authors formulated the model characteristics of seven macro technologies of production of hot-rolled products, representing production lines, which may be used in Polish metallurgy. The differences between them are mainly in the range of modernization of the starting technologies, which are presently used.

Space heating installations in single family houses

The energy demand for heating rooms in individual houses has been recalculated into useful energy. For calculations with the model EFOM-ENV various technologies of heating were introduced, utilizing various energy carriers: coal, coke, natural gas, wood, heating oil, electricity and heat from the municipal networks. In the existing buildings some possibility of substitution of fuels was allowed, first of all, increase of the share of natural gas and decrease of solid fuels, which is possible as a result of intensive gasification, carried out presently (every year about 200 thousand new individual users get access to the gas supplying network). In new buildings the competition of various technologies was allowed, taking into account the limitations related to availability of the network energy carriers.

Optional assumptions for scenario analysed

As it follows from the preliminary analyses, availability of the natural gas and social acceptance (or lack of it) for the development of nuclear power industry influence strongly the possibilities of reducing the CO_2 emission. Since it is still uncertain how much natural gas available from import and what will be the social and political decisions will be concerning building the nuclear power plants, three scenarios were investigated, representing the situations corresponding to different answers to these problems:

Scenario I
- wider access to natural gas
- acceptance for nuclear power development

Scenario II
- wider access to natural gas
- no nuclear power

Scenario III
- limited access to natural gas
- no nuclear power

Scenario I represents the situation when no political or social barriers exist which might limit either buying fuels for the prices of the international market, or development of any technologies of energy transformation. The remaining scenarios assume some influence of social, political or other reasons, making realization of the optimum strategies of developing the energy system more difficult. Scenarios with wider access to natural gas from import assume a possibility of importing gas in quantities specified in Table 9.7.10, and the remaining one assumes that no new pipeline is built and the imported natural gas will be supplied:

- from Russia through the existing pipeline, no more than 7.5 billion cubic meters per annum,
- from Norway through Germany, maximum to 2-3 billion cubic meters per annum,
- from Algeria - liquefied gas, imported by ships, 2-3 billion cubic meters per annum.

The scenario allowing the nuclear power industry assumes the maximal production of electricity from the nuclear power plants to equal 8 TWh in 2010 and 20 TWh in 2015. This is more than 10% of total production of electricity in the last year and it requires the power plants with total capacity of more than 3000 MW.

9.7.5. Optimal CO_2 emission reduction strategies

Definition of analysed scenarios and reduction cases

In the study under question, an optimization analysis of a number of reduction cases, distinguished in the three previously defined scenarios, has been done. For every case solutions have been found, which constitute optimal strategies for technological measures, ensuring satisfaction of energy requirements as well as attainment of assumed CO_2 emission quantity. For all the three scenarios the following cases have been analysed:

- reference case
  the solution for this case includes no CO_2 emission limitations, however, it realizes a range of energy saving, adapted for situation with no encouragement for this kind of measures.

- energy saving case
  like the reference case; it includes all energy saving measures rises being cost-effective from the point of view of the whole energy system.

- 5%, 10% etc. reduction cases
  these are cases with constrained CO_2 emission reduction; solutions obtained for these cases are technologically oriented, optimal reduction strategies for the given reduction level, the choice of technological options ensuring cost minimization.

Definitions of all analysed cases are shown in Tab. 9.7.18. For every scenario maximal possible reduction level is also given. The quantity of reference emission for the year 1988 is 454 million tonnes, according to the study [Cofala et al., 1991], taken into account in the work under question because of similar methods of CO_2 emission computation. The CO_2 reduction cases refer to this value (e.g. 10% reduction case means emission level in the year 2010 of 409 million tonnes). Official sources, e.g. [GUS, Gosp. Paliw-Enegr.], estimate emission quantity in Poland in 1988 at more than 518 million tonnes. In relation to this quantity, the 10% reduction modelling case means 21% CO_2 emission reduction.

Table 9.7.18 Definition of the analysed scenarios and cases

Scenario	Cases without CO_2 emission reduction		Exemplary reduction cases in relation to emissions in the year 1988		
	References	With optimal energy saving	5%	10%	15%
Scenario I	S1 ref	S1 save	S1 05	S1 10	S1 15
Scenario II	S2 ref	S2 save	S2 05	S2 10	S2 15
Scenario III	S3 ref	S2 save	S3 05	S3 10	S3 15

Quantities of CO_2 emissions

CO_2 emissions in different cases of the scenario I are shown in Fig. 9.7.8. The upper line represents emissions in the reference case, while the next line includes optimal range of application of energy saving measures. The second case includes all saving measures which cause decrease in total costs of satisfaction of energy requirements. The difference in CO_2 emissions between these two cases is about 8 million tonnes in the year 2010 and about 12 million tonnes in 2015. In both cases a significant emission increase occurs, but even in the final period it is lower than 1988 emission. Reduction cases assume emission decrease to the assumed level from the year 2000 onward. Quantities of emission for every case and scenario are given in Tab. 9.7.19.

Table 9.7.19 CO_2 emissions in reference and reduction cases in [thousand Gg]

Scenario	Case	1995	2000	2005	2010
Cases without CO_2 emission reduction					
Scenario I,II,III	S1,2 ref	376	397	416	425
	S1,2 save	376	392	409	417
Cases with constrained CO_2 emission reduction					
Scenario I,II,III	5% reduction	376	392	409	417
	10% reduction	376	393	409	409
	15% reduction	376	386	386	386
	20% reduction	376	363	363	363

Results obtained show that in the reference case limited natural gas access causes an increase of total costs and a rise of emissions, but not before the year 2015, which is not presented here. The lack of nuclear power does not cause this effect, which means that in cases without CO_2 emission reduction the nuclear power is not competitive for technologies based on fossil fuel combustion. It has turned out that for programmes of energy system development which don't take into account the greenhouse issue, the limitations introduced in the scenarios II and III become substantial only after the year 2010. The situation is different when CO_2 emission reductions are necessary, which is visible from the results of the reduction cases. In analogical reduction cases of the three analysed scenarios, the decrease of CO_2 emission (thus the absolute quantities of emission) is - as assumed - the same (shown in Tab. 9.7.19). However, due to different assumptions, the scenarios attain the decrease of emissions differently, through application of different technology combinations. Hence different emission reduction costs are the case (they are discussed further in this chapter).

The share of particular sectors in total emission for the reference case of the scenario I is presented in Tab. 9.7.20 and in Fig. 9.7.9. In this case the greatest emission increase takes place in public power plants and CHP plants, but also, in non-energy industry and transport. Emissions in housing sector decrease due to changes in fuel use pattern - rise of natural gas share and heat centralised at the cost of solid fuels.

Table 9.7.20. CO_2 emission in particular sectors in the reference case, Scenario I (S1-ref) [thousand Gg/annum]

Sector	1993	1995	2000	2005	2010
Public power plants	116	115	119	126	127
CHP plants	24	26	29	34	44
Industrial CHP plants	31	32	28	31	30
Fuel Industry	0	0	0	0	0
Other industries	57	58	69	69	71
Transport	18	23	27	32	36
Households	78	76	74	70	63
Tertiary	7	7	6	6	6
Total	369	376	392	409	417

The impact of national emission reduction level on CO_2 emissions from particular sectors in the year 2010 is given in Fig. 9.7.10. In the reduction cases, sector CO_2 emissions generally decrease, but the scale of emission reduction from particular sectors is not regular and reflects the emission reduction costs. Since in optimization computation the greatest emission reduction occurs when the reduction is the cheapest, therefore, on the basis of the described figure it is possible to ascertain that the greatest and relatively the cheapest possibilities for CO_2 emission reduction are in electricity sector, industry and households.

Primary energy use

Generally, reduction of CO_2 emissions leads to substantial changes in primary fuel use pattern, particularly in the case of Poland, where the energy balance is dominated by hard coal and lignite. To illustrate these changes, Fig. 9.7.11 and Tab. 9.7.21 give primary fuel use pattern in the reference case, and Fig. 9.7.12 shows changes of this pattern in the year 2010, due to decrease of admissible CO_2 emissions.

Table 9.7.21. Primary fuel use in the reference case, Scenario I and II [PJ]

Fuel	1995	2000	2005	2010
Solid fuels	3075	3183	3225	3181
Natural gas	378	420	496	645
Liquid fuels	781	832	963	1051
Other fuels	30	23	38	50
Renewable energy	37	47	54	60
Total	4301	4505	4776	4987

In the reference case pattern changes are not considerable. Coal use level is maintained, and it is more or less steady, while natural gas and liquid fuels use rises, which increases their share respectively from 8% to 13%, and from 15% to 21% in 2010. More substantial pattern changes can be observed in Fig. 9.7.12, where visibly more intensive CO_2 emission reductions require considerable decrease of coal share, increase of importance of gas fuels and, if there is a need, of nuclear power, as well as utilisation of renewable energy resources in economically cost efficient range. Liquid fuels use in all cases is relatively steady.

CO_2 emission reduction measures

The most important CO_2 reduction measures, considered in the study, were presented in Chapter 9.7.4. They differ one from another by unit costs of reduction as well as the maximal potential of CO_2 emission reduction, which depends on limited possibilities of development certain technologies in the considered time horizon (see e.g. assumed potentials of renewable energy use and energy savings presented in tables 9.7.15 - 9.7.17). Fig. 9.7.13 shows estimations of contribution of different types of reduction measures in total CO_2 emission reduction in 2010 in different reduction cases of the Scenario I. The presented reduction effects coming from fossil fuels substitution as well as energy efficiency increase refer to relatively broad range of measures aimed at replacing one technology with a more expensive but also more efficient and less polluting technology. One example of such enterprise is replacement of coal power plant with natural gas fired combine cycle power plant that reduces CO_2 emission both by efficiency increase and fuel substitution. Other example are development of cogeneration production (higher efficiency), introducing gas to individual heating systems in single family houses etc.

Presented emission reduction values were calculated by comparison of results from the reduction cases with emission from the reference case (S1_ref). While interpreting these values, one must remember, that reference case also includes a range of reduction options (e.g. a number of saving measures), that were considered as "determined", which means - independent from CO_2 reduction goals. So, presented reduction effects generated by distinguished types of reduction measures represent additional actions taken specially for CO_2 reduction.

The ranking of reduction measures according to the unit CO_2 reduction costs could be concluded from the order in which these measures became cost efficient. It could be noticed, that most of considered saving measures became cost efficient even without CO_2 constraints, consequently, they are cheaper, than adequate supply options. The next most cost efficient reduction measures are nuclear power plants and heat production from renewable energy. The level of 15% reduction of CO_2 emission could be achieved by realisation of large hydro power plants on the Vistula river, further utilization of renewable energy and significant changes in fossil fuels technologies. Further CO_2 emission reduction needs changes in technologies utilizing fossil fuels. High costs of such a type of measures result from the fact, that switching from coal to gas needs building new plant instead of relatively cheap modernization of existing coal plants. As it could be seen from the chart, CO_2 emission reduction potential of saving measures together with possible development of renewable energy use reaches 26 thousand of Gg per annum, while changes in technologies that utilize fossil fuels could result in further annual reduction of 60 thousand Gg.

Fig. 9.7.8 Emission of CO2 in analysed cases of Scenario I

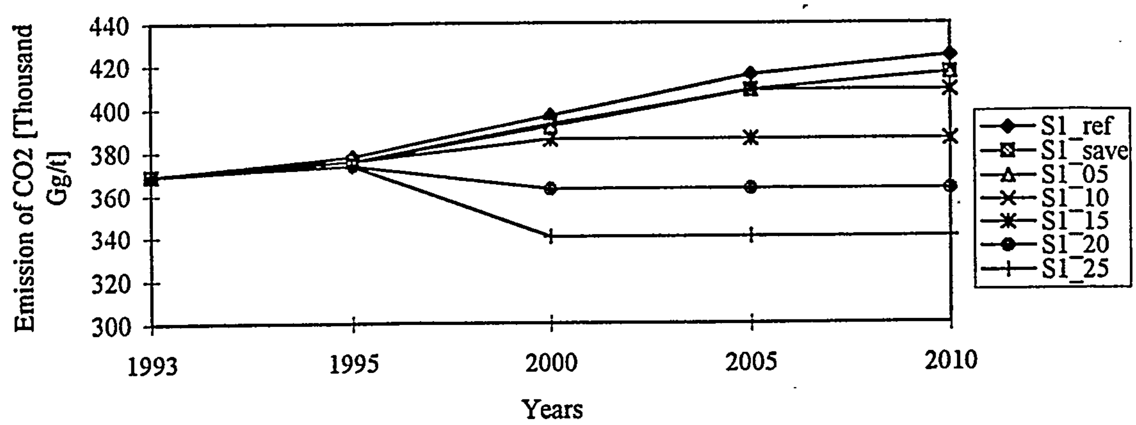


Fig. 9.7.9. Emission of CO2 by sectors in reference case of Scenario I

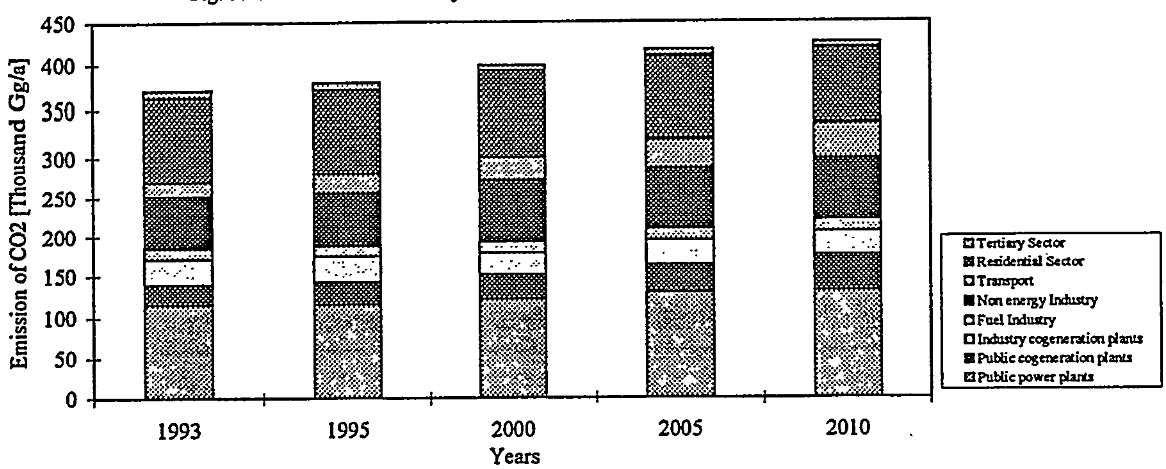


Fig. 9.7.10 Emission of CO2 in 2010 in reduction cases of Scenario I

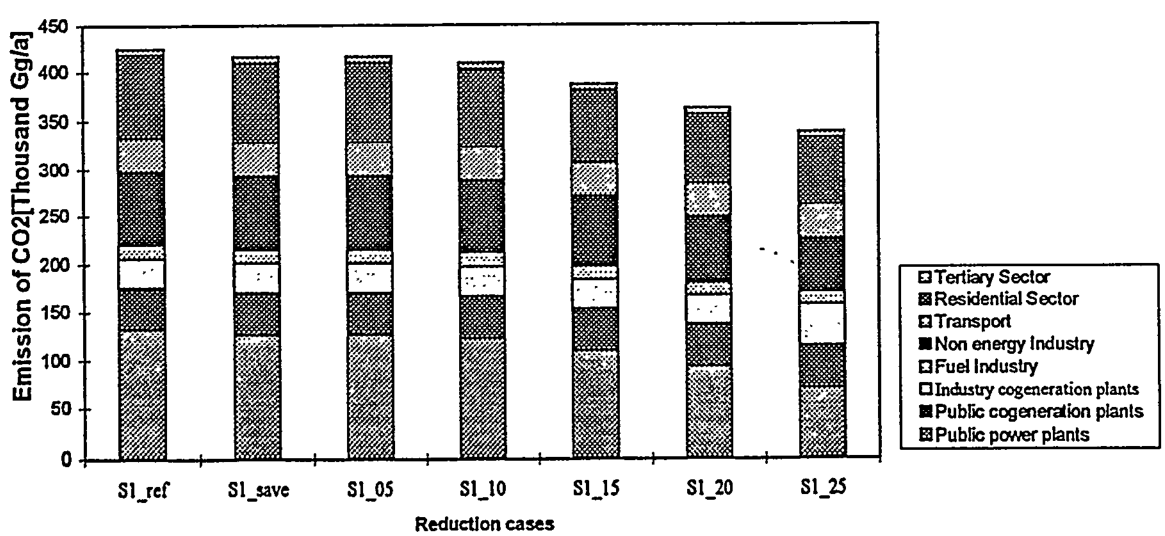


Fig. 9.7.11. Primary energy consumption in reference case of Scenario I

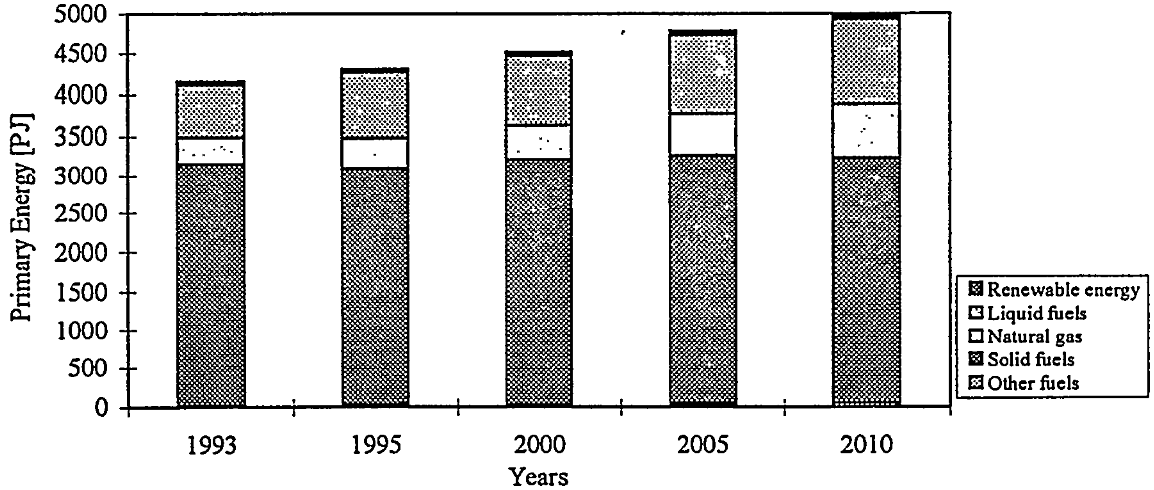


Fig. 9.7.12 Primary energy consumption in 2010 by cases analysed in Scenario I

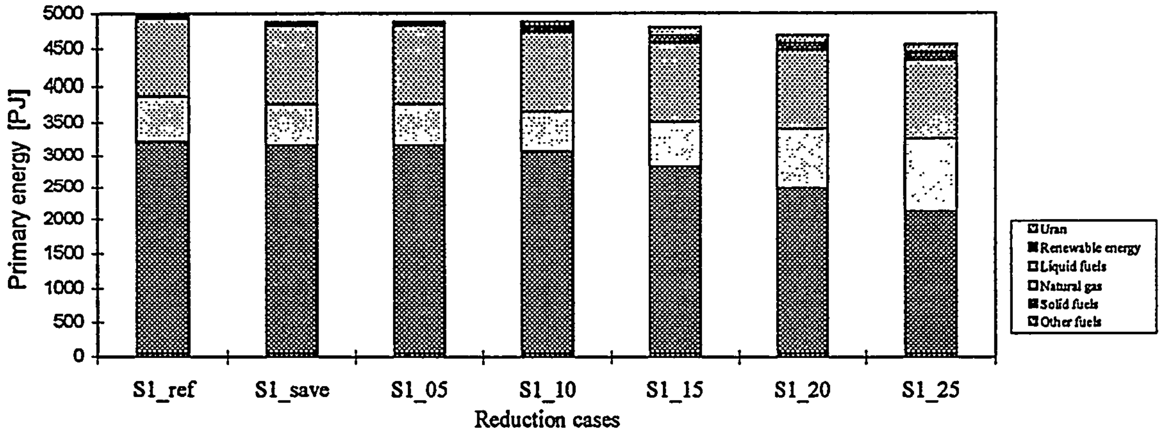
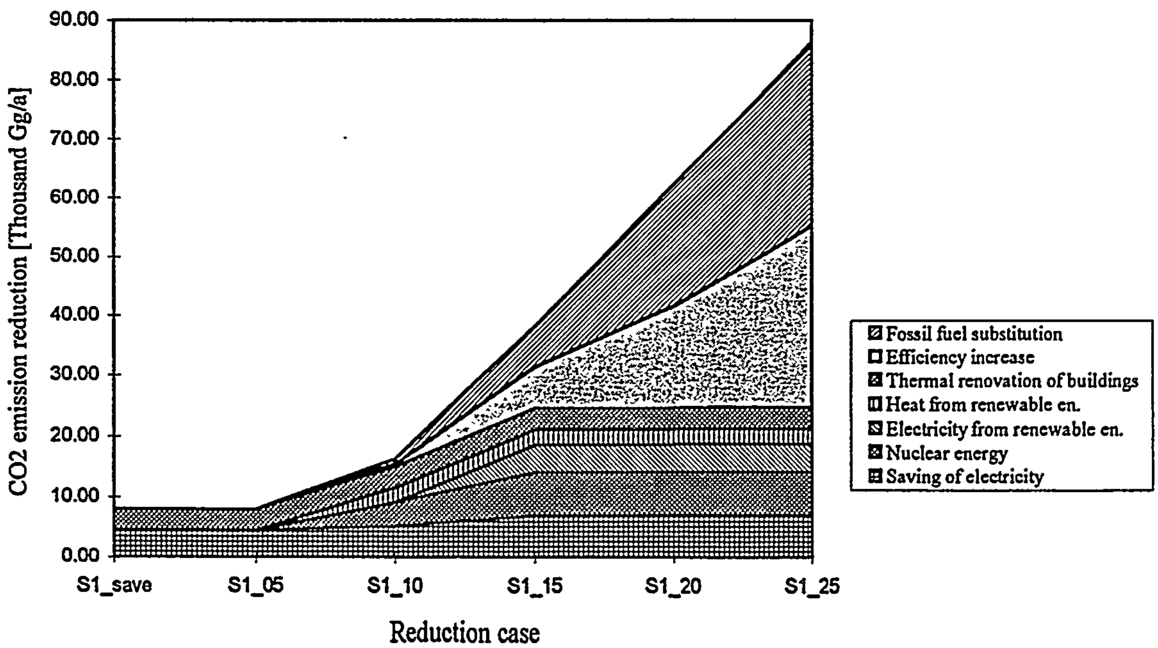


Fig. 9.7.13 CO2 emission reduction by reduction measures in different cases of Scenario I



CO_2 emission reduction costs

Total reduction costs

An important value which characterises optimal strategies defined for each scenario and CO_2 reduction cases, is total additional reduction cost. Tab. 9.7.22 below and figure 9.7.14 give values of total reduction costs for the period 1995-2015, discounted for the base year 1993. These costs are defined as a difference between respective reduction cases and the case without emission limitation. The latter case is the case with cost efficient range of energy saving measures (defined as S 1,2.3_save).

Table 9.7.22. Total discounted costs of CO_2 reduction according to the scenarios in [trillion Zl 1993)]

Scenario	Reference case	CO_2 emission reduction cases				
		5%	10%	15%	20%	25%
Scenario I	0	0.13	2.81	34.63	113.5	267.05
Scenario II	0	0.29	4.83	41.79	126.93	294.55
Scenario III	0	0.84	12.77	69.89	-	-

Total reduction costs are still relatively small, even with 5% reduction, but they rise quickly with further emission limitation. Reduction costs in the scenarios III with limited gas access and without nuclear power are about 5-6 times higher, with 5% and 10% reductions, in comparison with the scenario I, including no such limitations. While estimating these costs, it is purposeful to remember that these values are discounted, they allow comparison of different costs flows, of different time distributions, while reduction costs given in current non discounted monetary values are sensibly higher (they will be given further in this Chapter).

Tab. 9.7.23 shows annual reduction costs (in monetary units of steady purchase power in the year 1993, not discounted) with 10% emission decrease in relation to the case without emission limitations. The next table shows total reduction costs in 5-year periods, as well as in the whole analysed period.

Table 9.7.23. Annual reduction costs with 10% CO_2 emission reduction in the analysed scenarios

Scenario	1995	2000	2005	2010
Annual costs with 10% reduction [in trillion Zl (93)/annum]				
Scenario I	0	0	0.01	1.44
Scenario II	0	0	0.25	1.27
Scenario III	0	0	0.32	1.53
Annual costs with 10% reduction [in million USD(93)/annum]				
Scenario I	0	0	0.3	79
Scenario II	0	0	14	70
Scenario III	0	0	18	84

Table 9.7.24. Total reduction costs with 10 % CO_2 emission reduction in the analysed scenarios

Scenario	1996-2000	2001-2005	2006-2010	2011-2015	1996-2015
Total costs with 10% reduction in [trillion Zl (93)]					
Scenario I	0	0.02	4.32	11.09	15.43
Scenario II	0	0.75	4.30	21.15	26.18
Scenario III	0	0.97	5.24	64.97	71.18
Total costs with 10% reduction in [million USD (93)]					
Scenario I	0	1	238	611	851
Scenario II	0	41	237	1165	1443
Scenario III	0	53	289	3580	3922

Achievement of 10% emission reduction causes an increase of annual costs of energy requirements satisfaction already in the year 2000. A great difference in reduction costs between different scenarios can be seen. These costs rise in successive years to reach in 2015 the level from 150 million USD in the scenario I to 1137 million USD in the scenario III. Additional reduction costs for the whole analysed period until 2015 are from 850 million USD (Scenario I) to almost 4 milliard USD (Scenario III). These costs cumulate after 2005 in the last two periods. Tab. 9.7.25 gives average costs of CO_2 emission reduction by one tonne per annum in the year 2010. These values illustrate cost efficiency of applied reduction measures - the higher the costs, the lower the reduction effect related to expense.

Fig. 9.7.14. Total discounted costs of CO2 emission reduction in years 1995 - 2015

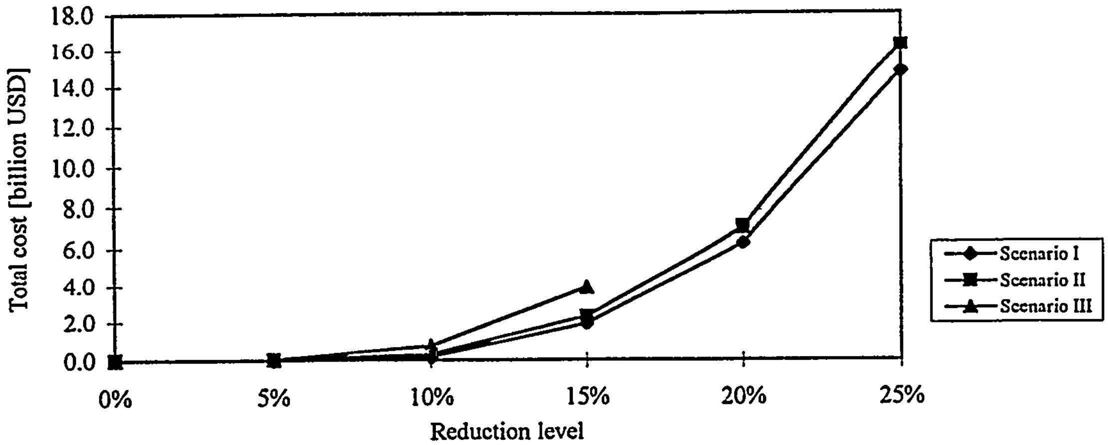


Fig. 9.7.15. Marginal costs of CO2 emission reduction in 2010 by reduction level

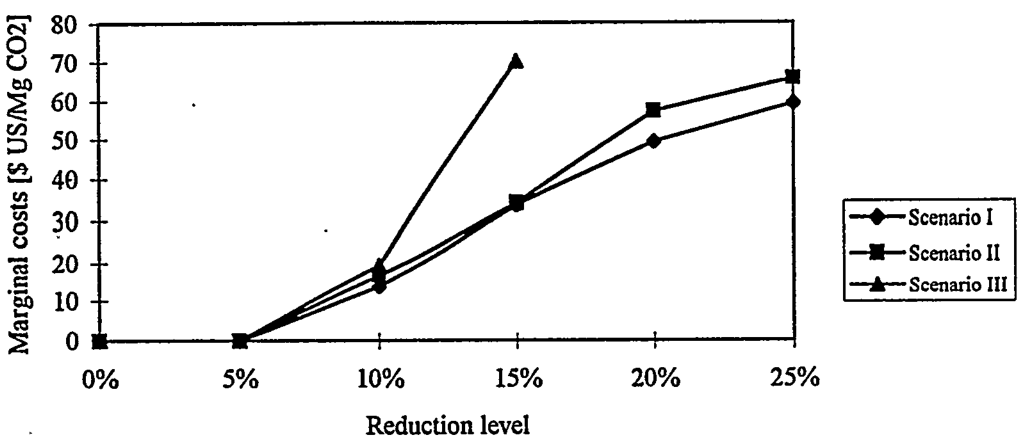


Table 9.7.25. Average CO_2 emission reduction costs in 2010 according to reduction degree

Scenario	CO_2 emission reduction degree				
	5%	10%	15%	20%	25%
Average CO_2 emission reduction costs in [thousand Zl/Mg CO_2]					
Scenario I	0	180	370	523	710
Scenario II	0	158	437	604	773
Scenario III	0	191	742	0	0
Average CO_2 emission reduction costs in [USD/Mg CO_2]					
Scenario I	0	10	20	29	39
Scenario II	0	10	24	33	43
Scenario III	0	11	41	0	0

Marginal costs

Marginal costs show how much should be paid to decrease the emission by next unit, e.g. one tonne of CO_2 emission per annum. It is clear that if the cheapest reduction options are used in every situation, marginal cost should rise along with the decrease of emissions, as cheaper possibilities become scarce.

Tab. 9.7.26 below and figure 9.7.15 present results of marginal costs computation for the three analysed scenarios. Costs are given in USD to allow comparisons with costs obtained for other countries. It is easy to observe that these costs rise with the increase of reduction level and in successive years when growing energy demand favours emission rise, not emission decline.

Table 9.7.26. Marginal costs of CO_2 reduction according to reduction degree for the three analysed scenarios

Year	Reference case	Reduction cases					
		5%	10%	15%	20%	25%	29.8%
Scenario I							
2000	0	0	0	14	34	148	1025
2005	0	0	2	31	46	50	156
2010	0	0	14	34	49	59	114
Scenario II							
2000	0	0	0	14	34	140	-
2005	0	0	0	30	44	47	-
2010	0	0	16	34	57	66	-
Scenario II							
2000	0	0	0	14	-	-	-
2005	0	0	0	37	-	-	-
2010	0	0	19	70	-	-	-

From the very definition, marginal costs are, higher or at least equal to the average emission reduction costs, which is confirmed by figures presented in Tab. 9.7.25 and Tab. 9.7.26. Simplifying the matter, marginal costs can be interpreted as amount of charges for CO_2 emission or coal tax (converted for pure coal), indispensable to reach the given reduction level. Introduction of one of these instruments would make all technological measures, necessary to attain assumed reduction level, cost efficient. If, in addition, we assume an ideal market and realization of all cost efficient measures, it is possible to suppose that the same emissions as those obtained in optimization computations can be reached when applying coal tax equalling computed marginal costs.

Presented results show that without additional costs it is possible to reach 5% reduction by the year 2010 in all the scenarios. Reaching further emission decrease would require technological options, more expensive than those in the reference cases. Marginal costs for the most optimistic scenario I, with 10%, don't seem high because they don't exceed 14 USD per tonne of CO_2 emission. However, this value converted into pure coal gives 51 USD per tonne of emitted coal. Therefore, to reach 10% reduction level through coal tax introduction, this tax should be at least 51 USD per tonne of coal, which would more or less double coal prices for electricity sector and cause an increase of 50% for individual energy users. With 15% reduction in the most optimistic scenario marginal costs reach 46 USD per tonne of CO_2. For better illustration of this quantity it is proper to say that with this reduction costs level, a cost efficient solution is to close existing power station which products electricity at 2.5 cent/kWh and to build a new gas power station of higher efficiency, generating twice as expensive electricity.

In other scenarios, less optimistic from the point of view of CO_2 emission possibilities, marginal costs are considerably higher. As it follows from comparison of the three scenarios results, the greatest reduction costs increase is caused by the lack of wide natural gas access. Generally, excluding nuclear power also causes generally a rise of reduction costs in the years 2010 and 2015, when this option could be used, but whether it is adopted or not, is not as important as gas accessibility problem.

Comparison of CO_2 emission reduction costs for Poland and the European Community countries

To compare results obtained for Poland with other countries, below are given results obtained in similar studies carried out for all the European Community countries in 1991 in the CRASH program. The results are extracted from synthetic report [COHERENCE, 1991], prepared for the European Commission. These studies use EFOM - ENV model in FORTRAN version, and computation is done with partly standardized assumptions for energy prices, discount rate (5-8%), etc. Furthermore, particular countries made a number of assumptions, among others, concerning admissible nuclear power development, quantities of imported gas, maximal renewable energy production potentials. Most of national studies assume lack of new nuclear power stations (Denmark, Germany, Greece, Italy, Netherlands, Portugal). Others admit a limited nuclear power development, except France, where no limitations are applied. Most countries (except Greece and Spain) assumed lack of limitations for natural gas importation. Tab. 9.7.27 presents, for Community countries, maximum reduction level in the year 2010 possible to reach through technologies.

Table 9.7.27. Maximal CO_2 emission reduction level in 2010 in the European Community countries and in Poland

Country	Maximal reduction level in 2010 in [%]
Belgium	-15
Denmark	-40
France	-20
Germany	-30
Greece	-10
Italy	-11
Netherlands	-6.5
Portugal	+50
Spain	-10
United Kingdom	-30
Poland	-30

The comparison shows that only Denmark has greater possibilities of emission decrease. Germany and United Kingdom maximal reduction level is similar to the Polish one. In the case of Portugal it has been estimated that the lowest emission level possible to reach is 50% higher than in 1988.

Table 9.7.28. Marginal reduction costs in 2010 [ECU/t CO_2]

Country	CO_2 reduction cases					
	Stabilization	5%	10%	15%	20%	30%
Belgium	15	15	39	290	-	-
Denmark	0	0	6	n.a.	11	32
France	0	0	19	n.a.	43	-
Germany	0	0	15	18	43	138
Greece	23	56	224	-	-	-
Italy	22	112	413	-	-	-
Netherlands	27	136	-	-	-	-
Portugal	12	-				
Spain	18	143	1556	-	-	-
United Kingdom	0	0	12	n.a.	35	63
Poland		0	13	28	47.5	

Table 9.7.29. Average reduction costs in 20010 in the European Community Countries and in Poland [ECU/t CO_2]

Country	CO_2 reduction cases					
	Stabilization	5%	10%	15%	20%	30%
Belgium	15	15	20	60	-	-
Denmark	0	0	6	n.a.	9	14
France	0	0	19	n.a.	34	-
Germany	0	0	15	16	24	53
Greece	23	25	36	-	-	-
Italy	22	34	75	-	-	-
Netherlands	27	49	-	-	-	-
Portugal	14	-				
Spain	18	29	137	-	-	-
United Kingdom	0	0	12	n.a.	27	42
Poland		0	7.5	20	28	-

Tab. 9.7.28 and Tab. 9.7.29 compare average and marginal costs of CO_2 emission reduction in the European Community countries and in Poland (scenario II results - without nuclear power). converting costs at the rate 1 ECU(90) = 1.2 USD(93). Results obtained for Poland approach the costs for France. Germany and United Kingdom. Denmark, which generates most of its electricity from hard coal, has the lowest reduction costs. In other countries reduction costs are higher than in Poland. In countries like Germany or United Kingdom, a great part of emission reduction is achieved, like in Poland, thanks to wider natural gas use, especially in electricity sector.

9.7.6 Conclusions

1. Technical possibilities accessible at present allow a decrease of national CO_2 emission in Poland by the year 2015 by 30% as compared with the emission in 1988. If, however, construction of new pipelines for natural gas importation is not realized and nuclear power stations are not built, maximal possible reduction declines to 16%.
2. With the rise of target reduction level, reduction costs rise quickly, but their amount depends considerably on quantities and prices of natural gas accessible from importation. Limited natural gas access causes sensible increase of reduction costs.
3. If present trends of energy intensity changes are maintained, it will allow a decrease of CO_2 emission by about 5% by 2010, without additional costs.
4. Reaching 10% emission reduction by the year 2015, for the adopted assumptions, requires an expense of about 15 to 70 trillion Zl of purchase power for the year 1993, which converted into USD gives from 850 million to almost 4 milliard USD in the period 2000-2015.
5. The greatest, considering potentials, and the cheapest possibilities of CO_2 emission reduction are in electricity sector, industry and households.
6. Among the analysed possibilities, the most cost efficient measures of considerable CO_2 emission reduction potentials are:
   - electricity and heat saving measures,
   - construction of new gas and, then, nuclear power stations,
   - increase of combined production in existing public CHP plant and heat plants,
   - wider natural gas use in industry heat plants and in individual houses for heating.
7. Energy saving measures, found and included in computations, constitute a particularly important option because a number of them is cheaper than respective offer options, and therefore, their realization causes an increase of total costs of energy requirements satisfaction. These measures are generally related to electricity saving and thermorenovation.
8. Comparison of results obtained for Poland with results of similar studies for the European Community countries shows that maximal possible reduction as well as reduction costs in Poland approach costs in countries like Germany and United Kingdom. Only Denmark has cheaper reduction possibilities, in other countries, reduction costs are higher and reduction possibilities fewer.

THE LIST OF ABBREVIATIONS

GHG	- greenhouse gases
OECD	- Organization for Economic Cooperation and Development
GDP	- Gross Domestic Product
IEA	- International Energy Agency
GUS	- Main Statistical Office
MPiH	- The Ministry of Industry and Trade
ZPE IPPT PAN	- Department of Energy Problems Institute of Fundamental Technological Research Polish Academy of Sciences
STRUK	- macroeconomy model used in the study
PROSK-E	- simulation model for energy demand calculation used in the study
EFOM-ENV	- optimization model of the Polish energy system used in the study
GAMS	- General Algebraic Modelling System
PGNiG	- Polish Oil and Gas Company
LNG	- liquefied natural gas
PSE SA	- Polish Electricity Grids
tkm	- tonne-kilometer
pkm	- passenger-kilometer
vkm	- vehicle-kilometer

10. Macroeconomic GHG emission abatement scenarios

10.1. Procedure of creating the macroeconomic GHG abatement scenarios

The Country Study has hierarchical structure which determines the procedure of creating the macroeconomic abatement scenarios. The block diagram of the procedure is presented in Figure 10.1. The modelling tools used at the particular stage of the work are marked.

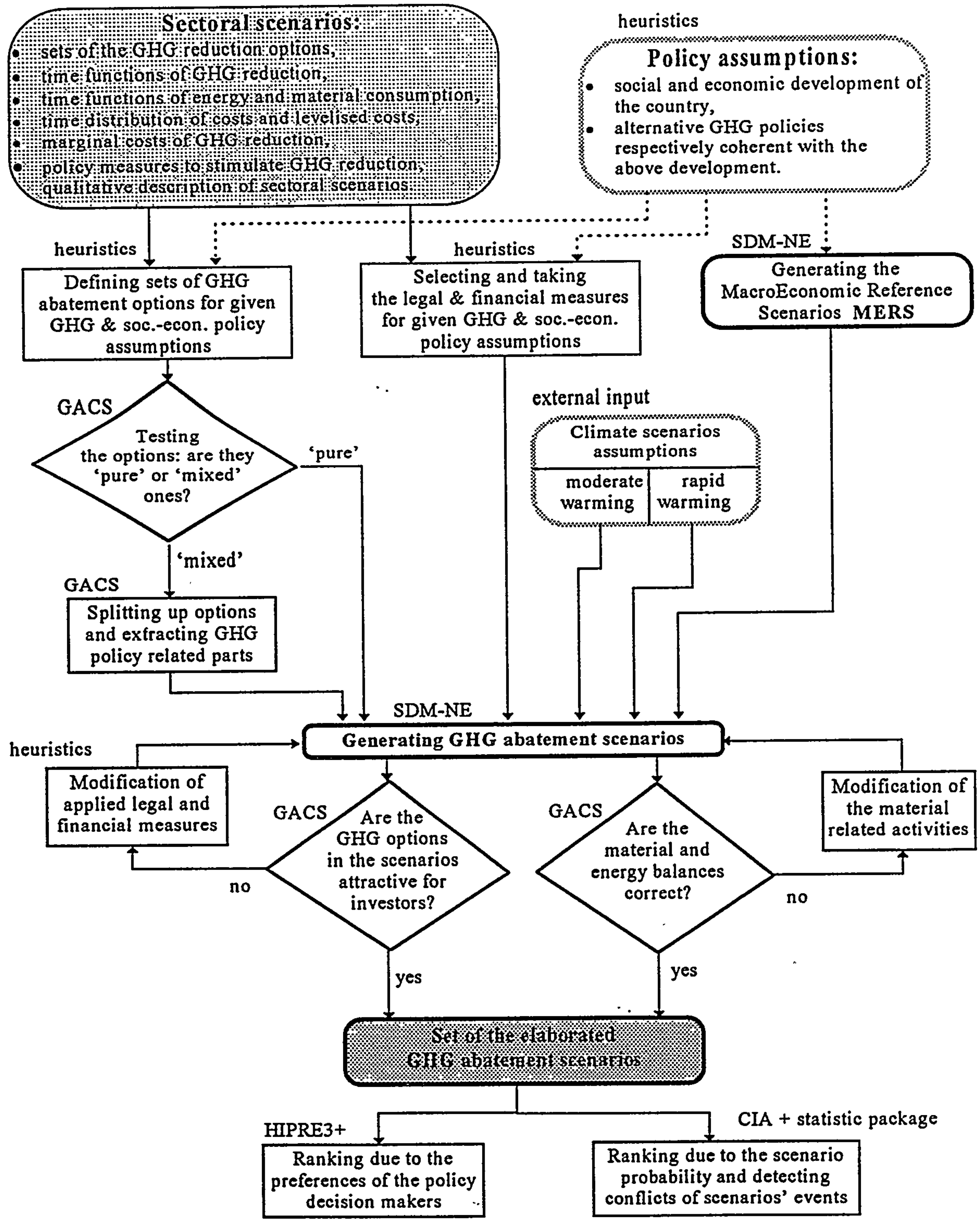


Figure 10.1. Simplified algorithm of creating the GHG abatement scenarios at a country level

Two areas may be distinguished in the diagram:

- elaborating sectoral scenarios (upper-left shaded block in Figure 10.1),
- integrating the sectoral scenarios into the country size macroeconomic scenarios (remaining blocks in Figure 10.1).

Particular technological options of GHG emission reduction and sink are analysed at the sectoral level. The cost-benefit analysis is here the main analytical method (see Chpt. 6.1.). In the case of the energy sector minimising of system costs method was additionally applied because of significance of the sector for the problem.

Although the resulting sectoral GHG abatement scenarios had different forms according to the specific features of a given sector, efforts to provide all data necessary for the following macroeconomic analysis were done. In particular the sectoral results should require:

- complete sets of GHG reduction options,
- time distribution of the GHG emission reduction,
- time distribution of the fuels, energy and materials use,
- time distribution of implementation costs of the GHG reduction options and the levelled costs,
- marginal costs of the GHG reduction,
- legal and financial measures proposed to activate the GHG abatement options,
- qualitative description of the sectoral scenarios.

Collisions among options and the double counting phenomena were carefully observed and eliminated while elaborating the sectoral scenarios.

The sectoral studies are treated in the Country Study as its independent, autonomous parts, consequently, used as a source of data for the procedure of generating the country size macroeconomic scenarios.

The macroeconomic procedure starts with defining alternative policy assumptions, which together with assumed alternative climate scenarios constitute the leading plot for variants of macroeconomic scenarios. Next, sets of GHG reduction options for the entire country, consistent with given policy assumptions, are defined on the bases of the sectoral scenarios. Collisions among options are eliminated with the CIA method. Particular options are tested in order to assign them to the reference or abatement scenarios. 'Mixed' options, partially belonging to both scenarios are split up [Gaj, 1995b]. Only the part activating by the policy measures applied in a given scenario are taken.

The policy measures are chosen in such a way that the GHG abatement options introduced to the scenario become attractive for the potential microeconomic decision maker (investor) [Gaj, 1995a].
The macroeconomic scenarios are also testing for detecting disagreements in the energy and/or material balances. The testing procedures are done with SDM-NE [Szukalski, 1995] and GACS [Gaj, 1994] models. The SDM-NE model indicates the macroeconomic implications of the policy measures and GHG reduction options introduced to a given scenario, while the GACS model enables to estimate influence of the applied policy measures on the economic effectiveness of the options.

The resulting scenarios are estimated according to political criteria (HIPRE3+ procedure) and probability of occurrence (CIA model).

The criteria and their weights have been widely discussed by experts of system analysis.

10.2. Main assumptions of scenarios

Analysis of the technological GHG abatement options (the bottom-up methodology) indicated small effectiveness of carbon tax at the applied range of 50 - 100 USD/Mg C (see Fig. 10.10 - 10.17.).
The macroeconomic simulations (top-down methodology) showed quite significant impact of the tax on inflation and economic recession.

On the other hand, carbon tax is considered in the literature as a main financial instrument of climate policy. Taking this into account, two policy measures stimulating GHG reduction were decided to be applied in this study:

- carbon tax in the range of 50 - 100 USD / Mg C, and
- investment subsidies in the range necessary to achieve required reduction of GHG emission.

Two variants of climate warming were assumed in the analysis:

- moderate warming 0.05 ^{0}C/a, and
- rapid warming 0.10 ^{0}C/a.

Thus, the GHG reduction scenarios were based on well defined although basic (not detailed) policy and climate assumptions. Combinations of these assumptions are the guide for GHG abatement options selection and estimation of the macroeconomic parameters of the SDM-NE model.
Schematically the combinations are presented in Table 10.1.

Table 10.1. Policy and climate assumptions for the macroeconomic GHG reduction scenarios

Paths of macroeconomic development													
Stagnation scenario		Base-line scenario						Chance scenario					
comparative without climate policy		reference without climate policy		abatement with weak climate policy		abatement with strong climate policy		reference without climate policy		abatement with weak climate policy		abatement with strong climate policy	
moderate climate warming	rapid climate warming	mode - rate clim. warm	rapid clim. warm	mode - rate clim. warm	rapid clim. warm	mode - rate clim. warm	rapid clim. warm	mode - rate clim. warm	rapid clim. warm	mode-rate clim. warm.	rapid clim. warm.	mode-rate clim. warm.	rapid clim. warm.
SPst1	SPst2	SOb1	SOb2	SRb1	SRb2	SRb3	SRb4	SOsz1	SOsz2	SRsz1	SRsz2	SRsz3	SRsz4

<u>Abbreviations used in Table 10.1.:</u>

SPst□ - Comparative Scenarios of Stagnation, without climate policy (low level of structural changes in the economy, lack of social acceptance for climate policy), two climate warming paths alternatively assumed, □ - N^0 of a given scenario,

SOb□ - Base-line Reference Scenarios (reference for the GHG abatement scenarios SRb□), present policy of the Polish government applied, two climate warming paths alternatively assumed, □ - N^0 of a given scenario,

SRb□ - Base-line GHG Abatement Scenario, created on the bases of SOb□ for two alternative levels of the policy stimulation of GHG reduction and two climate warming paths alternatively assumed, □ - N^0 of a given scenario,

SOsz□ - Reference Scenarios of Chance (reference for the GHG abatement scenarios SRsz□), structural changes in the economy deeper than assumed by the government, two climate warming paths alternatively assumed, □ - N^0 of a given scenario,

SRsz□ - GHG Abatement Scenario of Chance, created on the bases of SOsz□ for two alternative levels of the policy stimulation of GHG reduction and two climate warming paths alternatively assumed, □ - N^0 of a given scenario.

Base-line Scenario is the leading scenario in this Study. This is the main reference for all variants of sectoral and macroeconomic scenarios. The scenario is described in details in Chapter 7.
For the purpose of macroeconomic system analysis the Base-line Scenario has been modified slightly due to the opinions of chosen decision centres verifying the scenario. It has been also changed symmetrically to the Scenarios of Stagnation and Scenario of Chance.

The Scenario of Stagnation was created under the general assumption of:

- freezing of technical and technological structures of production,
- conservation of the material and energy intensive nature of the economy,
- very limited opening the economy to the international surroundings,

while the Scenario of Chance was drawn up under the general assumption of:

- deeper structural changes in the economy than declared and implemented by the government, to more energy and material efficient economy,
- full opening of the economy to the international surroundings.

Basic macroeconomic characteristics of the considered scenarios are presented in a comparative manner in Figures 10.2 - 10.9. The characteristics are done under the assumption of moderate climate warming (0.05 ^{0}C/a). The characteristics without climate warming are enclosed in Annex 2.
Lack of social acceptance for the climate policy of any kind has been assumed in the case of the Scenario of Stagnation. This assumption is coherent with all the remaining assumptions for this scenario (protection of coal industry, slow structural changes in the economy, raw-material nature of industry).
The remaining Base-line and Chance Scenarios were taken as the reference for introducing the GHG abatement measures - carbon tax 50 and 100 USD/MgC respectively and additionally investment subsidies for the variants of strong stimulation of GHG reduction.

The remaining Base-line and Chance Scenarios were taken as the reference for introducing the GHG abatement measures - carbon tax 50 and 100 USD/MgC respectively and additionally investment subsidies for the variants of strong stimulation of GHG reduction.

Applying two variants of climate change (moderate - 0.05 ^{0}C/a and rapid 0.10 ^{0}C/a warming) for each set of the policy assumptions, eight abatement scenarios were considered (see Table 10.1.).

The range of carbon tax <50,100> USD/MgC was adopted on the basis of initial macroeconomic simulations of sensitivity of the economy to the tax and confronting it with literature [Manne et al., 1993].

