POLISH COUNTRY STUDY TO ADDRESS CLIMATE CHANGE

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

SYNTHESIS

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the Government of the United States of America
and the Government of Poland

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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. Also we would like to express our thanks to the Department of Protection of Atmosphere and Earth Surface for substantial input and helpful assistance in implementation of this Study.

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.

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FOREWORD

When Poland was considering prior to the '92 Earth Summit in Rio de Janeiro the possibilities of signing the United Nations Framework Convention on Climate Change, the knowledge of pollutants responsible for climate changes and enterprises that could impede these changes was scattered and not yet systematised. The share of Poland in the world's balance of GHG emission, bringing about the greenhouse effect, does not exceed 1,5%. Despite the fact that since 1989 our country has been implementing social and economic changes, we can not fully forecast the outcome of those activities. Still, the Minister of Environmental Protection, Natural Resources and Forestry, signing the Framework Convention on behalf of the Government of the Republic of Poland, included our country in the international community that takes actions for the sake of hindering the negative effects civilisation causes to the environment of our planet.

Four years after the above-mentioned event, work on strategies and solutions is still carried out. The elaboration in question, the outcome of Polish-US co-operation, is the first complex attempt to evaluate both potential possibilities of GHG emission reduction in Poland in a long-term perspective and results of climate changes that can exert influence upon the Polish economy. All the proposals of scientists and experts circles have got to be constantly controlled against the background of the immediate solutions and forecasts elaborated and administered by the Government of Poland for the first decades of the following century. Conclusions and recommendations presented in this material can not be treated as binding guidelines of the macroeconomic socio-economic strategy of the country or its respective sectors, but rather they can and should be taken into account as options, suggestions, or proposals concerning governmental strategies of the economic development of Poland. In much the same way should be treated an outcome of the elaboration. I'm positive that scenarios presented in the elaboration will be made use of while creating the official policy of the Government.

On behalf of the Government of the Republic of Poland I wish to thank the Government of the United States of America for the assistance granted in the realisation of the Project and express hope that the fostered fruitful co-operation will bring concrete effects in the field of the environmental protection on our planet.

Stanisław Żelichowski

Minister of Environmental Protection,
Natural Resources and Forestry

1. INTRODUCTION

The idea of realisation of the Polish Country Study Project occurred 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 fulfil their obligations in terms of greenhouse gases emission inventory, preparation of strategies for the emission reduction, and adapting their economies to the changed climatic conditions. The Project was financed mutually by the Government of the United States of America and the Government of Poland.

The Study focused on analysing the economic situation until the year 2030 and its impact on emission of greenhouse gases (GHG). 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 of GHG concentration in the atmosphere.

Strategies and recommendations presented in the elaboration are meant for political and economic decision makers for whom detailed issues and solutions do not need to be of great prominence. Therefore, synthetic elaboration is limited to only the most important matters which were prepared within the Study, as well as, to basic conclusions and recommendations.

Full elaboration includes both the detailed analysis of particular options and proposed actions, whether they be macroeconomic or sector, and justification for conclusions presented below. While preparing the synthesis, authors were facing a difficult task of finding golden means between the necessity of synthetic presentation of assumptions and outputs, and need to provide exhausting information. Meeting both requirements is not always feasible. Hence, the readers interested in details should familiarise themselves with the full elaboration which is available at the Department of Protection of Atmosphere and Earth Surface of the Ministry of Environmental Protection, Natural Resources and Forestry, Climate Protection Centre of the Institute of Environmental Protection, as well as in the Country Study Management Team (CSMT) in the United States.

Formulation of objective and tasks, and basing the whole Project on them, required adopting certain general assumptions and taking into consideration the real social and economic situation of the country. It was assumed that climate changes resulting from human activities make up a real menace for the country economy, which requires undertaking preventing activities through GHG emission reduction. This is in line with assumptions agreed upon by the United Nations Framework Convention on Climate Change, to which Poland is a party. The scale of warming is not, however, clear cut. Therefore, two climate scenarios were adopted in considerations, simultaneously assuming a possibility of occurrence of several climate change scenarios. Another assumption is inevitability of climate change, and resulting from it necessity to analyse adaptation possibilities of the most vulnerable branches of the economy.

Adopting of these general assumptions gives rise to another challenge which is a necessity to gain a certain amount of knowledge on a scale of necessary activities and economic implications. It is also obvious that the proposed activities being the result of the Study realisation will bring about certain social, economic, and financial effects. Nevertheless, the majority of them has got to be undertaken due to reasons not connected with climate protection. In this sense the proposed strategies are in general agreement with long-term social and economic goals of the country.