Basic macroeconomic parameters of the alternative paths of the economic development of the country

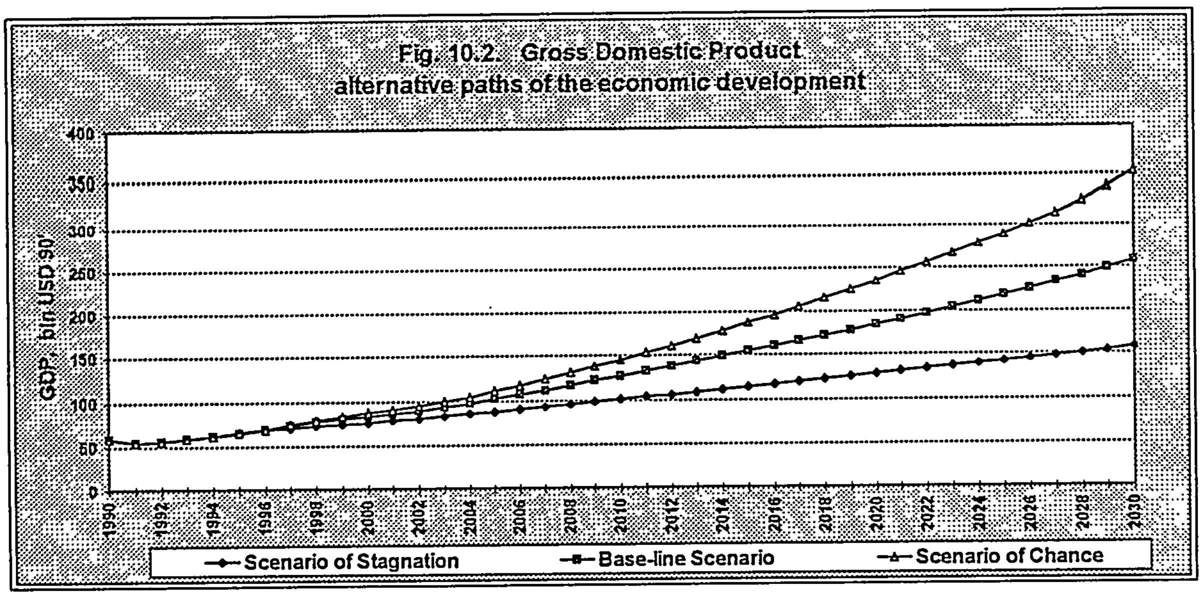


Fig. 10.2. Gross Domestic Product alternative paths of the economic development

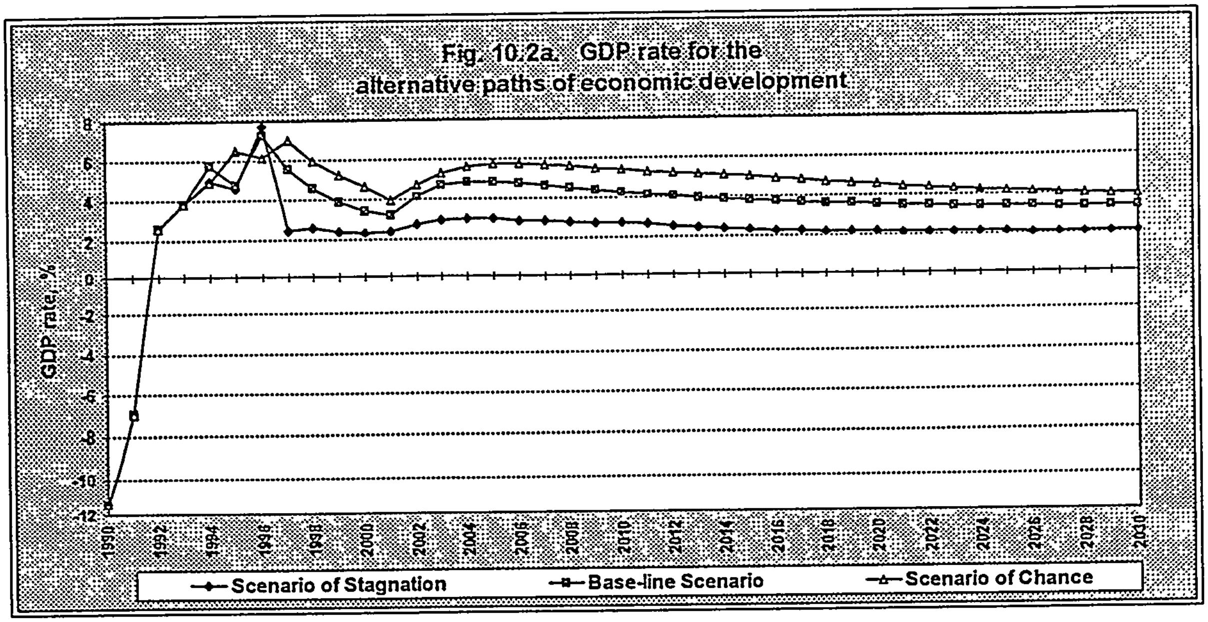


Fig. 10.2a. GDP rate for the
alternative paths of economic development
GDP rate, %
8
6
4
2
0
-2
-4
-6
-8
-10
-12
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028
2030
Scenario of Stagnation
Base-line Scenario
Scenario of Chance

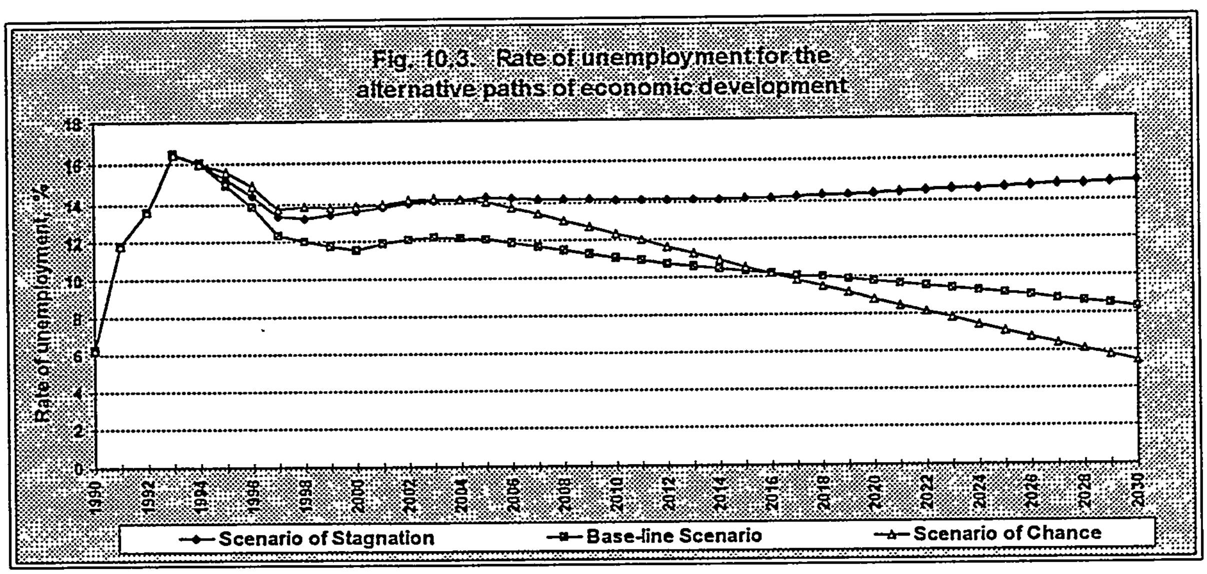
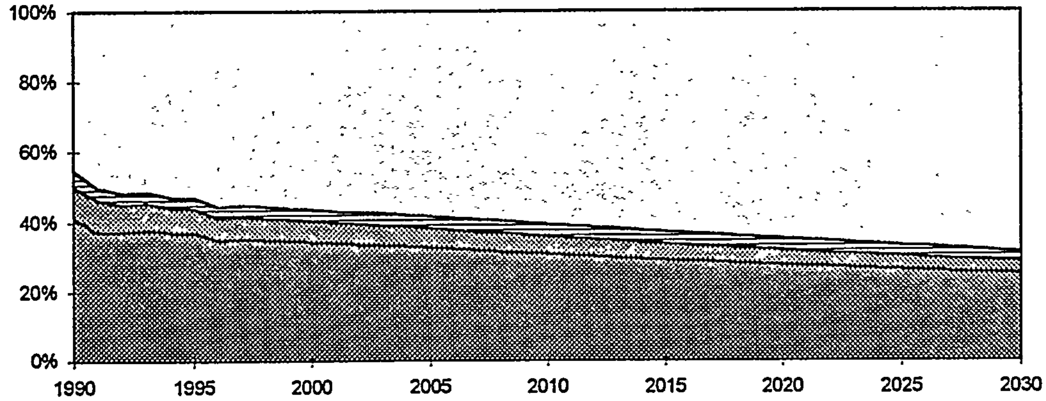
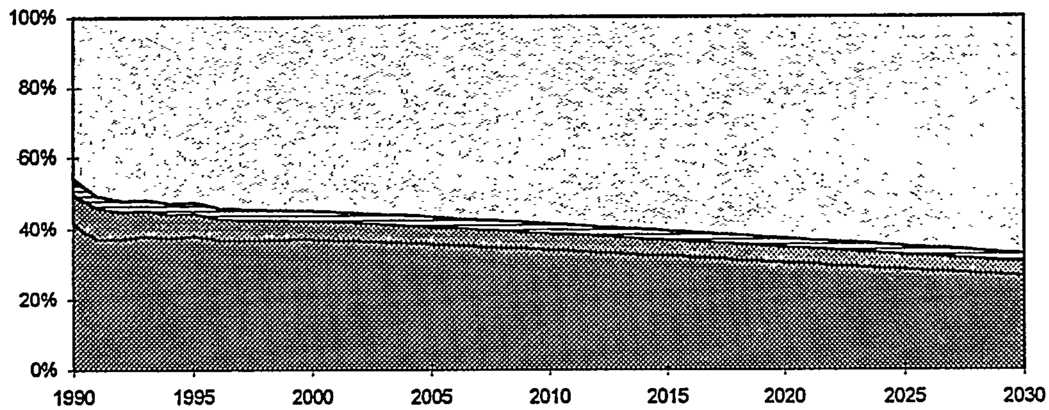


Fig. 10.3. Rate of unemployment for the
alternative paths of economic development
Rate of unemployment, %
18
16
14
12
10
8
6
4
2
0
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028
2030
Scenario of Stagnation
Base-line Scenario
Scenario of Chance

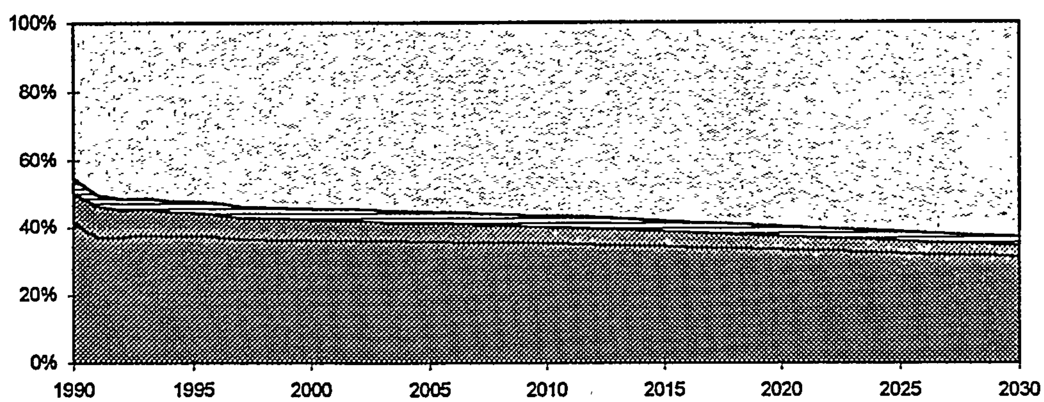
Fig. 10.4. Structure of the Domestic Economy for the alternative paths of economic development



Scenario of stagnation



Base-line scenario



Scenario of chance

Legend:

▨ Industry ▨ Agriculture ▤ Transport ☐ Services & misc.

Materials and energy use in the national economy for alternative paths of the economic devèlopment

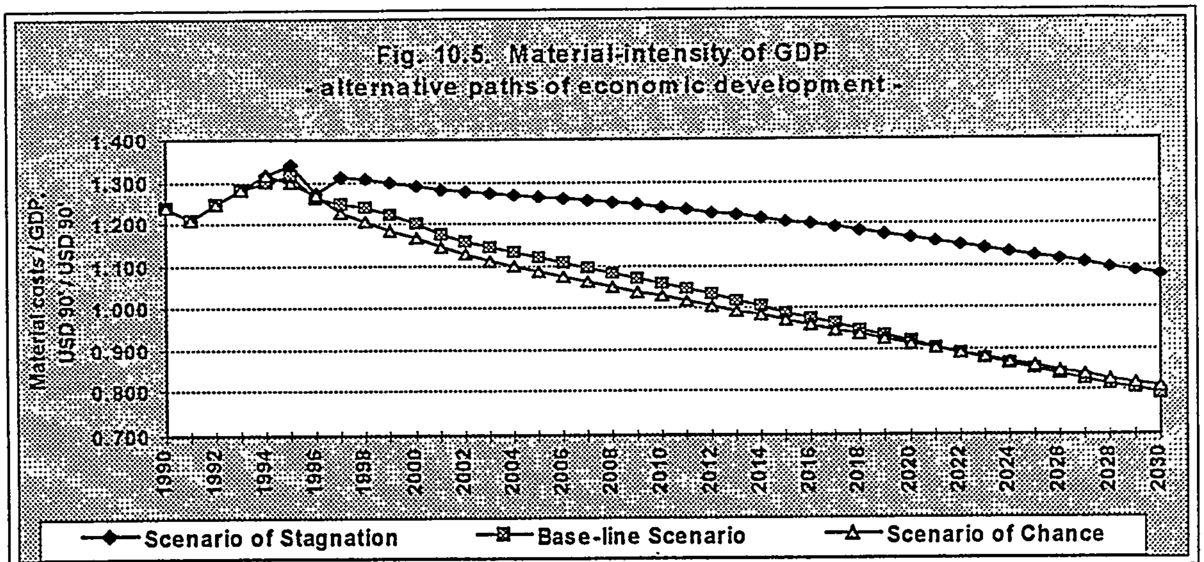


Fig. 10.5. Material-intensity of GDP
- alternative paths of economic development -

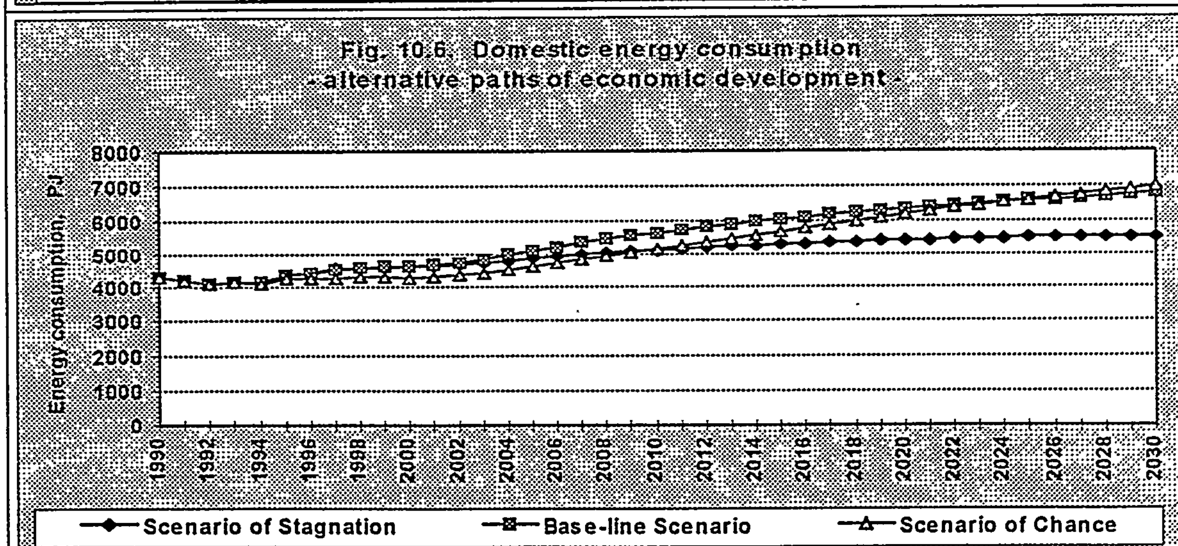


Fig. 10.6. Domestic energy consumption
- alternative paths of economic development -

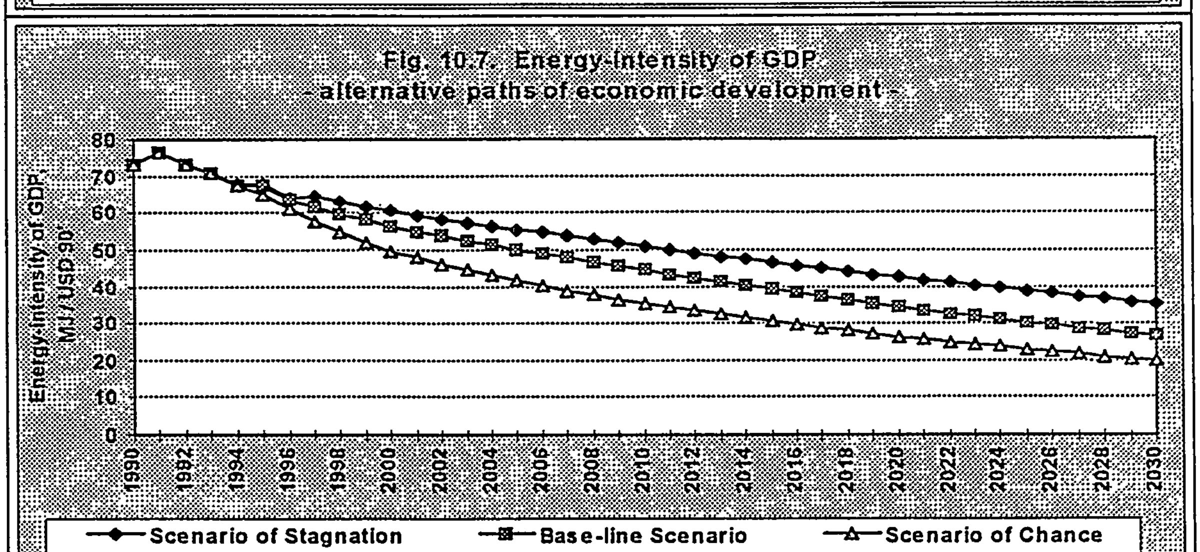
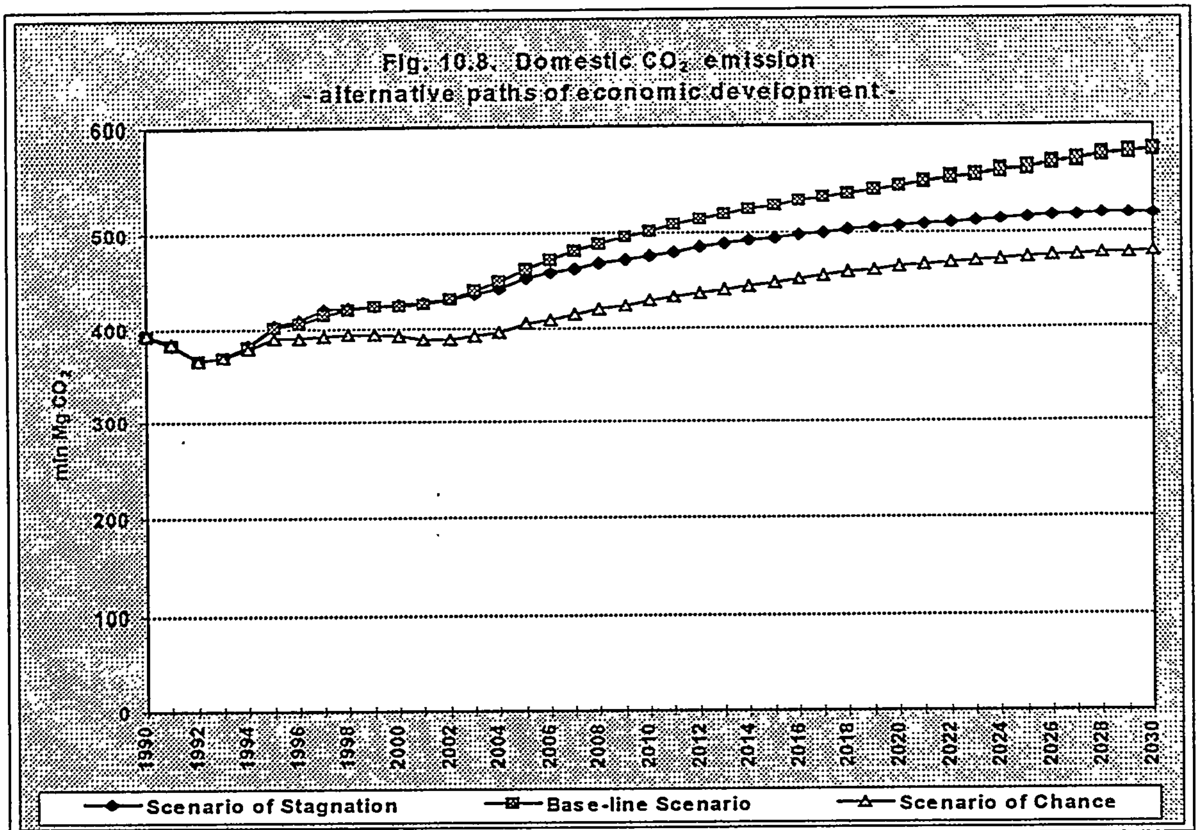
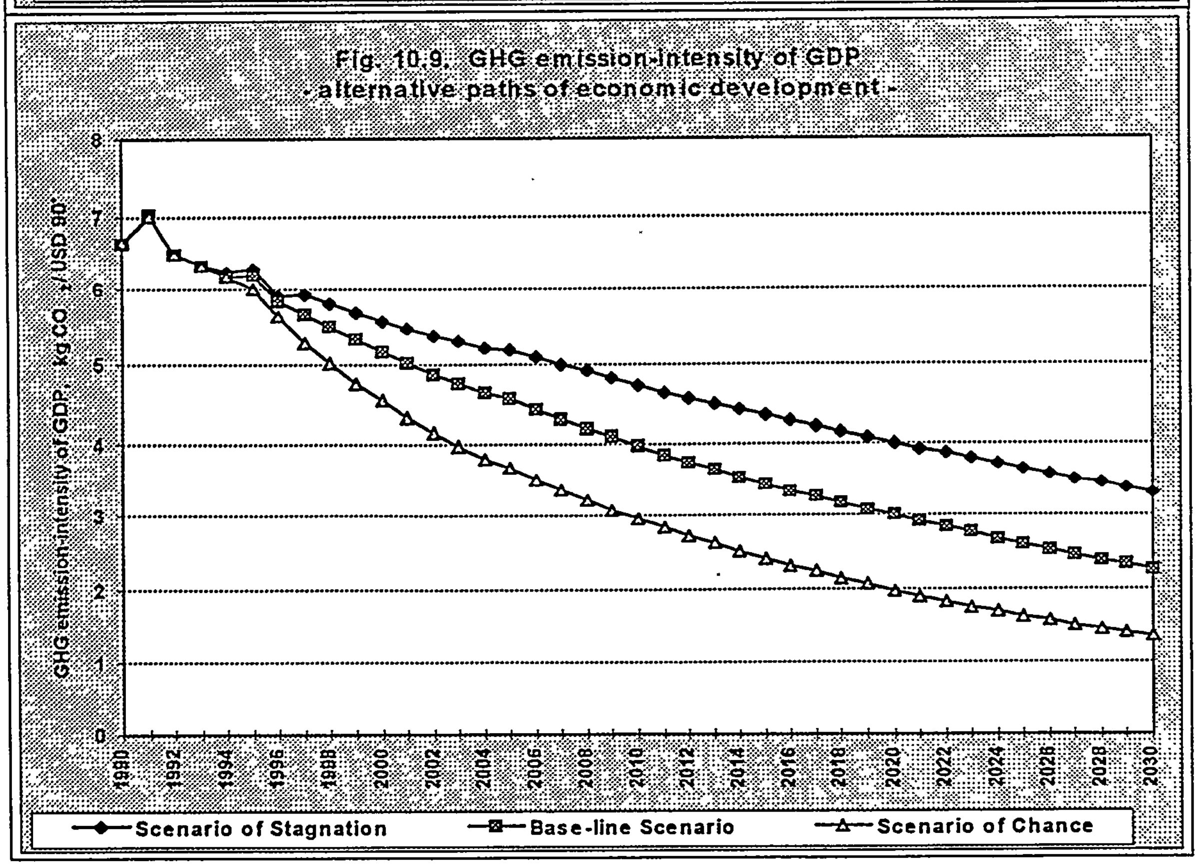


Fig. 10.7. Energy-intensity of GDP
- alternative paths of economic development -

GHG emission
for alternative paths of the economic development





10.3. Country GHG abatement scenarios and their macroeconomic implications

GHG abatement scenarios have been elaborated on the basis of the assumptions defined in Chapters 7.2 and 10.2.

The data for industrial (without power sector), house-hold, municipal, commercial, services sectors and for renewable energy sources elaborated in the format of GACS spreadsheet, were taken as a basic data base for the macroeconomic analysis.

This area contributes to 90% of GHG emission of the country (together with the emission in the power sector due to the consumption of electricity and combined heat in the area).

For the power sector, the results of sectoral optimizing calculations (see Chapter. 9.1.) containing investment programs and O&M costs were taken as the source of data. Wide spectrum of variants considered in this sector enabled quite precise assignment of proper variants to different macroeconomic scenarios.

For the transport sector economic parameters were not estimated at the sectoral level (investment costs, variable costs),(see Chapter. 9.4.). That is why streams of investments and other economic parameters were estimated at the level of macroeconomic modeling. While estimating the data agreement between the macroeconomic and sectoral results in the field of GHG emission, fuel consumption, transport intensity of GDP was carefully observed.

Agriculture was treated in the same way as transport sector considering that structural changes in the economy will govern much stronger behaviors of the sector than any GHG reduction actions in the sector. This does not mean that significance of agriculture as a sector giving input to the renewable energy technologies and being also an important consumer of renewable energy was underestimated. Agreement between the sectoral and macroeconomic results in this area was controlled at the level of final results.

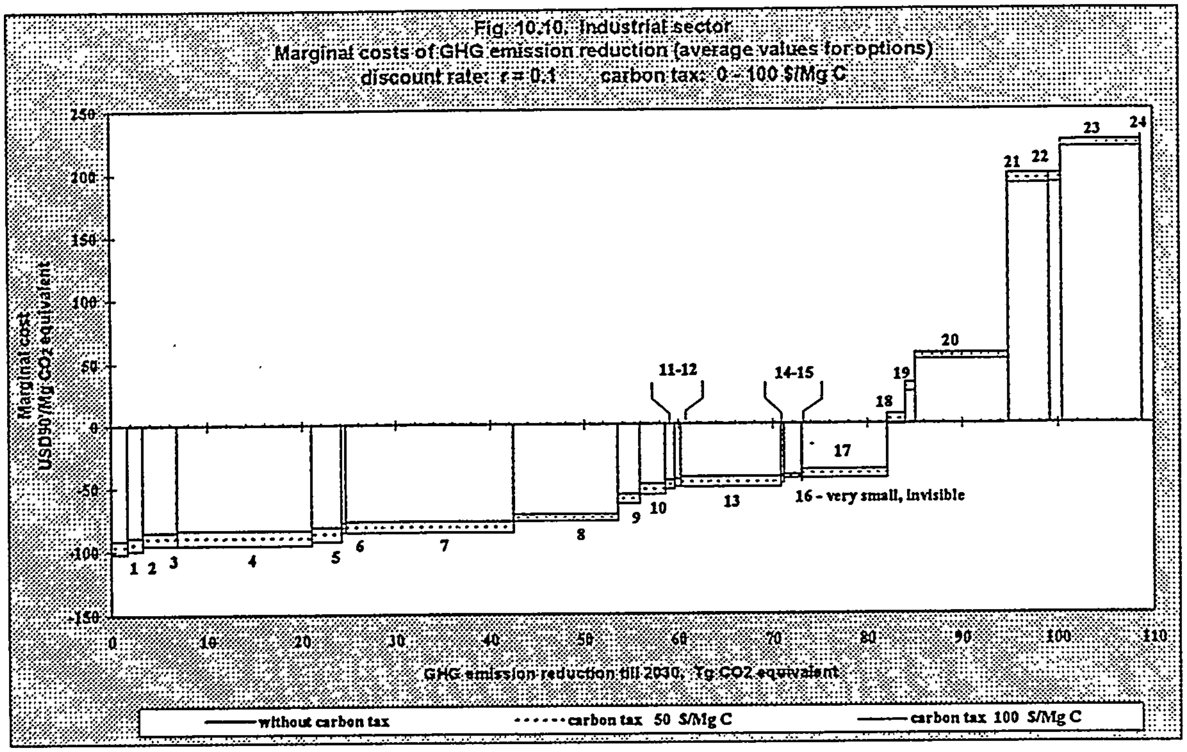
Sensitivity of the economy to carbon tax was initially tested by investigating influence of the tax on economic effectiveness of technological GHG reduction options for industrial , house-hold, municipal, commercial, services and renewable energy sectors. The results of calculations are presented in Figures 10.10. - 10.17. Weak influence of carbon tax on economic effectiveness of the GHG reduction options was stated. That is why for the chosen options, which implementation is required because of general needs of the economy (e.g. modernization of chemical and fuel and chemical industries), direct investment subventions were applied in order to activate the options.

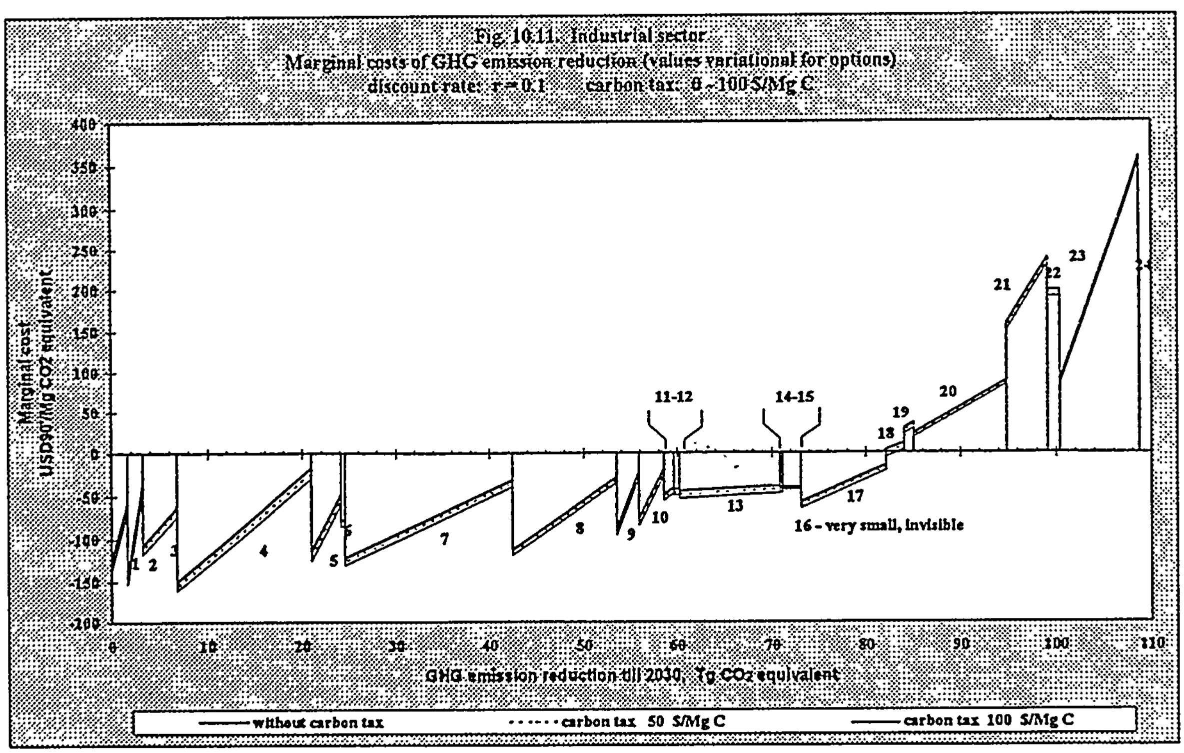
The technical potential of the GHG reduction options was estimated for the sectors (see Fig. 10.18 - 10.20). The GHG reduction under stimulation of carbon tax and investment subsidies for different macroeconomic scenarios is presented in Figure 10.21. The above data are the results of the technological, bottom-up procedure.

Investments, carbon tax, subsidies are the common input data for both bottom-up and top-down procedures. While elaborating macroeconomic scenarios, the consistency of the macro and sectoral results was carefully observed. Inconsistency of both bottom-up and top-down methods is a well known methodological problem.

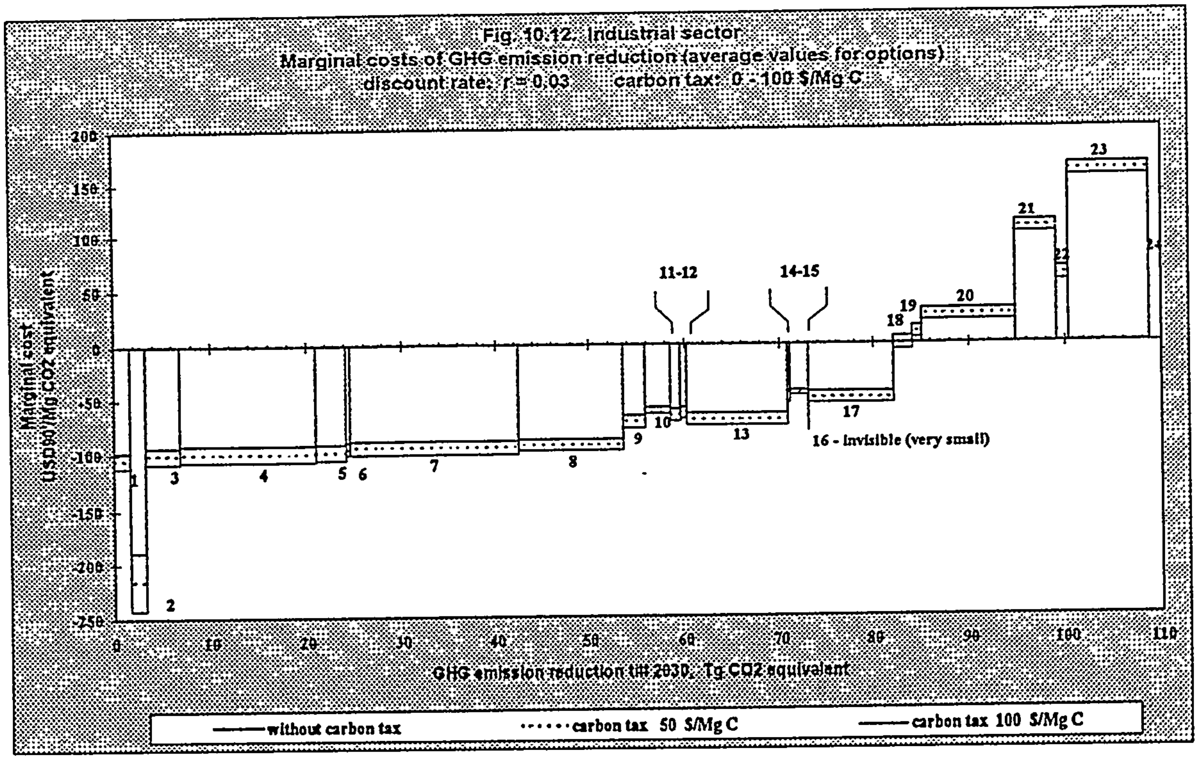
The problem related to this Study is discussed in Chapter 10.6.4.

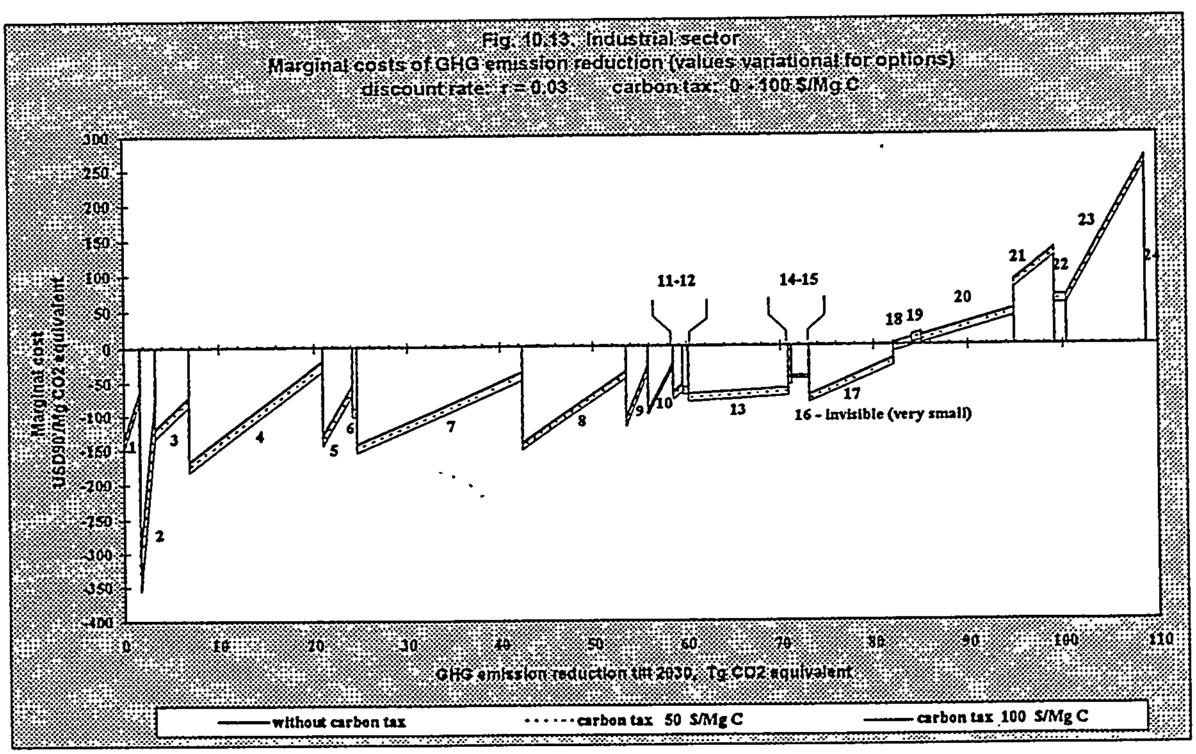
Marginal costs of the GHG emission reduction in the industrial sector discount rate r = 0.1



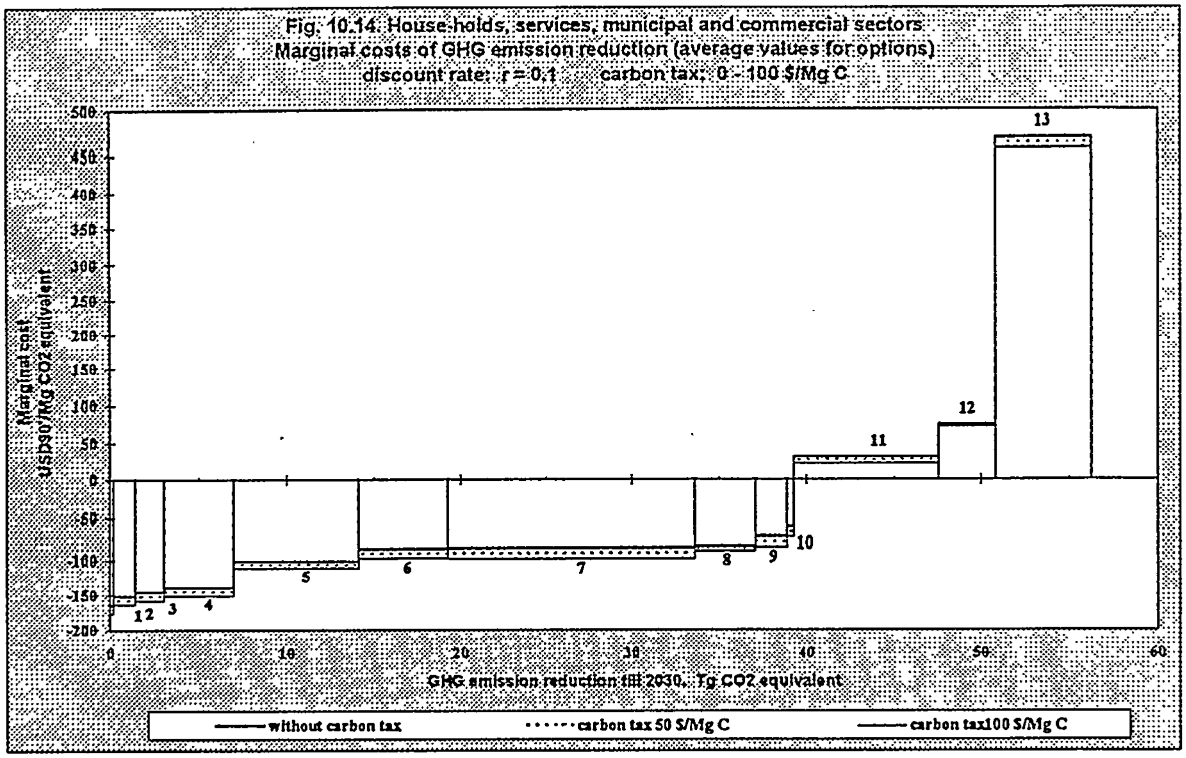


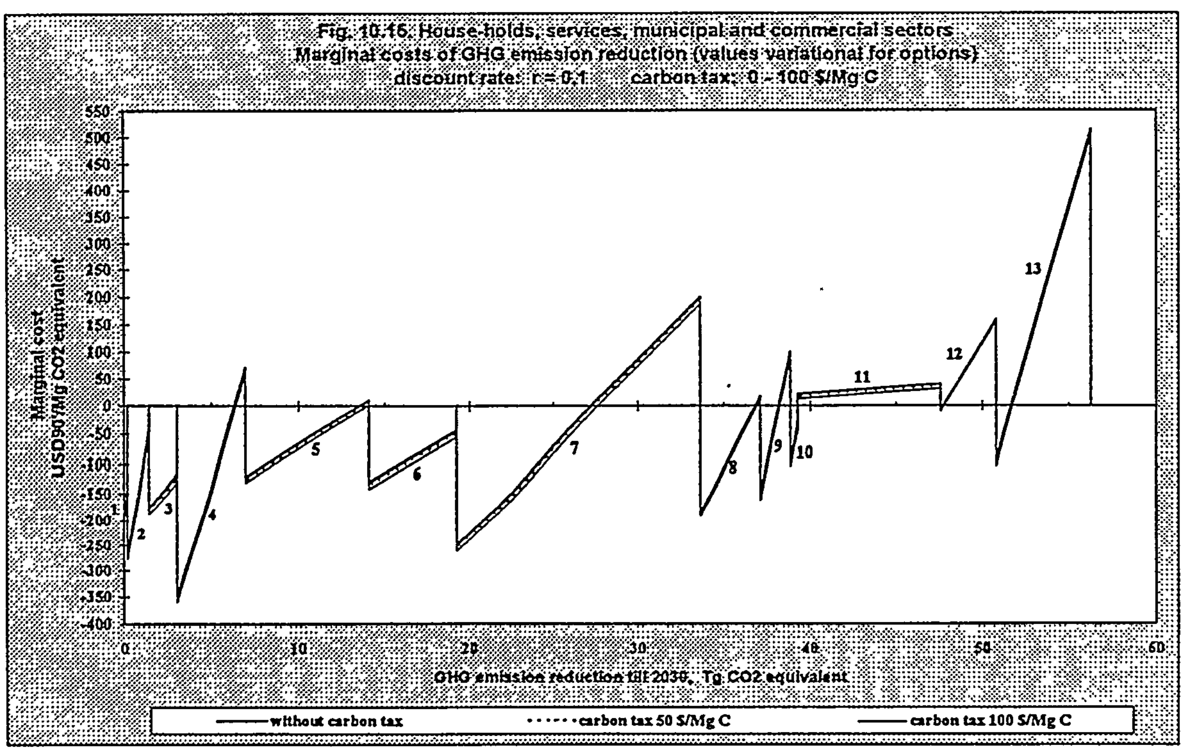
Marginal costs of the GHG emission reduction in the industrial sector discount rate r = 0.03



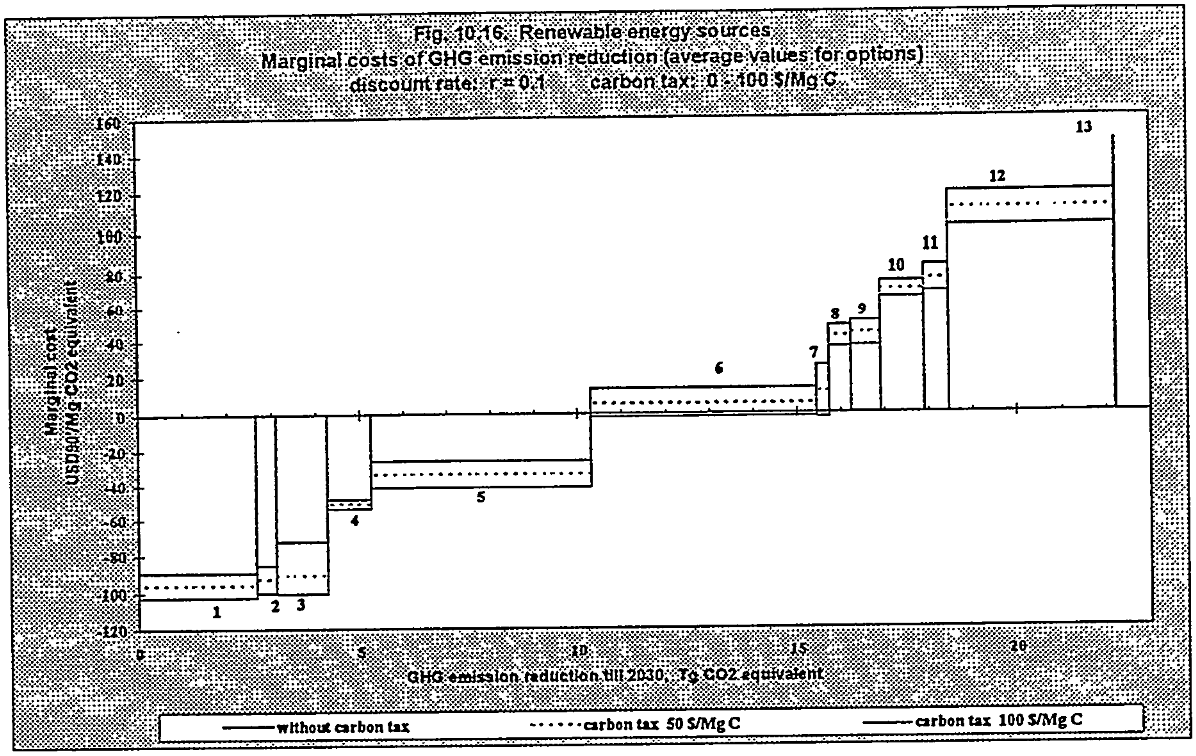


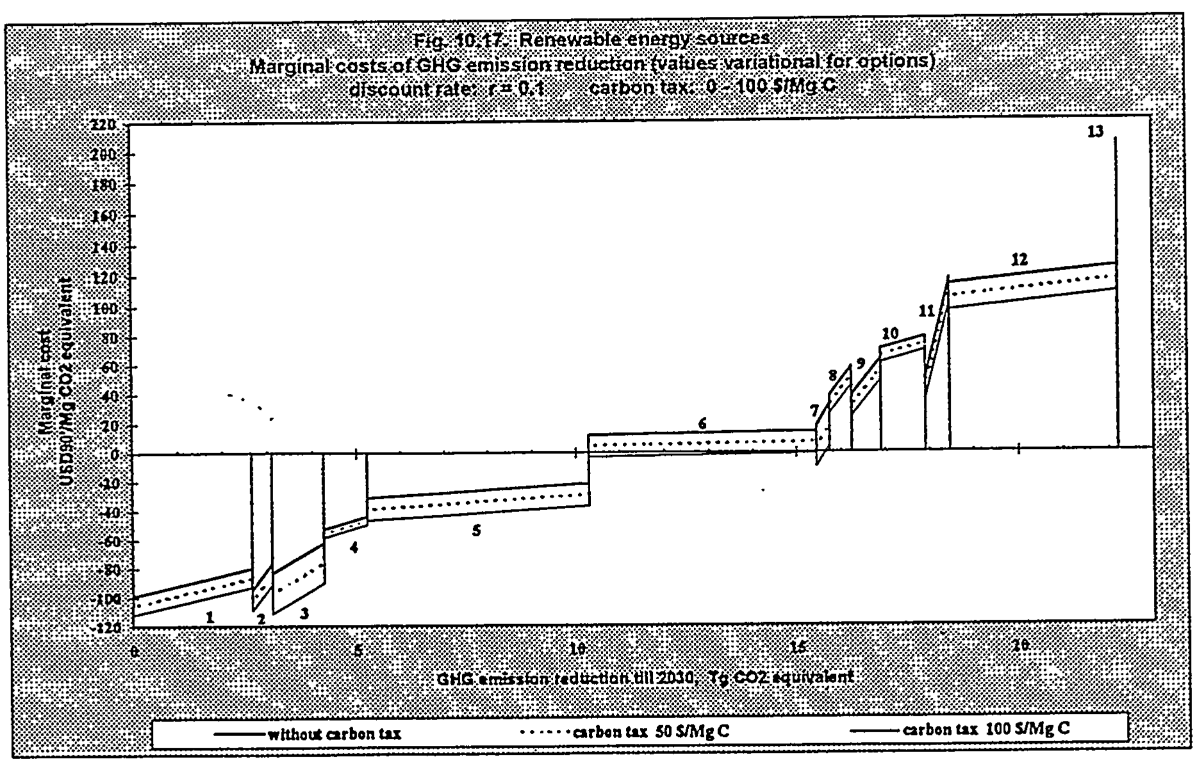
Marginal costs of the GHG emission reduction in house-holds, services, munnicipal and commercial sectors discount rate r = 0.1





Marginal costs of the GHG emission reduction for renewable energy sources discount rate r = 0.1