The realised project is the first in its kind to define part of sustainable development of the country till the 30's of the following century. A number of problems were just mentioned here, with no deeper analysis at all. Needless to say, tackling these issues needs to be continued, and scenarios updated. Moreover, the majority of the presented issues needs to be looked into more thoroughly.

The whole problem concerns climate protection to a very limited extent. Rather, this is the problem of the future development of the country. Hence, interdisciplinary teams should set off further research. The teams will be able to present a wide vision of Poland's development in the following century, considering issues of climate protection.

2. JUSTIFICATION FOR THE STUDY

Poland as the party to the United Nations Framework Convention on Climate Change is obliged, among other things, to work out and implement a strategy of stabilisation, and in the future, strategy for reduction of the GHG emission and adapting those sectors of the economy which are most dependent on climatic conditions to the expected climate changes, simultaneously realising that activities undertaken by Poland aiming to reduce GHG emission do not, by large, affect global climate change. While deciding to contribute to work on GHG emission reduction strategies, the government of Poland wishes to emphasise the will of Poland to join in efforts made by the world society.

For Poland, emitting about 1.5% of global amount of carbon dioxide (CO_2) into the atmosphere (mainly as a result of coal combustion), the issue of reduction of the emission of this gas is economically important. On the other hand, the period of transition does not favour 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, privatisation, creation of banking system, etc., long-term economic goals are not the most important problems.

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 emission, first of all through a rise of the country economy efficiency, including decrease of the energy and material intensity level.

3. STUDY OBJECTIVE

The objective of the Study was to elaborate a strategy for the stabilisation and reduction of GHG 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 emission reduction is to stimulate modernisation of the economy and to direct the economy into sustainable development principles. Specific objectives of the strategy included reduction of the GHG emission through a decrease of material and energy consumption in industrial production, better utilisation of ecosystems (managed and unmanaged), and rationalisation of energy and materials 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 co-ordinated 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.

During realisation of the Study elaborated were also: databases, detailed sectoral studies containing *inter alia* scenarios of GHG emission reduction and strategies of adaptation to the climate changes, 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 (utilising formal tools) for the creation of scenarios of GHG emission reduction 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 national economy based on the elaborated method of cost and benefit analysis;
- elaboration of sectoral scenarios for the emission reduction and increase sinks of GHG 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 adaptation to the climate changes in water and the Baltic Sea coastal management;

- proposing methodologies (utilising formal tools) for the construction of national policy concerning reduction of GHG emission in the relevant sectors of the economy;
- recommendation for development directions of relevant sectors of the national policy.

4. ORGANISATION OF THE STUDY

Prepared by the Ministry of Environmental Protection, Natural Resources and Forestry, the project of the Study was presented to the American partner. The project underwent analysis carried out by the American experts and CSMT. The latter of the above carried on detailed conversations with implementation team as well as representatives of the Ministry of Environmental Protection, Natural Resources and Forestry. As a consequence of those analysis, in summer 1993 the American side accepted the project consisting of 13 elements (Study elements - SE).

Modified according to mutual resolutions, the Study program constituted a basis for an agreement signed in November 1993 between the Department of Energy of the United States of America, and the Ministry of Environmental Protection, Natural Resources and Forestry of Poland as far as realisation of the Study is concerned. The agreement anticipated that the Study would be realised in the period from October 1993 to December 1995. 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. Unfortunately, an attempt to gain financial means for elaboration of strategy for the forestry sector was not a success. The same was the case with full elaboration of strategy (emission reduction and adaptation) in agriculture. For the purposes of macroeconomic scenario, partial agricultural expert appraisal was commissioned within the first element, and in a degree necessary for that element of the Study.

The Study was realised through 12 Study Elements (SE) co-ordinated by the Head of Climate Protection Centre of the Institute of Environmental Protection (SE 13). 13 teams including 51 scholars, research workers and engineers as well as 40 national and 18 foreign consultants and experts have been involved into the Project.:

1. **Macroeconomic approach applied to strategies for the reduction of GHG emission**
   (dr Edward Radwański – FEWE)
2. **Strategies for the CO_2 emission reduction by the year 2010 in the economy sectors dependent on the energy production**
   (dr Tadeusz Lis – IPPT PAN)
3. **Elaboration of a GHG emission reduction mathematical model for electricity and heat energy subsectors** (Ewaryst Hille – FEWE)
4. **Strategies of structural industry changes and technology development to enable GHG emission reduction** (dr Slawomir Pasierb – FEWE)
5. **Options of the Polish agriculture development under forthcoming greenhouse effect and possibility of adaptation to climate change** – developed as a subtopic under SE1
   (prof. Emil Nalborczyk – Warsaw Agriculture University)
6. **Regional scenarios of climate change** (Anna Olecka – Institute of Environmental Protection)
7. **Elaboration of a strategy and technology of utilisation of the renewable energy sources**
   (prof. Jerzy Tyminski – IBMER)
8. **Elaboration of a program for the GHG emission reduction in the transport sector**
   (prof. Wojciech Suchorzewski – Warsaw Technical University)
9. **Elaboration of a program for the GHG emission reduction in the municipal sector**
   (dr Pawel Skowronski – FEWE)
10. **Legal and economic aspects of the GHG emission reduction strategies in the Polish economy**
    (prof. Bazyli Poskrobko – Białystok Technical University)
11. **Strategies for the water management in face of climate change**
    (prof. Zdzislaw Kaczmarek – IGeof PAN)
12. **Coastal zone management and protection of Poland's coastal segments most vulnerable to climate change in the scale of decades and centuries** (Prof. Ryszard Zeidler – IBW PAN)
13. **Management and co-ordination of the project and preparation of the final report**
    (prof. Maciej Sadowski – Institute of Environmental Protection)

The Minister of Environmental Protection, Natural Resources and Forestry has nominated Prof. Maciej Sadowski, Head of Climate Protection Centre 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 Atmosphere and Earth Surface as well as the Department of International Co-operation.

The advisory body was the Commission for Sustainable Development, which passed opinion on the reference scenario elaborated within the Study.

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 others. Within CSMT, a Regional Project Co-ordinator – 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. CSP sponsors similar analysis in 57 countries.

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 co-operation* with CSMT. In accordance with the Agreement, quarterly interim reports on the work progress were prepared (seven reports in total), and submitted both to the Project Officer and the Ministry of Environmental Protection, Natural Resources and Forestry on a regular basis. Twelve members of the project implementation team visited the United States and other countries.

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 privatisation processes. In 1994 *Strategy for Poland* defines main objectives and tools for the implementation of the national social and economic policy until the year 1997. Its main assumptions include: acceleration of economic development of the country, macroeconomic and system stabilisation, 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 privatisation 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 (21.6% in 1995).

In 1991 the Parliament of the Republic of Poland (Sejm) adopted the *National Environmental Policy*, which set out priority objectives. At the beginning of 1995, the Parliament performed appraisal of 3-year period of realisation of that policy. The Parliament also accepted submitted by the government *Policy Implementation Program* for the years 1994-2000. 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 emission of harmful 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 trans-boundary 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 in Poland 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. At that time the outlays for the environmental protection oscillated between 1.1-1.3% of GDP.

5.2. DOMESTIC ECONOMY ASPECTS

Since 1992 the Gross Domestic Product (GDP) has shown a tendency of growth. In 1994 the growth reached 5% against the previous year, while in 1995 the growth amounted to 6.5%. The share of industry in the GDP 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%. Industry has been the main source of GDP having a 40% share in its generation 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.

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

The housing construction sector, after initial development tendencies recorded a period of stagnation and in 1994 grew only by 0.2% 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's. The main 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 the unemployed reached 16% of all capable of working 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.

Economic condition of the Polish agriculture comprising approx. 2 million individual farm holdings is very hard. Over 70% of holdings are low income farms with no chances for restructuring or modernising. As a result of liquidation of the State Agricultural Enterprise the area of fallow land is increasing. At present moment, according to the Agency of Agricultural Property of the State Treasury, those areas constitute about 0.5-0.7 million 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% comparing with 1990. Unfavourable agricultural and meteorological conditions during the recent years have depleted outputs of restructuring and financial activities undertaken to improve the condition of Polish agriculture.

One of branches of the economy that exerts the most adverse influence on the environment is fuel and energy sector. This is very much due to the fact that the Polish economy is still dominated by coal as energy primary source. However, in comparison with the year 1990, the share of this fuel decreased from the level when it stood at 76.5% to the level of 74% in 1994. This drop resulted from a tendency to shift to new energy carriers, i.e. oil and natural gas. Still, coal will long be a basic energy carrier in Poland. Furthermore, effective activities were undertaken to reduce emission from plants of the energy sector through decrease in use of low quality coal, construction of installations enhancing coal and desulphurising exhaust fumes, and, bettering effectiveness in halting dusts from waste gases. Elaborated in 1992, the *Energy Policy* included analysis of industry restructurisation, possibilities of improving energetic efficiency, and solutions in the sphere of ecological policy. The Energy Policy took over assumptions of the State Ecological Policy. Consequently, there appeared a substantial progress in including ecological issues in the national energy policy and programs in that field, in power generation sector at least. However, indicators of energy use are still at a very high level in Poland (energy intensity per capita: 2.5 toe, indicator of energy use per GDP unit: 1.7 toe/1000 USD).