Technical potential of GHG emission reduction in sectors.
- bottom-up results -

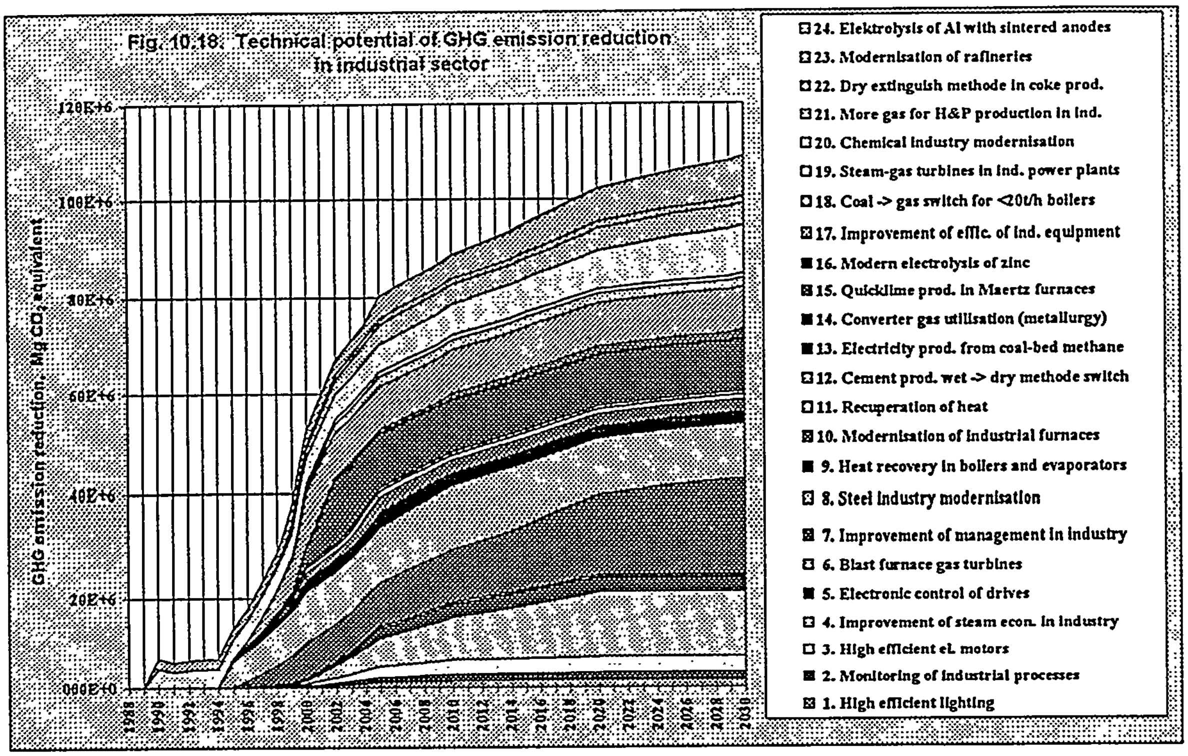


Fig. 10.18. Technical potential of GHG emission reduction in industrial sector

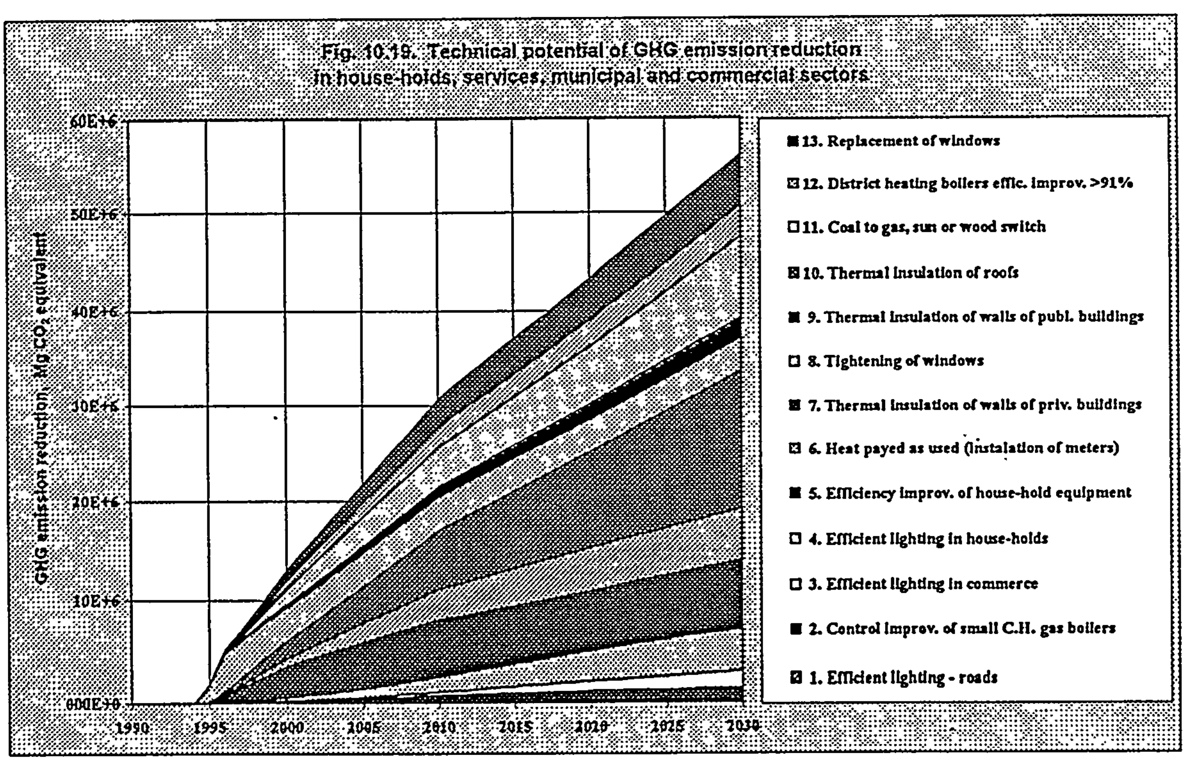
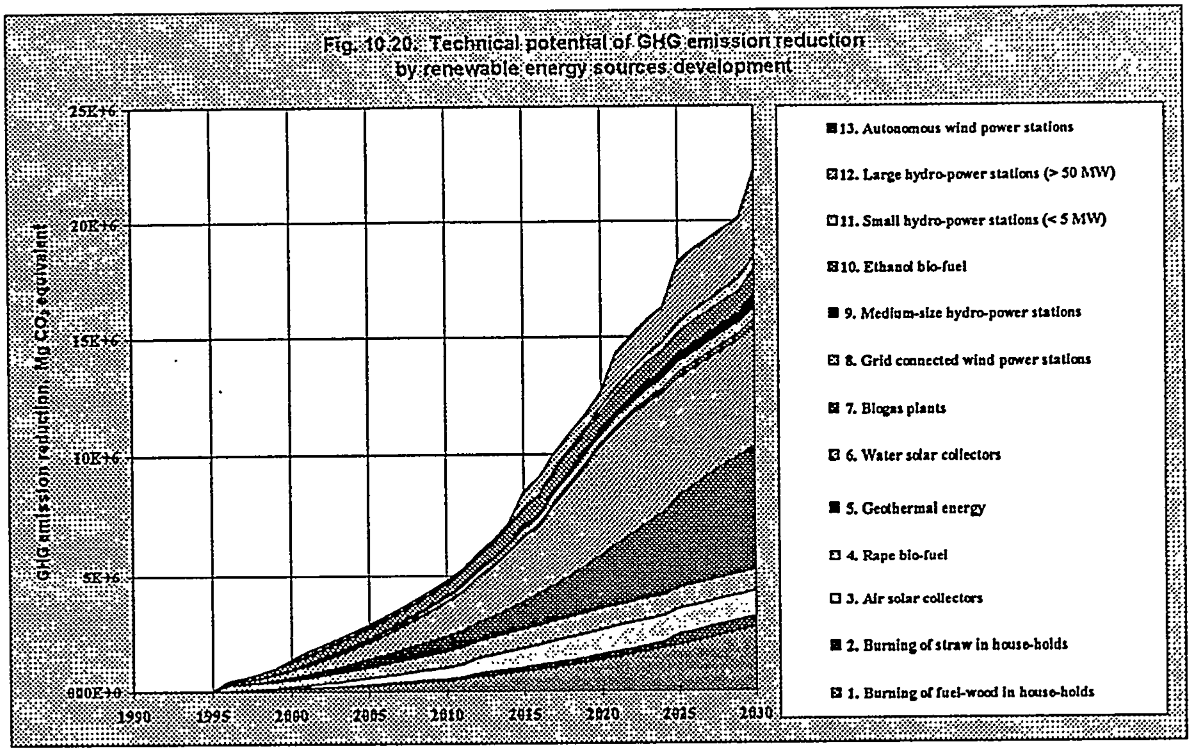
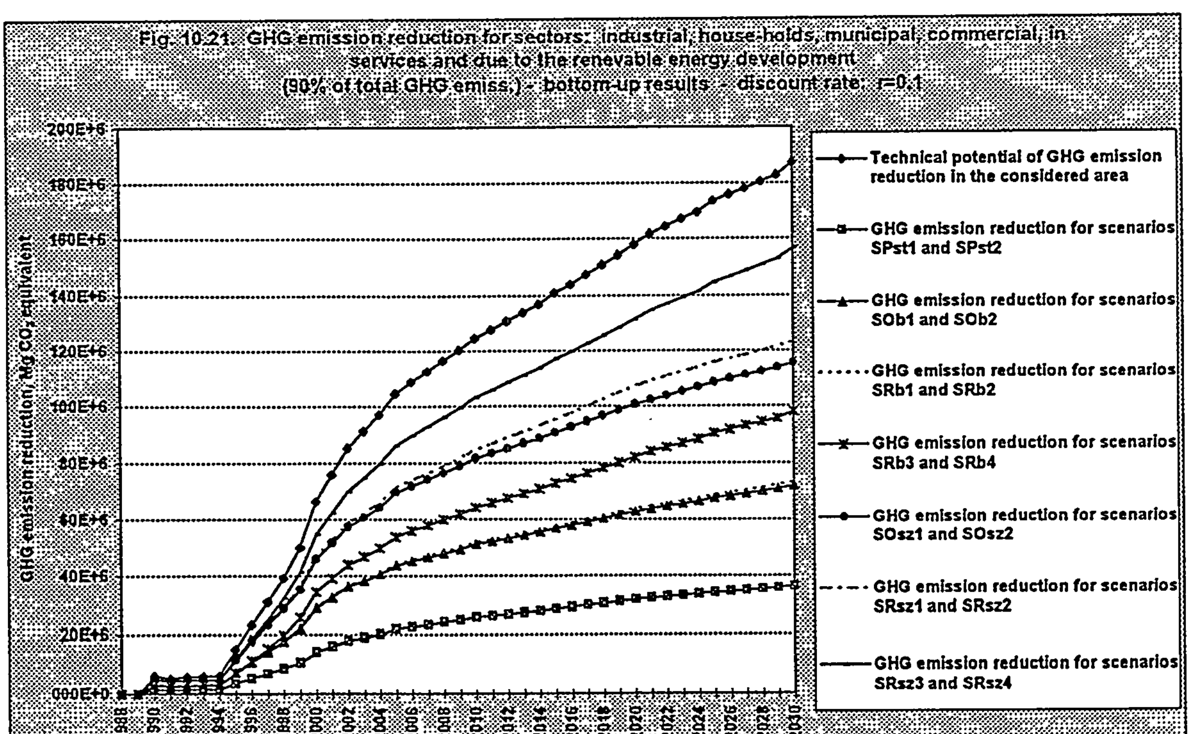


Fig. 10.19. Technical potential of GHG emission reduction in house-holds, services, municipal and commercial sectors

Technical potential of GHG emission reduction in sectors - bottom-up results -





10.3.1. GHG Abatement Scenarios referred to the Base-line Reference Scenarios

Four scenarios have been analysed for the following combinations of the input assumptions:

Abatement Scenarios */			Input assumptions		
Symbol	Policy stimulation	Climate warming	Carbon tax **/	Subventions for investors	Temperature growth rate
			USD 90'/Mg C	million USD 90'/a	$^0C/a$
SRb1	weak	moderate	50	-	0.05
SRb2	weak	rapid	50	-	0.10
SRb3	strong	moderate	50	approx. 75	0.05
SRb4	strong	rapid	50	approx. 75	0.10

*/ compare the definitions and symbols with Table 10.1.
**/ the carbon tax was introduced progressively from 2000 to 2030 (The values in the Table refer to the year 2030).

The total investments in the country are presented in Figure 10.22.

The investments for the GHG reduction options assigned to the considered here scenarios for the entire economy are presented in Figure 10.23. The values were assessed by sectoral data analysis.

On the basis of the above set of data macroeconomic simulations of the development of national economy was performed. The results are presented in Figures. 10.24. - 10.31.

10.3.2. GHG Abatement Scenarios referred to the Reference Scenarios of Chance

Four scenarios have been analysed for the following combinations of the input assumptions:

Abatement Scenarios */			Input assumptions		
Symbol	Policy stimulation	Climate warming	Carbon tax **/	Subventions for investors	Temperature growth rate
			USD 90'/Mg C	million USD 90'/a	$^0C/a$
SRsz1	weak	moderate	100	-	0.05
SRsz2	weak	rapid	100	-	0.10
SRsz3	strong	moderate	100	apr. 50	0.05
SRsz4	strong	rapid	100	apr. 50	0.10

*/ compare the definitions and symbols with Table 10.1.
**/ the carbon tax was introduced progressively since 2000 to 2030 (The values in the Table refers to the year 2030).

The adequate streams of investments for the entire economy for the reference scenarios SRsz1 and SRsz2 are presented in Figure 10.32., while the investments activating GHG reduction are presented in Figure 10.33.

On the base of the above set of data macroeconomic simulations of the development of national economy was performed The results are presented in Figures. 10.34. - 10.41.
Values of the main parameters of the elaborated macroeconomic scenarios in the numeric form are presented in Table 10.2.

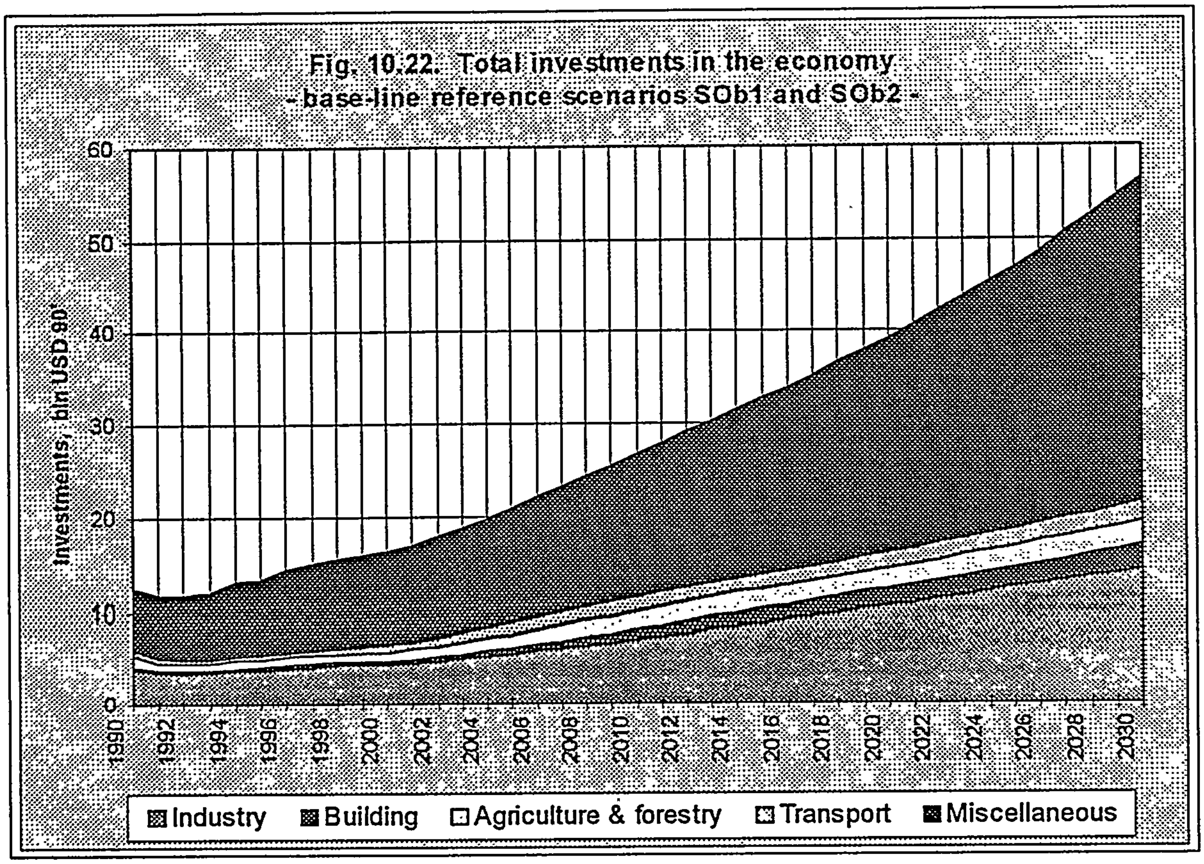
Table 10.2. Main parameters of the macroeconomic scenarios - numerical values

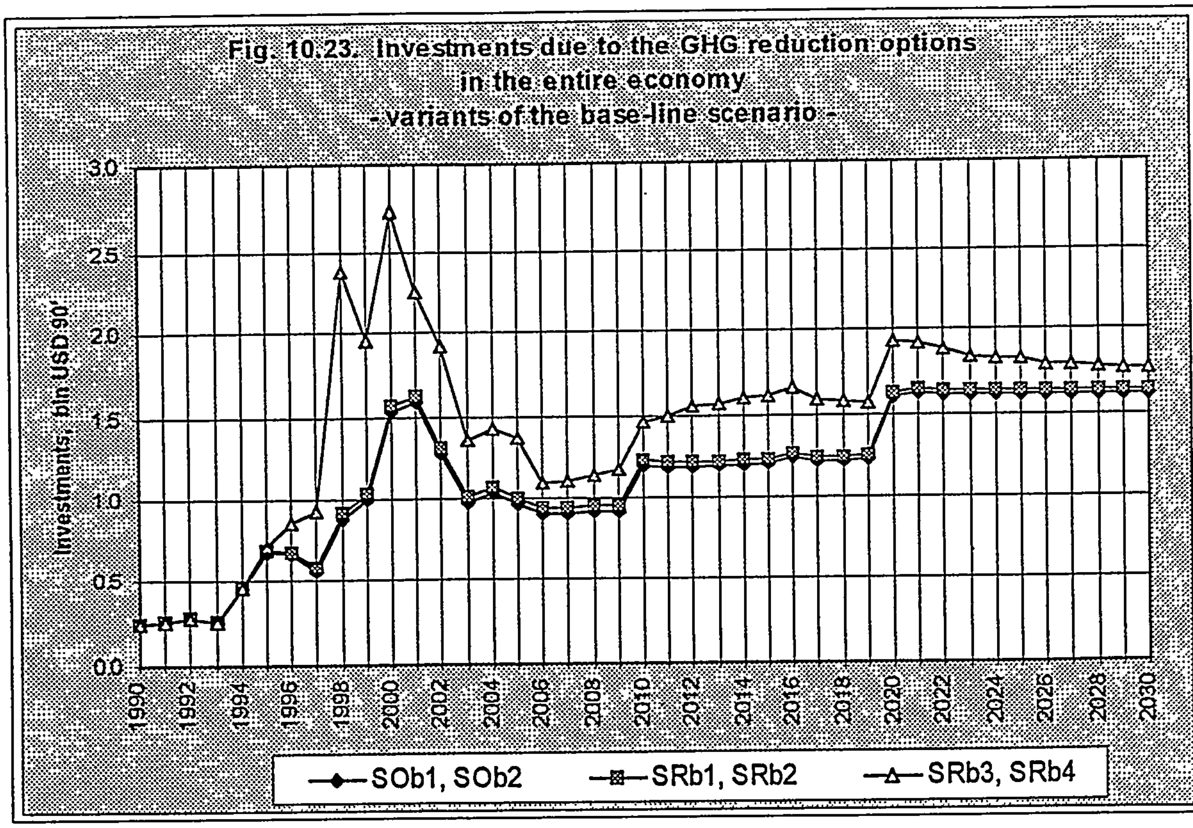
Scenarios	Gross Domestic Product bln USD 90'			Energy use PJ			Energy intensity of GDP MJ / USD 90'			Total investments in the economy bln USD 90'		
	1990	2010	2030	1990	2010	2030	1990	2010	2030	1990	2010	2030
SPst1	59	101	157	4323	5112	5529	73.3	50.8	35.2	11.9	23.5	43.5
SPst2	59	101	158	4323	5044	5340	73.3	49.9	33.7	11.9	23.5	43.5
SOb1	59	127	256	4323	5629	6795	73.3	44.4	26.5	11.9	26.6	56.4
SOb2	59	128	258	4323	5551	6560	73.3	43.5	25.4	11.9	26.6	56.4
SRb1	59	125	246	4319	5289	5990	73.2	42.4	24.4	11.9	26.6	56.4
SRb2	59	125	248	4319	5219	5802	73.2	41.6	23.4	11.9	26.6	56.4
SRb3	59	126	249	4182	5256	5803	70.9	41.6	23.3	11.9	26.9	56.5
SRb4	59	127	251	4182	5187	5619	70.9	40.8	22.4	11.9	26.9	56.5
SOsz1	59	145	352	4323	5121	7003	73.3	35.3	19.9	11.9	32.0	87.9
SOsz2	59	146	356	4323	5065	6819	73.3	34.7	19.2	11.9	32.0	87.9
SRsz1	59	141	321	4323	4663	5827	73.3	33.0	18.2	11.9	32.4	88.0
SRsz2	59	143	325	4323	4618	5693	73.3	32.4	17.5	11.9	32.4	88.0
SRsz3	59	145	333	4323	4627	5387	73.3	31.9	16.2	11.9	32.4	88.1
SRsz4	59	146	337	4323	4581	5259	73.3	31.3	15.6	11.9	32.4	88.1

Table 10.2. continued

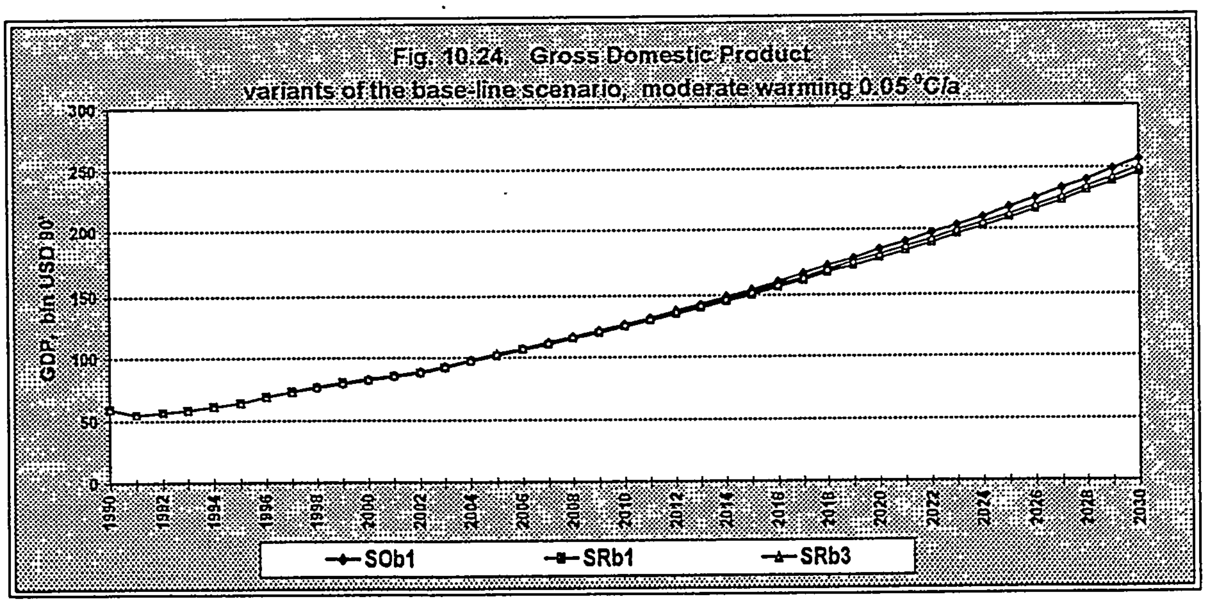
Scenariusze	Investments for the GHG reduction opt. mln USD 90'			GHG emission in the country mln Mg CO2			GHG emission reduction mln Mg CO2			Average macroecon. cost of GHG reduct. USD 90' / Mg CO2
	1990	2010	2030	1990	2010	2030	1990	2010	2030	1995 d0 2030
SPst1	125	596	809	393	476	521	-	-	-	-
SPst2	125	596	809	393	471	505	-	-	-	-
SOb1	250	1192	1618	393	502	578	-	-	-	-
SOb2	250	1192	1618	393	496	560	-	-	-	-
SRb1	250	1229	1645	393	469	501	0	33	77	55
SRb2	250	1229	1645	393	464	487	0	32	73	55
SRb3	250	1460	1767	393	470	495	0	32	83	4
SRb4	250	1460	1767	393	465	480	0	32	79	3
SOsz1	400	1907	2589	394	429	479	-	-	-	-
SOsz2	400	1907	2589	394	425	467	-	-	-	-
SRsz1	400	2300	2679	393	389	393	0	40	87	111
SRsz2	400	2300	2679	393	385	384	0	40	83	112
SRsz3	400	2336	2828	393	389	389	0	40	91	26
SRsz4	400	2336	2828	393	385	380	0	39	87	25

Investments in the national economy
- variants of the base-line scenario -





Gross Domestic Product
- variants of the base-line scenario -



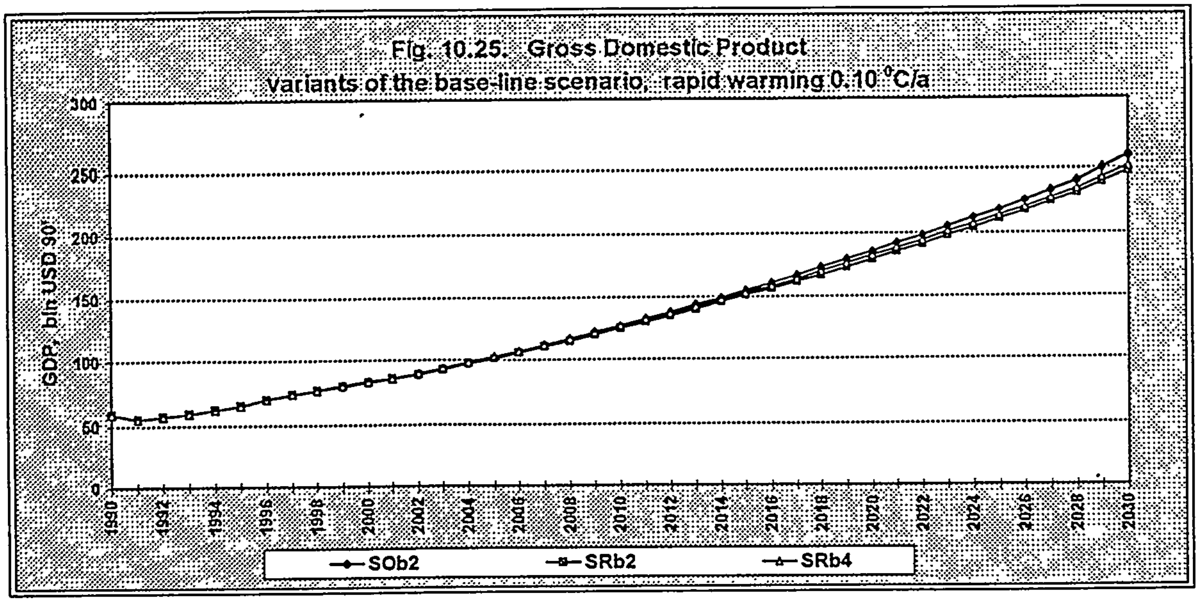


Fig. 10.25. Gross Domestic Product
variants of the base-line scenario, rapid warming 0.10 °C/a
GDP, bln USD 90'
SOb2
SRb2
SRb4

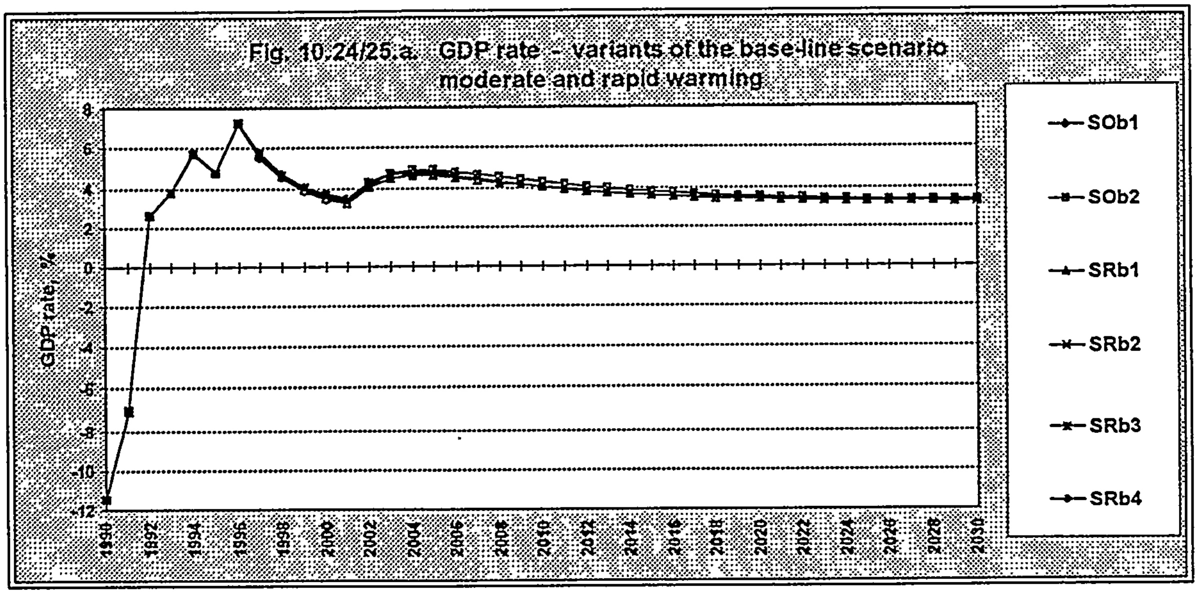
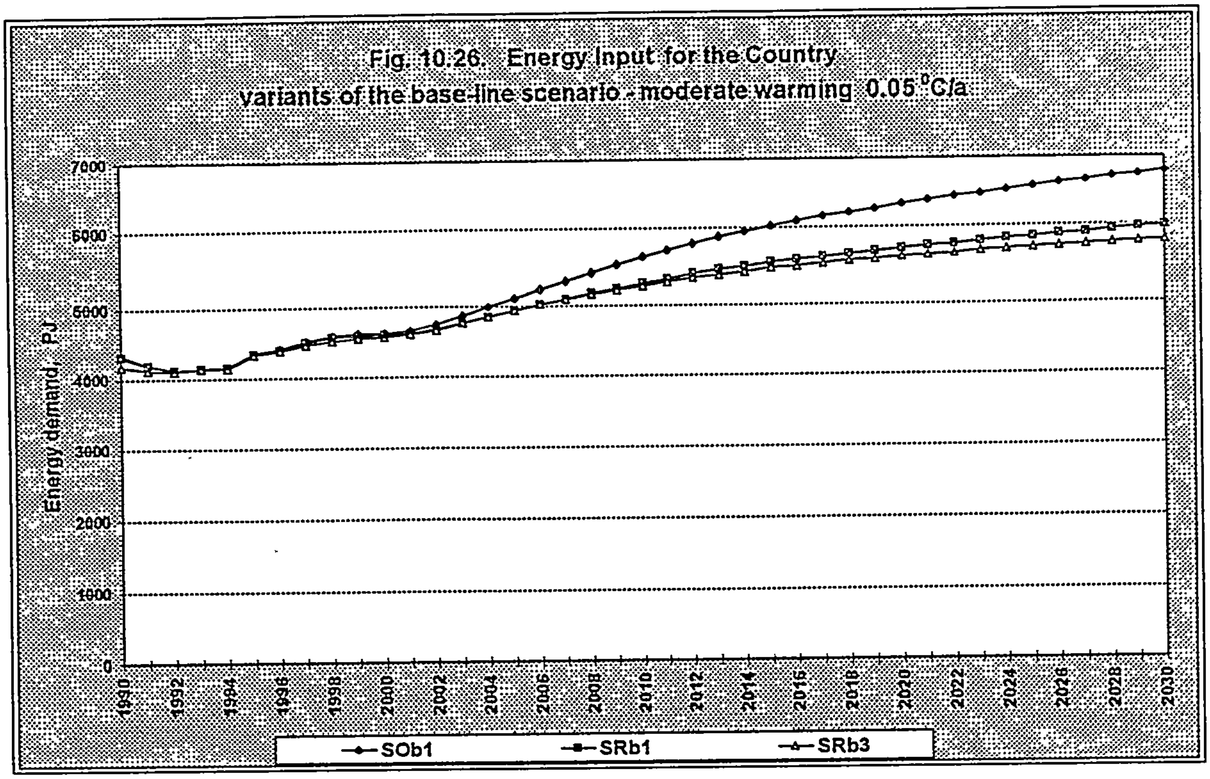


Fig. 10.24/25.a. GDP rate - variants of the base-line scenario
moderate and rapid warming
GDP rate, %
SOb1
SOb2
SRb1
SRb2
SRb3
SRb4

Energy supply to the national economy
- variants of the base-line scenario -



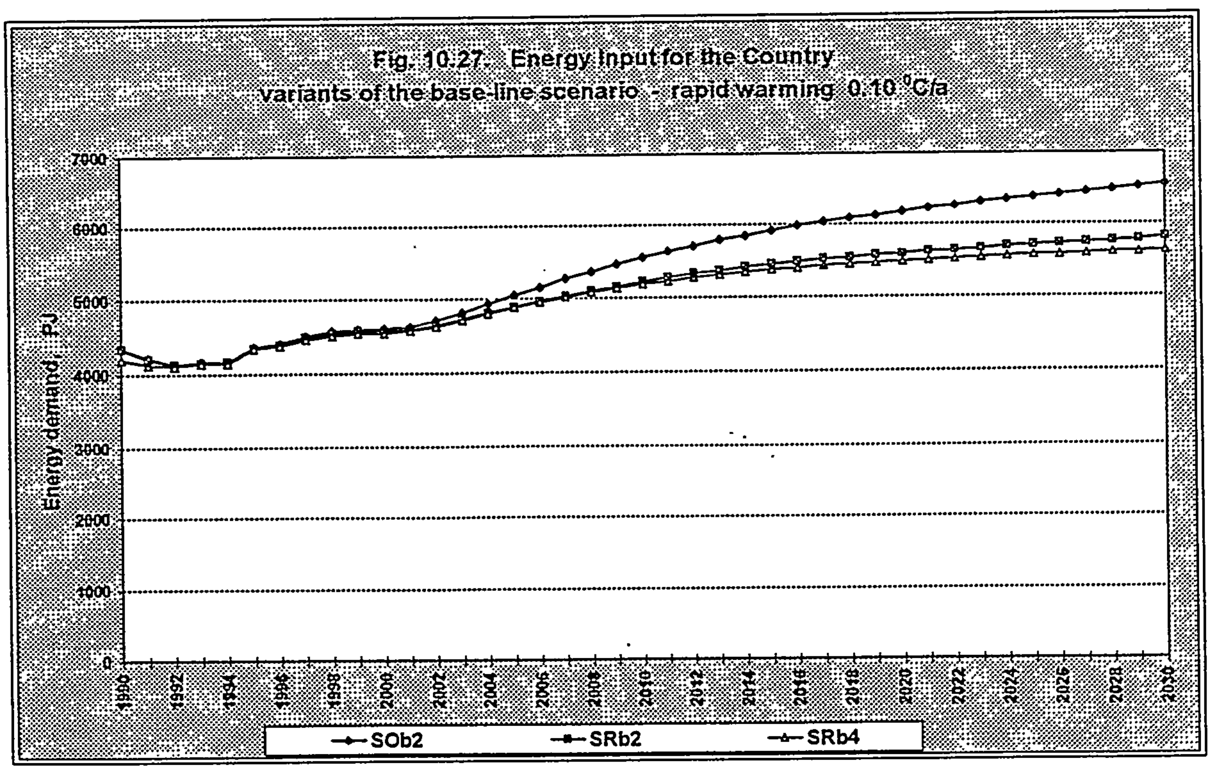
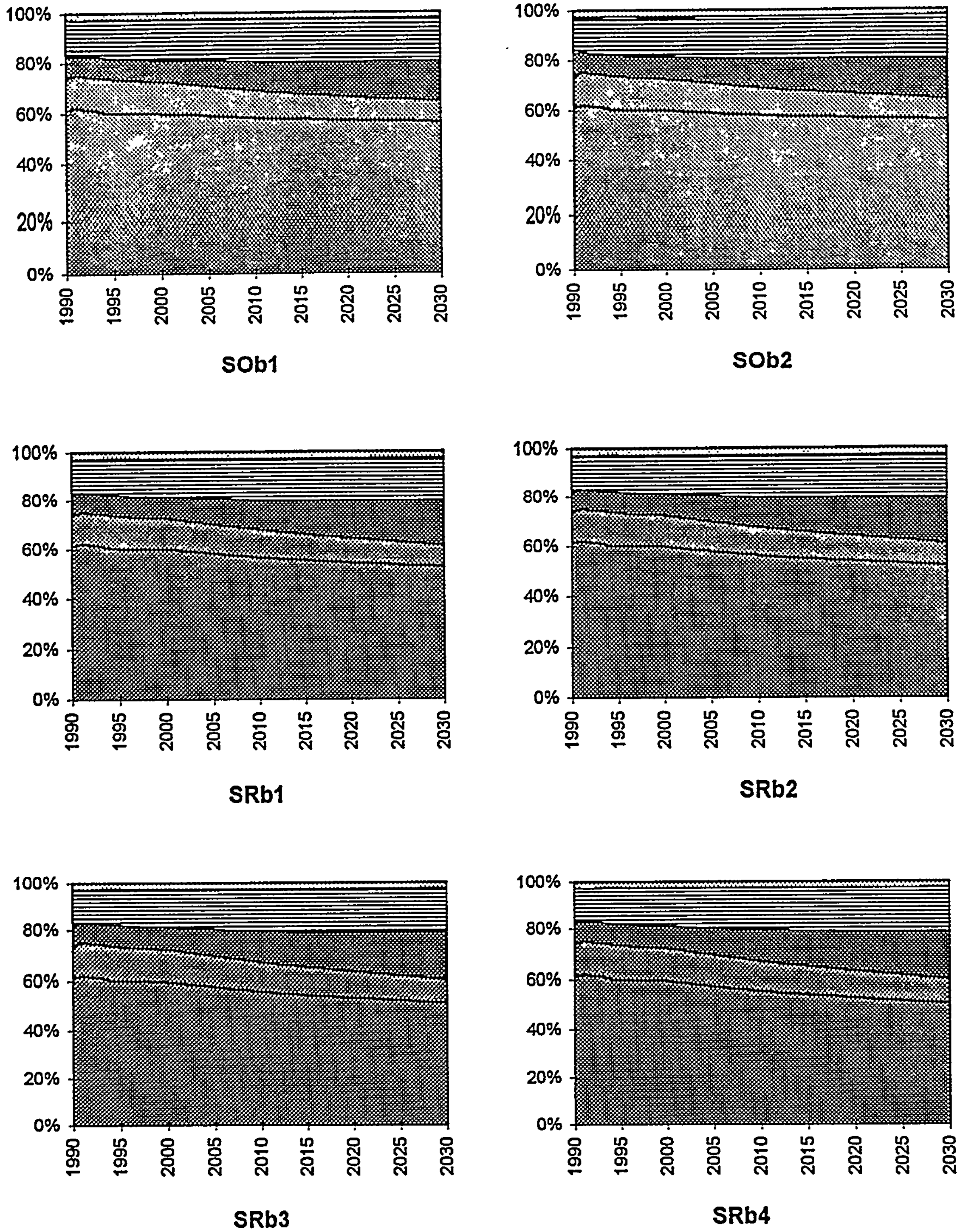


Fig. 10.28. Energy supply structure
- variants of the base-line scenario -

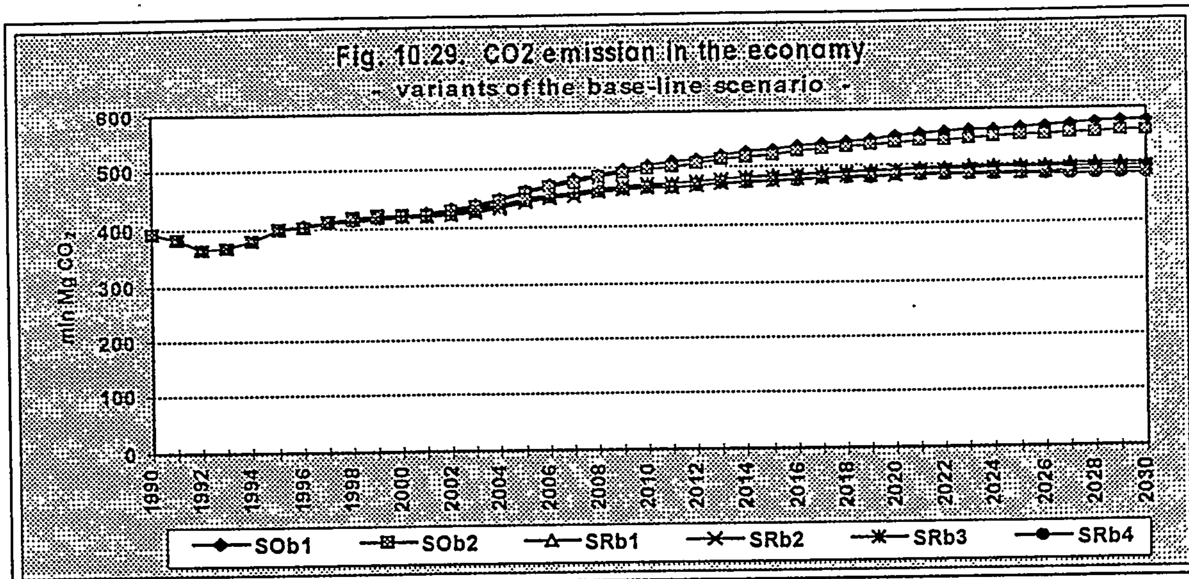


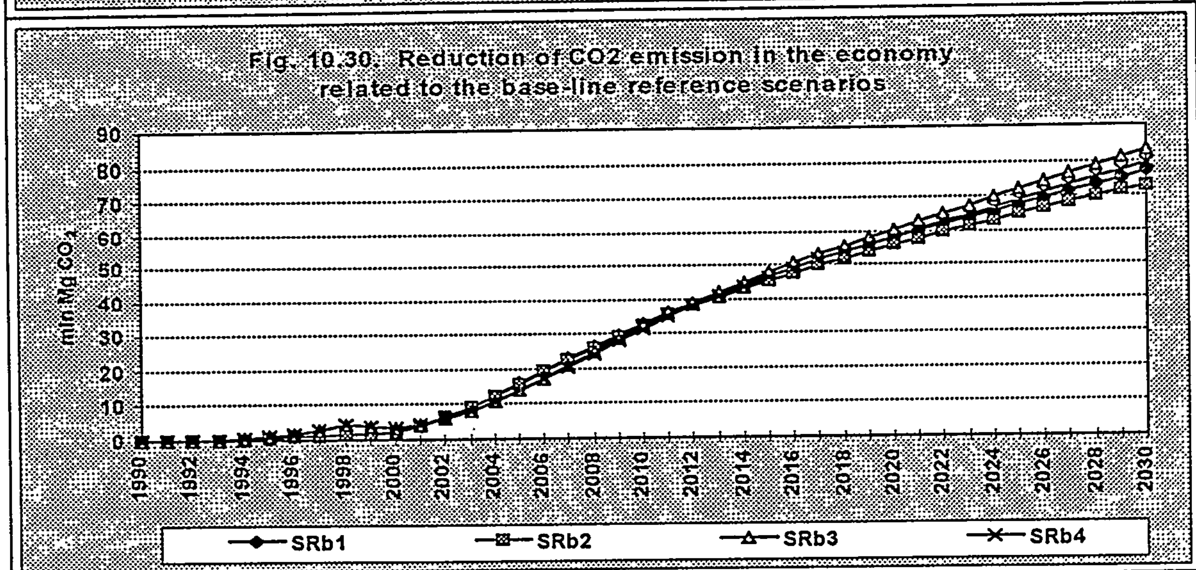
Legend:

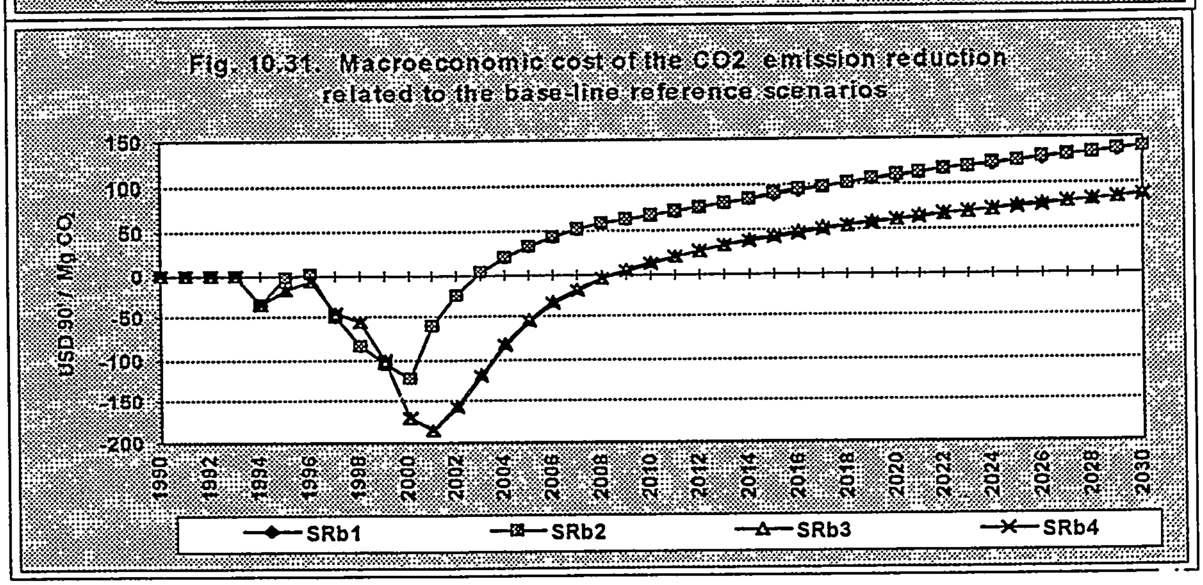
Hard coal | Brown Coal | Natural gas

Crude oil | Nuclear energy (lacking) | Hydro & other renewable

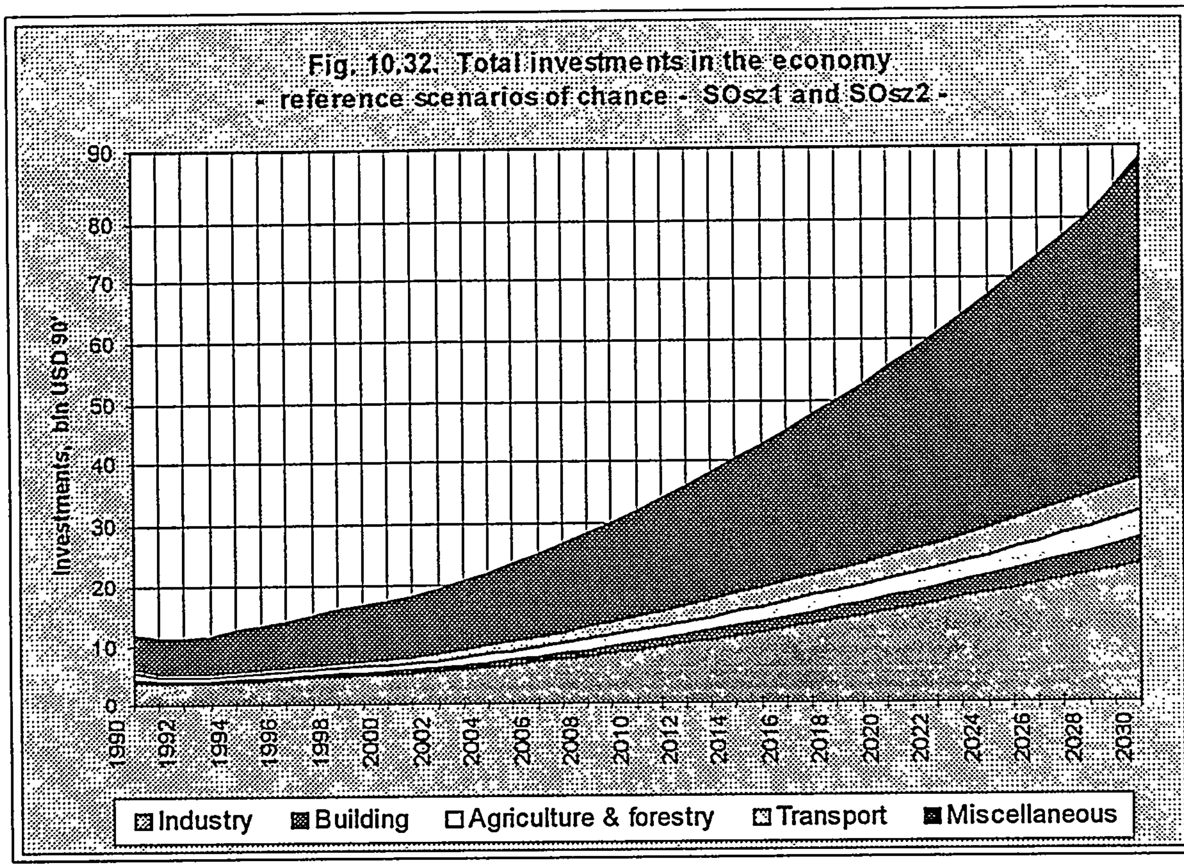
GHG emmision
- variants of the base-line scenario -

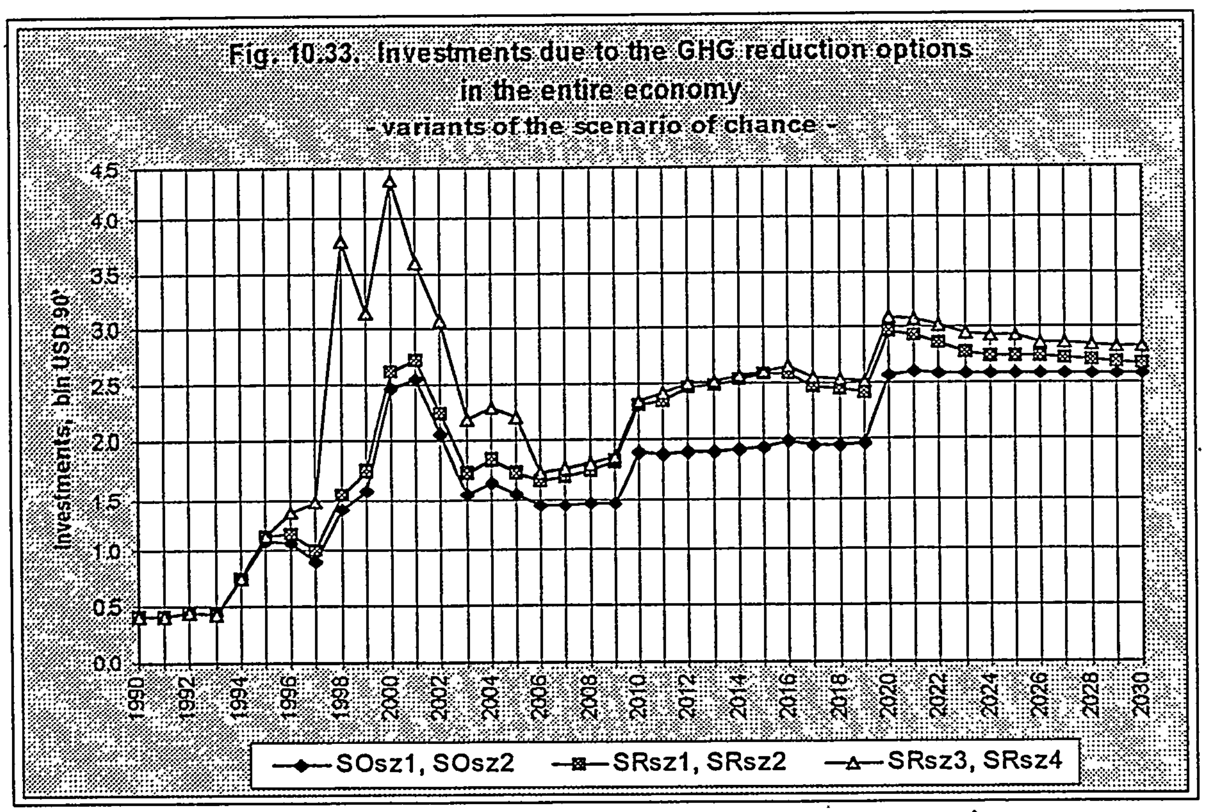




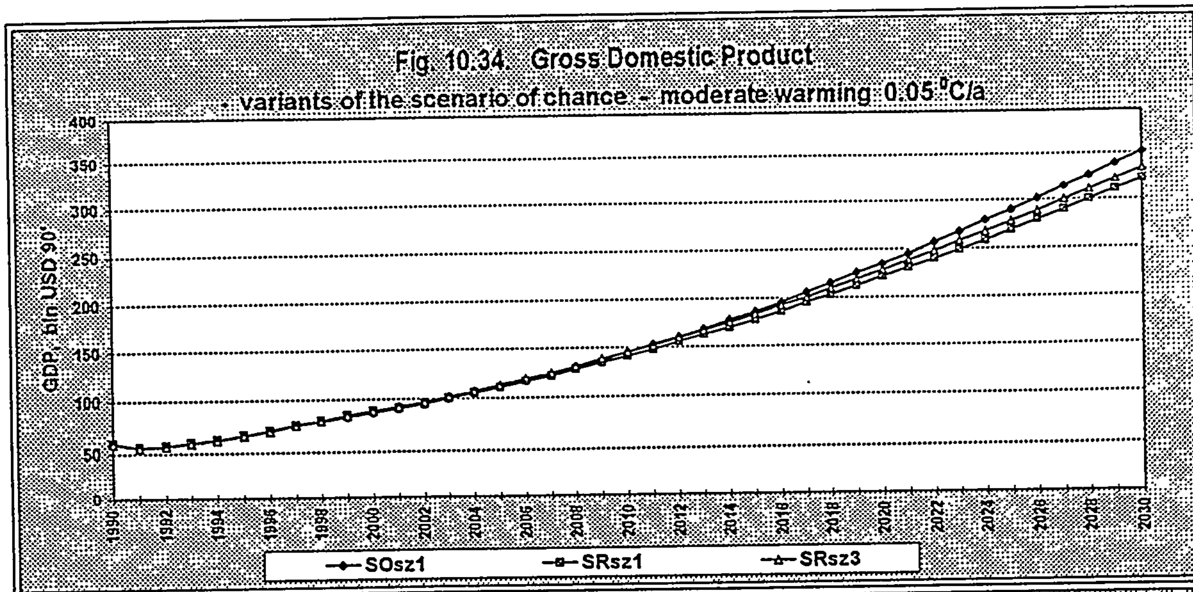


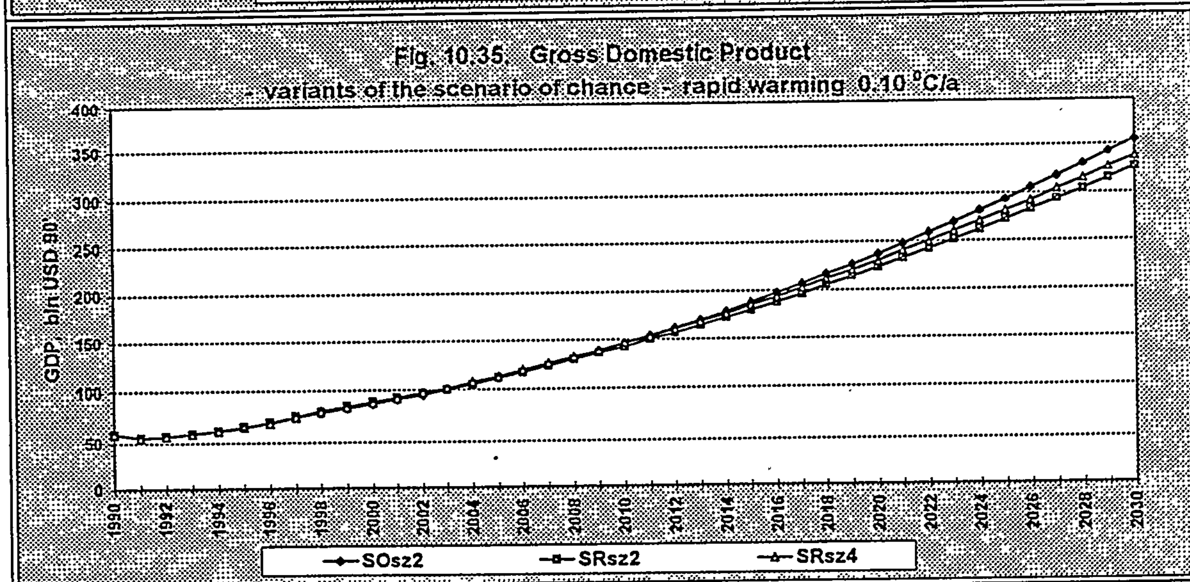
Investments in the national economy
- variants of the scenario of chance -

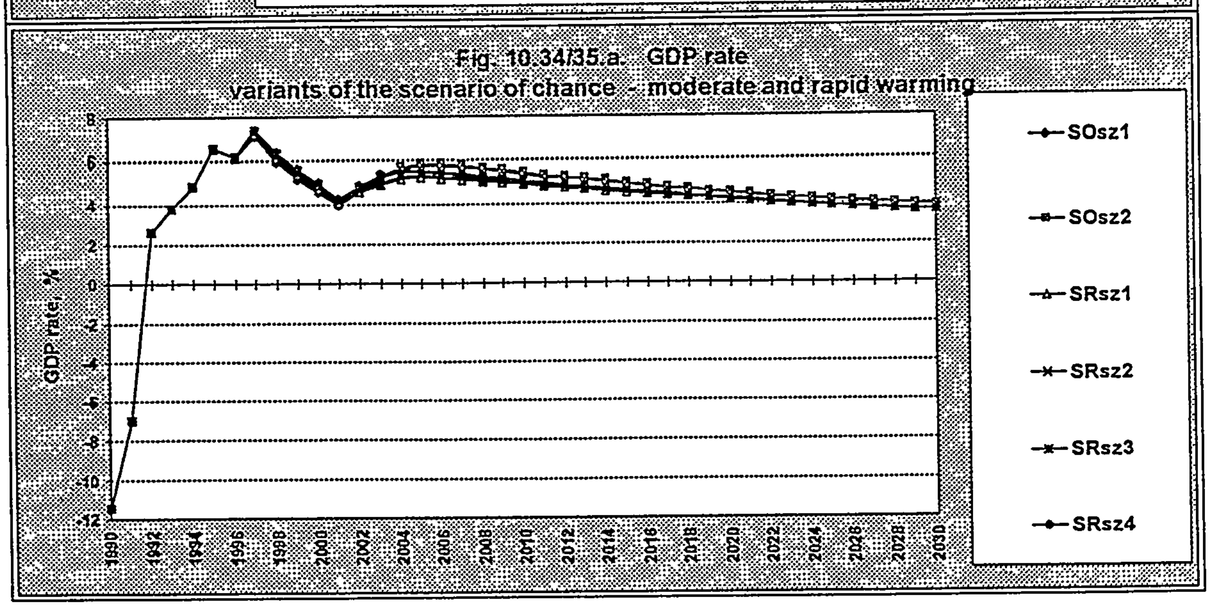




Gross Domestic Product
- variants of the scenario of chance -







Energy supply to the national economy
- variants of the scenario of chance -

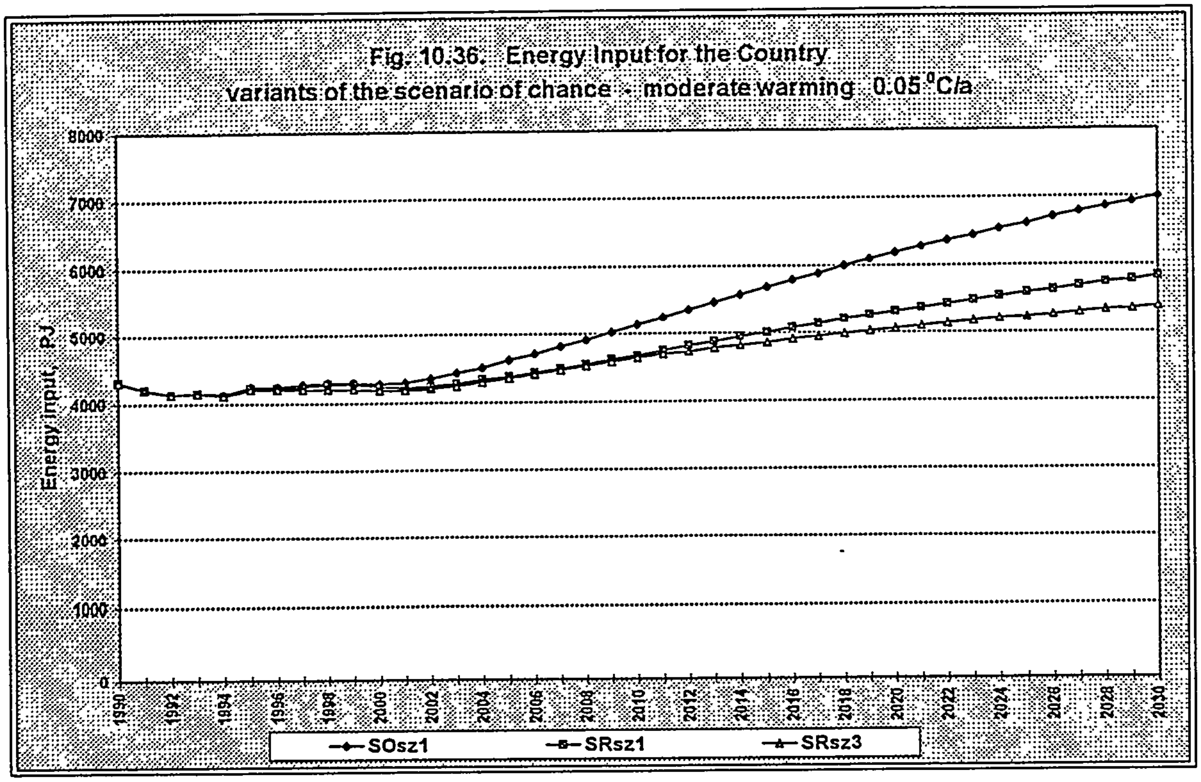


Fig. 10.36. Energy Input for the Country
variants of the scenario of chance - moderate warming 0.05 °C/a

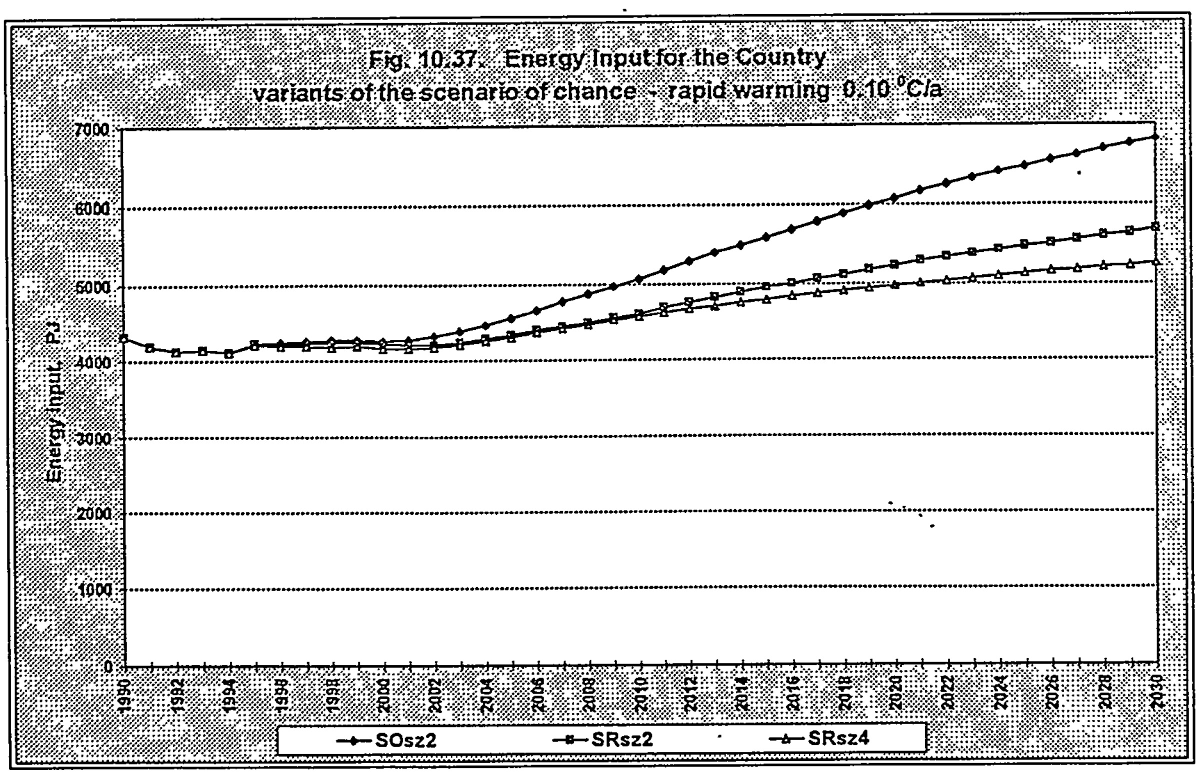
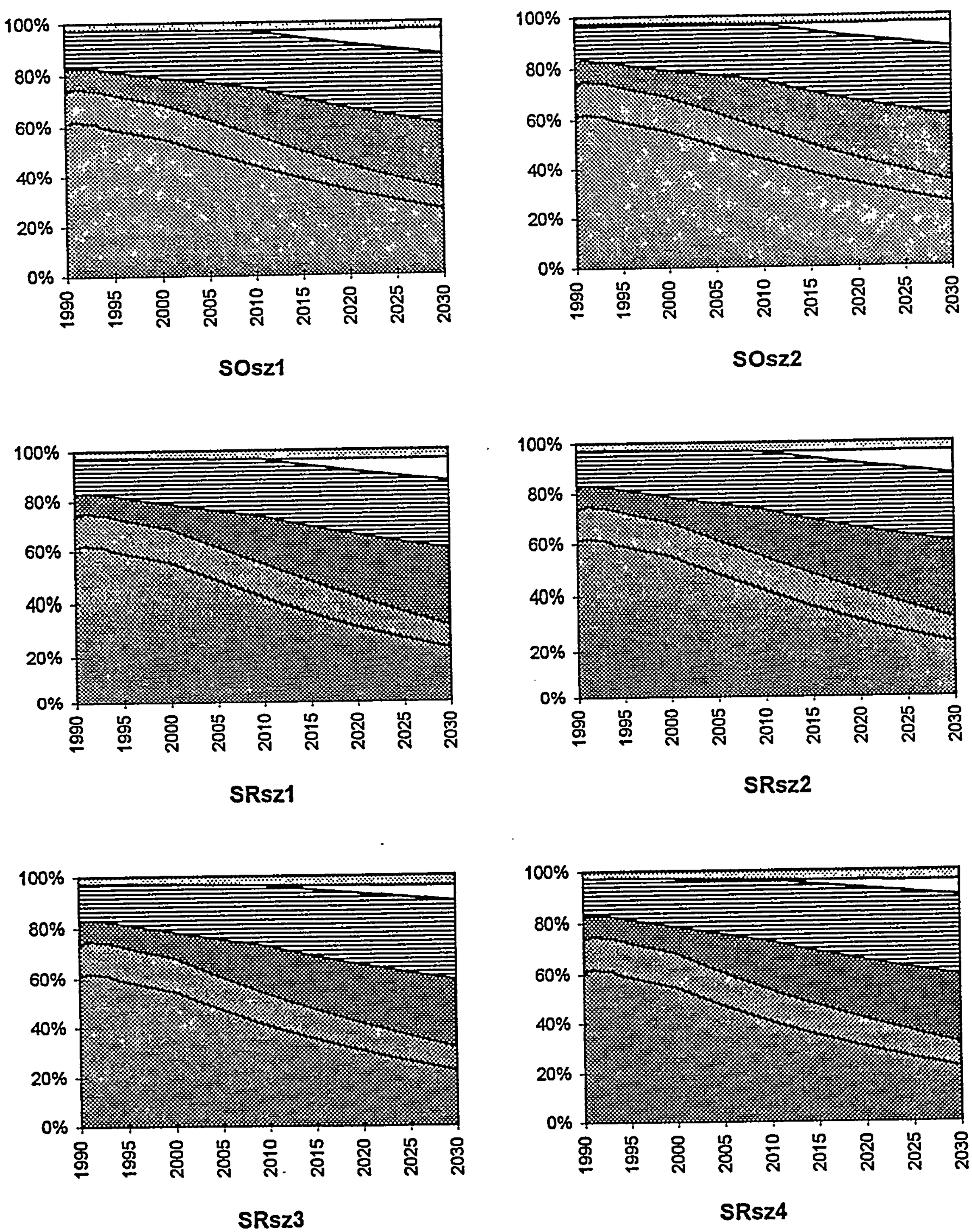


Fig. 10.37. Energy Input for the Country
variants of the scenario of chance - rapid warming 0.10 °C/a

Fig. 10.38. Energy supply structure
- variants of the scenario of chance -



Legend:

- Hard coal
- Natural gas
- Nuclear energy
- Brown Coal
- Crude oil
- Hydro & other renewable

GHG emmision
- variants of the scenario of chance -

Fig. 10.39. CO2 emission in the economy
- variants of the scenario of chance -

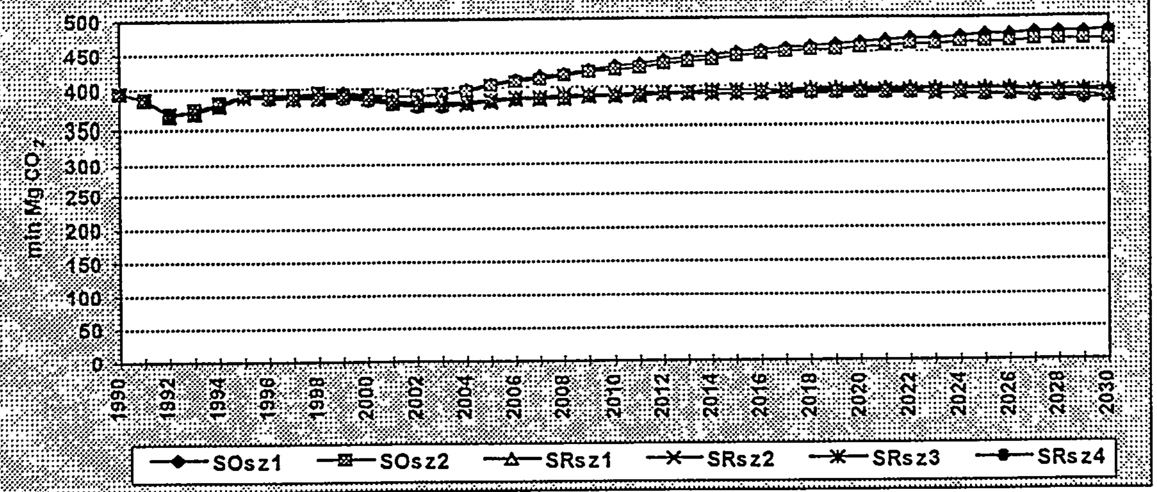


Fig. 10.40. Reduction of CO2 emission in the economy
related to the reference scenarios of chance

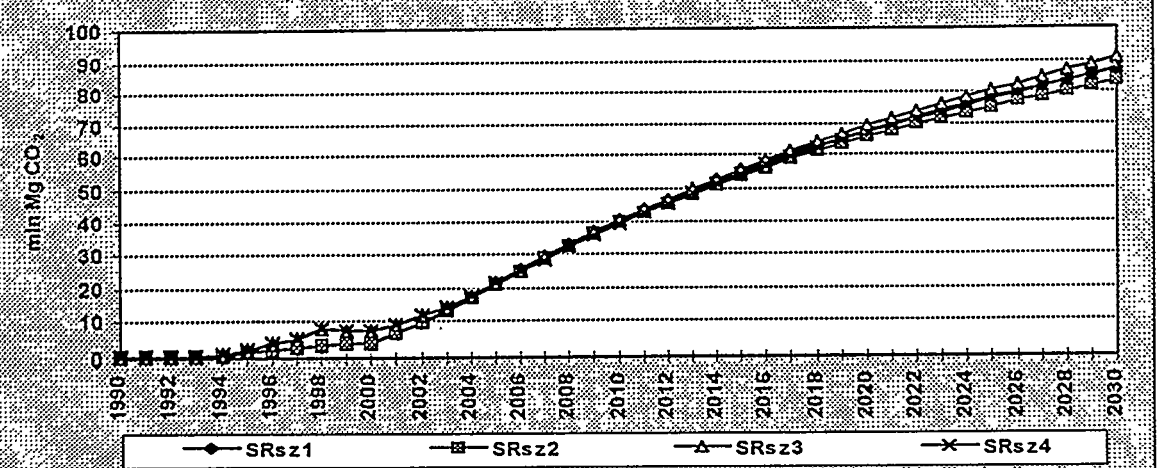
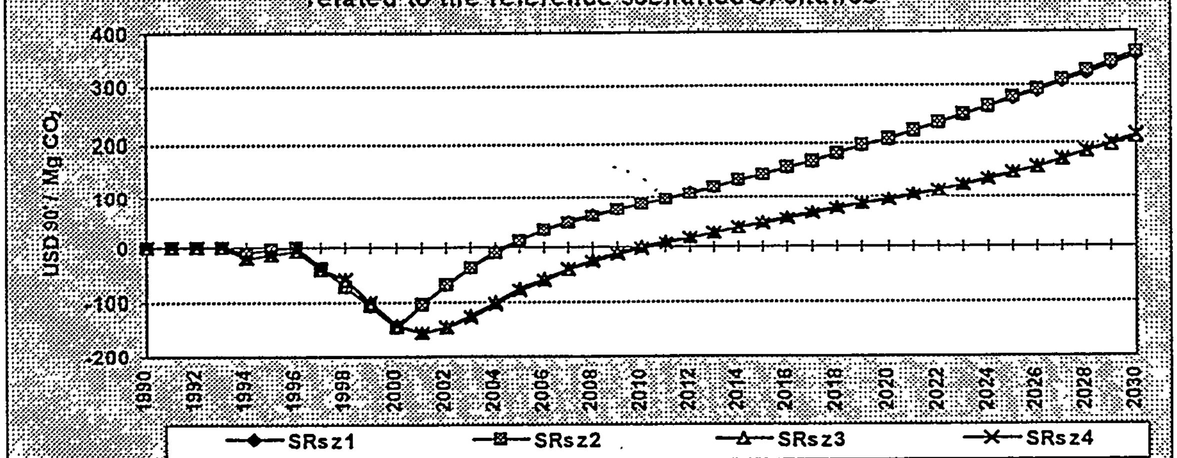


Fig. 10.41. Macroeconomic cost of the CO2 emission reduction
related to the reference scenarios of chance



10.4. Ranking of the GHG reduction scenarios according to the policy preferences (HIPRE3+)

The macroeconomic GHG reduction scenarios should be done respecting the preferences of the political decision makers. The Decision Analysis HIPRE3+ package was used to fulfil this requirement. A model reflecting the likely hierarchical structure of the criteria of assessment of alternative macroeconomic scenarios was elaborated (Fig. 10.42.). Mixed AHP + Smart technique (see description of the model Chapter 6.4.) was applied in the model.

The assessment criteria were defined with AHP technique at four hierarchy levels. The meaning of the criteria is as follows:

I level

A. 'Shrt hzn' - short horizon perspective (5 years),
b. 'Long hzn' - long horizon perspective (20 years and more),

II level

A. 'Economy' - national economy,
B. 'Soc.Prob.' - social problems,
C. 'Ecology' - natural environment,

III level

A. 'Internal' - internal aspects of the economic development of the country,
B. 'External' - international relations (foreign trade, foreign debt),
C. 'Absolute' - absolute level of social welfare,
D. 'Relative' - social justice, relations among social groups,
E. 'Global' - global environmental problems (mainly climate changes),
F. 'Local' - local environmental problems (SO2, NOx, CO, PM emission, surface water pollution etc.),

IV level

A. 'Struct' - structure of the economy,
B. 'En.Con.' - energy aspects of the economy (energy intensity of GDP etc.),
C. 'Growth' - economic development (dynamics of GDP, unemployment),
D. 'GHG p-cy' - climate policy,
E. 'Others' - other than climate related economic interrelations with international surrounding
F. 'Energy' - significance of the energy consumption for conservation of the natural environment
G. 'Technol' - significance of the technology of industrial production for the natural environment.

Assessment of weights of the criteria was done by experts from FEWE and chosen representatives of central offices.

Set of 34 attributes (see the last but one column in Fig. 10.42.) was defined to measure the alternative scenarios.

The resulting ranking of the scenarios is presented in Figure 10.43 a,b,c.

Both complex (Fig. 10.43.a) and more particular (short horizon - Fig. 10.43.b, long horizon - Fig. 10.43.c) assessments consider the scenarios of chance as strongly preferred, and scenarios of stagnation as the worst. The GHG reduction scenarios of chance are specially preferred because of their ecological positive features.

Full documentation of valorization of the scenarios contains additional valuable information. The documentation was not included in this report because of its size, but it is available in the archive of FEWE.

10.5. Ranking GHG reduction scenarios according to their probability (CIA)

Elaborated here GHG reduction scenarios (Chapter 10.3.) were assessed for the probability of occurrence. The CIA model was used for this purpose.

The CIA model is conceptually quite different from the SDM-NE macroeconomic model, which was the main tool for the scenarios creating. Also the procedure of the probability assessment is quite different and independent from the procedure of creating the scenarios. The CIA procedure is fully based on subjective opinions of experts. As a result, it gives much more different perspective of the assessment.

The CIA procedure starts with defining by experts the set of scenarios events (see the description of the method in Chapter. 6.3.) and the distribution functions of the probability of occurrence of the event under the assumption of the lack of inter-influence of the events in the set. The distribution functions are defined by the dead-lines of the events at two levels of probability $p = 0.1$ and $p = 0.9$. The events and dead-lines assessments are presented in Table 10.3.

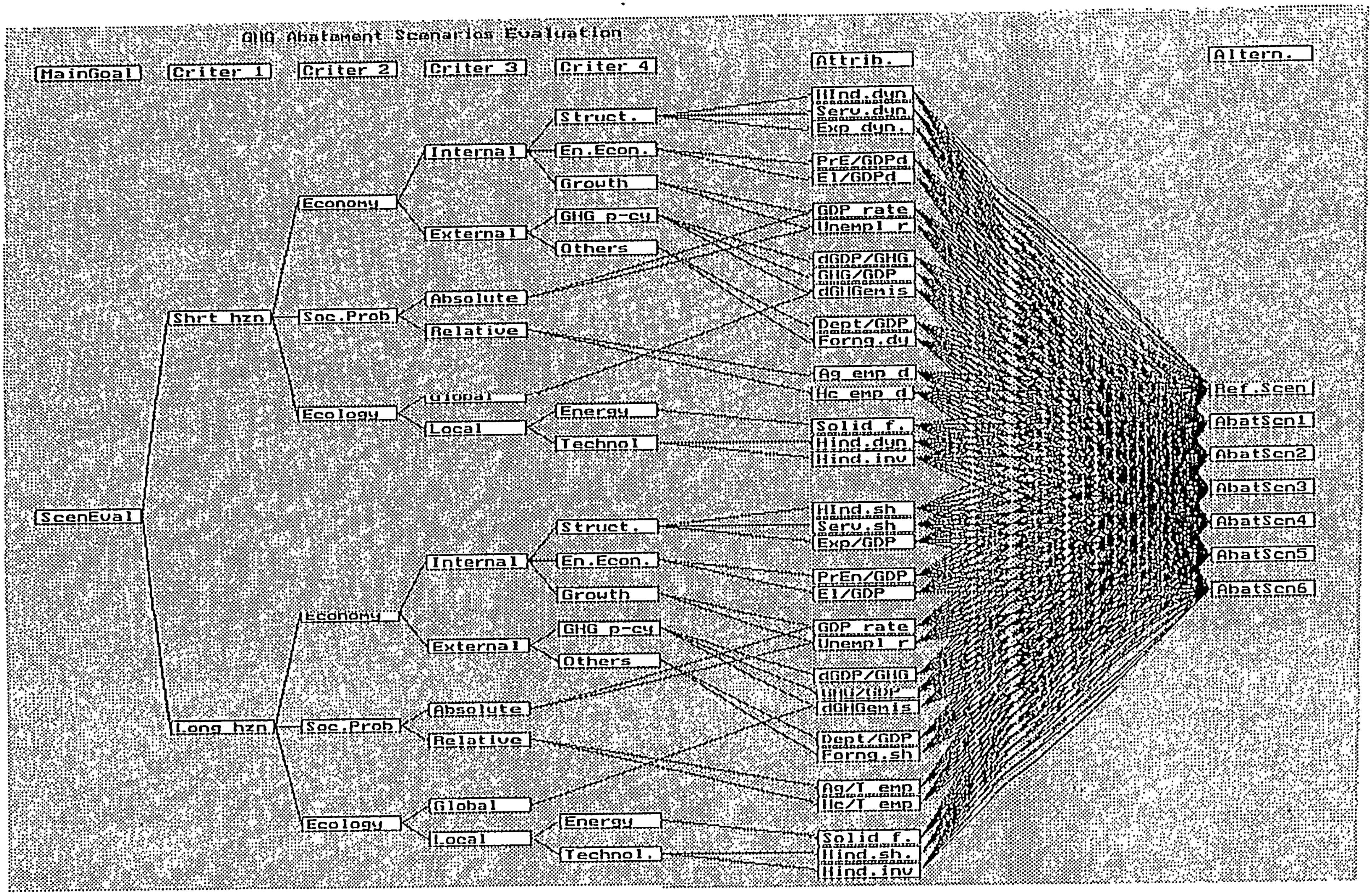
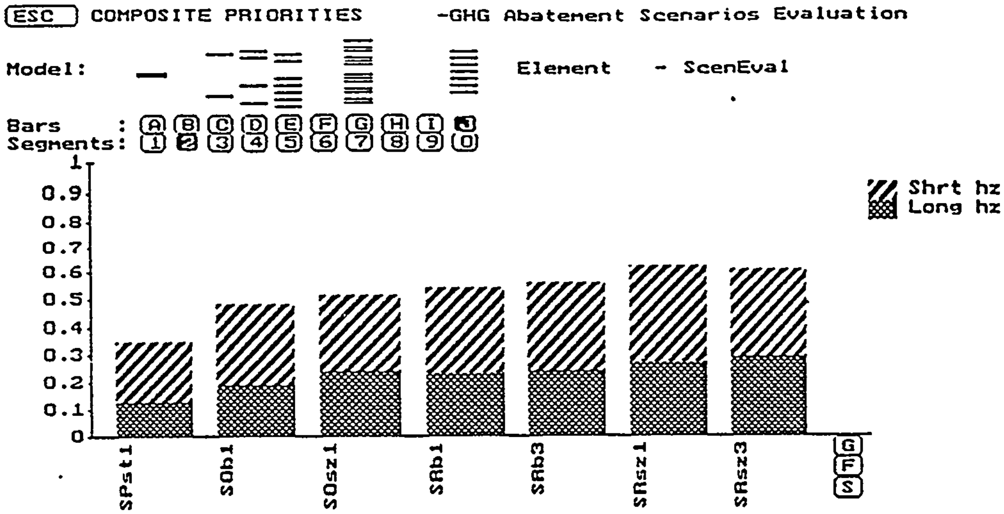
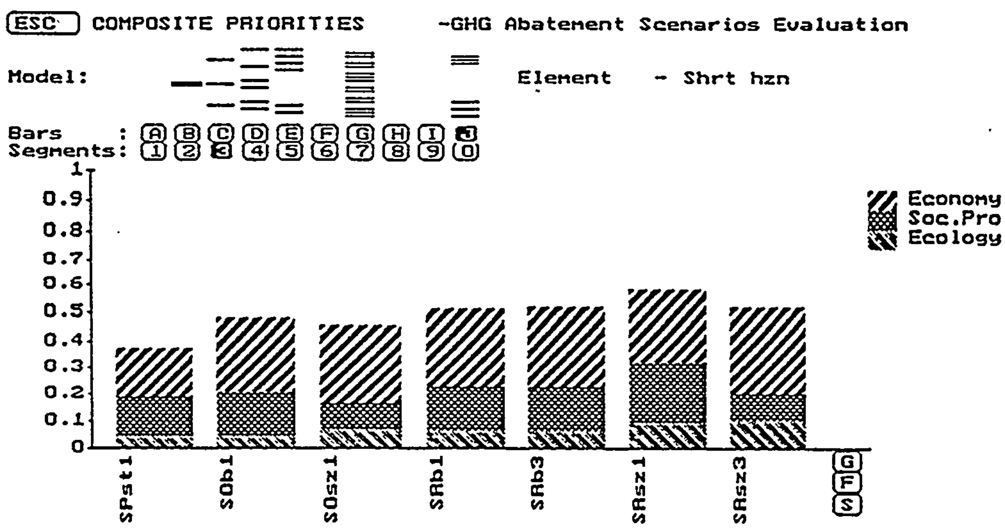


Fig. 10.42. Assessment of the GHG abatement scenarios - model of the decision process (HIPRE3+)

a) complex assessment of the scenarios



b) assessment of the scenarios from the short time horizon perspective



c) assessment of the scenarios from the long time horizon perspective

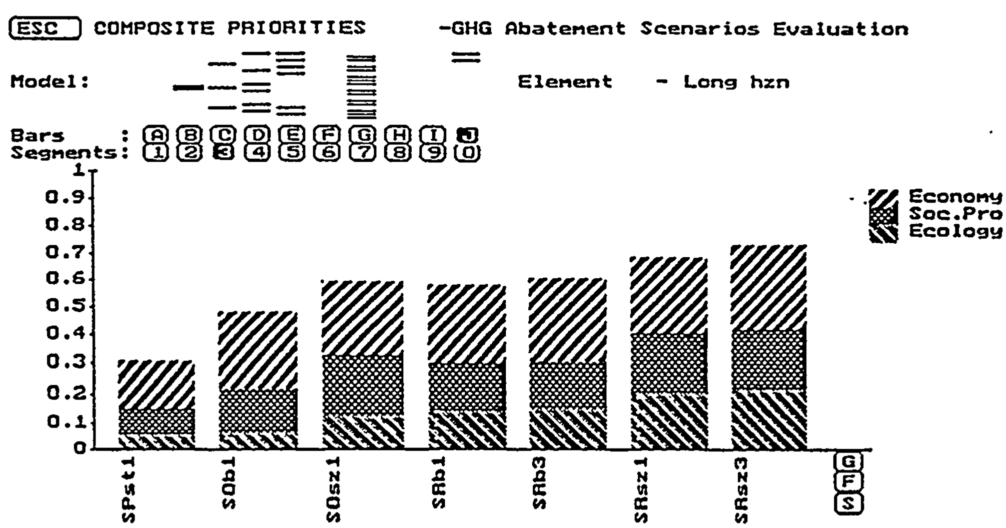


Fig. 10.43. Assessment of the macroeconomic scenarios due to the political preferences (results of the HIPRE3+ model)

Table 10. 3 . Set of the scenarios' events and assessment of their dead-lines for two levels of probability p= 0.1 and p = 0.9 (without inter-influence of the events in the set).

No	Events	Dead-lines at the probability:	
		10%	90%
1	GHG emission >1.2 x 1988 level	2007.5	2018.5
2	GDP/M >75% average in EC	2012.5	2027.5
3	Unemployment <6%	2007.5	2025.0
4	Agricult. and services similar to EC (+/- 20%)	2012.5	2025.0
5	Energy intensity of GDP < 1.2 x EC average	2007.5	2022.5
6	Number of high educated. people doubled	2010.0	2025.0
7	Purchase Power Parity = 0.9	1999.5	2007.5
8	Energy costs / total accommodation costs = 0.07	2005.0	2022.5
9	El.en./M > 0.6 x EC average	2007.5	2020.0
10	Hydrocarbon fuels >30% of primary energy	2010.0	2027.5
11	Renewable energy > 4% of primary energy	2017.5	2045.0
12	Nuclear energy >10% in the power sector f. mix	2022.5	2037.5
13	Yield of the 4 main rays >48q/h	2002.5	2017.5
14	>10h farms at = > 70% of agricultural area	2005.0	2020.0
15	Effective system of GHG policy regulations	2010.0	2027.5

Next the experts assessed inter influences the events in the set defining the cross impacts matrix (Table 10.4.).

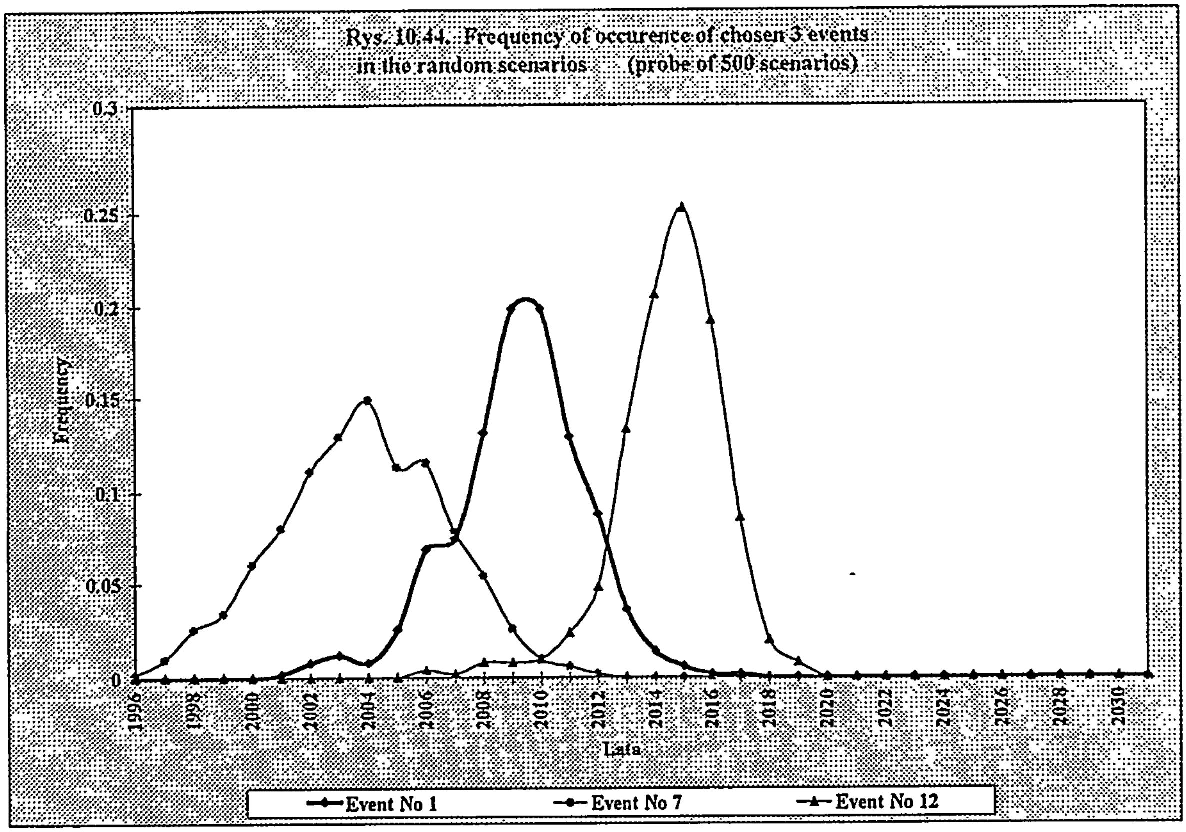
Force of impacts is scaled in the range <0,10>,and direction of the impacts defined by the sign (+/-).

Table. 10.4. Cross impacts matrix (numbers of events refers to the order in Table 10.3.)

affecting events \ affected events	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.0	3.0	2.0	1.0	-2.5	-0.5	-0.5	-0.5	2.5	2.0	4.5	1.0	0.5	1.0	5.0
2	6.0	0.0	6.0	7.5	7.5	7.0	7.5	7.0	8.0	6.5	4.5	1.0	5.5	3.5	6.5
3	5.0	6.5	0.0	7.0	2.5	5.5	3.0	5.5	6.5	2.0	3.5	0.0	-2.0	-2.0	3.5
4	-3.0	5.0	3.0	0.0	7.0	5.0	4.5	5.0	6.5	5.5	5.0	-1.5	7.5	8.0	3.5
5	-5.0	4.0	3.5	2.5	0.0	2.5	3.5	7.5	5.5	1.0	-1.5	-3.0	0.5	0.5	0.0
6	-3.0	7.5	6.0	5.5	6.5	0.0	3.0	3.0	3.5	5.0	6.5	1.0	6.5	7.5	6.5
7	-3.0	6.0	2.5	5.5	5.5	2.5	0.0	5.0	5.5	5.0	2.0	0.5	4.0	5.0	4.5
8	1.5	2.0	2.5	3.0	3.0	2.5	0.5	0.0	5.0	4.0	1.0	0.0	1.0	0.5	0.5
9	4.0	6.5	3.0	4.5	6.5	2.5	1.5	1.0	0.0	3.5	1.5	3.0	1.5	1.5	0.5
10	-4.5	5.0	-1.0	2.5	6.0	0.0	0.5	3.0	2.0	0.0	1.0	-2.0	0.5	0.5	0.0
11	-3.5	1.5	0.5	1.0	3.5	2.5	0.5	3.5	-0.5	-0.5	0.0	-1.5	2.0	2.5	3.0
12	-6.0	-1.0	-0.5	1.0	3.0	1.5	0.0	2.5	4.5	-2.0	-2.0	0.0	0.5	0.0	3.0
13	0.0	4.5	-1.5	4.0	2.5	0.5	1.0	0.0	2.0	3.5	2.5	0.0	0.0	5.5	0.5
14	-0.5	4.5	-2.0	5.0	2.5	1.5	1.0	1.5	2.5	3.0	2.5	0.0	7.5	0.0	1.5
15	-5.0	2.0	-1.0	4.0	5.5	3.0	0.5	0.0	2.0	4.5	5.5	5.0	3.0	2.0	0.0

Next, distribution functions of the internally independent events are modified with probabilistic procedure. Final shape of the distribution functions reflects the impact of the remaining events defined in the cross impacts matrix. Resulting distribution functions of probability are presented in Figure 10.44. for three chosen events as an example. The distribution functions describe the probability of occurrence of interrelated events in the period 1995 ... 2030.

Ranking of GHG reduction scenarios defined in the CIA format as a set of events is estimated from the point of relative probability of occurrence of a given scenario. Seven scenarios (see Table 10.5.) were taken as representative ones. The scenarios defined in the CIA format are presented in Table 10.5.



Rys. 10.44. Frequency of occurence of chosen 3 events in the random scenarios (probe of 500 scenarios)

Table. 10.5. Investigated scenarios written in the CIA format (times of occurrence of the considered events - see Table 10.2. for the meaning of the events)

	Ev1	Ev2	Ev3	Ev4	Ev5	Ev6	Ev7	Ev8	Ev9	Ev10	Ev11	Ev12	Ev13	Ev14	Ev15	p
SPst1	2013	2026	2030	2011	2030	2019	2025	2030	2017	2030	2030	2030	2020	2010	2030	8.47%
SOb1	2008	2014	2030	2010	2026	2013	2015	2030	2003	2020	2030	2030	2020	2010	2020	16.64%
SRb1	2012	2014	2030	2010	2024	2013	2015	2030	2003	2015	2030	2030	2020	2010	2020	17.78%
SRb3	2013	2014	2030	2009	2022	2011	2015	2030	2004	2010	2030	2030	2020	2010	2020	17.23%
SOsz1	2030	2011	2029	2000	2014	2005	2013	2026	2005	2005	2022	2030	2010	2005	2005	12.88%
SRsz1	2030	2011	2029	2000	2014	2005	2013	2026	2005	2005	2022	2030	2010	2005	2002	12.35%
SRsz3	2030	2011	2030	2000	2012	2004	2012	2030	2007	2001	2020	2030	2010	2005	2000	14.65%

The dates in the Table 10.5 are taken from the macroeconomic SDM-NE model.

Relative probabilities of the considered scenarios are presented in the last column of Table 10.5. The results indicate that the base-line scenarios SRb1, SRb3 and SOb1 are the most probable.

10.6. Comparative scenario analysis

Within the COUNTRY STUDY macroeconomic scenarios of Poland development have been elaborated, which determined GHG emission, represented by emission of CO2. Three scenarios were distinguished, each with different assumptions qualifying three different development paths, as follows:

- base scenario based mostly on actual political assumptions declared by the governmental authorities,
- chance scenario, elaborated on the assumption of fast and deep national economy structural changes, consisting in reconstruction of national property leading to GDP energy intensity decrease and fuel structure changes, taking into consideration the society adaptation to those changes and opening the Polish economy to international trade exchanges,
- stagnation scenario, created on the basis of assumption of lack or limitation of society adaptation for fast structural economy changes and concerned with them costs. It is the scenario with lower rate of transformation than in the base scenario.

The comparative analysis is presented for all reference and reduction scenarios.

The comparison is performed in the aspects of:

- macroeconomy,
- energy,
- emission,
- and relations between them.

10.6.1. Reference scenarios

Diagrams presenting runs of selected parameters, determining each scenario in the period of 1988-2030 are compiled in the Annex 2.

Gross domestic product

The greatest value of GDP in the considered period was obtained in chance scenario, then in base scenario, and stagnation scenario. Obtained values of GDP for the year 2030 related to GDP in 1990 are respectively higher :

- in base scenario 4.4 times,
- in chance scenario 5.9 times
- in stagnation scenario 2.7 times.

Sectoral changes of GDP structure are similar in all scenarios, but one should remember that they represent significantly different absolute values of GDP. Common tendency shown in diagrams in all scenarios (Fig,2 Annex 2) shows:

- increase of the share of service and small business (other sectors on the diagram) - from 30% in 1998 up to approximately 60$ in 2030.

The above-mentioned positive changes in service and small business occur in GDP. It is accompanied by decrease of the share of industry (fuel- energy industry and processing industry), whose share in 1990 was 41.1% and reached in 2000 respectively :

- base scenario about 27.4%,
- chance scenario about 31.5%,
- stagnation scenario about 25.5%.

In the considered period the relation between the processing industry and fuel and energy industry in GDP changed from about 3.5 in 1993 to the following figures in 2030:

- base scenario about 7.5,
- chance scenario about 8.5,
- stagnation scenario about 5.2.

The above changes result form the assumptions undertaken for individual scenarios. Among them, chance scenario distinguishes itself by the assumption of high technology goods production and competitiveness on the international market, along with deep change in energy supply structure. The share of natural gas and liquid fuels and eventually nuclear energy significantly increased (Fig.10, Annex 2).

The stagnation scenario has, of course, the greatest share of coal according to the assumptions (Fig.10, Annex 2).

The diagrams of material consumption (Fig.5, Annex 2) and energy intensity of GDP (Fig.11, Annex 2) reflect the above-described state.

The next consequences of the reference scenario assumptions, connected with the GDP, is relation between export and import and foreign trade balance (Fig.5, Annex 2). Base and chance scenarios have saldo in plus, and stagnation scenario in minus.

Very important differences between the reference scenarios, including greenhouse gases emission, will be present in the next part of this Chapter.

Investments

In the Chapter 7 it has been emphasized that by using SDM-NE model in the reference scenarios creation very important quantitative assumptions were: investment growth rate in relation to GNP and way of distribution of the investment between sectors and branches, and the efficiency of this investments as well.

Total investment share in the GDP (Fig.3, Annex 2) shows growing tendency in all scenarios, from 20% in 1990 up to values in 2030:

- base scenario - 22%,
- chance scenario - 25.3%
- stagnation scenario - 28,8%.

Taking into consideration the GDP value, the absolute investment value looks as it is shown below:

- base scenario - $56.4 * 10^9$ USD '90
- chance scenario - $87.9 * 10^9$ USD '90
- stagnation scenario - $43.5 * 10^9$ USD '90

have definitely different sectoral structure of investments.

This fact is supported by high investment share of fuel and energy industry in stagnation scenario (Fig.4, Annex 2). The second feature of sectoral structure investment run is the share of processing industry being almost at the same level in all scenarios. But, as it has been shown above, there are great differences in absolute values.

The best rate of investment has been assumed in chance scenario.

Employment

The problem of employment has a great role in the reference scenarios creation.