5.3. FOREIGN ECONOMY ASPECTS

Opening of the Polish economy onto western markets, increase of the Polish goods competitiveness, entering of the 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[1] 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

[1] 10^9

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 the former Soviet Union.

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 last year.

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.

5.4. 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 informatisation, 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 organisation, 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 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, organisational and legal changes, aiming at creation of opportunities for consideration of GHG emission reduction issues jointly with other social-economic aspects. Therefore, activities carried out within 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. MACROECONOMIC MODELS

Employed methodological solutions within modelling result from two-level system organisation of the Study – sectoral and country levels. At the sectoral level the energy and power sectors play the most significant role since 96% CO_2 emission is caused by fossil fuels burning. The two following *bottom-up* models are used to model problems of the energy management:

- Energy Flows Optimisation Model (EFOM) for general analysis of the national energy system,
- Energy and Power Evaluation Program (ENPEP) for detailed analysis of the power and energy sector.

The other sectoral teams have been equipped with the *GHG Abatement Cost Spreadsheet* (GACS), elaborated within the Study. This Spreadsheet is meant to investigate GHG emission reduction options through comparing two technologies: technology with low level of GHG emission, and the alternative one, used traditionally, technology with high level of GHG emission. Calculation of cost-benefit relation as a basic analytic method was applied in the GACS Spreadsheet. The outputs of research are sectoral reduction scenarios presented in a form of marginal step function of GHG emission reduction costs, GHG emission reduction time functions, particular costs elements time functions, fuel and energy demand time functions, and qualitative description of scenarios, containing legal and financial proposals of GHG emission reduction stimulators. By definition, *scenario* is a complex presentation of future state of system. In this case this is the economic one in the macro scale.

Results of sectoral analysis are fused in order to generate internally-cohesive, national, scenarios of GHG emission reduction.

For this purpose the Dynamic Simulation Model of the National Economy (SDM–NE) was elaborated within *Case Study 1993*, as the main macroeconomic modelling tool. The model belongs to the *top-down* family. Its methodology follows the general equilibrium philosophy.

Table 6.1. General scheme of the Polish Country Study GHG emission reduction 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	• Technology and economic data • Emission characteristics • Qualitative data
Elaborating: • Individual options • Integrated options • Sectoral scenarios	• Sectoral – Energy economy – Power sector – Other sectors	EFOM ENPEP GACS	*bottom-up*	• Technology options • Integrated options • Sectoral scenarios	• GHG emission reduction (t) • Energy (t) • Cost (t) • LNPC, IRR • Sectoral MC curve • Qualitative description
Creating the MERS	• Country	DSM–NE	*top-down*	MERS	• ME functions • ME parameters • Qualitative description
Creating the MEAS, defining collisions, ranking options		CIA HIPRE3+	Decision analysis	• Ranked sets of options • MC curves	• Collisions • GHG emission reduction (t) • Energy (t) • Cost (t) • Qualitative description
Defining policy measures to activate options		GACS DSM–NE	*bottom-up* *top-down*	Policy measures	• Taxes • Subsidies • Custom duties • Emission limits • Technology standards
Identifying the ME impacts of the policy measures		DSM–NE Emission Models	*top-down*	GHG emission reduction scenarios	• ME functions • ME parameters • Qualitative description
Evaluating the reduction scenarios		CIA HIPRE3+	Decision analysis	Final set of ME reduction scenarios	• ME functions • ME parameters • Qualitative description

The country level work on integrated scenarios started from creation of the Macroeconomic Reference Scenario (MERS) defined with macroeconomic functions and parameters. The MERS was elaborated in three variants in order to reflect uncertainty of the forecasts.

In order to choose reduction options from particular sectoral scenarios, and include them in the country scenario, two modelling tools of decisional analysis were employed – Cross-Impacts Analysis (CIA) and Hierarchical Preferences (HIPRE3+). The former 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.

The Dynamic Simulation Model of National Economy (SDM–NE) enables simulation of the GDP changes depending on the assumed rate of changes of investments in total in relation to the GDP used in the country, as well as, distribution of changes among branches of the economy (which in a sense reflects the state's policy). The majority of economic categories in a model is put in fixed prices. People's income is treated nominally, which allows to reflect equilibrium on the consumption goods market, and investigating impact of changes and income policy parameters on consumption demand.

Models of reduction greenhouse gases emission are presented in table 6.1.