The variables, taken into consideration, were effectiveness of employment and elasticity of employment in comparison to value added in all branches and strategy of employment declared by the government (Chapter 7). The above-mentioned variables have been applied for each reference scenarios according to the requirements of their assumption. As a result, the structure of employment as it has been elaborated is shown in diagram in Fig.7 (Annex 2). The common feature of these runs is growing, according to the sectoral structure of the GDP (Fig.2, Annex 2), rate of employment in services and small business and falling rate of the industries - fuel and energy and processing industry. The similar rate and stabilization of employment in industry is ensured in base and chance scenarios, and smaller one by stagnation scenario. Great

difference can be observed in the ratio of employment in processing industry to employment in fuel and energy industry. Value of this ratio is the smallest in stagnation scenario, in which a big share of mining industry with high capital expenditure has been assumed (Fig.4, Annex 2).
As a result of the assumption the unemployment rate is falling down most drastically in chance scenario, and less drastically in base scenario. In stagnation scenario it increases a little. The calculated unemployment rates for the year 2030 are (Fig.8, Annex 2):

- base scenario — about 8.3%,
- chance scenario — about 5.7%,
- stagnation scenario — about 14.8% - higher than it is now.

The obtained result for stagnation scenario should be treated as an important, from social point of view, warning against this way of the economy development.

Energy

The structure of the energy carriers supplying the economy is very different in each of the presented scenarios (Fig.10, Annex 2). In base scenario the structure is changing very slowly by the reduction of coal consumption and growing rate of hydrocarbon fuels (natural gas and liquid fuels). In chance scenario this structure is changing fundamentally towards the bigger rate of use of hydrocarbon fuels, which share in 2030 is about 52,4% . In the same scenario in 2015 nuclear energy appears. The share of coal (hard and lignite) in stagnation scenario is growing in 2030 up to 74%. It is the result of the assumption about supporting mining industry because of the difficulties with the restructuring and social problems connected whit it. Energy supply in base and chance scenario is at similar level - 7000 PJ in the year 2030, but on different runs. Realization of stagnation scenario is connected with energy supply in the year 2030 on the level of 5650 PJ (Fig.9, Annex 2). For an estimation the relation between energy supplying the economy and GDP, the energy intensity factor has been used - in GJ/million zł'90 and in TJ/million USD'90 (Fig.11 and 12, Annex 2).

These figures show the significant decrease of energy intensity in the period between 1995-2030 in all references scenarios. In relation to 1990, the reduction in 2030 presents as follows:

- base scenario : to 34.6%
- chance scenario : to 24.6%
- stagnation scenario : to 46.9%

The influence on the reduction of GDP energy intensity was contributed by :

- energy demand,
- energy carriers structure,
- technologies of energy transformation (including primary energy) into final energy carriers directly used in GDP creation,
- effectiveness of energy use.

This influence is different in each of the presenting scenarios.

CO_2 emission

The emission of greenhouse gases, calculated in macroeconomic reference scenarios, is represented by CO2 which is emitted from the fuels resulting from final energy demand structure (with fuels used in heat and electricity production).

Basing on greenhouse gases inventory elaborated in 1998 and 1992, it can be assumed, that the share of these emissions in CO2 emission from the whole economy is about 96%.

The result CO2 emissions in the references scenarios are rather underestimated. The emission of CH4 and N2O has been omitted, since they should be calculated by means of the bottom-up method. It was also the reason for not calculating the global warming potential , as a equivalent of CO2 .

Fig.13 (Annex 2) presents country CO2 emission runs for all reference scenarios in the background of CO2 emission in 1988, treated as the base year for emission reduction within Climate Change Convention.

The analysis shows that in 2030 the rate of emission in reference scenarios in relation to emission in 1988 is as follows:

- base scenario - 1.22,
- chance scenario - 1.02,
- stagnation scenario - 1.11.

The important factor is the relation of the CO_2 emission to energy supply - called emission intensity. The most important influence on this ratio has energy supply structure and technologies of energy transformation and, resulting from them, the final energy structure. This influence has the following effect on emission intensity (Fig.14, Annex 2):

- base scenario - 85.1 [kg/GJ],
- chance scenario - 68.6 [kg/GJ],
- stagnation scenario - 93.6 [kg/GJ].

The second factor used in estimation of greenhouse gases emission is the relation of CO_2 emission to GDP. Emission intensity of GDP (Fig.15, Annex 2) in all macroeconomic scenario has strong tendency to decrease, which is in correlation with energy intensity of GDP (Fig.11and Fig.12, Annex 2).

Emission intensity in relation to GDP in 2030 in relation to emission intensity in 1990 shows the decrease :

- base scenario - by up to 35.9%
- chance scenario - by up to 21.9%.
- stagnation scenario - by up to 50.8% of the 1990 value.

Taking into consideration emission intensity analysis of marcoeconomic scenario, the following conclusions can be drawn:

- the lowest CO_2 emission and emission intensity factors is achieved by chance scenario thanks to the assumed high technology development, high efficiency of investments, suitable structure of energy supply (increasing share of hydrocarbon fuels and nuclear energy at the end of the considered period) and high value of GDP,
- the highest CO_2 emission is presented by the development path of base scenario with the indirect (between chance and stagnation scenarios) emission intensity factors, emission intensity of GDP and energy intensity of GDP. It is the result of lower, than in chance scenario, investment efficiency and technological development, with simultaneously slower implementation of hydrocarbonic fuels and slower decrease of share of coal,
- in the stagnation scenario CO_2 emission is lower than in base scenario and higher than in chance scenario, but with the highest factors of energy intensity, emission intensity of energy supply and emission intensity of GDP. It is the result of coal structure of energy supply with a growing tendency of coal use in the period in question.

Presented reference scenarios considered as a economy development paths including the greenhouse gases emission, show variety of possibilities to make the political decisions according to both economy criteria and climate protection criteria.

The results are as follows:

- The chance scenario is the most profitable for economy development and fulfilling the commitments within the Climate Change Convention. Its realization needs the acceptance of society - due to relinquishment of life quality, especially at the beginning,
- the most probable is the base scenario, especially at the beginning, due to political decisions already made and other governmental documents, which present the economy and sectoral development forecasting. The corrections of the base scenario, according to the main assumption in chance scenario, can be profitable (especially for energy intensity of GDP and greenhouse gases emission reduction),
- realization of stagnation scenario is not very much probable due to developmental decisions already made and the society's accepting low living standards.

10.6.2. Reduction scenarios

The procedure of the country GHG emission scenarios creation has been presented in the Chapter 10.1.

These scenarios have been prepared on the basis of the presented (Annex 2) reference scenarios : base, chance and stagnation scenarios, comparison analyses of which including macroeconomy, energy and related to emission estimation and relations between them has been presented in the Chapter 10.6.1.

Chance of CO_2, CH_4, N_2O reduction and resulting from it global warming potential have been estimated by sectoral research teams, which submitted:

- set of reduction options, according to GACS method,
- sectoral scenarios of emission reduction, using the option in the period up to 230.

After research and calculation :

- influence of climate temperature changes on GDP, growth rate of GDP, sectoral structure of economy, material intensity of GDP, supply energy consumption, energy intensity of GDP, CO_2 emission and emission intensity of GDP (by the growth 0,05 ^{0} C /year) - Fig. 10.2 ÷10.9.
- influence of discount rate and carbon tax on averaging and variabling marginal costs of reduction options - Fig. 10.10 ÷10.17.
- estimation of technical potential of greenhouses gases emission reduction (showed in equivalent of CO_2) in industry, residential, public and commercial sector, services and trade and renewable energy sources - Fig. 10.18 ÷10.20,

The scenarios of greenhouses gases emission reduction have been prepared in relation to all reference scenarios: base, chance and stagnation, using the economic constraint and taking into consideration the climate warming; the economic constraint has been not used in stagnation scenario.

Basing on total potential of reduction equaling some 190 million tons of greenhouses gasses from researched sectors up to 2030 some special research has been made. The range of reduction in all scenarios has been established, with the use of such an economic constraint as carbon tax (50 USD/Mg C and 100 USD/Mg C) and subsidies (only for base and chance scenario).

Within reference scenario realization, taking into consideration usual technology modernization and more efficient way of energy use and processing, some part of reduction potential will be realized with the support of market stimulation (without constraint), particularly those with negative marginal costs (benefit). Summary results are presented on Fig.10.21 , according to the qualification of the scenarios shown in the Table 10.1.

Based on input assumption (carbon tax level, investment subsidy value) the financial investment flow considered scenarios (Fig.10.22 and 10.32) and financial investment flow leading to greenhouse gases emission reduction (Fig. 10.23 and 10.33) has been calculated. The base macroeconomy, energy and emission related parameters for each scenario have been calculated as well.

The results are shown in Fig. 10.24÷10.31 for base scenario and 10.34÷10.41 for chance scenario. Summary results, in macroeconomic perspective, are presented in Table 10.2 (Chapter 10.3.1.).

Below is presented the discussion of the results of research on greenhouses gases emission reduction for the year 2030.

Influence of the climate warming on the economic parameters and GHG emission

Study of influence of climate temperature growth has been done for all reference scenarios. Growth rate of temperature has been assumed according to the data presented in the Chapter 8.1. (Climate change scenarios) respectively in two variants of climate warming rate growth:

- 0,05 ^{0} C/a,
- 0,10 ^{0} C/a.

All reference scenarios presented in Chapter 6.1 have been considered.

The results of emission reduction, expressed in CO_2 emission, as a result of climate warming are as follows :(explanation as in Table 10.1):

Base scenario	Chance scenario	Stagnation scenario
SOb (base) - 597 million tons	SOsz - 492 million tons	SOst - 537 million tons
SOb1 (0,05 ° C/year) - 578 million tons	SOsz1 - 479 million tons	SOst1 - 521 million tons
SOb2 (0,10 ° C/year - 560 million tons	SOsz2 - 467 million tons	SOst 2- 505 million tons

The results of climate warming are changes in scenarios parameters calculated with the support of the computer model of economy SND-NE. Their absolute values for the year 2030 are as follows:

Increase of GDP	Decrease of energy supply	Decrease of energy intensity of GDP
SOb1 - by 0.7%	SOb1 - by 3.4%	SOb1 - by 3.8%
SOb2 - by 1.5%	SOb2 - by 6.8%	SOb2 - by 7.2%
SOsz1 - by 1.1%	SOsz1 - by 2.6%	SOsz1 - by 4.2%
SOsz1 - by 2.1%	SOsz2 - by 5.2%	SOsz2 - by 7.8%
SPst1 - by 0.9%	SPst1 - by 3.4%	Spst1 - by 4.6%
SPst2 - by 1.9%	SPst2 - by 6.7%	SPst2 - by 7.2%

The above results confirm the thesis that climate warming decreases the energy supply demand (mainly for space heating) and therefore, results in GDP growing. It must be emphasized that in macroeconomic analysis the cost of adaptation to climate changes has not been taken into consideration, however, they can reduce or extend above profits.

Influence of economy constrains on emission reduction

In Chapter 10.3.1 the method of economy constrains investigation has been presented, giving their value for each variant of base and chance scenario as an input data.

Simulation of the constrains has been carried out in relation to modified climate scenarios (SOb1, SOb2, SOsz1 and SOsz2).

For the sake of illustration, the discussion of the extreme reduction scenarios is presented below:

- with the moderate warming and lowest constraint,
- with the rapid warming and highest constraint.

Emission from the base scenario :	Emission from the chance scenario:
SRb1 - 501 million tons,	SRsz1 - 393 million tons
SRb4 - 480 million tons	SRsz4 - 380 million tons

The percentage ratio of emission reduction in the base scenario has been estimated with the constrains related to the emission resulting from warming SOb1 and SOb2.

The following data were obtained:

SRb1 - by 13.3%,
SRb4 - by 14.3%,

Whilst, for chance scenario respectively in relation to SOsz1 and SOsz2, according to the formulaspecified as in base scenario, percentage ratio of emission reduction is:

SRsz1 - by 18.0%,
SRsz4 - by 18.4%.

Total reduction stages in relation to emission in reference scenarios SOb and SOsz and without influence of warming are as follows :

SRb1 - by 16.1%	SRsz1 - by 20.1%
SRb4 - by 19.6%	SRsz4 - by 22.8%

The presentation of changes in economy and energy parameters of the investigated and presented above scenarios are limited only to the analysis of GDP energy intensity changes. which define the relation between energy supply and GDP.

Base scenario energy intensity decreased in relation to SOb1 and SOb2 :

SRb1 - by 7.1%,
SRb4 - by 11.1%.

Whilst in chance scenario in relation to SOsz1 and SOsz2 -

SRsz1 - by 9.5%
SRsz4 - by 20.0%.

The decrease of energy intensity of the investigated scenarios in relation to reference scenarios SOb and SOsz (without influence of climate warming) is presented below:

Base scenario	Chance scenario
SRb1 - by 10.7%	SRsz1 - by 12.4 %
SRb4 - by 17.5%	SRsz4 - by 26.3%

All presented results refer to 2030.

10.6.3. Final analysis of macroeconomic emission reduction scenario

The results of investigation of the reference scenarios and reductions of greenhouses gases emission as well as their analysis within the macroeconomic aspect in relation to economy development, energy problems and emission, and relation between them, allow to formulate the statements, requirements and suggestions:

1. Three reference scenarios have been considered : base, chance and stagnation scenario, which create a basis for wide analysis of economy development. The leading scenario is the base one. The chance and stagnation scenario delimit the border of possibilities of Polish economy development - progressive and preservative one. Modified versions of the scenarios, especially base and chance, from the point of view of greenhouse gases emission reduction through economy constrains and with climate warming, determine the set of scenarios, which can be used in the government climate policy creation.
2. Chance scenario is the most profitable for economy development and fulfilling the commitment within the Climate Change Convention. This scenario realization needs agreement of society as far as the relinquishment of life standard in the first several years is concerned. This scenario gives basis for climate policy implementation, and a rapid grow of economy will not suffer the unavoidable impulse of recession caused by financial regulators of that policy (carbon tax and financial investment subventions). Apart from it, chance scenario has the best rates of emission intensity (without climate policy). This opinion is confirmed by the results of investigation done by HIPRE 3+ model, presented in Fig.10.3 in Chapter 10.4, where chance scenario have the higher value of political preference.
   One problem, however, appears : it is the probability of this scenario realization. Basing on intuition, one can assume many obstacles in realization of chance scenario could appear, which are confirmed by the results of investigation of events interaction done by CIA model. According to the results (Table 10.5 in Chapter 10.5). chance scenario has lower probability value than base scenario.
3. Definitely unprofitable is stagnation scenario with regard to the highest material intensity of GDP (Fig,5, Annex 2), the highest energy intensity (Fig,11, Annex 2), the highest emission intensity of GDP (Fig.16, Annex 2), the highest increase rate of unemployment (Fig,8, Annex 2) and the lowest consumption per capita (Fig.17, Annex 2).
4. The most probable is the realization of the base scenario. According to the HIPRE 3+ results, it has the next, after chance scenario, value of political preferences (Fig. 10.43 in Chapter 10.4) and the highest probability of realization (Table 10.15, Chapter 10.5). Base scenario has been created taking into account current government programs, and therefore, its development creates condition for continuation. Unfortunately, this scenario presents the development path with the highest emission, although it has more profitable macroeconomic factors, especially in relation to stagnation scenario:

- there is no big difference in material intensity of GDP in relation to the chance scenario
- the lowest and still decreasing rate of unemployment up to the year 2015, but higher than in chance scenario after 2015,
- energy intensity has decreasing character (it is higher by 25% than in chance scenario),
- higher, unfortunately, by over 25% emission intensity of GDP in relation to chance scenario.

Apart from it , the base scenario can be susceptible to correction of development assumptions (which has not be done during its creation), which can allow to correct the above-mentioned factors.

5. The results of the investigation show, that implementing into the economy elements of climate policy is connected with necessity of cost increasing, expressed in macroeconomic scale by decrease of national product growth. Implemented scale of constraints within climate policy (carbon tax 50-100 USD/Mg C) introduced gradually in the period of 2000-2030 results in coal price increase - max. by 45%, and natural gas - by 25% at the end of the considered period. The financial investment subventions for greenhouses gases emission reduction amounted to 0.2-0.3% of total financial subventions.
   The above-mentioned economic regulator implementation caused, as simulation showed, a slight decrease of GDP at the end of considered period by about 5-10% depending on the scenario.
6. The influence of the climate policy regulators caused extremal greenhouses gases emission reduction (presented in CO_2 emission) to about 79-90 million Mg, which gives the possibility not to exceed the emission of 1988 up to year 2030. It is a good prognostic for Poland of meeting a potential and negotiable future commitments within Climate Change Convention.

10.6.4. Comparison of the results of sectoral (bottom-up) and macroeconomic (top-down) analysis

The bottom-up method does not consider the recession impact and synergetic interrelations in the economy caused by the applied policy measures. On the contrary, the top-down method considers that phenomena. This causes, that predictions of GHG reduction and its costs are very often higher when calculated with the top-down method than that calculated with the bottom-up method.

The results of the Country Study confirm this rule. Comparative presentation of GHG emission reduction obtained with bottom-up (see Fig. 10.21) and top-down (see Fig. 10.30 and 10.40) methods is given in Table 10.6.

If both methods were fully adequate, the values of the 'economic structure related GHG reduction' calculated with the top-down method (see column 6 in Table 10.6) and the 'market forced GHG reduction (see column 8 in Table 10.6) calculated with the bottom-up method would be equal respectively. In this Country Study the values are similar for the scenarios of chance with strong economic stimulation of GHG reduction (scenarios SRsz3 and SRsz4). For the remaining scenarios the top -down assessments are twice and more higher than the respective bottom-up assessments. These differences may indicate that the recession impact of the carbon tax was underestimated.

Table 10.6. Comparison of the sectoral (bottom-up) and macroeconomic (top-down) methods

Scenario	Top-down method				
	Country GHG emisson in 2030	GDP decrease related to reference scenario (in 2030)	GHG emission reduction related to the reference scen. in 2030		
			total	recession related	economic and fuel structures related
	mln Mg CO2	%	mln Mg CO2	mln Mg CO2	mln Mg CO2
1	2	3	4	5	6
SOb1	578	-	-	-	-
SOb2	560	-	-	-	-
SRb1	501	4.1	77	21	56
SRb2	487	3.3	73	16	57
SRb3	495	3.6	83	18	65
SRb4	480	2.7	79	13	66
SOsz1	479	-	-	-	-
SOsz2	467	-	-	-	-
SRsz1	393	8.8	87	35	52
SRsz2	384	8.5	83	33	51
SRsz3	389	6.4	91	25	66
SRsz4	380	6.2	87	20	68

Table 10.6. continued

Scenario	Bottom-up method	
	GHG emission reduction in 2030	
	Technical potential *	Market induced **
	mln Mg CO2	mln Mg CO2
1	7	8
SOb1	204.3	-
SOb2	209.3	-
SRb1	204.3	9.8
SRb2	204.3	12.3
SRb3	209.3	34.3
SRb4	209.3	36.8
SOsz1	208.3	-
SOsz2	213.3	-
SRsz1	208.3	24.8
SRsz2	208.3	28.8
SRsz3	213.3	58.0
SRsz4	213.3	62.0

*/ Technological reduction potential of the GHG abatement options identified in the entire economy (including transport, agriculture and forestry)

**/ Market related GHG emission reduction in the entire economy (including transport, agriculture and forestry)

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11. Legal and economic aspects of GHG's emission reduction

11.1. Introduction

In Poland, the main objective of legal and economical mechanisms should be modernization and restructuring of economy to follow the principle of sustainable development and, what follows, the reduction (on a global scale) of greenhouse gases emission through greater economic efficiency, reduction of material- and energy-consumption in industrial production, wiser environmental exploitation (of life, forest, and water resources), as well as the result of more rational energy- and matter-consumption in households. The principle of sustainable development is accompanying economic and social changes which have already taken place and those which will soon affect Polish economy. Implementation of sustainable development principle consists in several coordinated strategic actions ranging from the changes in social and political system to particular actions such as implementation of recycling, improvement of the methods and instruments of environmental protection management, etc.

The Project :

1. Identified general political, legal, and economic conditioning as well as determining the measures and instruments of the management of greenhouse gases emission in Poland in accordance with the requirements of the United Nations Convention on Climate Changes;
2. Presented general assumptions of the system controlling the reduction of greenhouse gases emission, including the project of particular instruments of control and evaluation of economic, social, and environmental effectiveness of their functioning; and
3. Recommended implementation strategies for the decision-makers (authorities).

The system will be aimed mainly at the reduction of carbon dioxide and methane emission. Our analysis will focus on economic, and legal and administrative instruments controlling the reduction of greenhouse gases emission, as well as on the factors which determine proper functioning of those instruments. The system should regulate the activities of economic entities and households_and, to some extend, also the activities of government agencies and local governments. Recommended solutions will enable the implementation of technical and technological measures developed as a part of the strategy.

This paper consists of four chapters. The first chapter discusses political, legal, and economic conditioning of the implementation of the strategy of greenhouse gases reduction, the second presents the project of the system for controlling greenhouse gases emission in Poland, the third offers the analysis of economic and financial aspects of implementation and functioning of the system, whereas the fourth and the last of the four chapters provides recommended implementation strategies for the decision-makers.

11.2. Political, legal, and economic aspects of implementation of the strategy of GHG's emission reduction

11.2.1. Political Aspects

Important political and legal aspects of the problem of greenhouse gases emission include:

- political system and economic transformation that Poland is undergoing;
- ratification by Polish Sejm of the United Nations Convention on Climate Changes;
- Poland's plans of joining the European Union; and
- new provisions of particular policies, in particular in environmental protection policy, energy policy, and industrial policy.

The system controlling the reduction of greenhouse gases emission will ensure the fulfilment of the obligations resulting from the Climate Convention and from the agreement with the European Union. It will also serve as an instrument for the implementation of the state policy. The project should facilitate the implementation of the following recommendations:

a) Within the scope of environmental policy

- reduce environmental nuisance of fuel and energy sektor, through:
- energy savings as a result of the introduction of market pricing mechanisms;
- modernization of combustion technologies in coal-fired power plants;
- gradual changes in the structure of energy carriers consumption; and
- promoting unconventional and renewable energy sources.
- reduction of greenhouse gases emission, through:
- reduction of energy- and material -consumption of production processes;
- introduction of so-called "less polluting" and "clean" technologies;

- production process containment; and
- introduction of more strict requirements for material and product quality.

b) Within the scope of energy policy to implement a market mechanism regulating the energy and fuel prices.

c) Within the scope of industrial policy
- promote modernization activities and activities aimed at the implementation of proenvironmental procedures and technologies;
- follow the principle of "clean production"; and
- improve product quality.

11.2.2. Legal Aspects

Legal aspects of the problem of reduction of greenhouse gases emission are connected with general regulations of environmental protection included in the basic legal acts of the country, the provisions of the Vienna Convention for the Protection of the Ozone Layer, the stipulations of the Montreal Protocol on substances that deplete the ozone layer, and the United Nations Convention on Climate Changes.

The most important regulations connected with climate protection are the Law of January 31, 1980 on Environmental Protection and Management (the Law), executive acts issued on the grounds of the Law, and the Law on Forests, Farmland, and Forests Protection and the Energy Law.

The following institutions and legal instruments provided for in the above listed legal acts have been created to serve the purpose of air protection:

1) legal control of air pollution emitted by organizational units (carbon monoxide);
2) obligation to raise the charges for emissions of halogen-derivatives of hydrocarbons, carbon monoxide, carbon dioxide and methane token payment in case of carbon monoxide and methane;
3) system of fines imposed by voivodeship environmental inspectors for exceeding of emission standards and for emissions of substances other than the ones described in emission license issued by the Voivode;
4) imposing the obligation to measure in a continuous manner the amounts of carbon dioxide, methane, and halogen-derivatives of hydrocarbons released into the air;
5) legal regulation of the process of land release for the purposes other than farming or forest-planting; and
6) limitations resulting from the new energy law.

The system for controlling the reduction of greenhouse gases emission is also determined by the local spatial management projects prepared on the basis of the law on spatial management, decisions on the investment sitting and conditions for construction, forest management projects, and environmental impact assessments (Fig. 11.2.1).

State administrative bodies can realize the commissioned tasks in form of so-called environmental recommendations. Environmental recommendations aimed at the climate protection may take the form of information about the achievements and abilities of research and development units, or the form of a guide-book on services and new solutions for more efficient energy consumption, economic utilization of methane, or new agricultural methods, etc. In Poland the most competent body to issue such recommendations would be the Commission for Sustainable Development Issues.

11.2.3. Economic and Social Aspects

The most important economic and social aspects are determined by the following factors:
- the society is rather sensitive to any direct regulations, since such regulations remind them of the "old" management system;
- fuel and energy consumption is relatively insensitive to short-term economic incentives (changes of prices);
- production costs will increase, in particular shortly after the implementation of the instruments of the RGHG'S strategy;
- inflation will grow due to the so-called "quasi" taxable instruments; only if this incentive function of new instruments is strong enough to cause more rational energy consumption, inflation pressure of the system of controlling greenhouse gases reduction will be reduced; and
- economic instruments of the RGHG'S system will be reflected in the prices of energy and fuel and will include practically all production and consumption processes.

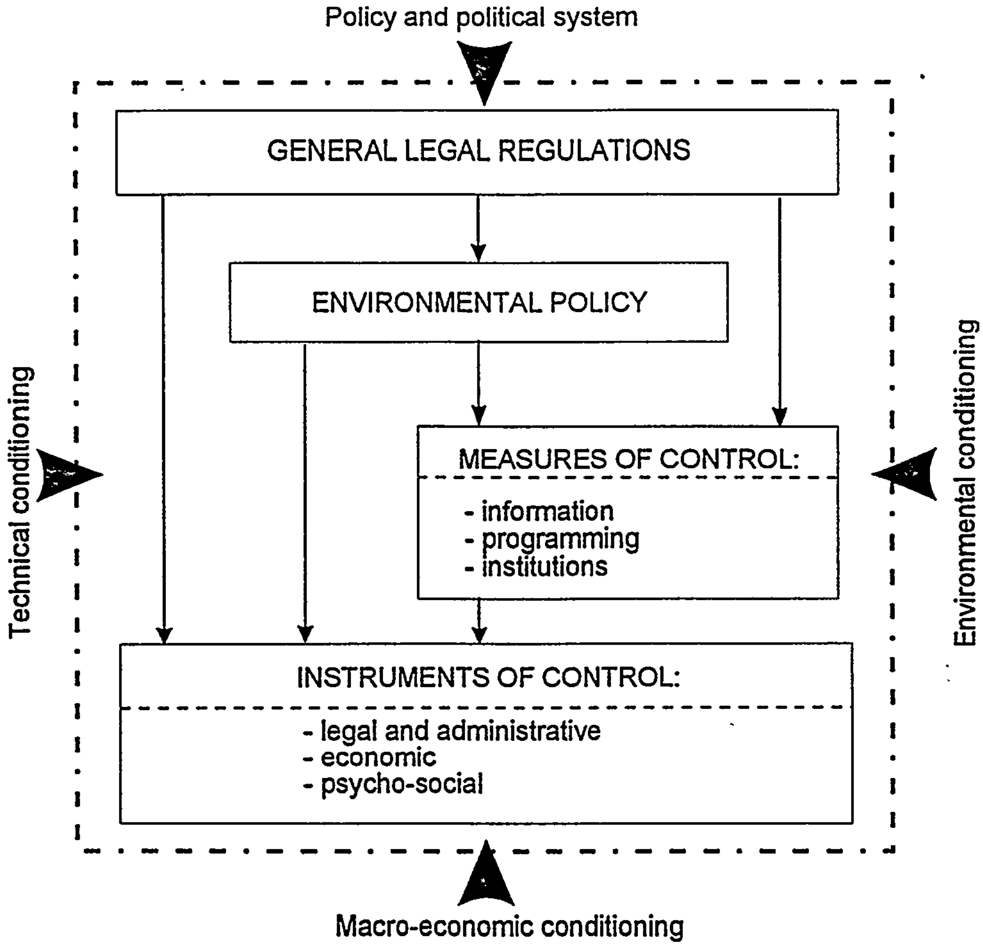

Fig.11.2.1. Legal and administrative conditioning in controlling the reduction of greenhouse gases emission

11.2.4. Environmental Awareness of the Society

The term "environmental awareness" is defined as the level of knowledge, attitudes and ideas of the society with regard to potential hazard to the environment (climate) and with regard to the measures and methods which could prevent the disaster. Environmental awareness belongs to the category of subjective phenomena since it is determined by individual features of every human being. Environmental awareness is being shaped in the process of environmental education. The same process determines environmental imagination. The researches on environmental awareness prove that:

- Polish society attaches great importance to environmental values as necessary for regular vital functions of a human being;
- the emission of greenhouse gases itself does not pose a direct threat to human health, therefore, it seems very likely that the implementation of the instruments controlling greenhouse gases emission may not be accepted by the society;
- recognition of environmental values does not entail protecting of those values; it means that even if people recognize the need to protect the environmental value of the climate, they may not cease to continue or undertake activities which endanger this value;
- recognition of environmental hazard is accompanied by relatively little knowledge of the sources and effects of those hazards; and
- there is an interdependence between the environmental awareness level and actual degradation of natural environment on the local level.

Even though the existence of the above described barriers does not preclude the implementation of the RGHG'S system, it proves that more information about the reasons and impacts of greenhouse effect, as well as more detailed information about preventive methods has to provided.

11.3. Control system of the GHG's emission reduction in Poland

11.3.1. Assumptions of the Strategy for Controlling the Reduction of GHG's Emission

Every system of control differentiates between the things that are being controlled (the object of control) and the manner of controlling (the system of control). The system for controlling the reduction of greenhouse gases emission focuses on economic entities and households and includes all informative and decision-making processes realized with regard to controlling the above mentioned domains. The system of control has three different sets of instruments:

1) general legal instruments;
2) measures and institutions of the system of control (management); and
3) instruments of control (instruments of management).

The system of control and the objects (the things) which are being controlled interact with each other. The form and the intensity of such interactions depends upon the instruments of control which are applied in each situation.

In construction of a system aimed at controlling the reduction of greenhouse gases emission the following interdependencies should be considered:

1. The system of control aimed at environmental protection has to be in compliance with the system controlling economy and society;
2. The subsystems of the system of control have to be harmonized. For example, introduction of carbon tax before certain necessary changes of the monitoring system, as well as changes in the structure of environmental protection institutions have taken place is likely to hinder the effectiveness of this instrument; and
3. The system responsible for controlling the reduction of greenhouse gases emission should account for both the assumptions of market economy, and for specific aspects of its implementation, in particular for the fact that excessive exploitation of natural resources and other environmental values (which are considered "free goods") is one of the main characteristics of market economy. The same refers to natural assimilative capacity of the atmosphere (fig.11.3.1).

11.3.2. Instruments of Control

Legal and Administrative Instruments

General Legal Regulations

The implementation of the RGHG'S system should be accompanied by the changes of the legal system. The minimum of such changes should include a new Law on Environmental Protection and Management and adoption of adequate executive acts necessary for the implementation of this new law. The following changes and amendments to general legal regulations should take place:

- introduction into the Constitution of the provision on the duty of environmental protection and adoption of the sustainable development principle
- adoption of the new revised project of the Penal Code including the chapter on crimes against the natural environment; it would be advisable to clearly determine the offences due to the failure to undertake activities aimed at the reduction of greenhouse gases emission;
- amendments to the Civil Code aimed at providing a more clear definition of the scope of and the procedure for the claims for compensation for unduly environmental exploitation, including the claims for the authorities' ordering to stop activities hazardous to the environment; and
- more efficient procedure of processing the claims for compensation due to unduly environmental exploitation (amendments to the Code of Administrative Procedure, the Code of Penal Procedure, and the Code of Civil Procedure).

Environmental Standards

The term environmental standards denotes legal and administrative instruments which can be applied by the system controlling the reduction of greenhouse gases emission. Environmental standards include ambient air quality standards, emission standards, product standards, emission standards based upon the level of available technology, and technical and technological standards.

Ambient air quality standards determine average concentration of air pollutants permitted in a determined unit of time for a particular area. With regard to greenhouse gases ambient air quality standards have been introduced for carbon monoxide emissions. The project of the RGHG'S system does not provide for any changes in the currently binding system of ambient air quality standards.

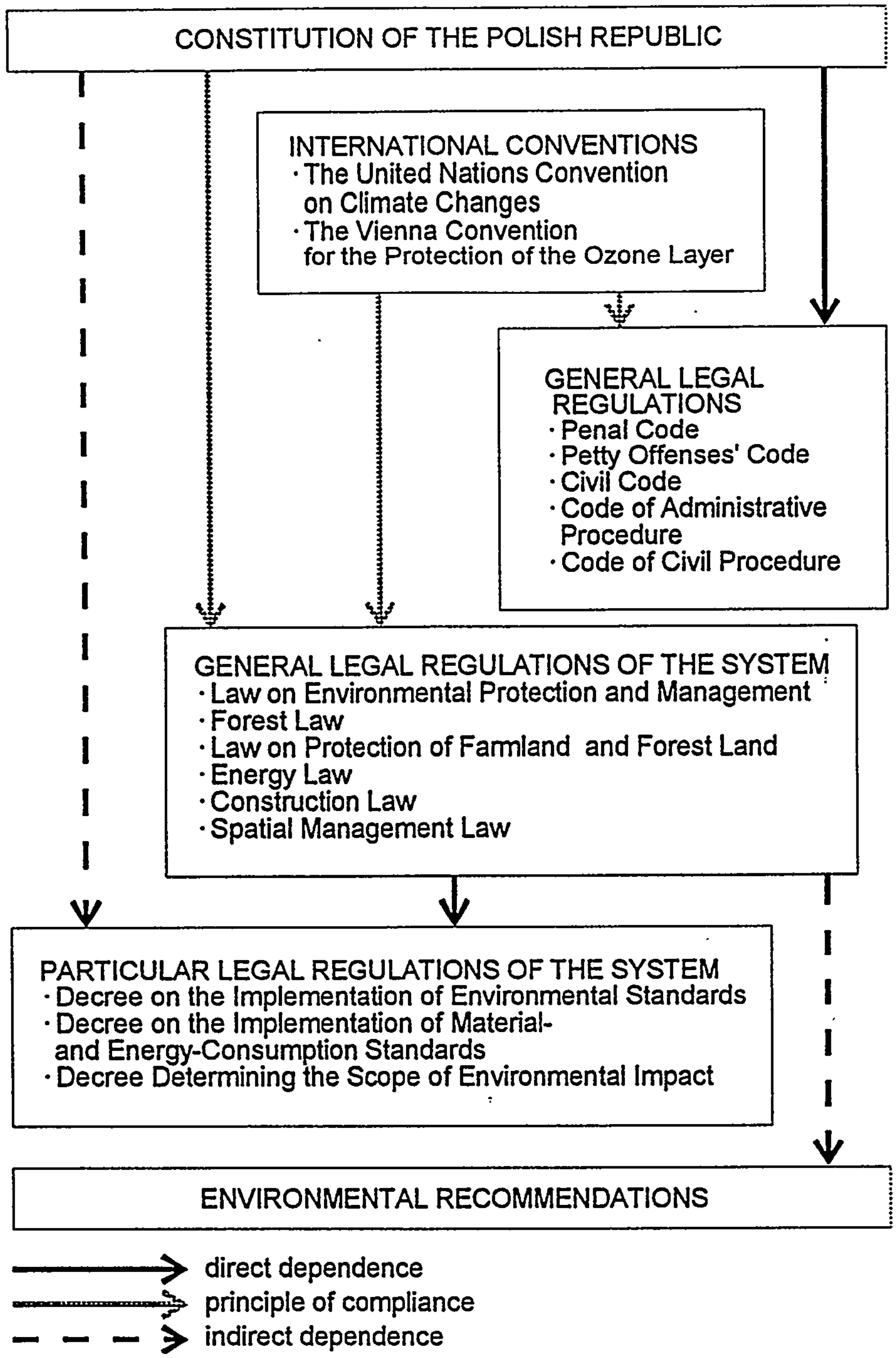

Fig.11.3.1. System controlling the reduction of greenhouse gases emission

Emission standards determine the top permitted level of emission of different pollutants by different emitters. Emission standards will not play any important role as an instrument facilitating the reduction of greenhouse gases emission.

Emission standards based upon the level of available technology. Implementation of emission standards very often implies the necessity of applying the highest possible level of available technology or the best available and relatively cheap facilities. The emission standards based upon the level of available technology are broadly applied in the member countries of the European Union and in the United States. The system of emission licenses is adopted to technical progress. The procedure of setting the permitted standards of emission on the basis of the level of the best available technology may be applied by the RGHG'S system with regard to, e.g., the reduction of nitrogen monoxide emission in chemical plants, the reduction of methane in mines, etc.

The group of technical and technological standards includes product quality standards and required technology standards. Since they have a so-called "binding power", they may prove very effective in developing pro-environmental attitude of economic entities. Technological standards are often used in power industry and construction. They are connected with the requirement to apply particular materials and raw materials. Some of them determine the minimum level of energy-efficiency of various primary energy carriers, as well as the type of production technology or protective technology.

In Poland technical and technological standards are determined by:

- the Decree of the Minister of Environmental Protection, Natural Resources and Forestry with regard to permissible level of pollution and types of pollutants emitted by the exhausting system of a vehicle. The Decree determines the permissible concentration of carbon monoxide emitted into the atmosphere by a combustion engine measured while idling; and
- the law of April 6, 1984 on energy industry and executive acts issued on the basis of the law which determine the standards of unitary fuel and energy consumption for particular electric devices.

In 1994 the European Commission presented the project of a directive determining energy efficiency requirements for refrigerators and freezers. The project set forth the deadline (the year 2000) for meeting the above requirements. Such requirements should be introduced also in Poland.

The reduction of greenhouse gases emission is facilitated also by the requirements with regard to thermal insulation of buildings. Article 10 of the Construction Law prevents the constructors from using materials which do not comply with so-called "Polish Standards". The same refers to materials which do not have technical certificates. The same aim is attained through §133 of the Ordinance of the Minister of Spatial Management and Construction issued on December 14, 1994. The Minister allows for accepting only such heating equipment which will ensure compliance with energy-savings requirements. The heating equipment which is exposed to cool air should be insulated against excessive heat losses.

Legal and Administrative Permissions

Permissions and licenses constitute limitations of the citizens' rights to start and conduct economic activity. In the RGHG'S strategy the most important are the licenses for the construction of dumping sites, licenses for the extraction of various minerals, permissions to remove trees and bushes, and the sitting decisions.

Economic Instruments for Managing the Environment

The term economic instruments suggests that such instruments should influence the account of profits and costs of alternative activities available to economic entities, which, in consequence, should choose the most profitable solutions allowing for attaining desired environmental effects. The most important of economic instruments, as far as the reduction of greenhouse gases is concerned, are charges and subventions.

Charges for using the environment may, to some extend, be treated as the price paid for pollution. For the reduction of greenhouse gases emission, the most important charges are the charges for pollution emission and so-called product charges. Emission charges depend on the volume and/or the quality of pollutants emitted into the environment. In Poland, the following charges influencing the reduction of greenhouse gases emission are being applied, the charge for carbon dioxide emission ($ 0.042/t CO_2), the charge for the emission of halogen derivatives of hydrocarbons ($ 25,750/t CFC_5), and the charge for methane emission ($ 0.042/t CH_4). The measures received as a result of introduction of the above described charges are allocated to environmental funds. According to the currently binding legal regulations these measures may be used for preferential credits for investments aimed at production technology or technical change in order to reduce greenhouse gases emission. The money may also be allocated to scientific research or environmental education of the society.

Another type of charges for using the environment are the charges for removing trees and bushes. These charges, to some extend, reduce tree and bushes removal and, what follows, increase the level of carbon dioxide absorption. The receipts from such charges are allocated to local (voivodeship) environmental protection funds and may be used only for the purposes connected with the reduction of greenhouse gases emission.

Product charges are generally included into the prices of products which constitute the source of pollution, both in the processes of their production and consumption. The literature points to relatively high effectiveness of product charges resulting from very simple method of calculation, as well as from the fact that this obligation is very easy to enforce. In Poland the project of introducing such charges is still at the stage of analysis.

Another kind of charges, which may help to reduce greenhouse gases emission, are the charges for waste storage. Their role in the RGHG'S system consists in generating financial measures to subsidy the construction of special equipment for collecting and utilizing methane generated by dumping sites.

Apart from the system of various charges, the RGHG'S strategy applies so-called environmental taxes. The main difference between the environmental charges and the environmental taxes is that the taxes are not allocated to any special funds. The receipts from environmental taxes go straight to the state or local budget and they are referred to either costs or benefits of the enterprise. In Poland such tax could be introduced only after the period of economic and political transition is ended and the new and comprehensive financial system of the state and self-governments is implemented.

Subventions is a general term used to describe various forms of financial aid aimed at encouraging more environment-friendly patterns of behaviour of economic entities. Such financial aid can be granted in form of grants, i.e., non-refundable financial aid, preferential credits (subvention is to compensate for the difference in interest rate between commercial and preferential credits), and tax allowances. In Poland the following subventions are applied with regard to providing financial aid to the investments aimed at the reduction of greenhouse gases emission:

- grants from the National Environmental Protection and Water Management Fund, from relevant voivodeship funds, and state and local budgets for the financing of environmental protection investments, scientific research, and environmental education;
- low interest credits granted by the National Environmental Protection and Water Management Fund and relevant voivodeship funds with the possibility of partial amortization, if the environmental friendly tasks and aims have been achieved according to the schedule;
- preferential credits granted by the Environmental Protection Bank; and
- income tax allowances for companies with foreign capital participation with regard to the investments aimed at the reduction of greenhouse gases emission.

Economic instruments of environmental protection currently applied in Poland have to undergo serious changes since none of our instruments proved really effective with regard to the reduction of greenhouse gases emission.

The most important of the instruments implemented as a part of the RGHG'S strategy is the so-called carbon-tax. It can take the form of the charge for CO_2 emission or the product charge for fuel (imposed on the input product in the process). The latter can take the form of 1) tax on energy volume of fuel, 2) tax on carbon content in fuel, or 3) mixed carbon/energy tax. The currently binding in Poland emission charge for CO_2 emission (0.042 $/ton of CO_2) has two main functions, implementation and educational. It does not function as a stimulus to reduce the emission. This is due to the fact that we still lack a reliable method of reducing CO_2 emission output. Thus, it seems that a more reasonable solution would be the introduction of the product charge for fuel. Out of the three aforementioned forms of the fuel charge the most effective solution would be the mixed carbon/energy tax, which is calculated on the basis of carbon content in one energy unit of a given fuel. In our opinion it is the best possible choice for Poland, too. The tax should include the following types of fuel: hard coal, brown coal (lignite), heating oil, natural gas, and petrol. The main objects which are to be achieved through the introduction of the carbon/energy tax include the following:

a) in economy:
  - restructuring of energy carriers consumption in Polish economy in favour of liquid and gas fuel;
  - reduction of material- and energy-consumption of production processes in Polish economy; and
  - increase of the efficiency of fuel consumption and energy utilization;

b) in environmental protection:
  - reduction of pollution emission, and in particular reduction of CO_2 emission.

In order to determine the maximum tax rate the researchers used 8 different variants. They chose the rate of currently binding in Poland emission charge for CO_2 emission, i.e., 0.042 $/ton of CO_2 (the base rate in variant "0") as the minimum, and the carbon tax rate of 22 $/ton of emission, suggested by the European Commission, as the maximum. Within the range of 0.042 to 22 $/t of CO_2, they selected 6 variants, each being the multiplicity of the base rate.

The increase of fuel and energy prices results in the increase of current costs incurred by the households. The simulation studies in this regard were based upon current expenditure of the households (households of working people, farmers, pensioners, and the households having other than work sources of income) calculated at 1993 rates of energy, heating, electricity, and gas. The introduction of the carbon tax may result in the increase of this expenditure from 0.01% to 7.77%, in proportion to the tax rate and the type of a household. Our calculations, however, do not account for the increase of the prices of manufactured goods and agricultural products, as another result of the introduction of carbon tax. The highest (in %) increase of the household expenditure due to the introduction of carbon tax will affect the pensioners' households. It is connected with the structure of fuel consumption which is the most unfavourable for this very group. The way carbon tax will influence the energy prices and the increase of household expenditure caused by the introduction of such tax should be the basis for determining the tax rates. Considering energy expenditure, which could hardly be called mediocre, carbon tax should not result in higher than 0.5% increase of household expenditure. It means that only the fourth of the above presented variants could be accepted by the society. The tax rate of the fourth variant would result in 4.8% increase of the hard coal prices, 6.2% increase of the heating oil prices, and 2.0% increase of gas prices. Gas would become the relatively cheapest heating fuel and as such it would become more and more popular for house heating.

The results of the introduction of carbon tax in industry are dependent upon the branch and the sector of industry it affects. It is obvious that the introduction of carbon tax will affect mainly those sectors which spend the largest sums of money on fuel and energy, namely, power industry, metallurgic industry, and chemical industry. According to the balance sheet on brown coal exploitation and consumption in Poland, 97.8% of the yield is consumed by power plants, heat and power generating plants, and heat-generating plants (energy industry). Other sectors, which do not consume such enormous quantities of coal should not suffer any serious production cost increase as a result of the introduction of carbon tax. However, the balance sheets on hard coal and heating oil indicate that making these energy carriers taxable should affect power industry (54% of hard coal consumption and 50% of heating oil consumption) as well. This change will also be reflected in the costs of energy generation. The simulation studies proved that if the fuel and energy prices increased up to 2.10 $/t of CO_2, the increase of the total costs in the most energy-intensive industries would not exceed 2%.

The carbon tax receipts accumulated on the National Fund of Environmental Protection and Water Management account should be used for the projects aimed at:

- reduction of energy- and material-consumption level in Polish economy;
- expanding the forest area of the country through financial incentives in form of a forest subvention;
- gasification of Polish towns and villages.
- development of energy auditing systems; and
- environmental education.

The measures for realization of the above listed projects should be granted on competition basis. The carbon tax at the above given rate would allow for promoting energy saving projects, including the implementation of economic instruments such as preferential credits and price discounts for energy-saving products, etc. As a result of such actions, within 10 to 12 years Poland would be able to adjust to the energy-consumption standards of the present Western Europe economies.

Another instrument of the system for controlling the reduction of greenhouse gases emission is the charge for methane emission. In Poland the main sources of methane emission are hard coal mines, coal yards, large breeding farms, dumping sites, filling stations, airports, and swamplands.

The charge for methane emission allows us to control the emission. The charge for methane emission amounting to 0.042 $/t of CH_4 has already been introduced in Poland. This is just a token charge to facilitate the introduction of a more effective instrument. Introduction of a more effective charge, as suggested by this paper, is in accordance both with the directives of the environmental policy of the state, and with the main assumptions of energy policy.

In order to avoid the introduction of a relatively expensive system of monitoring, which will result in even higher operating costs, the charge for methane emission should be imposed on:

- large breeding farms;
- hard coal mines; and
- municipal (urban and rural) dumping sites.

The charge for methane emitted by large breeding farms should include only methane generated in the process of anaerobic fermentation of liquid manure due to high environmental nuisance of liquid manure and the possibility of economic utilization of the gas generated in its fermentation. In order to provide incentive function, the charge should be proportionate to the price of fuel (natural gas). The charge should constitute a part of the fuel price. For the purpose of our analysis we decided to apply the following rates: 10%, 25%, 33%, and 50% of the price of natural gas in industry. Only large breeding farms can afford the installations for collecting and utilization of biological gas, thus, the charge for methane emission should be imposed only on the farms of 50 or more heads of cattle, at least 150 pigs, and 6,000 birds (poultry fowls).

For the purpose of our calculations we applied the term "animal unit" denoting a farm of 50-100 heads of cattle (150-300 pigs, or 6,000-12,000 birds). The charge per unit of emitted methane would be multiplied in proportion to the number of animals. And so, for farms of:

- up to 50 heads of cattle (and its equivalent in case of pigs and birds) 0 rate;
- 51-100 heads base rate x 1;
- 101-150 heads base rate x 2;
- 151-200 heads base rate x 3, etc.

Annual charge for one "animal unit" would amount to $306.6. It would provide the receipts of $16 million annually (variant 10%).

The charges for methane emitted by large breeding farms should be calculated by local authorities. The measures generated by the charge should be allocated to local environmental protection funds. The procedure will require average 1/5 of the full time work and will incur the annual costs of $2-3 million (for the whole country).

The charge for methane emitted by dumping sites should be imposed on large dumping sites, which have been operated for at least 15 years. It is estimated that such dumping sites "receive" approx. 70% of all wastes. The charge should be calculated on the basis of the amount of wastes dumped in a particular dumping site, including the amount of methane generated by such wastes.

Introduction of the charge amounting to 10% or 50% of natural gas price would entail 0.2-1.0% increase of the prices for waste collection, respectively, and 0.002-0.009% increase of the maintenance costs in households.

The charge for methane emission in dumping sites can be set according to the fourth variant, i.e. it can amount to 50% of the natural gas prices. The estimated receipts generated by such charge would amount to $77.4 million annually. The system of calculating and collecting the charges for methane emitted by dumping sites (in form of higher charges for wastes disposal) is the same as in case of the charge paid by large breeding farms and will incur the same costs.

The charge for methane emitted by coal mines has already been exercised in Poland since January 1, 1995. The charge for one unit of methane emitted into the atmosphere amounts to $0.042/t and its function is limited to informational and educational aspects. Thus, there is a need to introduce the charge which would also fulfil the instrumental function, i.e. the charge proportionate to the price of natural gas. For further analysis, we decided to apply the following rates: 10%, 25%, 33%, and 50% of the price of natural gas in industry.

The new higher charge for methane emission can be applied only to the emission from ventilation systems since only this emission can be effectively controlled. It is estimated that methane emission from the coal mines polluted with methane amounts to 200,000 ton per year. The rate of the new charge will be proportionate to the price of 1 ton of natural gas in industrial sector. Assuming that this price is approx. $100 per one ton of natural gas, we can expect the receipts of $2.0 million up to $10.0 million depending on the rate (10-50% of the price of natural gas in industry). The introduction of higher rate of the charge for methane emission in coal mines will increase the costs of extraction of 1 ton of coal by 0.16-0.80%. Only the first of the presented above variants can be accepted by the society, i.e., the one which will increase the costs of coal extraction by 0.16% per one ton of coal. The introduction of the charge for methane emission in methane polluted coal mines will weaken their position on the market until the equipment for methane collection is installed. Then, the mines will recover their position since they will no longer have to pay the charges for methane emission and, what is more, there will be some profit from the sale of methane.

Pursuant to the currently binding regulations, the charges for methane emission in coal mines are calculated and collected by the Voivode. The measures generated by such charges are allocated to voivodeship environmental protection funds. There is no need to change this procedure.

Introduction of the charge for methane emitted by large breeding farms and dumping sites, as well as the increase of the charge which has already been collected from coal mines (according to the variants chosen for this analysis) would bring annual receipts of $95.4 million.

All economic entities which start the construction of special equipment for collecting and utilization of methane should be exempted of the obligation to pay such charges.