7. ADAPTATION OF THE ECONOMY TO CLIMATE CHANGE

7.1. CLIMATE CHANGE SCENARIOS

Within the scope of the Study, 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 and farming, the results of two general circulation models were analysed, while for the needs of coastal zone management applied were the scenarios of the sea level rise based on observations, trends and research carried out within the IPCC.

Among a wide variety of global circulation models, for the purposes of the Study in question used were results of two such models (GCM) recommended by CSMT. On their basis elaborated were possible Polish climate changes. These models are: GFDL and GISS. During realisation of the Study there appeared newer versions of the above global circulation models (GCM). However, their results do not differ much from results coming from versions actually used in the Study.

According to the 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 to about 700 mm in conditions of doubling of CO_2 concentration in the atmosphere. The GFDL model, in turn, predicts a higher growth of temperature than GISS – by about 5°C. Precipitation sums are forecast to stay level or slightly decrease (by about 450 mm).

In the part concerning climate change impact on water resources used were two GCM-based equilibrium climate models: GFDL model (R–15 version) and GISS model (1982 version). The above-mentioned models reflect considerably well the current Poland's climate. Moreover, they show different conditions in the future. The first model can be characterised as *warm and dry*, whereas the second can be referred to as *warm and humid*.

In the analysis of the Polish coast vulnerability to climate changes considered were, first and foremost, accelerated increase of the sea level within a range of 30-100 cm per century (according to world research – anticipated rise of the sea level will amount to some 65 cm/100 years). Assumed were also changes in atmospheric circulation on the Baltic Sea and strengthening of storms. Adopted assumptions enabled to carry out quantitative appraisal of dangers, e.g. erosion and loss of sea shore, as well as necessity to protect sea shore, and estimation of costs of related enterprises. Those assumptions are correlated with other scenarios applied in the Study by a direct connection with the GISS and GDFL models results, e.g. in assumption concerning intensification of western wind. The principle generally-adopted in the analysis of sea coast is similar to other elements of the Study: research based upon global models enable defining of range of potential consequences of climate change, which in turn, stimulates undertaking preventive measures.

Basing on the results of GISS and GFDL, four climate change scenarios were carried out, which condition the development of the Polish agriculture to the year 2030:

1. Warm and humid climate

- increase of precipitation by about 20% (up to 700 mm)
- increase of temperature by about 2°C
- CO_2 concentration – 450 ppm

2. Very warm and humid climate

- increase of precipitation by about 20% (up to 700 mm)
- increase of temperature by about 4°C
- CO_2 concentration – 600 ppm

3. Warm and dry climate

- decrease of precipitation by about 20% (up to 450 mm)
- increase of temperature by about 2°C
- CO_2 concentration – 450 ppm

4. Very warm and dry climate

- decrease of precipitation by about 20% (up to 450 mm)
- increase of temperature by about 4°C
- CO_2 concentration – 600 ppm

7.2. ADAPTATION OF WATER MANAGEMENT TO CLIMATE CHANGE

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 of the country. 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.

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. Variations of country's runoff oscillated between 34.4 km^3 in 1952 and 79.5 km^3 in 1981. Due to the inter-annual and inter-annual variability of hydrologic processes, the reliable water resources, available by 95% of time, are equal to about 22 km^3 . Due to environmental needs 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.

Sensitivity analysis 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, and become a barrier to sustainable development of the country 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.

On the basis of analysis conducted by the Institute of Geophysics of the Polish Academy of Sciences in the years 1993-1994, assessed were possible changes in quantity and quality of the Polish water resources for several assumed climate scenarios. Then, two river basins were selected for more detailed investigation of water–management relations in conditions of changing climate of catchment areas of the Warta and Wieprz rivers, which already suffer from periodical water shortages.

For the assessment of vulnerability of water resources in Poland to climate change, a water balance model CLIRUN3 was elaborated in the Institute of Geophysics of the Polish Academy of Sciences. The input data are either period series of precipitation and potential evaporation (for simulation model), or parameters of probability distribution of those variables (for matrix model). The model includes three parameters identified basing on minimisation of squares sum of variations between measured and calculated values of runoff from basin. Parameters of CLIRUN3 model were identified for river basins, and then interpolated to grid areas. As a result obtained were monthly statistic characteristics of water balance constituents for all the grid areas, considering the current climatic conditions, and the GFDL and GISS models.

In both cases there is a decreasing trend of runoff and soil moisture during summer-autumn period. Conducted analysis shows also a possibility of shift in the floods occurrence from March-April to January-February, which is connected with changes in accumulation processes and snow melting. These results should be seen as preliminary assessment of possible changes of hydrological regime in Poland due to climate change.

Influence of climate changes upon simulated time series of water resources in catchments of the Warta and Wieprz rivers is insignificant. In case of the GFDL model obtained was a decrease by 20% of water resources during summer and autumn period, and in case of the GISS model increase of mean annual flow by about 10% with a slight decrease of flows during summer drought periods. Simulated time series of flows were then employed in water management calculations through comparison with water demand.

Expected changes of water temperature and flows regime can disturb equilibrium in water ecosystems through changes in oxygen balance, thermal pollution, increase of water fertility, eutrophication, toxicity, etc. Since chemical reactions and biochemical processes in living organisms depend on temperature, one should expect an increase of metabolism. Due to changes in ground waters swelling conditions their quality may lessen.

Temperature constitutes a very important factor responsible for water quality. In the Warta river catchment area the highest rise in temperature in summer months, corresponding to the GFDL model, reaches 4.1°C, which means a possibility of exceeding the T_w value = 26°C, which is considered in Poland as the maximal admissible value for water ecosystems. There will also be a change in conditions of creation and disappearance of ice cover which plays an important role in shaping thermal conditions, and warming balance, particularly of low-depth lakes.

Changes in the surface water temperature, ice cover and lake stratification pattern is likely to affect the aquatic ecosystem. Because the aquatic processes are influenced by a number of complex, seasonally variable processes, thus no universal statements can be given. For instance, certain water organisms are favoured by higher water temperature, but alteration in other climate factors (e.g. wind speed) can restrict development of primary production. 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 ecosystems.

Calculations done for rivers in Central Poland allow to conclude that the length of period of water temperature appropriate for high decomposition rate may increase by about 30-50%. This means that, in natural, unregulated rivers lowering of water quality may appear. This also concerns not stratified lakes and reservoirs.

Quality of water resources is indirectly affected by hydrological processes. Reduced runoffs are synonymous with worsening of conditions for sewage dissolving, and consequently, increase of concentration of contaminants. Intensity of area contaminants depends largely on shaping of outflow on the earth surface. Reducing of runoffs is accompanied by prolongation of sewage existence in water bodies, and intensification of biological processes. One could expect that influence of climate changes will be thus more significant in middle and low stretches of rivers, rather than in source areas, which are typically characterised by a short concentration period.

In case of the Warta and Wieprz catchments predicted changes in annual runoff are insignificant, particularly for the GISS model. Only in summer possible decrease of low flows may cause worsening of water quality. It will exert heavier influence on the Warta river waters quality due to a high level of organic pollution in this catchment area.

Summing up, no drastic water quality changes should be expected in Poland due to climate alteration. This is particularly true for clean water bodies. For contaminated waters climate change adds to uncertainty as far as shaping of water resources in the future is concerned. This problem needs thorough research. Because those changes will take effect considerably slowly there are conditions to observe their impact and to prepare additional adaptation measures.

Analyses was also carried out on possibility to change the country water demand. In case of the planning work performed so far, assessment of water changes on the basis of analysis of demographic and economic processes, without appropriate consideration of environmental factors, including climate conditions changes. It was research on long-term water management strategies in Poland that usually led to overestimation of water demand. Therefore, harder difficulties should be looked for in the context of expected climate changes.

In 1990 a sample amount of 7.93 km^3 of water was intaken for the needs of various branches of the economy, except for open freezing systems. According to author's estimate, water demands in the middle of next century will not exceed 70% of current demand level due to non-climatic factors. One could preliminary assume that impact of climate factors on water use in industry and municipal sector will not be significant. Agriculture is the sector that is characterised by a high degree of uncertainty. Agriculture now uses small amounts of water to irrigate arable land areas. This situation may however change, because threshold between irrigated and non-irrigated agriculture can be surpassed in most of the Poland's lowlands territory in warmer climatic conditions.

For the purpose of this study it was assumed that the area of irrigated agriculture in Poland will 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. 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 the GFDL model. Respective values for the Wieprz river basin are 28% and 62%. For the GISS model changes in irrigation demand are negligible. According to the above assumptions, water demand of the whole country and of the analysed catchment areas were estimated (tab. 7.1)

Table 7.1. Annual water demand in Poland in years: 1990, 2020, 2050 for selected climate change models

Sector	Water demand in years [km^3]				
	1990	2020		2050	
	Reference	GFDL	GISS	GFDL	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

Analysis of the obtained results for the Warta and Wieprz catchments allows to conclude that the predicted changes in runoff in respond to the GFDL and GISS models 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 model (about 17-25%) is accompanied by the increase of minimum flows, which may have a positive impact on reliability of supply during drought periods. In case of the GISS model the water supply conditions generally improve. However, 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 results of vulnerability analysis of water resources 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 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 the GFDL model may be significant.