Forest subventions can be granted from the measures accumulated on the Forest Fund in form of grants compensating for the costs of tree or forestry planting. Such grants should cover:

- in case of forestry planting – material and transportation costs, as well as the costs of preparing the area; the grants should not cover the costs of actual planting; and
- in case of tree planting – costs of seedlings and costs of transportation.

The terms and conditions of such grants will be determined by a separate agreement between the District Head Office for State Forest Management (DHOSFM) and the owners of farmland reclaimed for forestry planting (pursuant to the local spatial management projects). The subvention cannot be allocated to forestry planting on felling sites. Forest subvention could be used for farming on so-called "formerly arable" areas provided that such action is controlled by forest service.

Forest subvention can also prove very helpful in the implementation of one of the long-term priorities of the national environmental policy, namely, expanding forest areas up to 30% of the total territory of the country. It means that the forest area should be increased by 2.17%, which entails the necessity to plant forests on 678,526 hectares of the farmland. This task can be realized since as many as 2,238,000 hectares of the farmland (VI and VIz class) in Poland do not provide profitable agricultural production and should be reclaimed for forestry planting. In the years 1990-1995 this task was hardly fulfilled. At the current pace of forestry planting, it will take approximately 200 years to achieve the 30% threshold. Therefore, there is a need to implement special instruments which will ensure that this threshold is reached much earlier.

Assuming that 10% of the receipts from the carbon tax is allocated to this purpose, i.e. forest subvention, in case of variant IV, it will amount to $80 million annually. This sum should provide subsiding measures for 100,000 hectare of farmland per year. After three or four years, the pace of forest planting should be lowered and part of the measures should be allocated to the forests which have been recently planted. Forest subvention will allow for the implementation of the objectives of national environmental policy within 11-12 years.

(The above suggested charges will influence the costs connected with power generation as well as the energy price. Therefore, the initial rates of the charges should be relatively low. After a few years the rates would either grow gradually on annual basis or be raised considerably every few years. The rates should be determined for the period of at least ten years. Another solution which could be implemented immediately and which would not affect the competitive position of Polish products on international markets is a form of tax allowance for natural and legal persons for the purchase of energy-saving equipment. The list of such equipment, manufactured in Poland, should be published on annual basis. The decrease of income from the taxes would be compensated by the increased income from VAT and from the tax on payment. The latter would increase as a result of the growth of employment in the sector manufacturing energy-saving equipment for households and industry.

Supporting Instruments

The system for controlling the reduction of greenhouse gases emission can be also equipped with so-called supporting instruments such as:

1) joint implementation;
2) tradable absorption obligations (CO_2);
3) environmental education; and
4) services facilitating more rational power consumption.

11.3.3 Measures and Iimplementation of the System

The subsystem of "measures of control" includes the tools used for implementing the goals of environmental policy. These are informative, organizational, institutional, and technical and technological measures. The main function of the measures of control consists in facilitating the implementation of the instruments of environmental protection.

In Poland there is a possibility of ensuring effective functioning of the RGHG'S system without the need to create new legal and organizational institutions. It would entail relatively small increase of employment in the existing offices and institutions, mainly in National Environmental Protection and Water Management Fund, in the Forest Fund, and in the monitoring system of the Environmental Protection Inspectorate.

Local governments should take more and more interest in activities aimed at controlling the greenhouse gases emission. However, any of such actions should be preceded by development of information and educational systems. There is also the necessity to revise local governments' powers concerning environmental protection management with regard to holding local governments responsible for solving the problem of greenhouse gases emission. One should not forget about independent social organizations which can also help to prevent global climate changes.

The system for controlling the reduction of greenhouse gases emission should not ignore **technical and technological** capability of the national economy. Poland is one of those countries which are at least ten years late with regard to the standards and requirements applied in energy sector. On the one hand, such a situation allows for achieving considerable progress in the reduction of greenhouse gases emission due to the very change of production methods and technologies, whereas, on the other hand, it prevents the RGHG'S system from effective management of climate protection processes. The latest technologies are relatively expensive and rarely available on the Polish market.

11.3.4. General evaluation of effectiveness and efficiency of the control system of GHG's emission reduction

Assessment of Receipts and Costs of the Strategy Implementation

There are two approaches which can be applied with regard to the strategy of the reduction of greenhouse gases emission. The broader approach assumes the necessity to introduce certain technological and technical changes and the need to restructure Polish economy for more rational energy consumption. Such changes will facilitate the implementation of the instruments of RGHG'S system. However, assessment of the results does not entail that these results will be attained.

The narrow approach focuses on preparing and implementation of the system. From this point of view, we conducted the analysis of the costs of preparation and implementation of the system and then we evaluated the very system. The results of analysis and evaluation are the basis for actions recommended with regard to spending financial measures collected through the system.

The system of financing for the RGHG'S strategy is constituted by:

1) Financial measures generated by the RGHG'S system;
2) Supporting measures provided by foreign crediting sources;
3) Supporting measures provided by foreign aid and eco-conversion of the Polish debt;
4) Financial and in-kind measures generated by economic entities (firms and households), including credits;
5) Budgetary financial measures allocated to the realization of the strategic objectives by the public sector (state administration and self-governments); and
6) Supporting measures, not subject to repayment, for environmental protection (budget, environmental funds, etc.).

Analysis of the Implementation and Operating Costs of the System

In the analysis of the costs of implementation and functioning of the RGHG'S system it is necessary to account for the costs connected with preparation of the concept of the system and the projects of legal regulations, costs of implementation, operating costs, and other costs. One should not forget that the system will constitute the source of considerable income.

In our analysis we decided to ignore the financial measures which cannot be determined in a clear way. Hence, the most important source of income are the receipts from carbon tax and the charge for methane emission (approx. $800 million per year). The operating costs will amount to 7% of the receipts generated by the system. Should the rest of the receipts be allocated to supporting actions aimed at the reduction of greenhouse gases emission, the main objectives of the RGHG'S system will soon be attained.

Evaluation of the Effectiveness and Efficiency of the Implementation of the RGHG'S System

All actions prepared and undertaken as a part of the RGHG'S strategy should be evaluated with regard to the five following criteria: environmental effectiveness, economic effectiveness, social approval, social justice (distribution), and administrative enforceability.

<u>Environmental effectiveness</u> is always referred to particular objectives of environmental policy. Environmental effectiveness is assessed through referring particular phenomenon to various environmental standards functioning as indices in the realization of environmental policy objectives. With regard to the RGHG'S strategy the main objective is the reduction of greenhouse gases emission.

We can assume that suggested above instruments will have favourable environmental effects such as the reduction of carbon dioxide and methane emissions (including the reduction of other greenhouse gases), and the economic growth according to the "Strategy for Poland" standards. The RGHG'S system will allow for a considerable reduction of other pollution (e.g., heavy metals, sulphur dioxide, nitrogen monoxide). Environmental effectiveness of particular instruments will be determined by the response of the economic entities affected by those instruments. Should the necessity to implement the RGHG'S system be ignored, the process of ecologization of Polish economy will be postponed, and Polish economy itself will not be able to keep pace with the changes taking place in modern economies of the developed countries.

<u>Economic effectiveness</u> is usually treated as the reduction of total costs of achieving a desired environmental benefit. With regard to almost all economic instruments for managing the environment, the higher discrepancy between marginal costs of the pollution reduction and/or the more flexible demand for the polluting products or substances, the higher economic effectiveness. Another factor demonstrating economic effectiveness of the RGHG'S system is the ability to generate economic (and financial) surplus in comparison to the costs of preparation, implementation and operation of the system. Such economic surplus will mean that

there is a possibility of certain extra activities such as activities aimed at the reduction of greenhouse gases emission, or more efficient energy consumption, etc. Our analysis clearly proves that the system of the reduction of greenhouse gases emission will generate a considerable surplus in comparison to its operating costs.

Social approval will be determined by the scope and the methods of teaching the social group (economic groups included) affected by a particular instrument about the objectives and financial consequences connected with that instrument, as well as about technical solutions with regard to adjusting to different conditions of conducting economic activity, etc. Moreover, in order to achieve certain consensus about the implementation of a new instrument, if any, it would be highly recommended to consult the parties concerned.

Social justice denotes a close correlation between the level of economic burden of a particular economic entity and its share in the greenhouse gases emission, as well as equal treatment of all entities, in particular with regard to their chances of adopting to the new requirements, e.g. access to methods, technical solutions, and equipment for substituting one energy carrier with a more environment-friendly one. This criterion constitutes a crucial part of Country Study project since all of the instruments presented in this paper have been designed with regard to this very criterion.

Administrative enforceability. Administrative enforceability means actual possibilities of the implementation of a particular instrument of the RGHG'S system. The system is to be based on the existing institutions which should facilitate its implementation.

In consideration of the above, we may assume that the system suggested in our Country Study meets all the criteria of effectiveness. It means that the only question left is whether there is enough political willingness and involvement for the project to be developed and implemented.

12. Recommendations

In order for the Polish economy to adapt to climate changes and achieve the GHG emission reduction defined by the Frame Convention of the United Nations on the Climate Changes, it is recommended that the following enterprises should be undertaken in the analysed sectors of the economy :

General

1. It is essential to draw up scenarios of long-term (at least up to 2030) economic strategy of the state taking into account the problem of climate changes and the necessity to reduce GHG emission.

2. Work aiming at elaborating the strategy of GHG emission should continue. The Study in question is the first elaboration of this kind, and a number of ratios as well as assumptions requires additional research and assessment.

3. It is necessary to adjust the state statistical system to the changed political and economic conditions and extending the system over activities leading to GHG emission reduction.

Adaptations to the climate changes

Water resources

1. The following should be counted among the main kinds of activities aiming at preventing from negative results of climate changes :

   a) new economic and legal means oriented to cost-effective (rational) use of water by the population and industry,

   b) periodical limitations in water in-taking by industry and agriculture during drought periods,

   c) effective management of the existing water resources,

   d) development of the technical infrastructure of the water management, i.e. construction of new storage reservoirs, transfer of water between reception basins and others.

2. Function of new water investments in a shape adjusted to the forecast needs must be thoroughly analysed by the decision-making bodies. At present, one can observe in Poland an increase of opposition against large scale water investments. The reasons are as follows : density of population, lack of areas that could be used for creating additional capacity, problems connected with the environment protection as well as insufficient financial means.

3. The most probable adaptation directions are rationalisation of water use and more efficient management systems. An important supporting activity is development of "small" retention. Its modernisation can contribute to a considerable increase of water resources and create possibilities of improving the potential of renewable energy. The promotional policy of establishing local water enterprises should be in favour of it.

4. One of possible options is limiting the amount of irrigated area and solving the problem of food supply through introduction of species resistant to drought, or food import.

5. It is essential to start a research program in the sphere of sensitivity of the state agriculture to climate changes, particularly investigating irrigation strategies.

6. As it is shown in experiences of several European countries, rationalisation of water use in the communal and industrial sector can be an effective and economically justified way of counteracting water shortages.

Coastal zone

Due to the actual threat to the whole coast resulting from the increase of the sea level - as a consequence of the climate changes, it is recommended to :

1. immediately set off preparations for investment activities aiming at protection of the coast, particularly, the most endangered and valuable stretches.

2. improve social awareness of the threats resulting from the climate changes and the necessity to undertake protective measures.

3. make efforts to gain foreign aid for the good of the coastal zone protection needs.

4. cause to practically implement the principles of the Integrated Coastal Zone Management (ICZM) in order to enable realisation of the balanced coastal development.

Agriculture

Accidental influence of the climate changes on the net global agricultural production is difficult to assess. Higher levels of crops in some regions (or years) can balance the decline of the level of crops in other regions (or years). It will, however, depend both on many controlled and independent from producers factors. Also difficult to anticipate is the scale of potential losses endangering current food producers because of climate changes, as well as effect of these changes upon change of directions and structure of production. Agriculture characteristics depends, among other things, on the fact that the changes in direction and structure of production are “extorted” from the producers through climate changes. The rate and costs of those changes, however, depend on the adaptation capability of the state agricultural policy as well as efficiency of activities and amount of measures meant to smoothen the unfavourable results of the climate changes.

Considering a very complex and difficult to anticipate nature of effects of the climate changes upon the agriculture in the perspective till 2030, it is necessary to immediately undertake research aiming at preparation of the Polish agriculture to effective functioning in the conditions of changing climate. Research of this type is already under way on the large scale in many countries world-wide.

Emission reduction

Energy and heating sectors

1. Considering the dynamic and crucial character of phenomena taking currently place both in the field of technology, organisation, law and in the aspect of understanding the concept of

development (and resulting from it revaluing various objectives of the Polish society), it is purposeful to postpone making developmental decisions in the energy sector which can be risky due to permanent entering path of wrong developmental strategy, i.e. mainly decisions on extend the systems capacity.

2. A high priority should be given to enterprises creating chances for improving effectiveness of electricity and heat use as well as capacity of existing systems at the level of end users.

3. The main instrument for realisation of those objectives should be a consistent implementation of principles of market economy at the highest possible rate to which enterprises and Polish society are not able to adjust.

4. The following are suggested within domain of the implementation of the above-mentioned principles :

- augment of the role of the local authorities in defining directions of development of local energy economy (participation in regulations, influence through local financial and economic instruments, restricted joint ownership on equal basis),
- promotion of participation of autonomous producers in the energy system,
- creation of technical infrastructure and legal basis enabling a flexible co-operation of economic enterprises within decentralised system,
- implementation of new energetic law and executory acts stimulating competition, both among supply enterprises, and supply enterprises and enterprises reducing demand,
- implementation of principles allowing for introduction of modernisation enterprises at energy users, financed or stimulated by energetic companies,
- further division of energetic systems through consistent implementation of the access principles "of the third party" in network,
- acceptation of tariff principles on the basis of energy value on the market, in connection with final costs in the function of time and location of users,
- shifting the decision-making process, shaping the development of the whole system, towards the final user, thus strengthening the role of distribution enterprises, and energy and power turnover in the short- and long-term managing the system,
- adopting the principle of autonomy of decisions of the heat and power generating plant within suggesting relations and prices level on the energy and heat market,
- consistent preference, in the legal and financial systems, of enterprises improving efficiency of energy use,
- training in order to change attitude towards problems of the energy sector development. Promotion of methods of searching common, long-term benefits of users and suppliers within the course of negotiations ,
- governmental guarantees for projects improving energetic effectiveness,
- stimulating creation of financing systems and securities for pro-effectiveness enterprises,

↳ attitude towards final users consisting in tax casements, labelling, informational programs, educational programs for children and youngsters.

5. Favourable conditions should be created to save energy since there is a considerable sphere of profitable enterprises which are not realised for non-economic reasons, such as lack of appropriate knowledge, money, reluctance to undertake activities and so on and so forth. Chóice of proper solutions in this sphere should be a result of a complex investigation into the saving enterprises and analysis of technical, economic, organisational conditions of their realisation.

6. It is recommended to undertake preparations for implementation of coal payment, taking into consideration :

- need to synchronise the introduction of the payment in Poland with other countries of the European Union,
- introduction of tax "vacations" and gradual increase of unit payments,
- synchronising the amount of unit payments with the development of energetic investments.

A safe scale of the coal tax is 50 - 100 USD/Mg C, and investment subsidies - 0.2 - 0.3 % of total investment. Making use of the coal tax and investment subsidies at this amount should bring about GHG emission reduction in the economy, which, in turn, would result in :

- not exceeding the emission level from 1988,
- or, stabilisation of emission at the level from 1990 (with the most favourable conditions of the economic environment).

The decision of introducing the coal tax declared a few years in advance requires that its results be analysed in the background of influence of other economic mechanisms. Such analysis should consider, in particular, at least three following aspects : use universality, scope of destination of income from this tax to activities promoting GHG emission reduction, as well as danger of hampering the dynamics of the economic development and restricting interest in the increase of effectiveness of energy use on the demand side.

It is not recommended to introduce this tax before the year 2000.

7. In steering the GHG emission reduction an important role will be played by macro-economic regulations, such as budget, employment, income of families. We view the use of positive mechanisms as the most efficient for they encourage to desired, but free choices.

The negative mechanisms (e.g. penalties, additional taxes, standards) as the ones that restrict dynamics of changes should only be a supplement for eliminating from the economy insufficient phenomena, i.e. products particularly insensitive to market influence of producers.

8. Mechanisms of financial incentives should be established for producers and purchasers of devices compliant with the defined energetic and ecological standards.

9. In the nearest future energy sector should be developed basing on gas fuels. This concerns realisation of both peak and basic needs. Use of natural gas becomes profitable also in the energy sector, thus causing the emission of pollutants, including CO_2 into the atmosphere. Therefore, we should aim at increasing the supply of the natural gas from import, however,

without infringing the energy safety. It can be achieved through ensuring diversification of deliveries. Necessary are the Government's decisions extorting the activities of the Polish Crude Oil Mining and Gas Manufacture (PCOMGM) in order to gain the gas from new sources.

10. Increase of the share of the natural gas in the country fuel balance should be controlled in respect to maintaining a rational level of energy safety and changes of prices level on the highly monopolised international market.

11. Owing to the possibility of gaining a more considerable improvement in use of primary fuels in production in associated system of the energy and heat in comparison with separable system in the case of using coal rather than gas. In the light of restricted accessibility to the natural gas it should be used mainly in condensation regime production (preferred combined cycles) and dispersed sources. Production in large, system energy generation plants should be based on coal fuel. A supplementary argument in such recommendations is the possibility to better control the quality of work (including pollutants emission) of large units. Increase of the natural gas share in the country fuel balance should be controlled with respect to maintaining the rational energy safety level and changes of prices level on highly monopolised international markets.

12. Owing to ecological and economic potential attractiveness of the nuclear energy, in the second forecast period (after 2015), the world technological advancement in this field should be traced carefully. Also research work should be carried out on safety of this option. On the other hand, however, depending on the obtained results, work should be conducted to persuade Polish society to accept nuclear energy as perspective source of energy.

In case of making decision as for the future development of nuclear energy, it is essential to draw up a detailed program of realisation that would consider choice of technology, its safety, way of carrying the investment into effect, supervising the quality of investment realisation, management of waste materials and other factors in the whole exploitation cycle.

13. Although energy and renewable fuels do not constitute, as far as the horizon of conducted research is concerned, the source of energy that could solve energetic and ecological problems of the Polish economy, we recommend that research is continued on their micro-economic attractiveness in the case of adopting the principles of setting prices based on energy value and actual final costs of energy in the time and location function.

14. Intensified should be the activities aiming at use of the following :

- geothermal energy,
- biomass,
- water energy.

In the agriculture sector, biomass and solar energy for drying crops and preparing hot water for the needs of breeding the cattle should be considered as the most interesting sources of energy.

15. It is found necessary to popularise discussion on comprehensive energetic policy and its economic, ecological and social implications. It will serve the function of shaping the society's acceptation for adopting decision criteria governing the economy, taking into account interest of future generations and global problems, before another stage of socio-economic development. It should lead to society's acceptance for potential, negative results resulting from modification of the life standard in order to avoid an increase of greenhouse gases emission and reduction of threats of greenhouse effect.

16. It is necessary to immediately undertake intense and interdisciplinary research in order to further make probable the possibilities of postponing development of supply capabilities of the energy and heat generation system and concentrating resources available in the economy for bettering the effectiveness of use of those energy carriers.

Executory decisions resulting from the above-mentioned research, and concerning the economic instruments, should be implemented, in its pilot version, in 1997, and on the full scale - in 1998 at the latest. Current interest of hard coal and lignite miners and workers of the energetic sector should not make up an obstacle in the introduction. Otherwise, it will be necessary to make investment decisions concerning modernisation of capacity in the sources in 1998, or accept bearing costs of realisation of energy and heat needs of Polish users by foreign energetic companies (as a result of the European energetic treaty) from 2002 at the latest. Import of energy is an alternative.

17. There is no justification of distinguishing any of scenarios as the so called reference scenario assuming certain "model" development of the economy. Scale, time horizon and interdiscipline of the problem of defining of the country developmental strategy against the background of variable and uncertain internal and external conditions cause that the so called reference scenario can be a contractual category merely. In the situation of significant economic and social transformations rising from the economic level characterised by low effectiveness, the trenchant majority of GHG emission reduction should be linked with improvement of efficiency.

18. It is recommended that during international negotiations the 1998 emission be treated as the reference level of emission. Still the decision on system transformations passed in 1989 remains the most efficient political decision within the GHG emission reduction. There is, nevertheless, a justification for creation of "recommended" scenario. The third, presented in Chapter 9.2, scenario constitutes a recommendation of the proper way of use of previously made decisions.

One should aim at avoiding making commitments by Poland on CO2 emission reduction, which would additionally financially weigh on the country. On the basis of carried out analysis one could state that with rational energetic policy it is possible to achieve 5 % reduction in 2010 with no costs at all. Greater reduction will probably not be feasible without additional financial outlays, though.

19. In the light of results of comparison of reduction costs for Poland and countries of the European Union, it is worth mentioning that with equal commitments as for CO2 emission reduction level for all countries, additional obligations in the virtue of such commitment would be for Poland comparable with commitments of such countries like Germany or Great Britain. Considering this, our objective should be to differentiate emission reduction commitments.

Industrial sector

Polish industry has chances to considerably decrease the GHG emission thanks to reconstruction of industry and adjusting it to the international requirements. This feature of Polish industry development can provide Poland with a number of economic and political arguments on the international forum as criteria favouring political and economic integration of Poland with countries incorporated in OECD.

1. Therefore, we should aspire to prepare and realise strategies of the GHG emission reduction in industry, within the integrated energetic and ecological policy. Similarly we should aim at active participation in the international institutions of the climate protection.

2. Reduction of the GHG emission in industry by approx. 40 % in comparison with the base year, can be a subject to commitments of Poland within international conventions, and seems to be a level of moderate political risk since the effect of GHG emission reduction in industry is

underestimated. Underestimation results from the fact that some 30 % of industrial technology was not included in the analysis. Also the effect of implementation of nòn- and low-investment enterprises resulting from a better management of energy.

3. Period till 2000 should be used for preparing instruments of energetic and ecological policy in industry that would improve effectiveness of energy use and depleting energy consumption in production.

Till 2005, achieving the reduction of the GHG emission by some 20 % (in relation to the base scenario) should stimulate instruments of the state industrial policy aiming at reconstruction of Polish industry.

After 2005, within the power of instruments influence upon the GHG emission reduction strategy realisation prevailing should be developed tools of the integrated energetic and ecological policy. Simultaneously, part of the tools can be adapted within the international co-operation on climate protection.

Transport sector

1. Among the objectives of the economic, transport and spatial policy of the state and local authorities there should be hampering and reversing the tendency in the spatial transformations and communal behaviour causing an increase of transport needs (i.e. as a result of cities development) and a growing dependence on road transport. Achieving those goals would serve not only the function of depleting the greenhouse effect, but a general improvement of the state of the environment as well.

2. Measures of the policy leading to the GHG emission reduction in Chapter 9.4 include nation-wide and local activities. In the first stage, the following are recommended as the most promising :

⇒ sharpening standards of fuel consumption and emission for internal-combustion engines, particularly, taking into account compounds bringing about the greenhouse effect),

⇒ supporting group transport in all its forms (including bus transport) by policy of rehabilitation and modernisation of railways as well as tramway and bus communication in cities,

⇒ beginning to use fiscal instruments, starting from payments for parking in excessively congested urban areas,

⇒ any possible measures of spatial policy counteracting spreading of infrastructure within urban areas,

⇒ possibly wide informational and teaching activities intended to convince about the necessity of changing behaviour.

3. In the second stage the most important are activities causing radical abatement of "transport-absorbing" and energy consumption. Apart from the mentioned-above activities, the most promising are implementation of sharpened standards of energy consumption for motor vehicles, as well as fiscal measures in the form of a tax for fuels and payments for using roads. Thus a user would bear all the costs connected with using given means of transportation. (including coverage of external costs).

Agriculture sector

1. Realisation of respective options of the GHG emission reduction in agriculture requires both more intensive use of the existing technologies and elaborating and implementation of new ones. The former will not cause much difficulty, the latter, however, what is needed is parallel modernisation of the scientific and research base as well as productive activity connected with the use of research results in the actual performance of agricultural producers.

2. In the nearest future it is necessary to :

- draw up a program specifying directions of activities efficiency in agriculture steered at implementing options reducing emission,
- activating research supporting those activities,
- this program should consider emission reduction both through implementation of new technologies in agricultural production, and through more effective use of energy, including renewable energy.

It is crucial to start research on :

- elaboration of bio-technological method of gaining seedling of *Miscanthus giganteus* plants *in vitro* as well as setting off their mass-production,
- growing new varieties of rape and hybrid of wheat and rye for the energetic purposes (enhanced content of reduced fatty acids in rape and increased activity of amylolitic enzymes in hybrid of wheat and rye),
- drawing up new technologies of growing and harvesting plant biomass with destining in to renewable sources of energy,
- gaining transgenic varieties of potato resistant to the potato-beetle,
- increase of activity and effectiveness of assimilating atmospheric nitrogen by symbiotic and land bacteria,
- increase of effectiveness of feeding stuff use as well as cows milk productiveness,
- elaborating new technologies of production of plant protein confection for food production,
- growing new varieties of all elementary cultivating plants characterised by enhanced resistance to drought and high temperature as well as more effectively using higher concentration of atmospheric CO_2,
- accelerating the rate of afforestation up to 30 000 per annum.

Renewable energy sources

1. It is crucial to introduce financial incentives for production and exploitation of energy coming from renewable sources. For all sources of renewable energy, except for biomass, it is necessary to use direct financial incentives.

2. Within agricultural production, use of energy from renewable sources should be supported. This is particularly true about :

◊ timber and straw as fuels,

◊ solar energy,

◊ wind energy,

◊ geothermal energy sources,

◊ liquid bio-fuels as well as rape and hybrid of wheat and rye,

◊ biogas.

3. It is suggested to make use of the following economic instruments :

* non-returnable subsidies, reaching up to 50 % of outlays in the first implementation of a given technology, and gradually lower, in the course of implementing it,

* preferential credits.

4. It is also suggested to make use of the following social and political instruments :

✓ comprehensive and progressive information and social education (radio, television, leaflets, brochures) and the like,

✓ development of marketing of the tried out devices,

✓ free of charge help rendered by trained staff, e.g. Agricultural Advisory Centres (AAC), energy generation plants, technical schools (particularly agricultural ones),

✓ linking programs on use of renewable energy sources with programs on energy saving,

✓ including the private sector (through incentives, i.e. lowering tax) in creation of the market of devices, facilities using renewable energy sources,

✓ introduction to the draft of the Energetic Law a statement on non-transferable right of individual users who are not economic entities to use renewable energy sources for their own needs, as well as possibility to transfer extra amount of produced energy outside the network system,

✓ elaborating and adopting by the Economic Committee by the Council of Ministers the comprehensive program of renewable energy development in Poland together with all its elements, i.e. economic, social and legal instruments.

Municipal sector

1. Undertaking a successive change of the admissible building thermal standards and the required energetic quality of devices (particularly, small water boilers, household facilities, audio-visual equipment), as well as introduction of legal regulations that would oblige distributors and users of network heat to adjust, in a specified time horizon , exploited systems to the state enabling to calculate, according to the results of measurements, used amount of energy and power, and abandoning the idea of global calculations,

2. Establishment of mechanisms of financial incentives, e.g. system of tax release for users to make an investment in the circuits of weather automatics and temperature regulation, as well as replacement of the exploited facilities and equipment for more energy-effective or less energy consuming facilities,

3. Maintaining and extending over all groups of buildings owners the system of subsiding thermal renovation of buildings,

4. Supplementing curricula in primary and secondary schools with subjects concerning environment use, not only its protection, promoting behaviours and developing habits favouring energy saving and rational use of the environment.

Legal and economic mechanisms

Implementation of the strategy of the GHG emission reduction requires that a number of political, legislative, organisational and educational activities be undertaken. Those activities should result from decisions of the Climatic Convention of the United Nations in the Matter of Climate Changes, Convention on Ozone Layer Protection as well as specific social, economic and ecological situation of our country. In order to ensure a competent implementation and functioning of the GHG emission reduction system the following should be undertaken :

<u>In the sphere of political and organisational activities</u>

1. A statement should be introduced in the draft of the new constitution on eco-development as a basis for activities in the economic, political and social sphere. Similarly, another statement should be supplemented that would safeguard equal rights for using the goods and assets of the environment for economic entities and physical persons. Currently, work on new constitution is under way. This constitution will be in force for many years and a gravity of its decisions will decide about the extent of the country eco-development of the economy and society.

2. In legal acts of system nature :

   - in new penal code a chapter should be introduced which would be devoted to crimes committed against the environment,
   - in the offence code a codification should be introduced of offences against the environment included in the Statute on Protection and Shaping the Environment. Also regulated should be acts consisting in avoiding an obligation to undertake activities defined by the decisions of the state ecological policy (e.g. management of methane coming from the coal mines),
   - in the civil proceedings code there should be introduced a release from registration fees for civil issues within the environment protection.

3. The following changes should be included in the tax law :

a) in the Statute on Tax for Goods and Services, the Minister of Finance should be authorised to make use of lower tariffs of the VAT tax with respect to the economic entities whose production is based on the best possible technology,

b) in the Statute on Income-tax for Physical Persons and in the Statute on Income-tax for Legal Entities, extended should be a range of tax easements for expenses borne in connection with replacement of energy consuming equipment as well as for expenses connected with improving thermal insulating properties of buildings.

4. In the new drafting of the State Ecological Policy the following issues should be emphasised :

- problem of the GHG emission reduction as an important contribution to eco-development implementation as well as meeting the modern times challenges by the Polish economy.
- need to activate strong incentives to engage economic entities' and households' own means for the sake of widely understood energy saving,
- role of the environmental, raw materials and energetic auditing.

5. In the new drafting of the energetic policy the following issues should be highlighted :

- necessity to introduce energetic facilities measuring,
- energetic auditing as an important tool for realisation of the energy saving program,
- activities for the good of broader diversity of the structure of energy carriers,
- activities being in line with development of unconventional energy sources.

6. While formulating the state transport policy, the problem of the GHG emission reduction should be stressed. It concerns particularly :

- elaboration and compliance with energetic and ecological standards in the national production of motor vehicles and their import,
- introduction of preferential customs duty for motor vehicles with better technical parameters than the binding standards,
- compliance with technical standards while designing motor vehicles,
- system of motor vehicles technical control (especially engines),
- systems of organisation of group transportation and so on and so forth.

7. While formulating the state agricultural policy; the following statements should be introduced :

- ← preferring cultivation with a high ratio of CO2 escapement,
- ← considering rationalisation of the energy management in agriculture.
- ← acknowledging agriculture as the bio-fuels producer,
- ← promoting use of renewable energy,
- ← favouring rationalisation of use of nitrogen fertilisers,
- ← supporting reduction of methane emission in cattle growing.

In the sphere of the environment protection law

a). General legal regulations of implementation of the system of strategies of the GHG emission reduction.

8. In the new drafting or amendment to the Statute on Protection and Shaping the Environment the following activities should be undertaken :

a) to bring into prominence the problem of climate protection and the significance of enterprises for the sake of the GHG emission reduction as well as their role in implementation of the idea of eco-development and modernisation of the economy,

b) to introduce new instruments : coal payment, payment for methane emission from farms and communal dumping sites as well as forest subsidy,

c) to point at the way of gathering and distributing means connected with functioning of the newly implemented instruments, stressing that part, i.e. 10 % of the income from the coal payment is destined for the forest subsidy. The remaining part should be devoted for :

- supporting and organising the environmental auditing,
- granting the credits guarantees risen in connection with realisation of investments affecting the GHG emission reduction,
- ecological education.

It would be purposeful to devote the income from payments for methane emission to realisation of enterprises connected with elaboration and implementation of systems serving the function of carrying away, accumulating and utilisation of methane emitted into the atmosphere from mines, cultivation farms and dumping sites,

d) explain in detail the term of the best available technology, i.e. best technology from the point of view of preventing, reducing or neutralising waste materials. The term "available technology" does not mean technology universally used, but the one which is used at least by one producer, even if he is outside his own country. Applying the best available technology can not result in enormous amounts of money needed. It is assumed that the excessive costs are those which are not proportional to the obtained results.

9. In the Statute on Forests, another source of Forest Fund should be pointed at, i.e. 10 % of income from the coal payment. Also the statement should be provided with stipulation of use of that income for forest subsidies. This statement is necessary to ensure proper functioning of the strategy of the GHG emission reduction.

10. Basing on the draft of the Energetic Law, whose legislative process is under way in the Sejm of the Republic of Poland, one can surely state that a considerable number of its resolutions can support the climate policy (directly or indirectly). The resolutions are as follows :

- obligation to shape the energy policy and forecast the development of the energy management in the periods not shorter than 10 years (Art. 13 and 16),
- identification of programs of activities for their realisation,
- meeting the condition of defining the needs for fuels and energy in relation to the GDP (Art. 17), taking into account protection of the environment and rationalisation of the use of fuels and energy,
- defining the price and tariffs policy,
- proprietary transformations,
- obligation of the energetic enterprises to deplete and save energy at users' side and promotion of unconventional energy,
- obligation to popularise the increase of effectiveness of use of energy through licensed enterprises (Art. 25 and 26),
- obligation to produce and import facilities and installations compliant with the defined requirements (Art. 53),
- energetic labelling of products,
- defining fuel quality requirements (Art. 56).

Despite many positive legal regulations in the energetic economy included in the draft of the Statute, a small number of resolutions concerning direct use of fuels and energy by dispersed users should be emphasised.

The following issues should be introduced in the new Energetic Law :

- obligation to implement within the period of 5 years measuring of energy consumption of all facilities,
- introduction of licensing of economic activities within generation, transfer, distribution, and fuels and energy trade towards meeting ecological requirements, including the GHG emission reduction,
- introduction of licensing of economic activities within generation, transfer, distribution, and fuels and energy trade, call into being the Office for Regulating Energetics, which would be obliged to supervise implementation of energy

consumption measuring, as well as execute resolutions of the State Ecological Policy,

- defining the legal bases for functioning of energetic supervision based on energetic auditing.

Additionally, it is postulated to :

- promote high-efficiency facilities, which favour the environment protection and use of the renewable energy beyond the legally formulated requirements, through putting a lower VAT tax on them,

b). Detailed legal regulations of implementation of the GHG emission reduction system.

1. Decree of the Council of Ministers on the coal payment.

The decree can be brought into life on the basis of the amendment to the Statute on Protection and Shaping the Environment, or on the basis of a new statute with statements suggested in the recommendation in question. The following problems would have to be included in the Decree :

- regulation subject : sale of hard coal, lignite, furnace oil, diesel oil, natural gas and petrol,
- way of calculating the payment and paying in of means : payment is calculated by producers and importers of fuels and paid in it to the subaccount of the National Fund of Environment Protection and Water Management,
- way of calculating the unit sum of payment : sum of payment depends on CO_2 emission in relation to the unit of produced energy from a given fuel.

2. Decree of the Council of Ministers on Payments for Methane Emission from Farms and Communal Dumping Sites.

The decree can be brought into life on the basis of the amendment to the Statute on Protection and Shaping the Environment, or on the basis of a new statute with statements suggested in the recommendation in question. The following problems would have to be included in the Decree subject : methane emission,

? economic entities : owners of farms with more than 50 head of cattle, 150 head of pigs, 6000 head of poultry as well as administrator of communal dumping sites which are exploited for more than 15 years,

? way of calculating and amount of the unit sum of payment : payment would be calculated on the basis of every m3 of communal waste materials (also from the agricultural and food industries) taken to dumping sites, in relation to farms on the basis of the administration decision declared by the commune's organs.

? way of calculating and paying in : administrative decisions on the amount of payment for methane emission are granted by communes' or towns' offices. Thus obtained means replenish communes' environmental protection and water management funds. Payment for methane emission from dumping sites, on the basis of the general regulation. is calculated by units exploiting the dumping sites basing on the voucher for accumulating waste materials,

? entity easements : owners of farms and administrators of dumping sites who pull out methane and use it.

3. Change of the Decree on Payments for Economic Use of the Environment and Introducing Changes to It.

A new rate of payment for methane emission should be incorporated in the Decree.

4. Decree of the Minister of Industry and Trade and the Minister of Environmental Protection, Natural Resources and Forestry on the Course of Acknowledging Technologies As Compliant With the Criteria of the Best Available Technology.

The decree can be brought into life on the basis of the amendment to the Statute on Protection and Shaping the Environment, or on the basis of a new statute with statements suggested in the recommendation in question. The aim of the Decree is to define criteria of subsidising the purchase of modern technologies.

- subject : definition of the best available technology and conditions for its implementation, as well as the course of qualitative evaluation of the technology,

- economic entity : economic units.

The source of subsidising can be means coming from the coal payment. Subsidies should be granted on the basis of competition of quality certificates granted by the State Committee of Normalisation of Measurements and Quality, or the Agency of Technique and Technology.

5. Decree of the Minister of Environmental Protection, Natural Resources and Forestry on Principles of Granting Forest Subsidy.

The Decree can be brought into life on the basis of the amendment to the Statute on Forests. The Decree should concern :

- subject : principles of entering into a contract on subsidy among owners of land, Regional Directorate of State Forests and the Forest Fund.

In an appendix to the Decree : pattern of a contract on subsidy.

6. Decree of the Minister of Industry and Trade on defining standards of energy use by household equipment.

The Decree can be issued on the basis of a new Energetic Law. The Decree should concern :

Subject : household equipment,

Entity : designers, producers, importers of household equipment.

7. Decree of the Council of Ministers on Negotiating Conditions of Implementation of Programs of Pro-ecological Restructuring of Enterprises.

Subject :

- appointing a proxy of the government for pro-ecological restructuring of enterprises, as well as defining range of his competencies,
- defining a scope of the pro-ecological restructuring of enterprises, constituting the subject of negotiations,
- defining a scope of the state and territorial self-government aid in realisation of the restructuring program.

Entity :

- economic units, organs of territorial self-government, state administration organs.

c). Shaping ecological awareness

The following issues should be elaborated and introduced :

* program of children and youth education in the sphere of problems connected with climate protection, particularly, focusing on forms and methods of the GHG emission reduction,
* program of promoting energy-saving consumption model,
* implementation of issues concerning climate changes and climate protection, already at the level of elementary education,
* establishing secondary schools teaching specialists oriented to rationalisation of energy use and appropriate energy management in conditions of the market economy,
* program of development of publications addressed to energy users taking into consideration problems of climate protection.

Summing up, one can state that :

1. Consistent realisation of the current direction of the state economic policy constitutes a solid base for a steady economic growth and gradual implementation of the elements of the climate protection policy in the future.

2. Accelerating the rate of structural changes in the economy is beneficial owing to the economic development and fulfilment of commitments within the Frame Convention of the United Nations on Climate Change. However, those structural changes can be hampered by heavy social friction connected with a lack of acceptance for further limitation of consumption for the sake of accumulation in the initial period of changes (till 2000).

3. Return to the economic structures before 1989, maintaining the material-consuming economy is extremely dangerous from the point of view of achieving the economic and political strategic

goals, such as joining the family of highly developed countries, integration with the European economic structures.

4. Effective and safe financial tools of the climate protection policy are the coal tax and investment subsidies oriented to enterprises connected with the GHG emission reduction. The condition of introducing those tools is consistent realisation of the structural economic changes according to the current political course.

5. A consequence of the implemented policy of climate protection is a change of energy use in the country towards the increase of share of the imported hydrocarbon fuels. This is particularly significant from the point of view of the state energetic safety. Directions of import of the natural gas, crude oil and processed liquid fuels should be diversified in such a way that the import of those fuels is autonomous enough from potential changes of the international situation.

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We are very grateful to our American colleagues for their readiness in providing us any necessary assistance and support in fulfilling our difficult and pioneer task.

We hope that results of this Study will serve not only to the Polish environmental and economic decision makers but also will be of some interest for our US partner and international community dealing with climate change issue.

Annex 1

MACROECONOMIC REFERENCE SCENARIO OF POLAND'S ECONOMY DEVELOPMENT BY THE YEAR 2030

ASSUMPTIONS

Elaborated by the Polish Country Study Team

Macroeconomic Reference Scenario (MERS) describes long-term development of the national economy relating to the following macroeconomic variables:
- gross domestic product (GDP),
- total investments in the National Economy (NE),
- import and export,
- employment and rate of unemployment, and
resulting structures of:
- GDP,
- investment,
- employment.

National strategy of the GHG's emission reduction will be created on the base of MERS.

The following assumptions were done for the MERS Reference Scenario:
- growth of the GDP should be relativel high (3-5% per year) to assure reaching the mean European level of different macroeconomic parameters,
- reduction of employment in agriculture will appear after year 2000,
- investments will be directed on services and transportation,
- increase of unemployment will be the fundamental barrier for fast structural changes in the NE.

To create the MERS for such country like Poland which is in transition period causes substantial problems, especially in estimation parameters for economic equations. Main calculations were made by means the modified methodology based on Simulation Dynamic Model (SDM-NE) presented in the *Case Study of GHG's Emission in Poland* [FEWE 1993,Warsaw].

Following main results have been obtained by the MERS :

<u>a) rate of mean annual growth of main macroeconomic values in the period 1993 -2030 (in per cent)</u>

- population - 0.2,
- employment - 0.4,
- GDP - 4.1,
- GDP per capita - 3.9,
- material intensity of GDP - -1.6,
- GDP used in the country - 3.5,
- total investments - 4.1,
- total consumption - 3.4,
- consumption per capita - 3.9,
- investments per capita - 3.9,
- total productivity - 3.2,

Time changes of some macroeconomic parameters by the year 2030 are presented on following diagrams:
- GDP (fig.1),
- structure of GDP by sectors (fig.2),
- investment share in GDP (fig.3),
- investment shares in 1993 and 2030 by sectors (fig 4&5),
- employment structure by sectors (fig.6),
- shares of import-export in GDP (fig.7),
- unemployment rate (fig.8),
- CO_2 emission (fig.9).

In spite of high economic growth, the reduction of unemployment from present value of 16.3% to expected 10% in 2030 will be reached due to simultaneous structural changes of economy and resulting changes in employment structure by sectors (mainly by progress of service demands).

The MERS is treated as business as usual scenario where neither special measures to reduce the GHG's emission nor adaptation of economy to changing climate are included.

As assumptions as well results of the MERS have been discussed among the whole Country Study Team and with some consultants outside the Project.

Final results were presented to the National Comission for Sustainable Development and through it to all ministries and other governmental agencies for review. Obtained suggestions and amandments were included into the scenario.