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

- strengthening legal and economic policies aimed at protecting quantity and quality of regional water resources,
- rationalisation of water use in all sectors of the economy,
- optimal use of water stored in existing and designed reservoirs,
- development of technical infrastructure by increasing the storage capacity to 600 million m^3 (+ additionally 60 million m^3 in the case of the GFDL model), and by constructing facilities allowing water transfers up to 100 million m^3/year between various parts of the basin (+ additionally 30 million m^3 in the case of the GFDL model),
- preference for investments robust to unexpected changes in functions or priorities, and objects that can be further developed.

Water management system of the Wieprz river catchment area is referred to as the most threatened with water scarcity and periodical disappearance of water bodies within areas of depression crater around the city of Lublin. Fulfilment of forecasts according to the GFDL model brings limitation of surface waters resources of the Wieprz river catchment by 25%. It can make feeding of the system Wieprz–Krzna Canal and restoration of ground waters resources difficult around the city of Lublin through swelling water bodies within the depression crater. Completely opposite course changes is anticipated according to the GISS model in which Krasnystaw shows increase in the mean annual resources from 7.4% (the year 2020) to the level of 14.3% (the year 2050), and at the same time, remarkable increase in minimal runoff by 66.6% and 71.4% respectively. Thus, realisation of this scenario promises a substantial improvement in the sphere of potential use of surface waters resources for the water management in the Wieprz river catchment area.

Anticipated size of demand increase, both in conditions with and without climate change, in the GFDL and GISS models, lead to doubling of water demand in 2050 (increase by 90% or 103%). In the light of the present water management situation in the Wieprz river catchment area excludes a possibility to fulfil tasks without undertaking actions on a wider scale. Based on the analysis, and on a number of earlier studies concerning water management in the Wieprz basin, one can indicate the following main directions of adaptation activities in case of climate change:

- limitation of groundwater consumption by industry and rationalisation of water and surface water use,
- modernisation of arable land irrigation systems, e.g. by application of capillary irrigation, water reservoirs, to limit water misuse and implementation of closed rotation systems in partial reception basins,
- use of treated municipal wastes for agriculture irrigation,
- construction of storage reservoirs in the Wieprz–Krzna Canal water in-takes capable of shaping water resources of this river,
- modernisation of the existing water management facilities, especially the Wieprz–Krzna system,
- water transfer from the San river or Middle Vistula to the Wieprz catchment (in case of improvement of water quality in the Vistula river).

Albeit the Study research focused on two river basins, some general conclusions may be drawn for the future Poland's water policy.

- new structural and non-structural means of water supply will have to be implemented to assure reliable water supply for sustainable development of the country, despite of possibilities of climate change,
- 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,
- there is also no possibility to estimate costs of adaptation of water management to the climate changes, because it heavily depends on the adopted strategy of the country development and necessity to meet water demands,
- it is difficult to formulate a definite list of necessary adaptation actions, unless more reliable information on future climate will be available,

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

1. 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.

2. 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.
3. The vulnerability of water systems to hydrologic non-stationary changes decrease as the level of water system development and water management increase.
4. 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.
5. 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.
6. 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 generalised in the form of a guideline for adaptation strategies.

7.3. POLAND'S COAST VULNERABILITY TO CLIMATE CHANGE AND ADAPTATION ASSESSMENT

Because of its diversified features, Poland's coast, referred to as *Study Area* henceforth, has been split up into following areas (fig. 7.1):

- the Odra Estuary (*Area 1*),
- western dunes and barrier beaches (*Area 2*),
- central-east dunes and barrier beaches with the Hel Peninsula (*Area 3*),
- the Vistula Delta (*Area 4*)

Area 1 includes the agglomeration of Szczecin and Œwinoujœcie, while Area 4 encompasses the conurbation of Gdañsk, Gdynia and Sopot, together with Elbl¹g.

The Polish coast consists of two basic groups: dunes and barrier beaches, and cliffs. The latter 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.

For the purposes of the Study in question assumed were four scenarios of the sea level rise:

- till 2030: rise by 10 and 30 cm
- till 2100: rise by 30 and 100 cm

Latest examination of trends and statistical distributions in sea level data sets, revised and updated for the Polish coast, confirmed some earlier conclusions drawn for mean sea level and exposed new findings for extreme sea levels. The trends are illustrated in table 7.2.

For the study area, the anticipated growth of population is faster than for the whole country, as the world-wide tendency shows a growing population of coastal communities. Moreover, some centres, such as Elbl¹g will also grow faster than average agglomerations in Poland. 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.