Fig.1 Gross Domestic Product

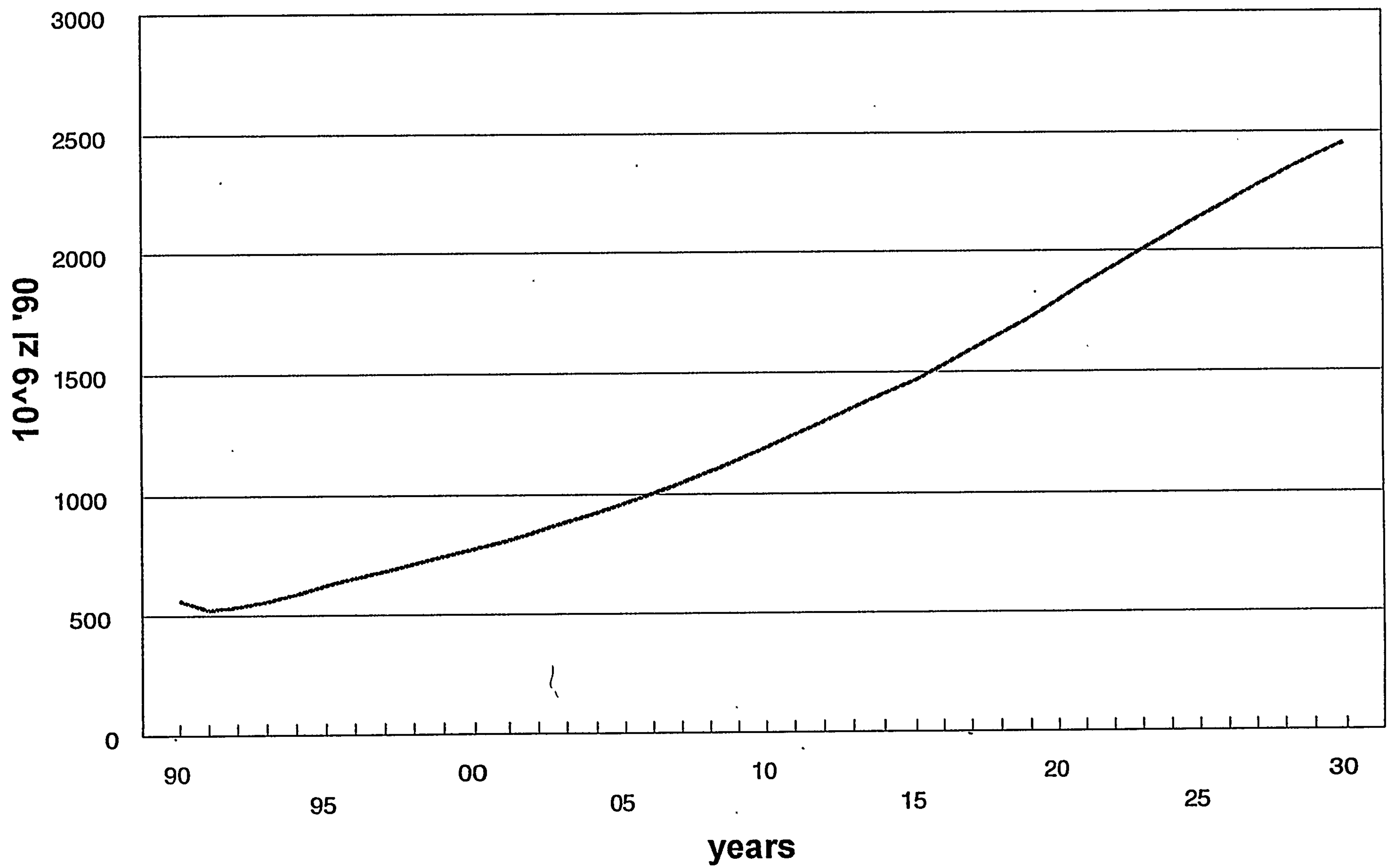


Fig.2 Structure of GDP by Sectors

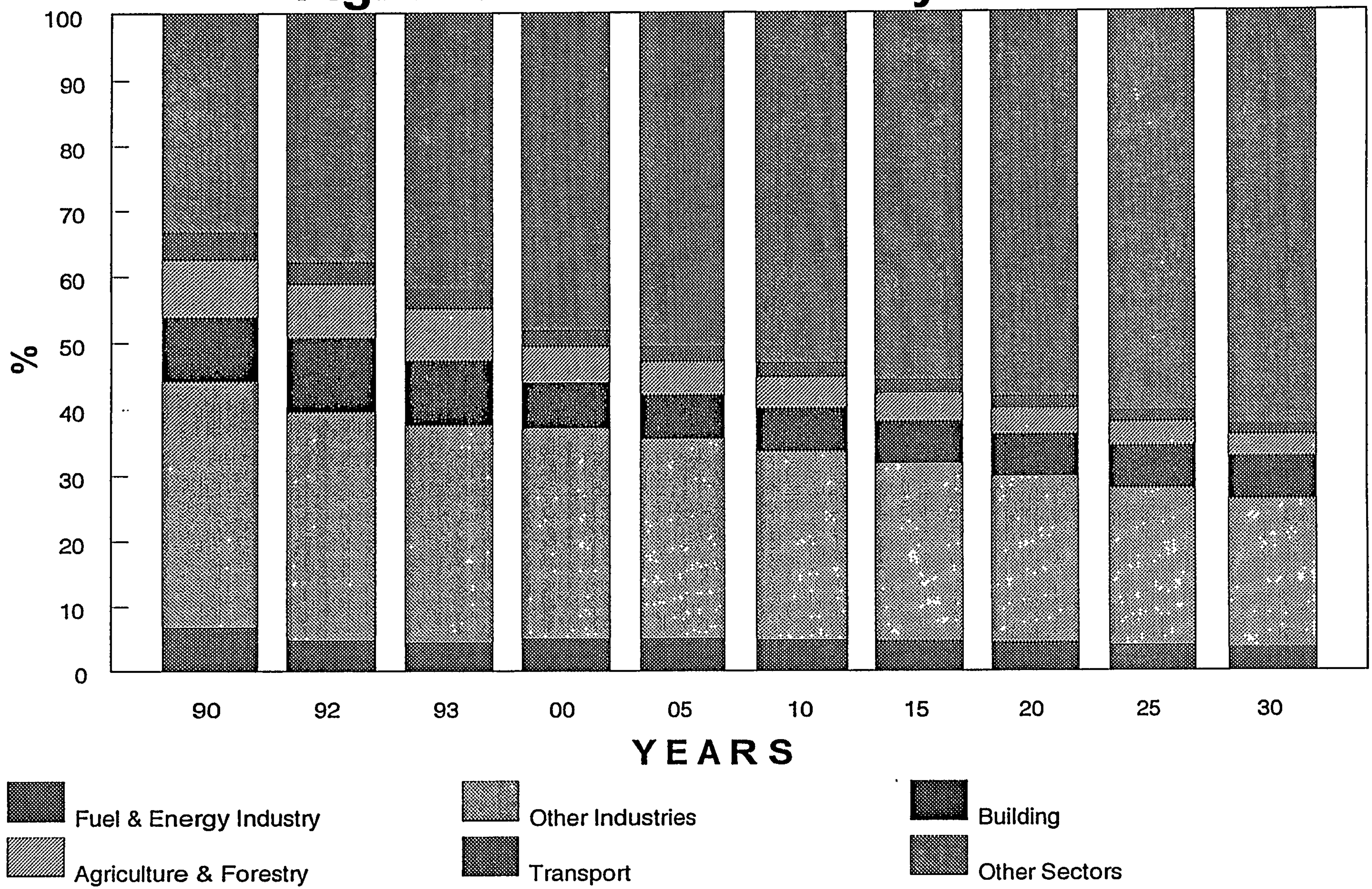


Fig.3 Investment Share in GDP & GNP

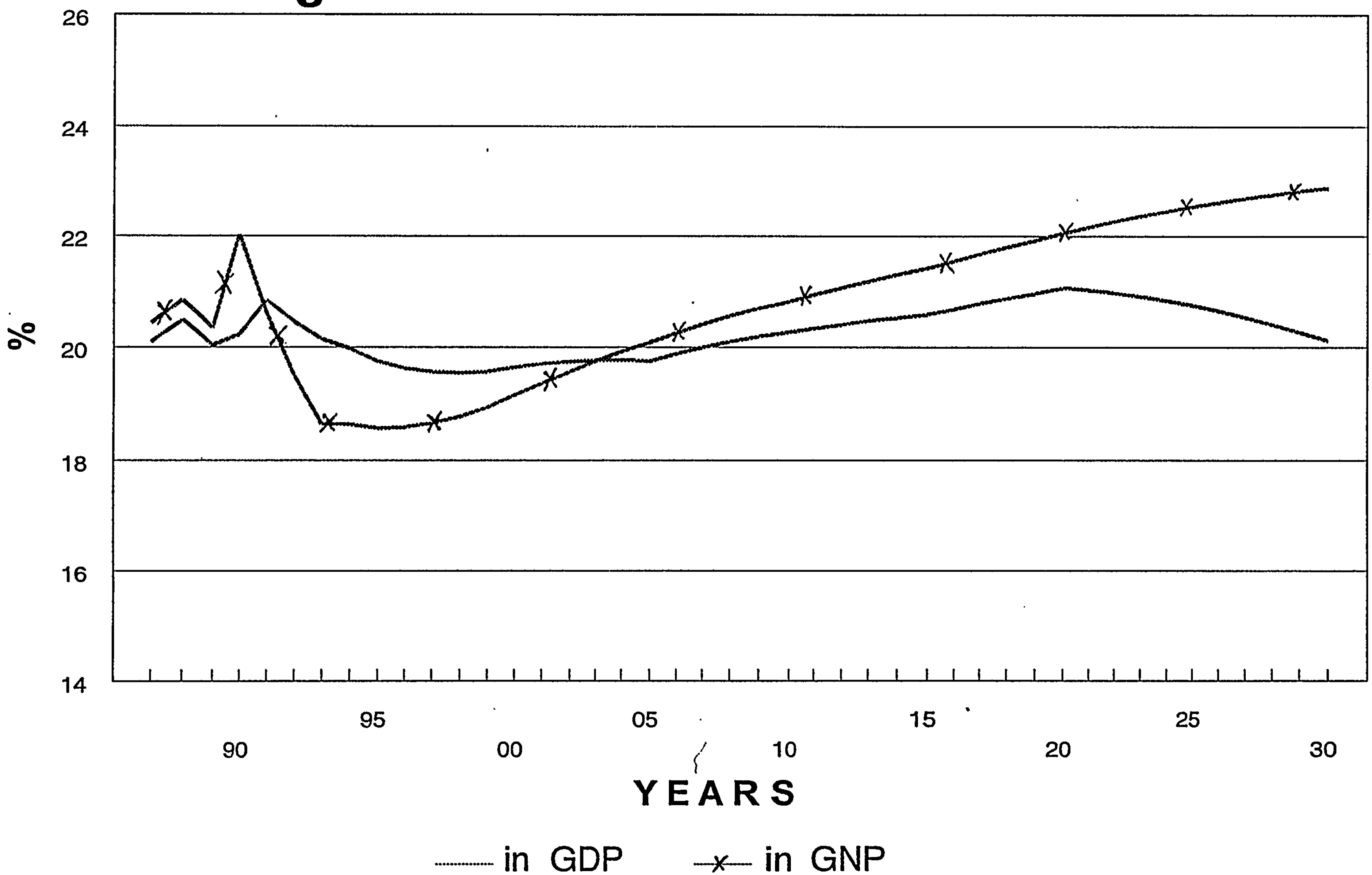
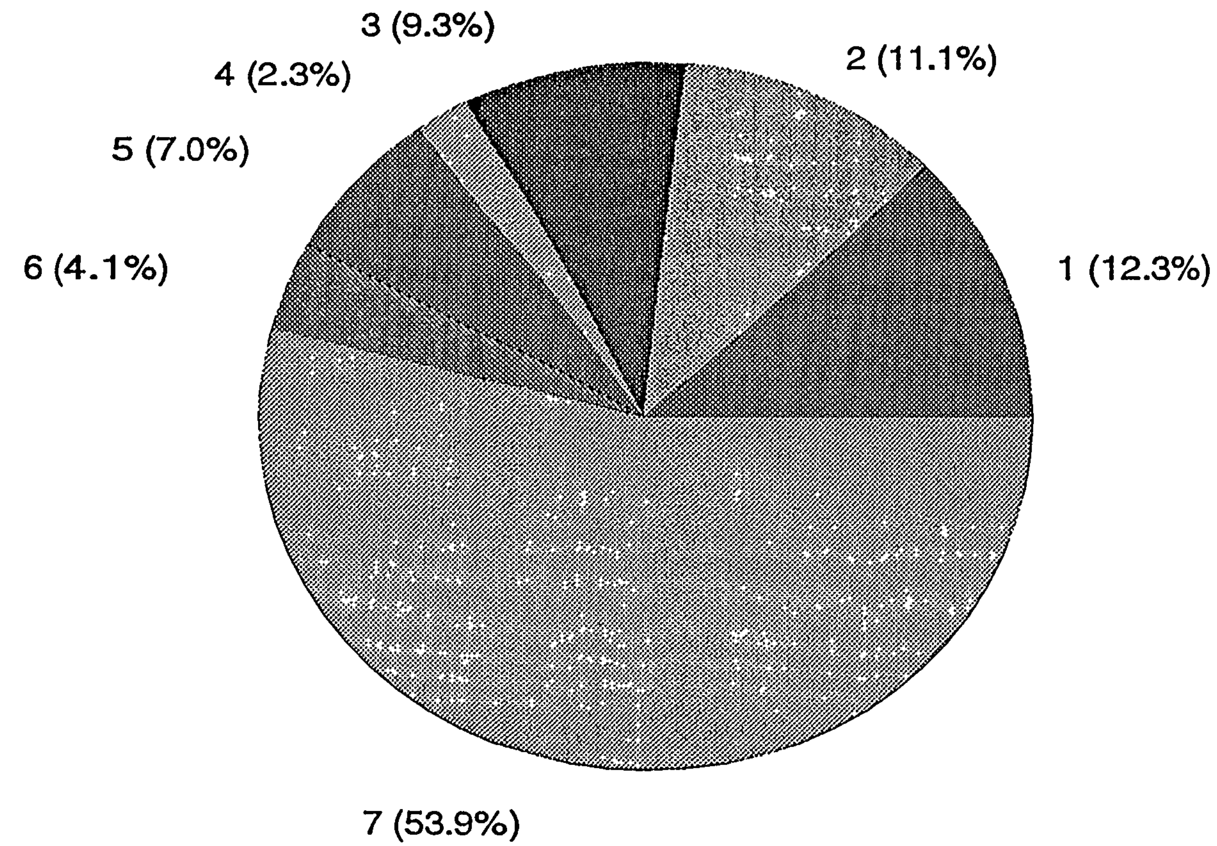
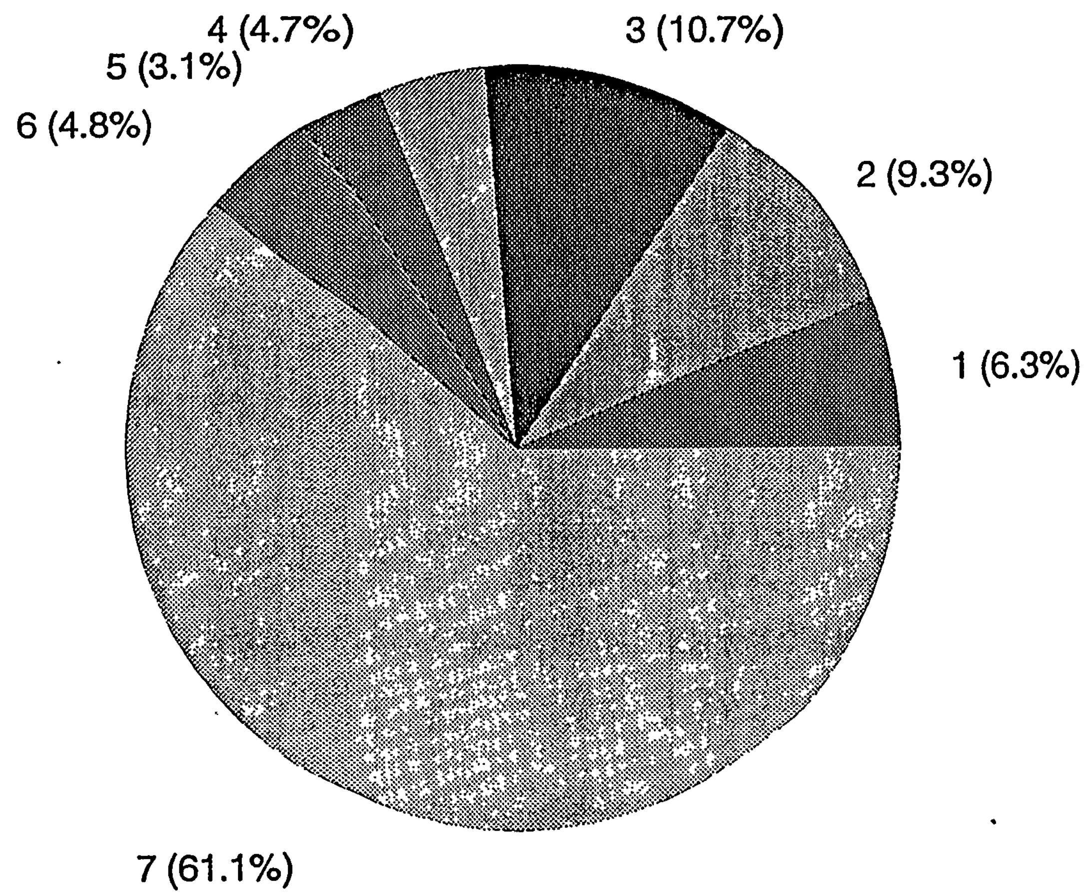


Fig.4 INVESTMENT STRUCTURE by SECTORS 1993 year



1- Fuel & Energy Industry; 2- Heavy Industry; 3- Other Industries; 4- Building; ; 6- Transport; 7- Other Sectors

Fig.5 INVESTMENT STRUCTURE by SECTORS
2030 year



1- Fuel & Energy Industry; 2- Heavy Industry; 3- Other Industries; 4- Building; 5- Agriculture & Forestry; 6- Transport; 7- Other Sectors

Fig.6 Employment Structure by Sectors

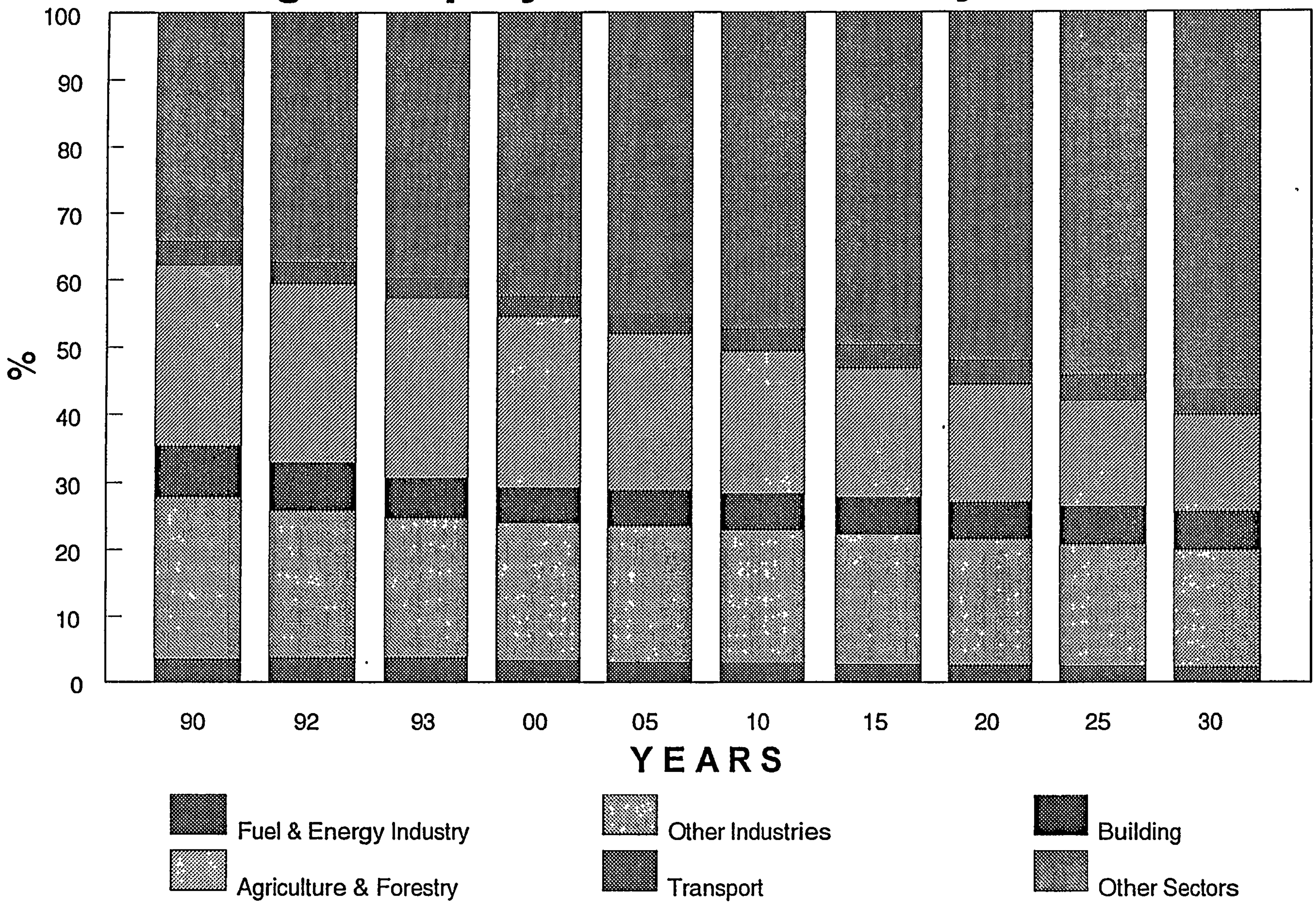


Fig.7 Share of Export & Import in GDP

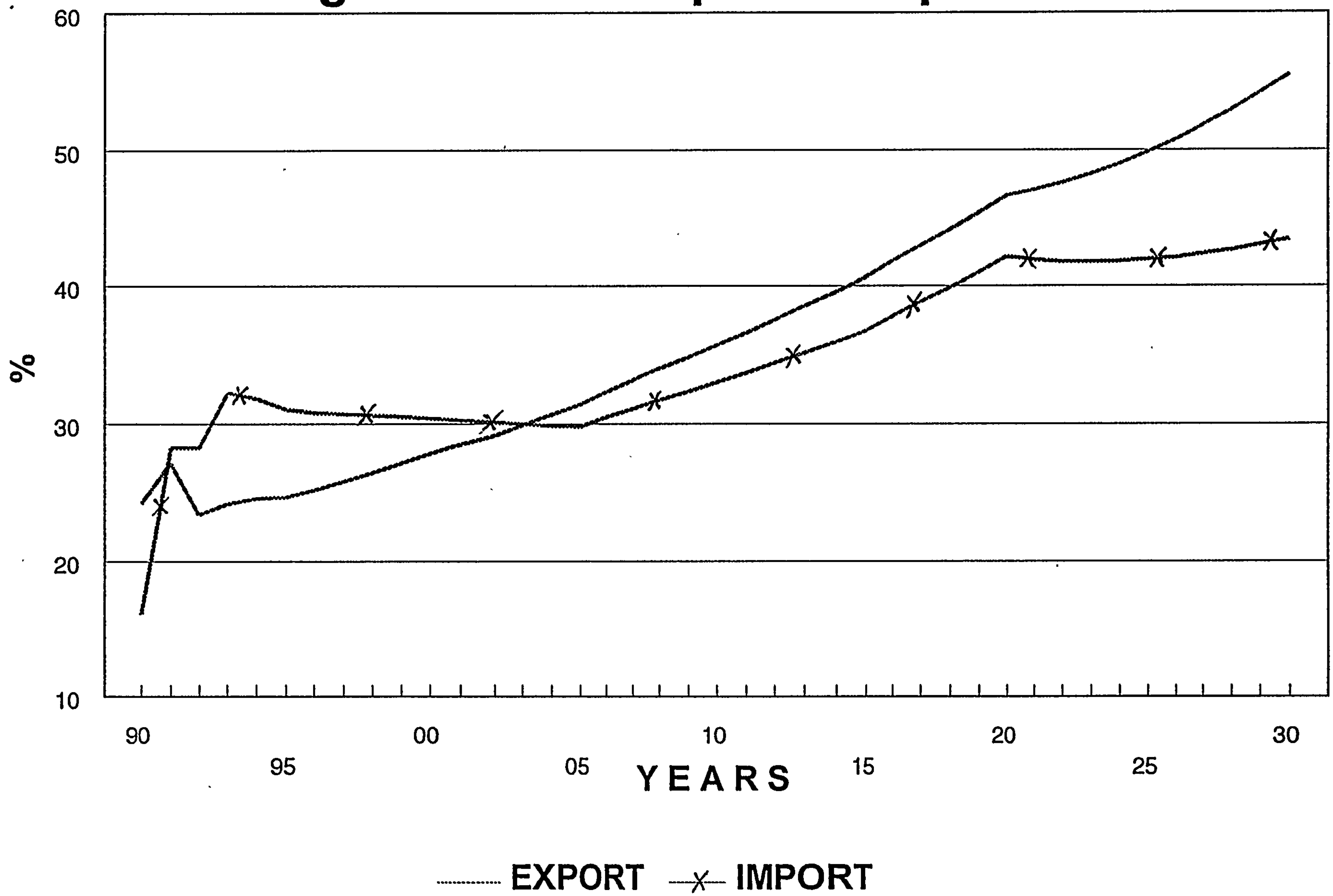


Fig.8 Rate of Unemployment

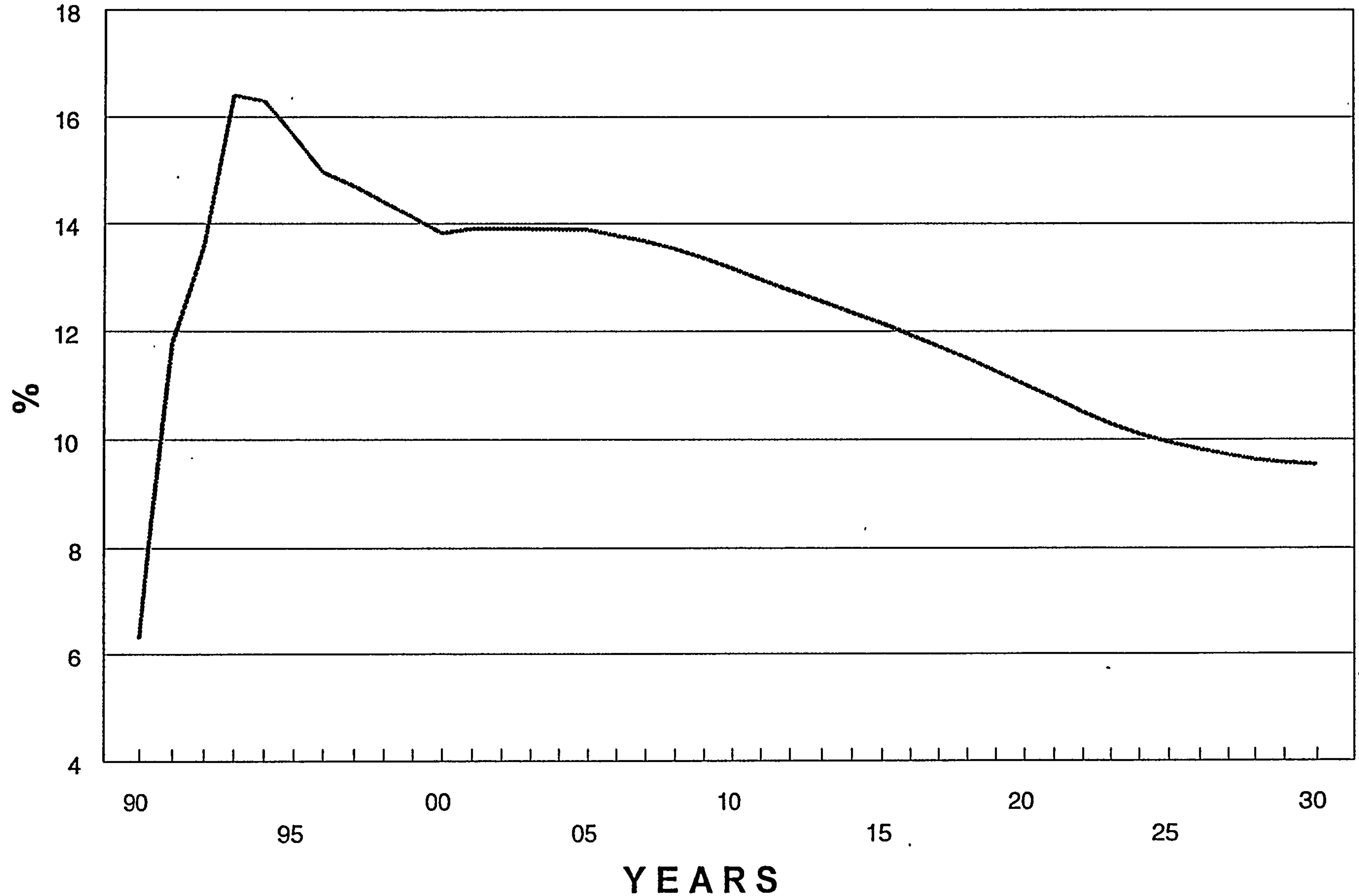
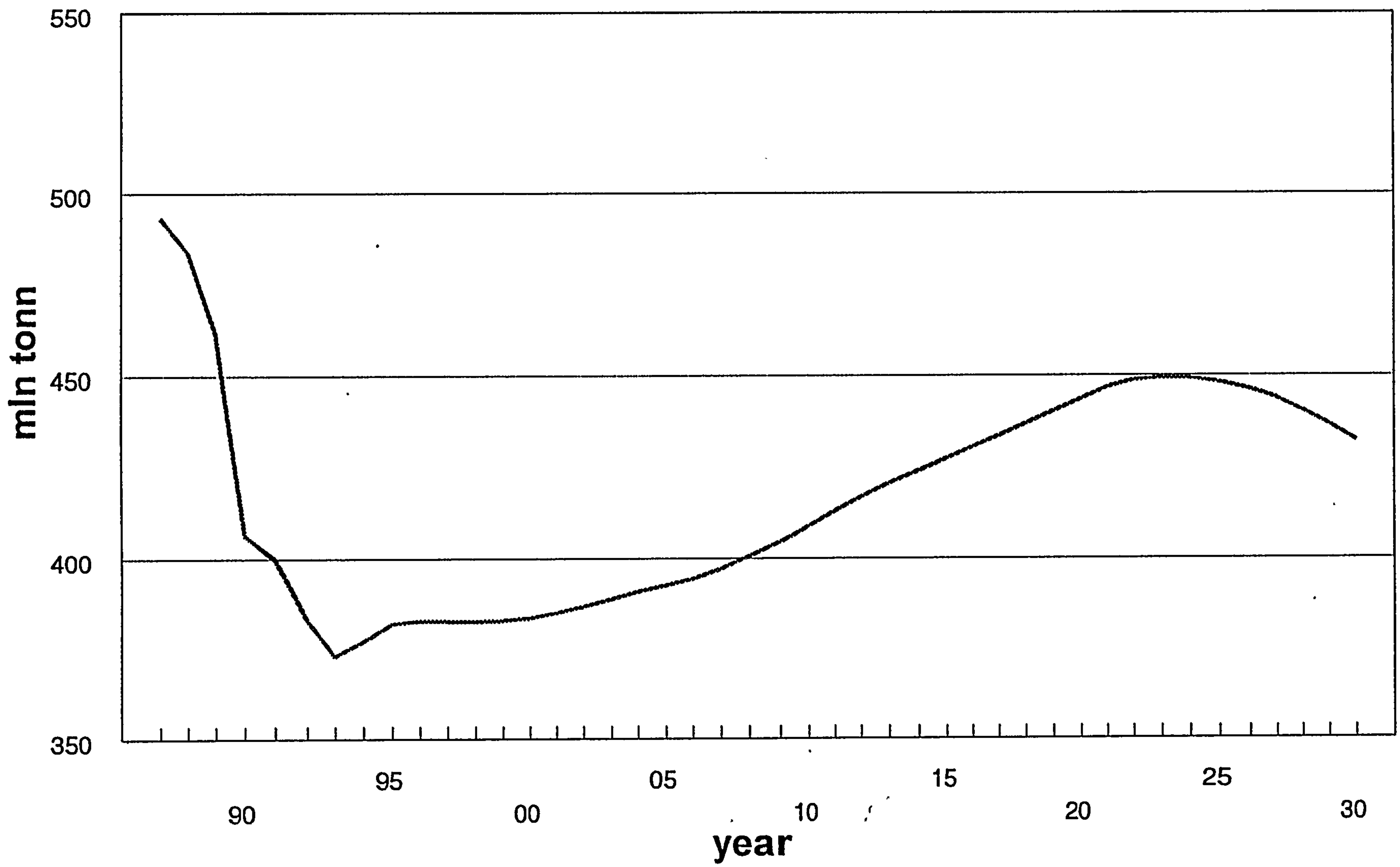


Fig.9 CO2 Emission



REFERENCE SCENARIOS COMPARATIVE CHARACTERISTICS OF MACROECONOMIC SCENARIOS VARIANTS (BASE, CHANCE AND STAGNATION) WITHOUT TAKING INTO CONSIDERATION THE IMPACTS OF CLIMATE CHANGE AND ECOLOGICAL POLICY INSTRUMENTS

COMPARISON OF REFERENCE SCENARIOS

The reference scenario (MERS) is presented by diagrams in Annex 1 and it function in methodology of Country Study performance is described in chapter 7.3.

The sectoral research teams used dates of reference scenario (MERS) for creation the sectoral emission reduction scenarios based on elaborated technological options. Additionally, were used the opinions and comments from the governmental institutions regard the reference scenario (MERS).

On the next step of Country Study it was decided on the in-depth analysis to use three variants of reference scenarios: base, chance and stagnation for elaboration the GHG emission reduction scenarios. The procedure for creation emission reduction scenarios was described in chapter 10.1 and the principal assumptions in chapter 10.2. The reference scenarios (base, chance and stagnation) presented in this annex were elaborated by use SDM-NE model and by modification of the assumptions, undertaken by elaboration of MERS, on the base of governmental institutions opinions and comments regard to MERS. During the reference scenarios results verification and acceptation were done a special consistence analyses for the fundamental macroeconomic magnitudes obtained from model and results delivered in frames of elaborated sectoral scenarios.

The reference scenarios (base, chance and stagnation) in the present annex (no 2) were showed by comparative diagrams of principal macroeconomic , energy and emission parameters.

They present following comparisons for time run 1988-2030:

* GDP - fig.1.,
* structure of GDP - fig.2.,
* investments share in GDP - fig. 2.,
* structure of investments by sectors - fig.4.,
* material intensity of GDP - fig.5.,
* export, import and foreign trade balance - fig.6.,
* structure of employment by sectors - fig. 7.,
* unemployment rate - fig.8.,
* country energy supply - fig. 9.,
* structure of country energy supply - fig.10.,
* energy intensity of GDP- [mln zl'90] - fig 11.,
* energy intensity of GDP - [mln USD '90] - fig .12.,
* CO_2 emission - fig.13.,
* aggregate emission factor of energy supply - fig. 14.,
* emission intensity of GDP [mln zl'90] - fig.15.,
* emission intensity of GDP [mln USD '90] - fig. 16.,
* consumption per capita - fig. 17.

The presented reference scenarios (base, chance and stagnation) comparisons determine the bases for elaboration macroeconomic GHG emission reduction scenarios taking into consideration the climate changes and use of GHG reduction policy measures.

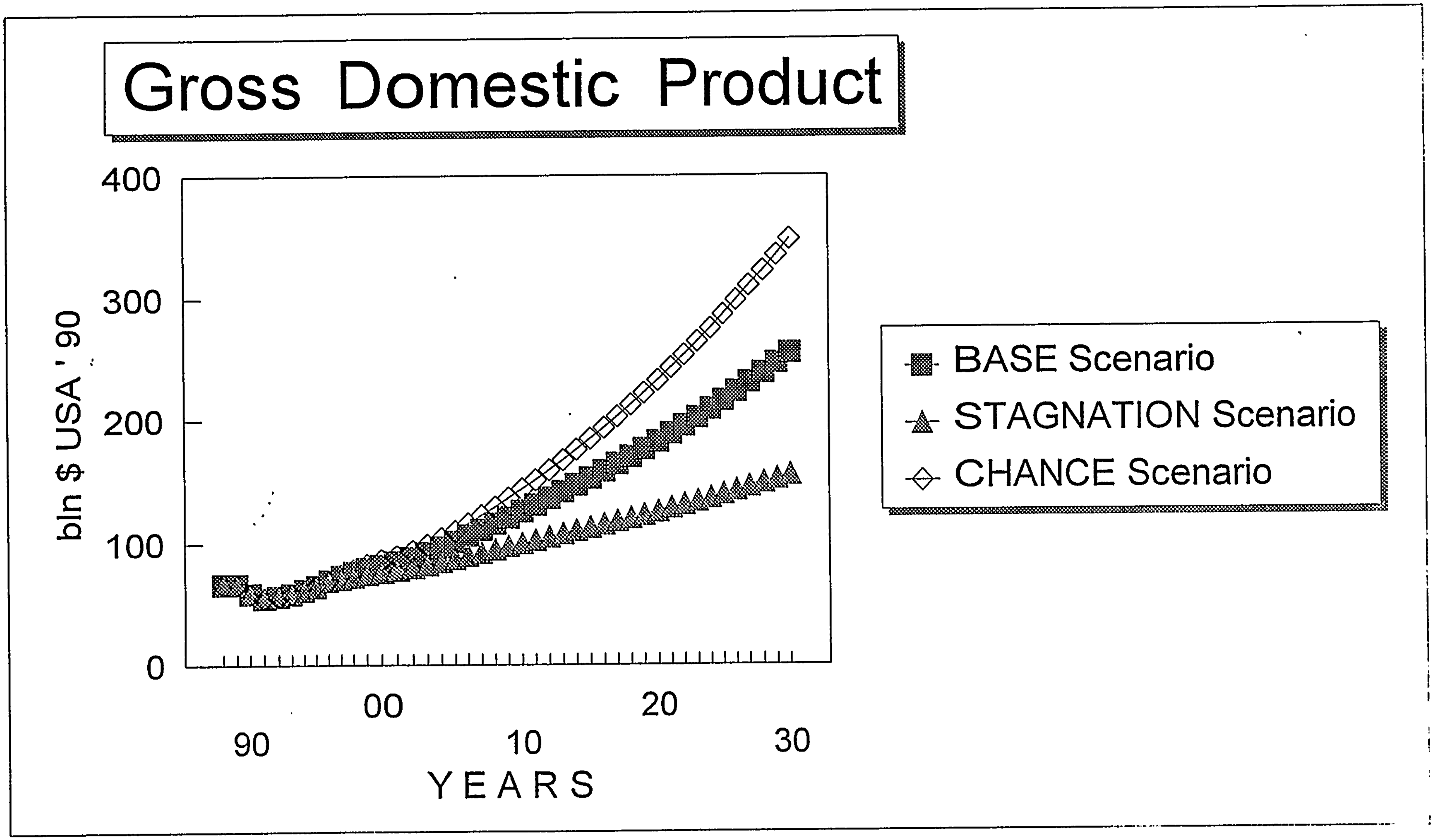
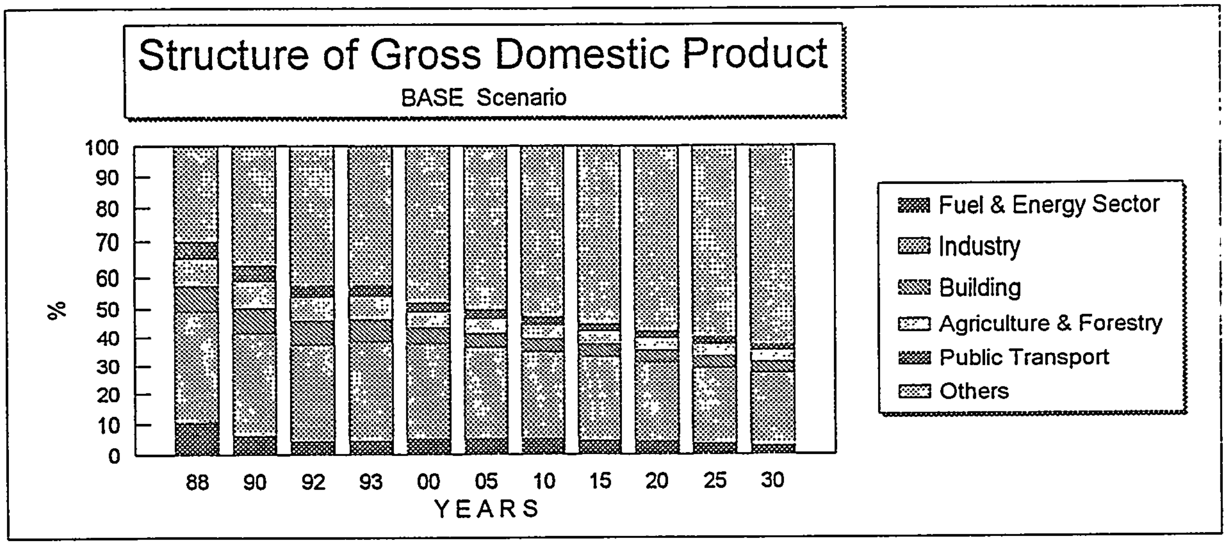
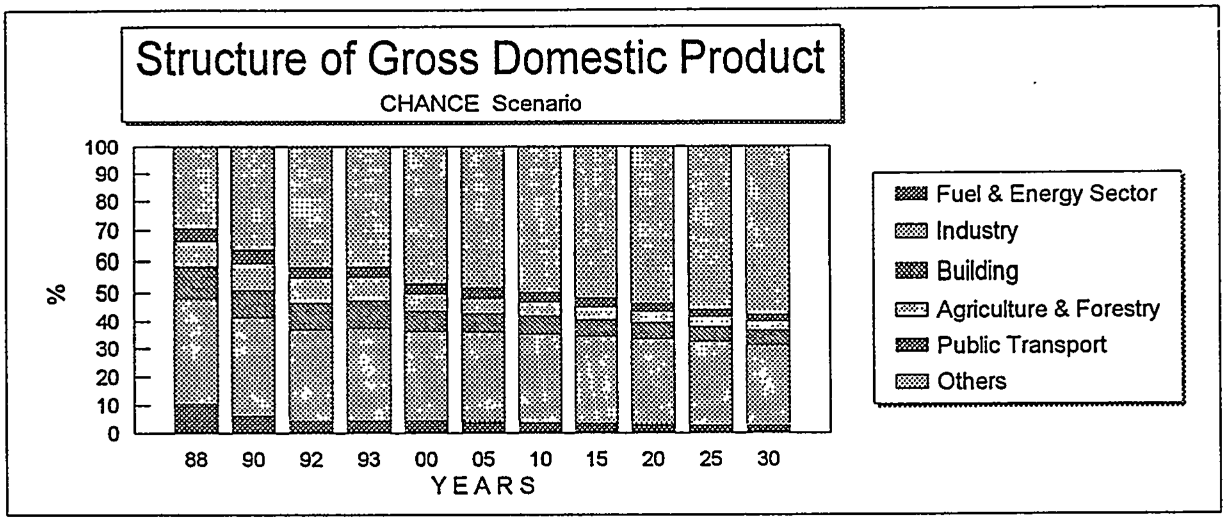

Gross Domestic Product
bln $ USA ' 90
400
300
200
100
0
90
00
10
20
30
YEARS
BASE Scenario
STAGNATION Scenario
CHANCE Scenario

Fig. 1

STRUCTURE of GROSS DOMESTIC PRODUCT





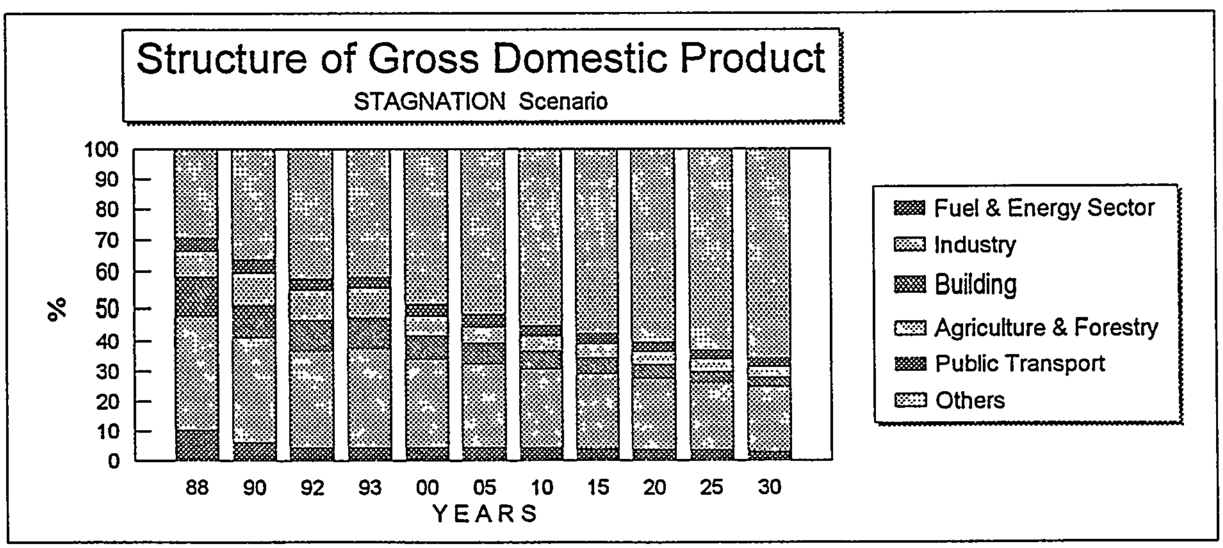
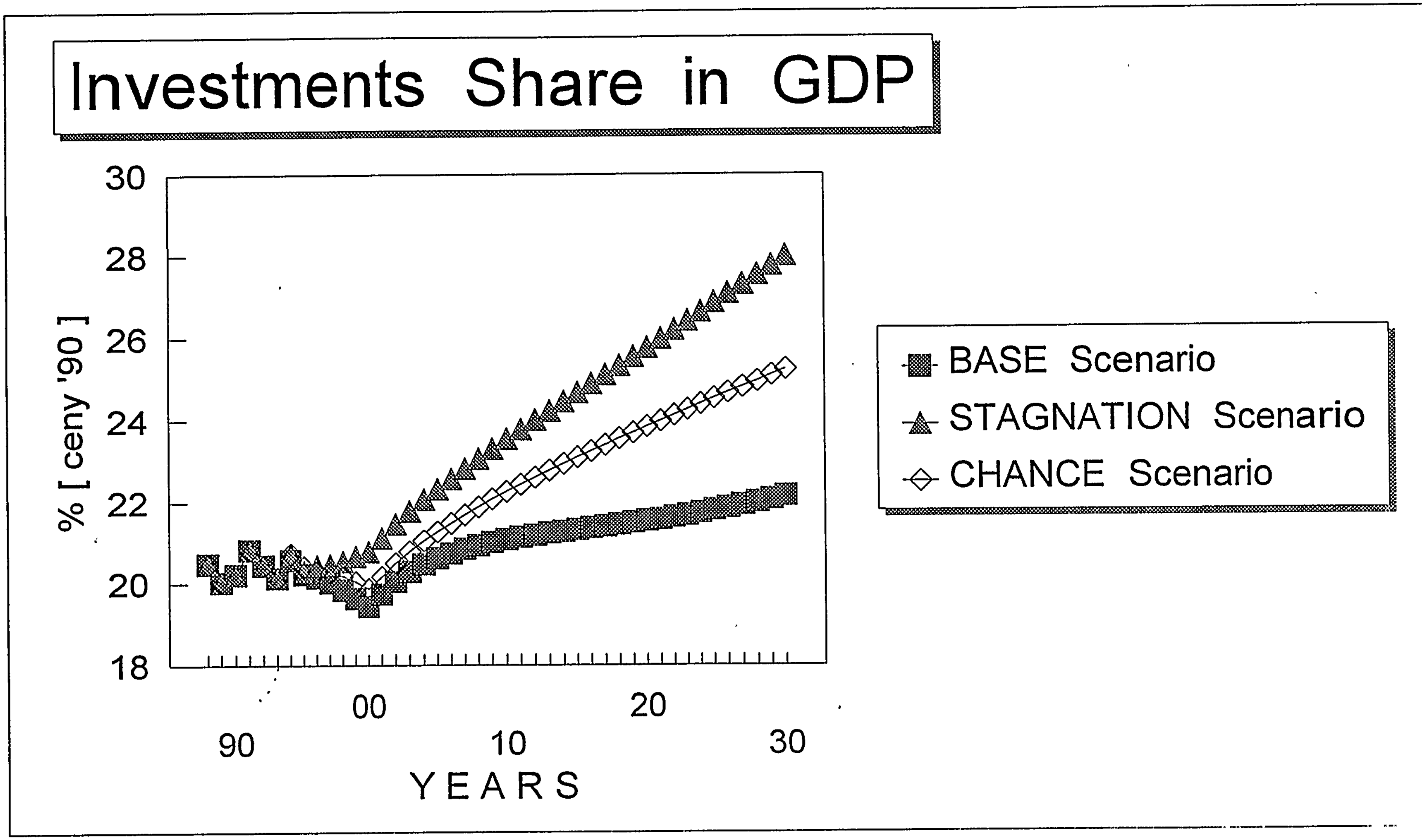


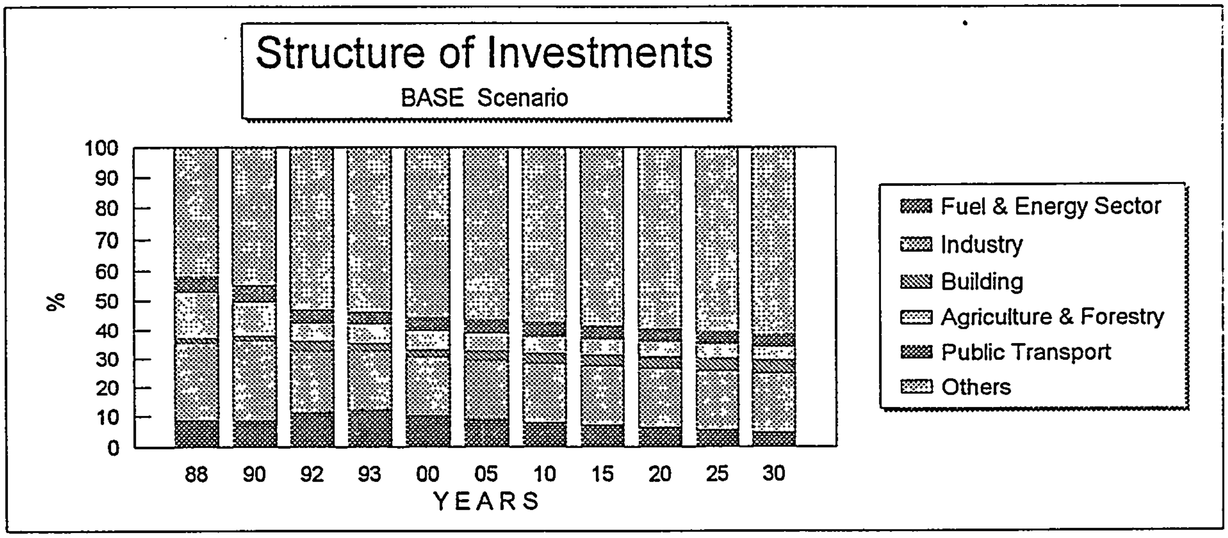
Fig. 2

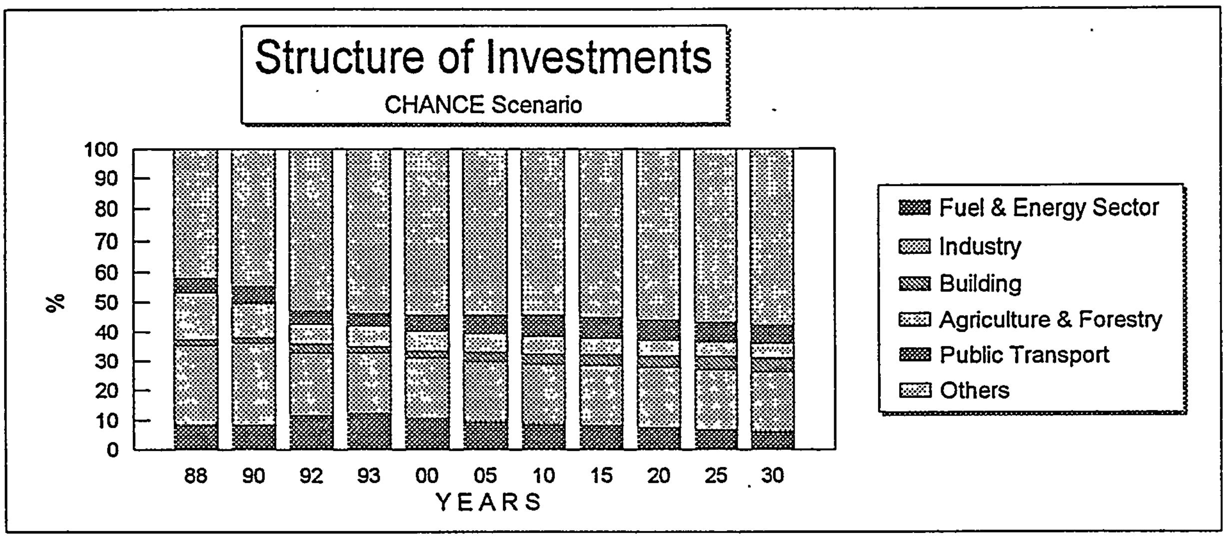


Investments Share in GDP
30
28
26
24
22
20
18
% [ceny '90]
90
00
10
20
30
YEARS
BASE Scenario
STAGNATION Scenario
CHANCE Scenario

Fig. 3

STRUCTURE of INVESTMENTS





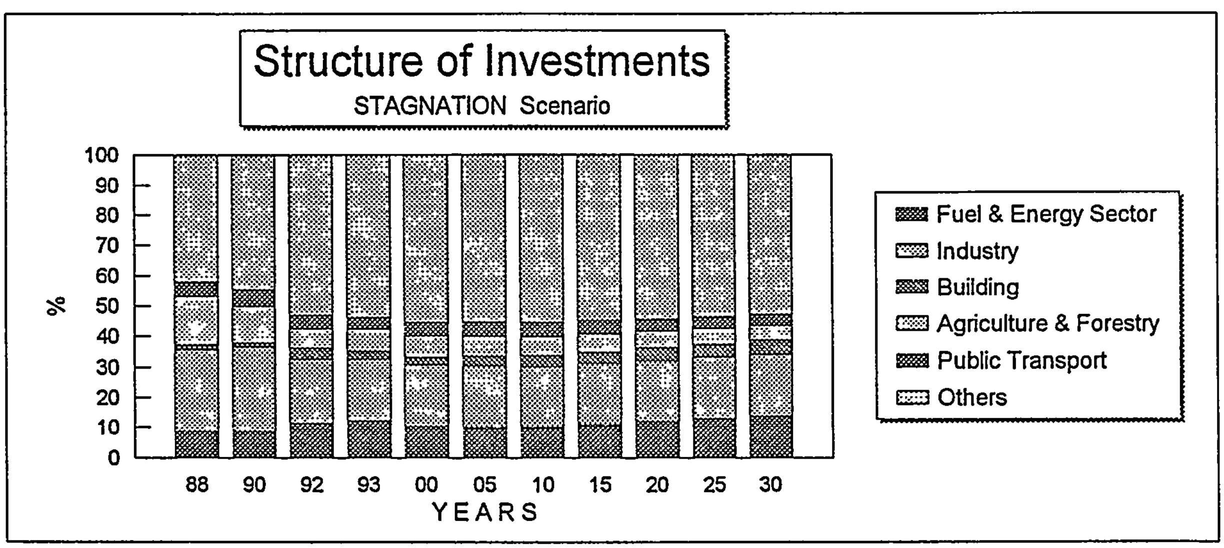


Fig. 4

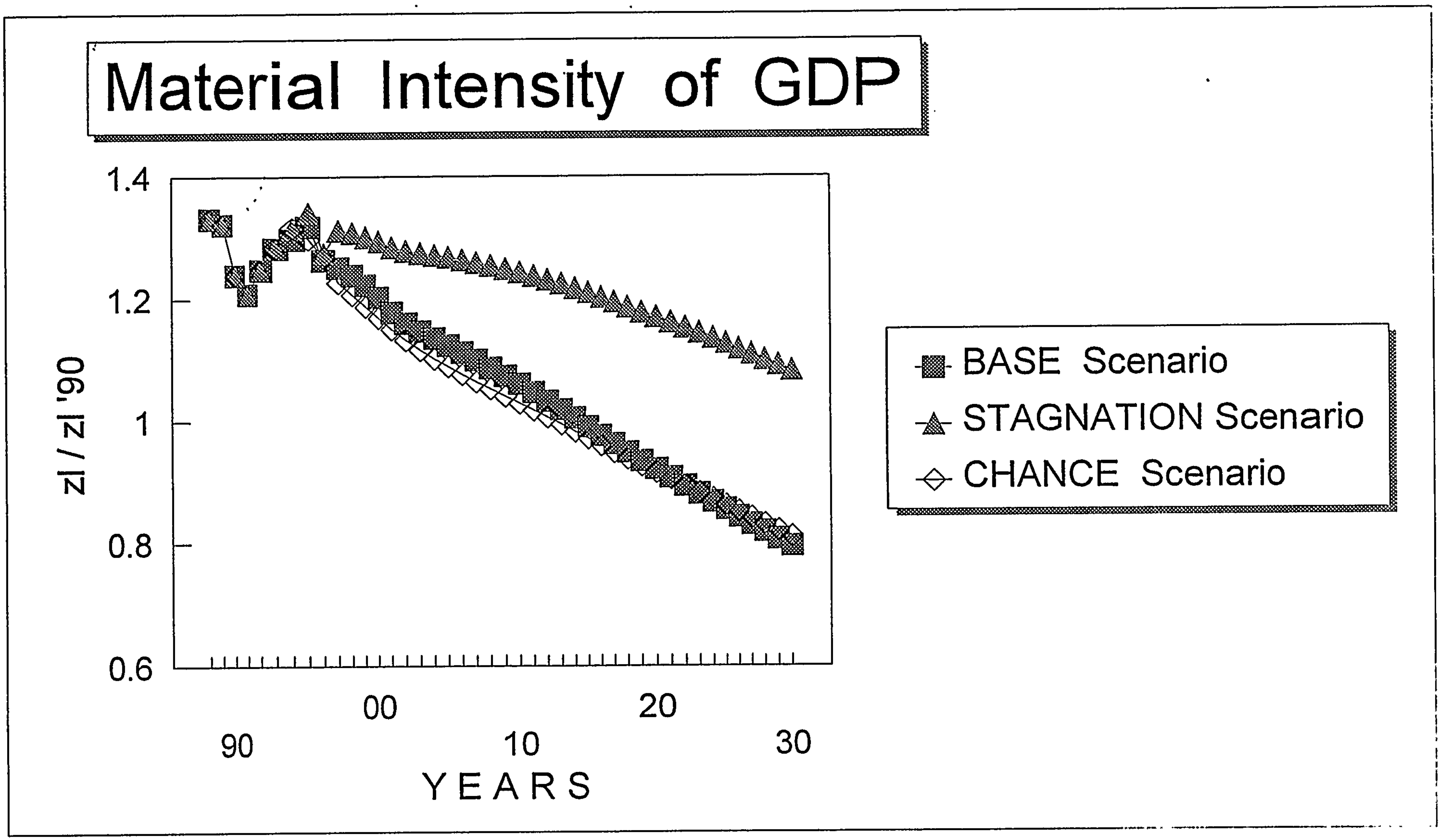

Material Intensity of GDP
1.4
1.2
1
0.8
0.6
zI / zI '90
90
00
10
20
30
YEARS
BASE Scenario
STAGNATION Scenario
CHANCE Scenario

Fig. 5

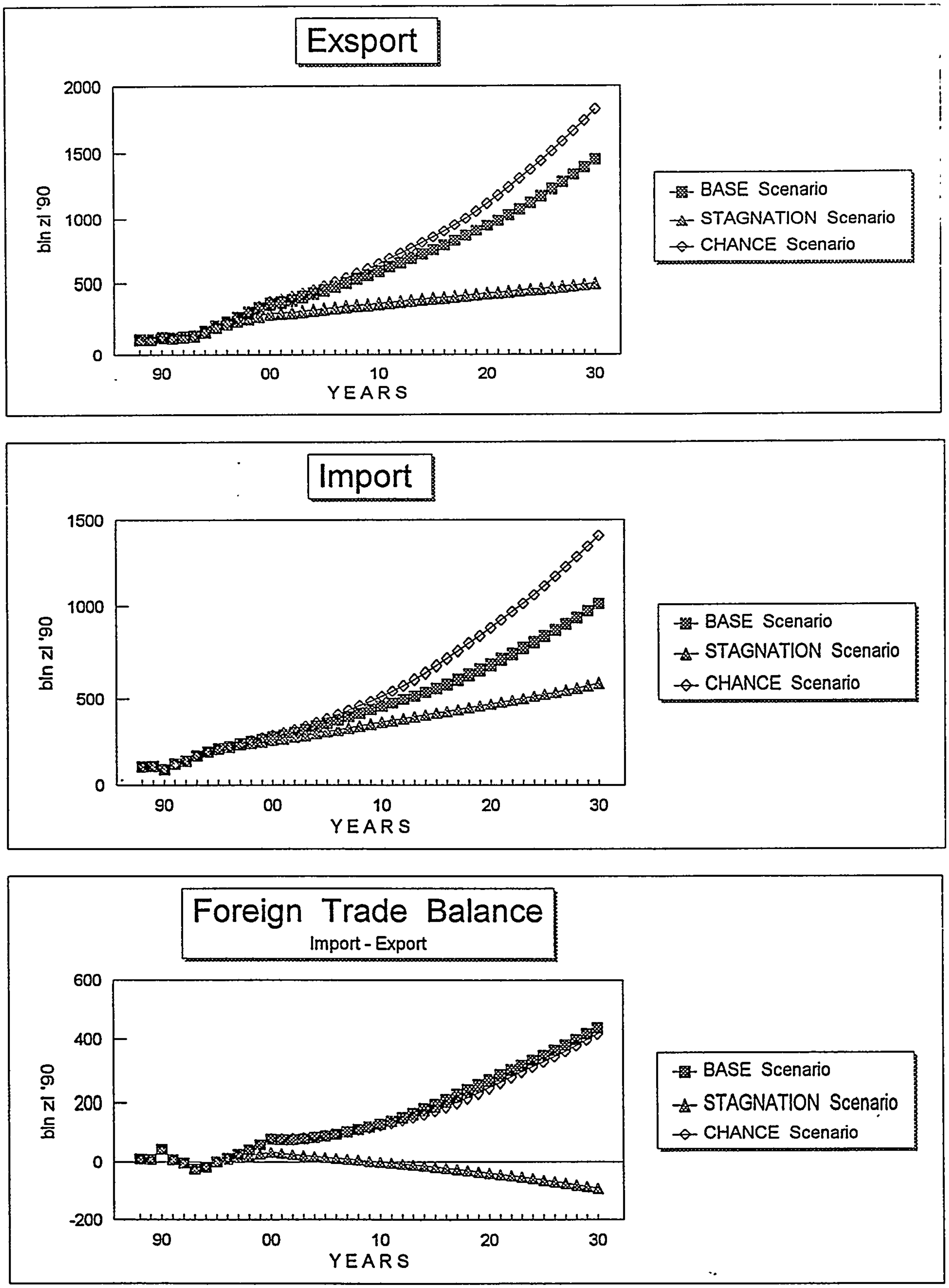
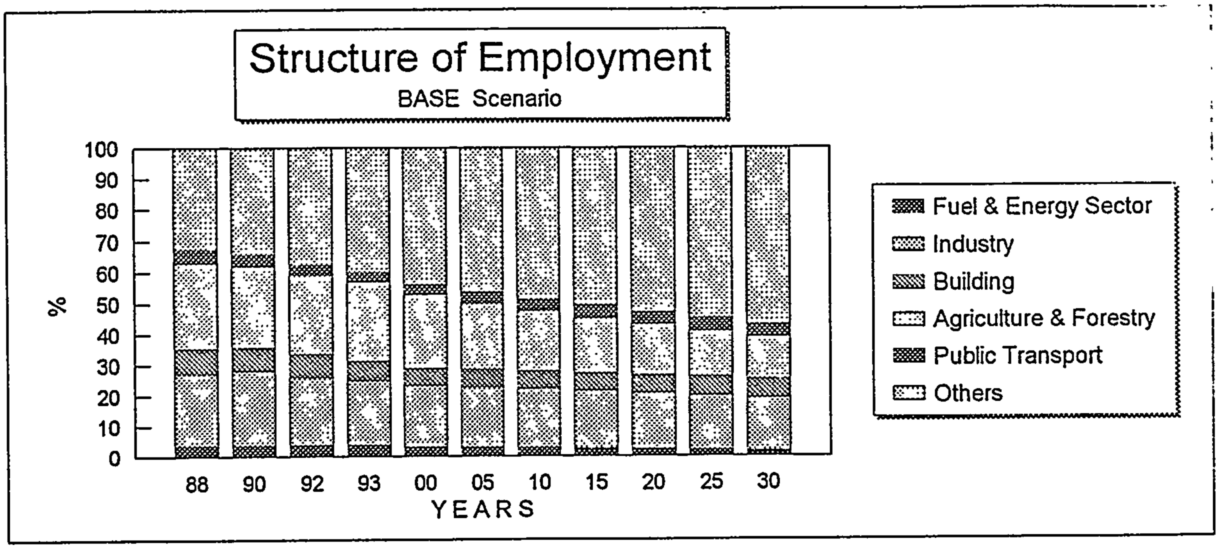
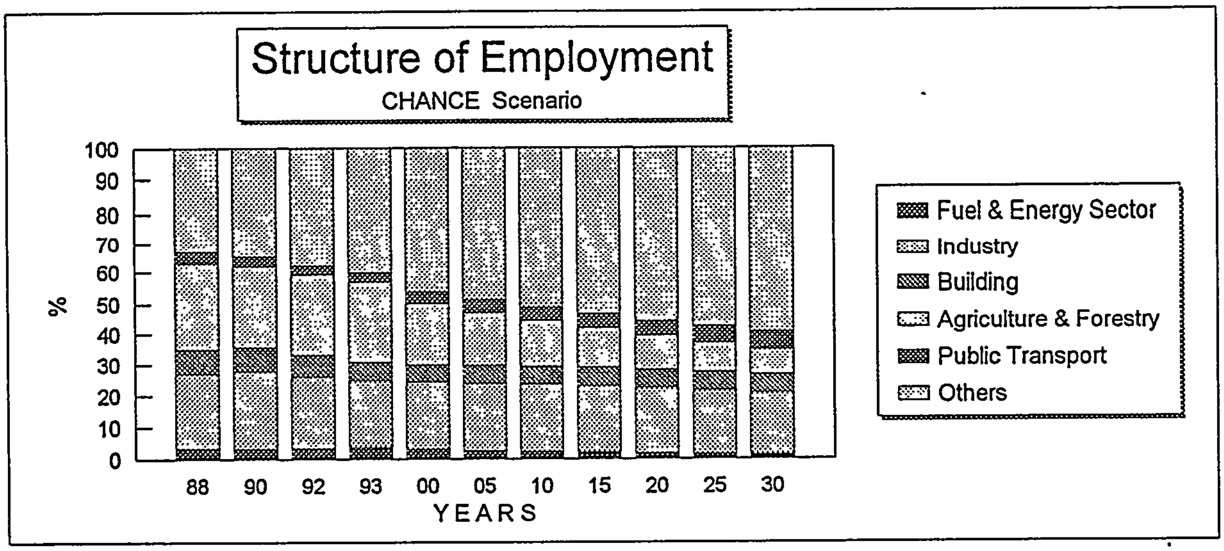

Exsport
2000
1500
1000
500
0
bln zl '90
90
00
10
20
30
YEARS
BASE Scenario
STAGNATION Scenario
CHANCE Scenario
Import
1500
1000
500
0
bln zl '90
90
00
10
20
30
YEARS
BASE Scenario
STAGNATION Scenario
CHANCE Scenario
Foreign Trade Balance
Import - Export
600
400
200
0
-200
bln zl '90
90
00
10
20
30
YEARS
BASE Scenario
STAGNATION Scenario
CHANCE Scenario

Fig. 6

STRUCTURE of EMPLOYMENT





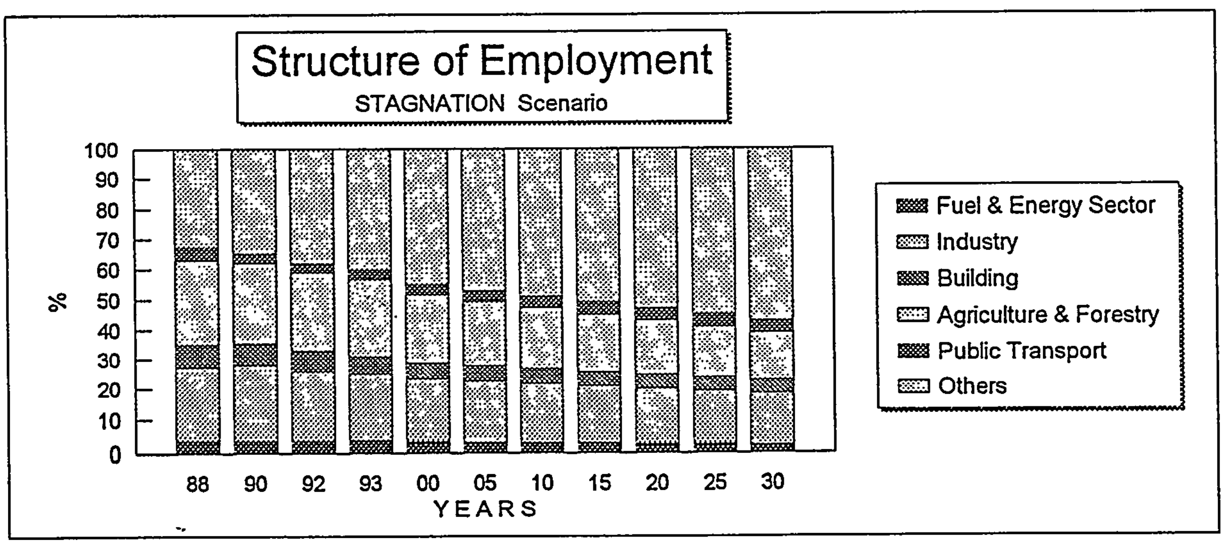


Fig. 7


Unemployment Rate
%
18
16
14
12
10
8
6
4
90
00
10
20
30
YEARS
BASE Scenario
STAGNATION Scenario
CHANCE Scenario

Fig. 8.

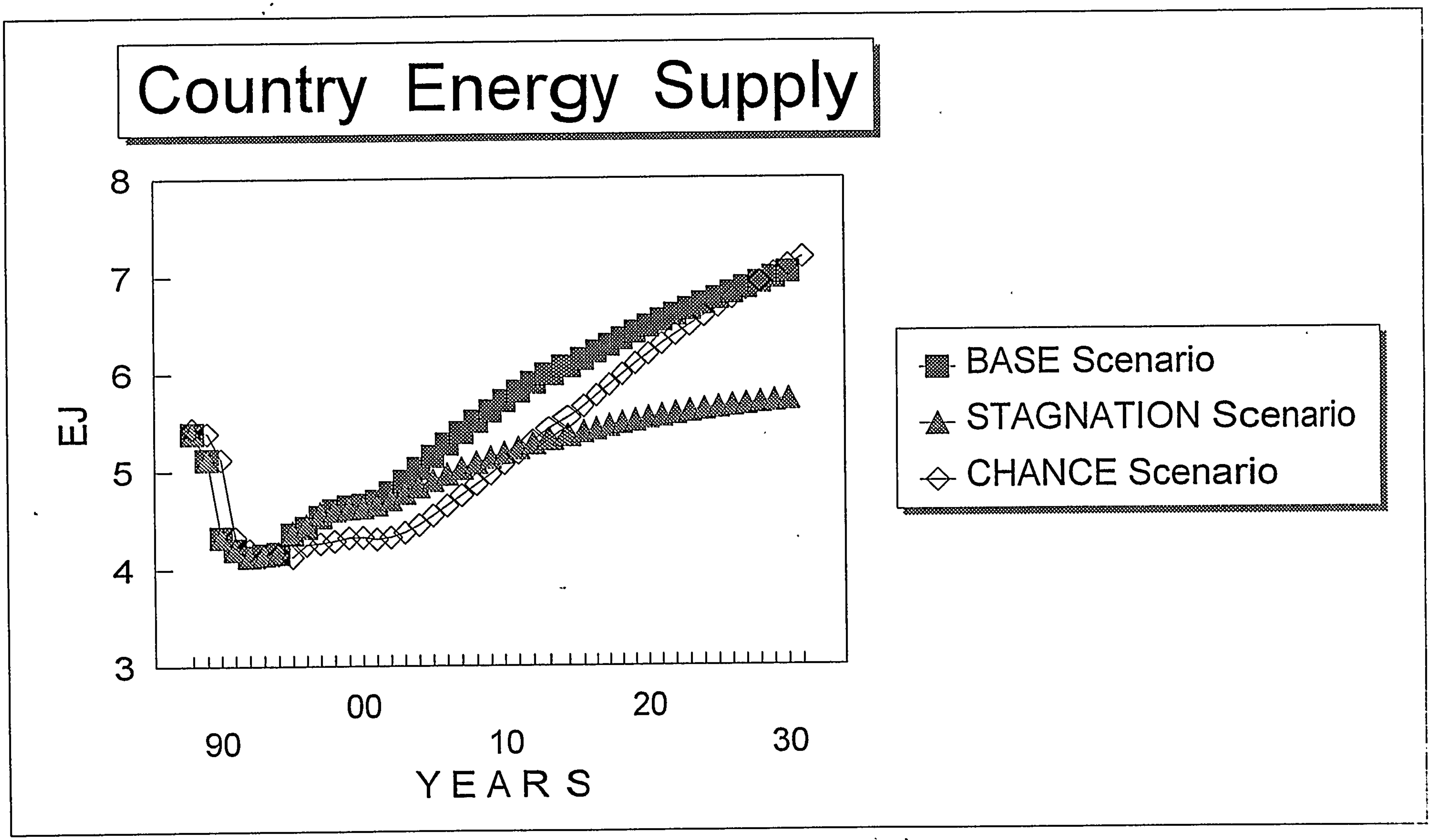
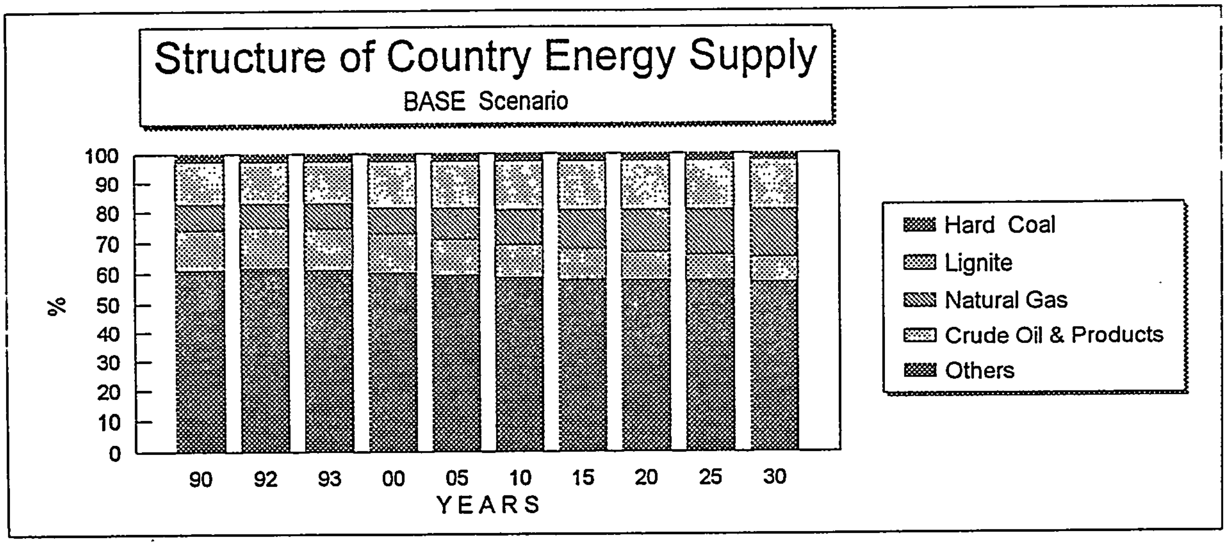
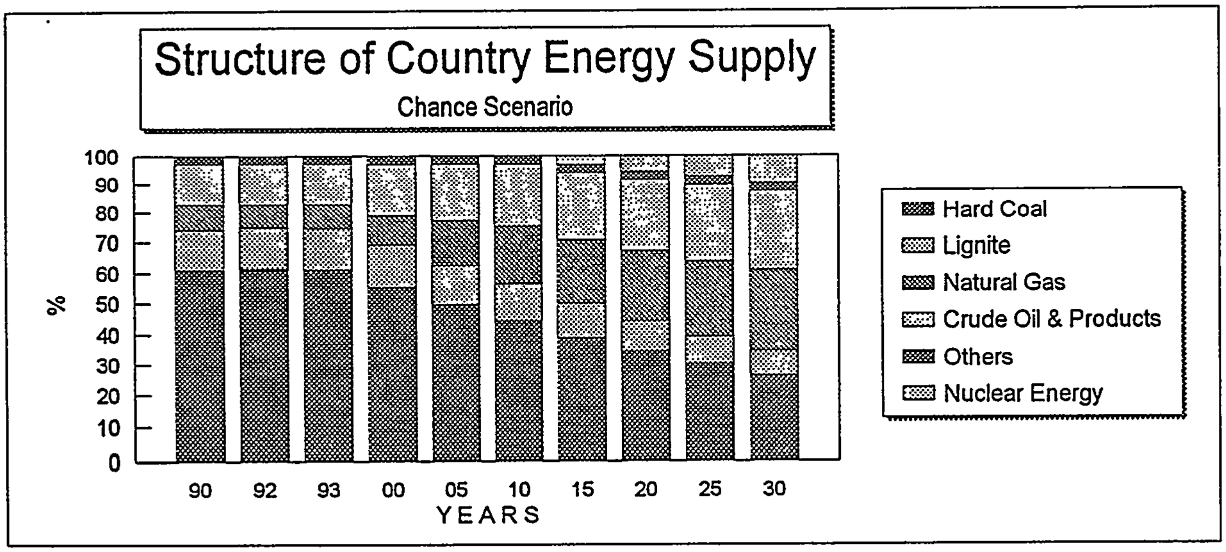

Country Energy Supply
EJ
8
7
6
5
4
3
90
00
10
20
30
YEARS
BASE Scenario
STAGNATION Scenario
CHANCE Scenario

Fig. 9.

STRUCTURE of COUNTRY ENERGY SUPPLY





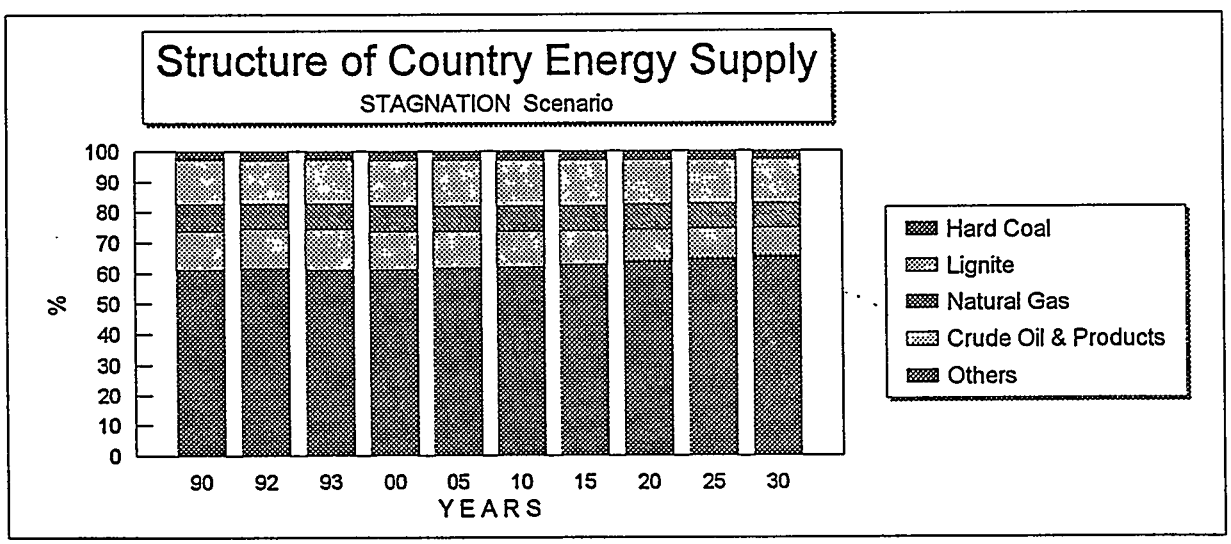


Fig. 10

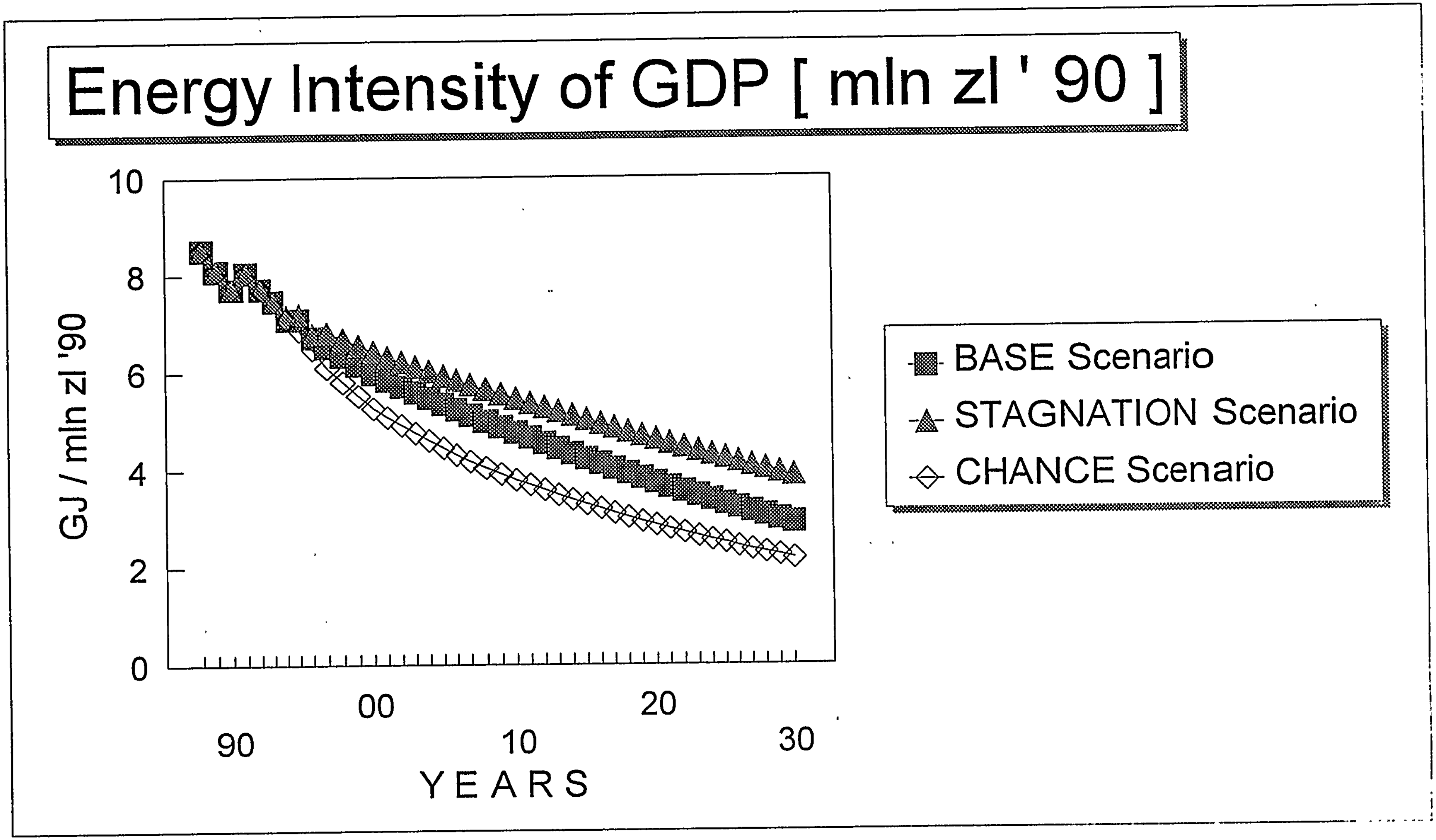
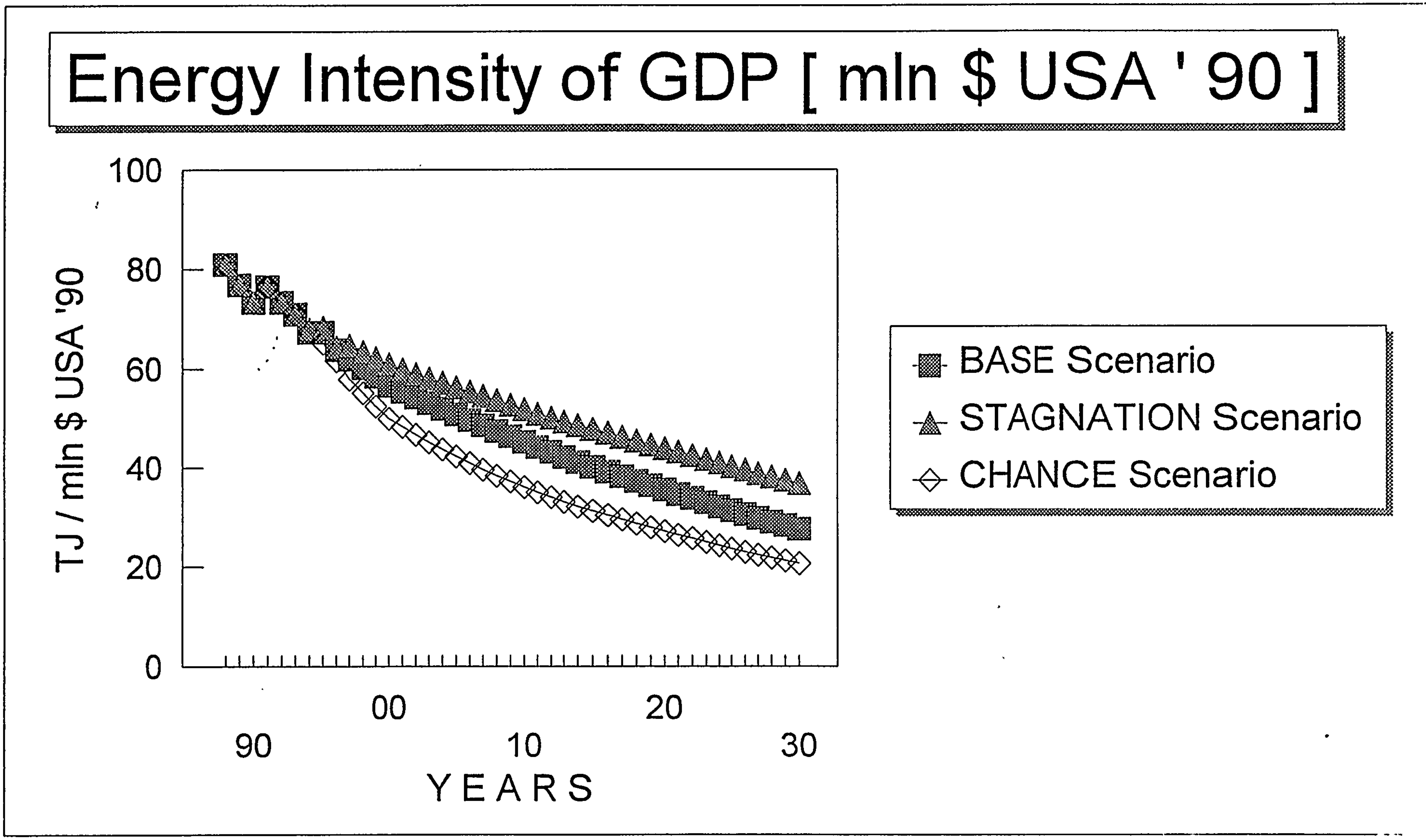

Energy Intensity of GDP [mln zl ' 90]
GJ / mln zl '90
10
8
6
4
2
0
90
00
10
20
30
YEARS
BASE Scenario
STAGNATION Scenario
CHANCE Scenario

Fig. 11.



Energy Intensity of GDP [mln $ USA ' 90]
100
80
60
40
20
0
TJ / mln $ USA '90
90
00
10
20
30
YEARS
BASE Scenario
STAGNATION Scenario
CHANCE Scenario

Fig. 12.

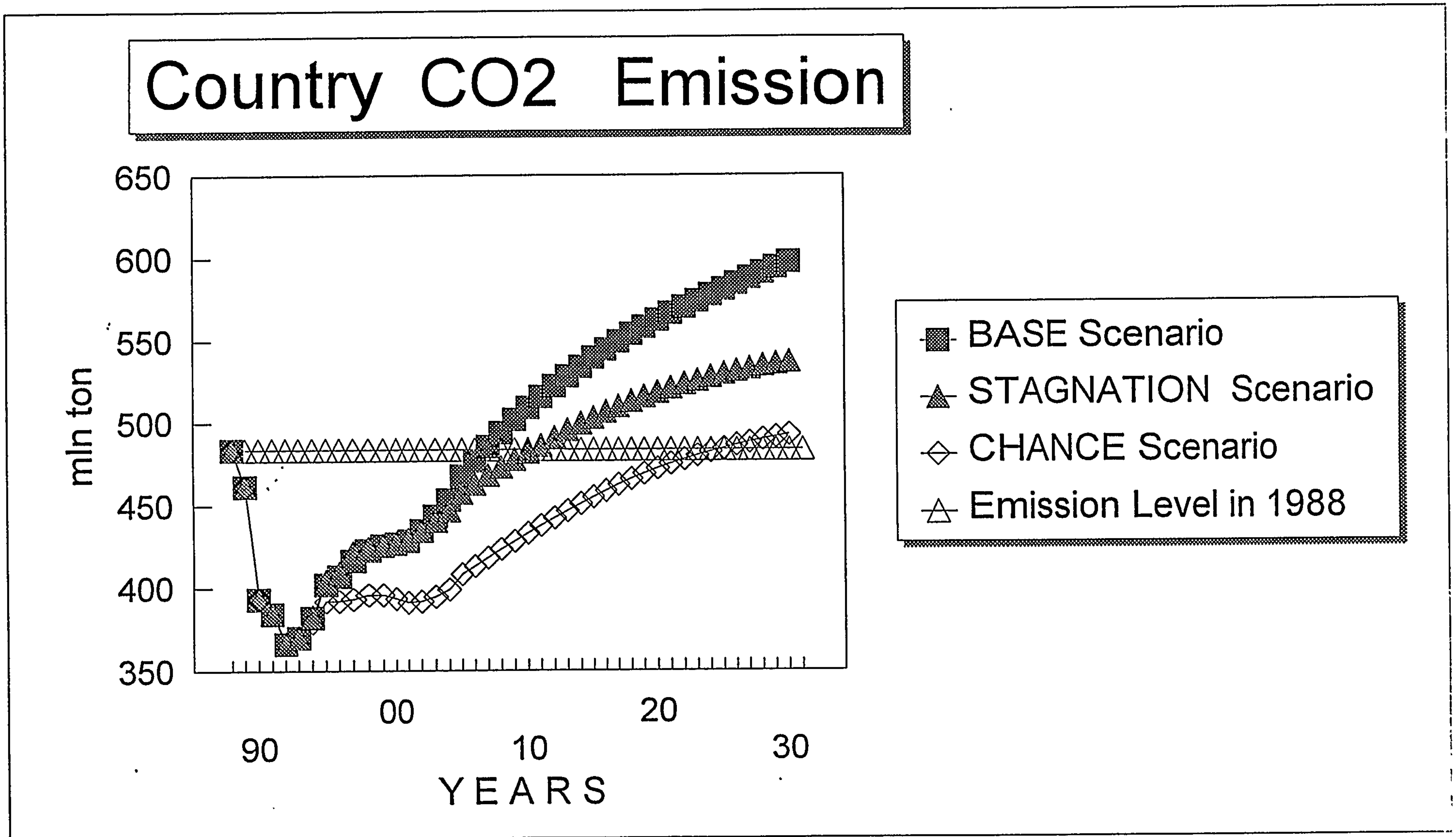

Country CO2 Emission
mln ton
650
600
550
500
450
400
350
90
00
10
20
30
YEARS
BASE Scenario
STAGNATION Scenario
CHANCE Scenario
Emission Level in 1988

Fig. 13.

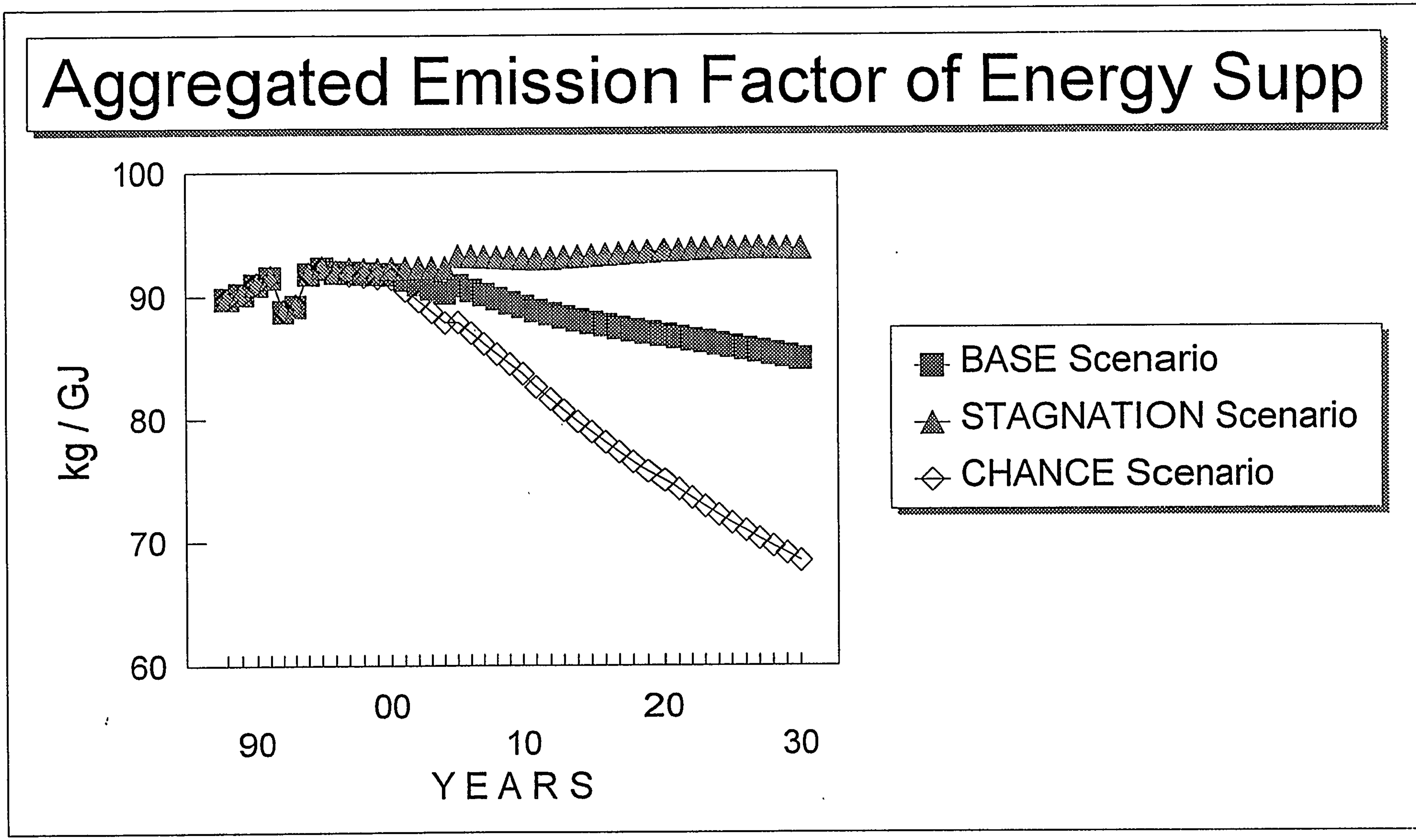

Aggregated Emission Factor of Energy Supp
kg / GJ
100
90
80
70
60
90
00
10
20
30
YEARS
BASE Scenario
STAGNATION Scenario
CHANCE Scenario

Fig. 14

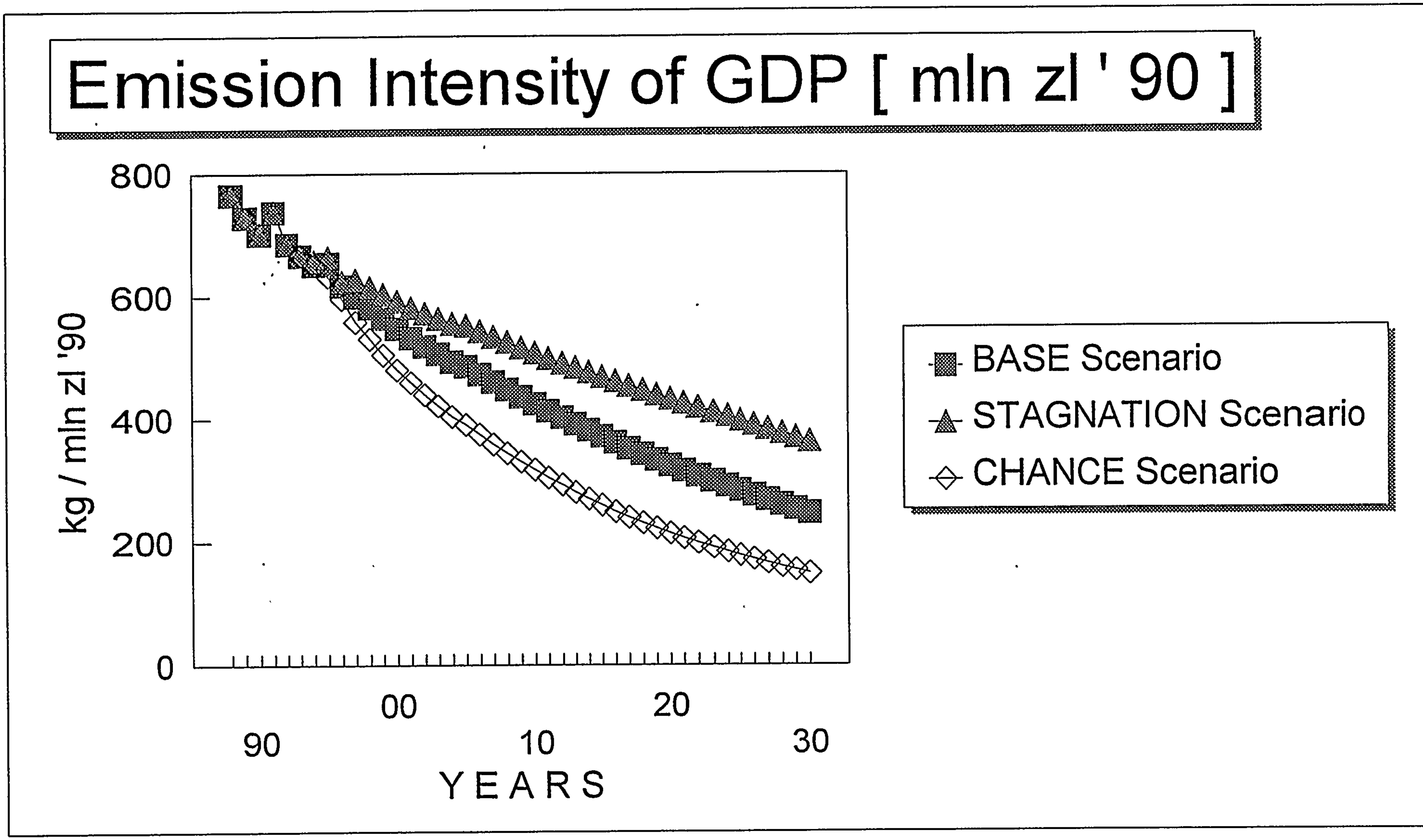

Emission Intensity of GDP [mln zl ' 90]
kg / mln zl '90
800
600
400
200
0
90
00
10
20
30
YEARS
BASE Scenario
STAGNATION Scenario
CHANCE Scenario

Fig. 15.

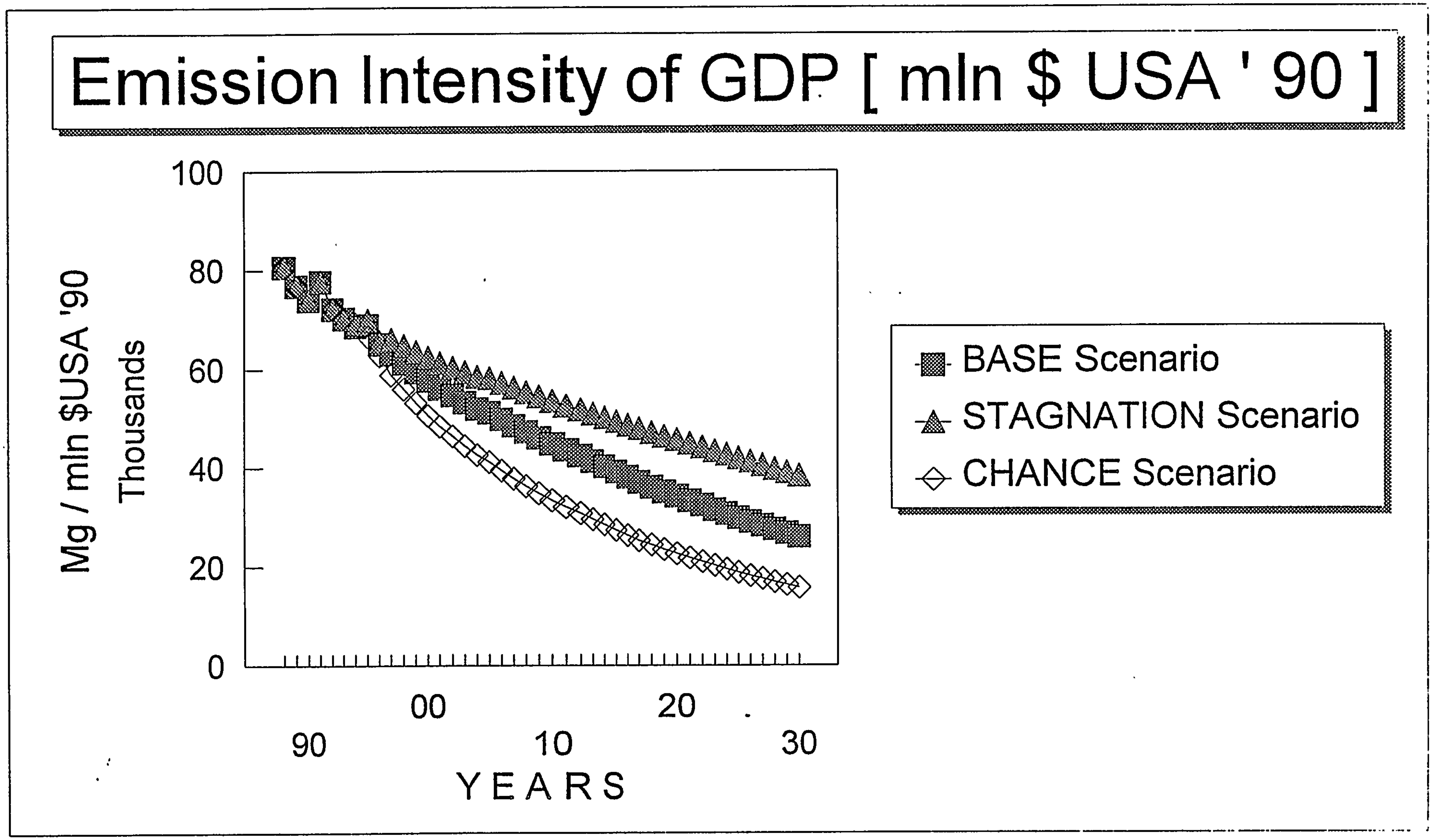

Emission Intensity of GDP [mln $ USA ' 90]
Mg / mln $USA '90
Thousands
100
80
60
40
20
0
90
00
10
20
30
YEARS
BASE Scenario
STAGNATION Scenario
CHANCE Scenario

Fig. 16.

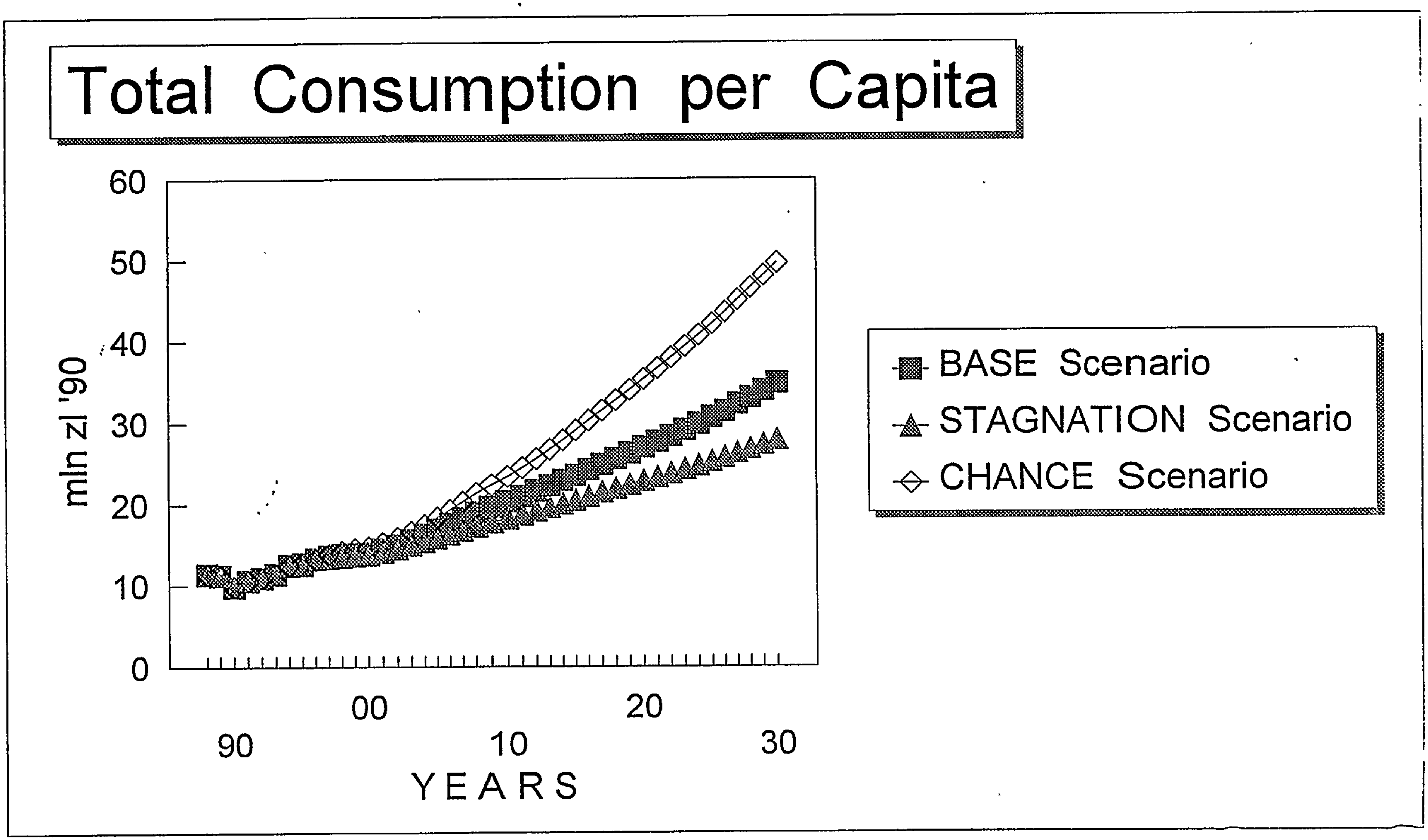

Total Consumption per Capita
60
50
40
30
20
10
0
mln zl '90
90
00
10
20
30
YEARS
BASE Scenario
STAGNATION Scenario
CHANCE Scenario

Fig. 17