On the central coast, one can expect that the present functional links between Koszalin and Ko³obrzeg, and Ustka and S³upsk, will give birth to two additional urbanised units of diversified marine-oriented functions. On the east coast, Elbl¹g will play a more and more important role, not only for its geographic situation close to the developing Baltic states and Kaliningrad but also because it is well industrialised and experiences more and more access to the sea (via the Vistula Lagoon). One can assume that the following maritime agglomerations are likely to materialise in the future, from east to west: Elbl¹g, Gdañsk–Gdynia, Ustka–S³upsk, Koszalin–Ko³obrzeg, and Szczecin–Œwinoujœcie. One can also identify a few major recreation strips to develop more rapidly.

Oil and gas have been prospected in Poland's coastal zone; it is estimated that the amounts extracted off 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 changes in the use of land. Gravel and sand on an area of 10 km^2 are disposable at £awica S³upska as some 24 million tons, which are already mined.

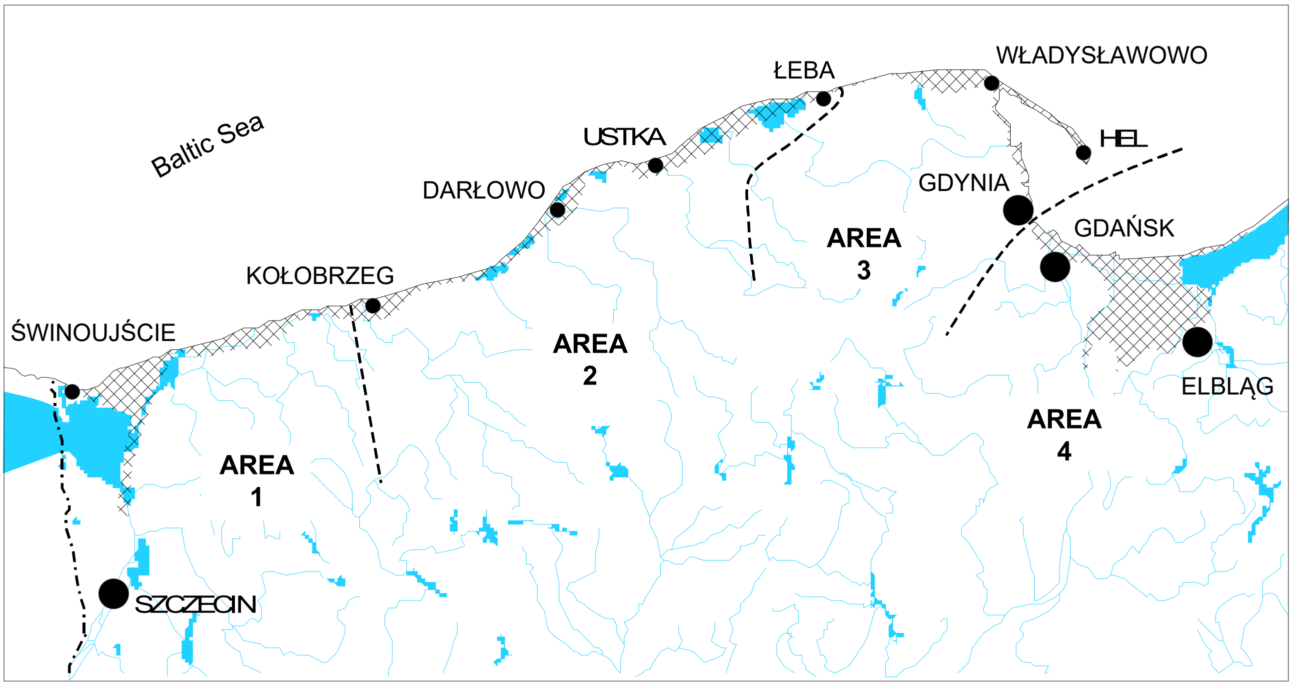

Figure 7.1. Poland's coast split up into four areas; impact zones by 2.5 m – isolines; lagoons, lakes

Table 7.2. Sea level at ten Polish stations: mean values and rise rate for the years 1951-1985

Station	Mean sea level [cm]	Growth rate [mm/year]
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

Tide gauge zero: -500 cm NN$_{55}$ (Amsterdam) and -508 cm H$_r$ (Kronstadt)

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–Szczecin. One new motorway should materialise on the route from Scandinavia via Gdañsk (somewhere east of downtown) to the Balkan Peninsula and the Middle East. A large ferry terminal with motels etc. can be located between Wis³a Œmia³a and Sobieszewo.

The major sea level rise impact within the Odra river mouth will consist in inundation of numerous low lands and aquatic bodies extending at adopted scenario up to River Rurzyca (km 695). At higher stages most polder dikes will be overtopped. The inundated polders will include those of Miêdzyodrze (between East and West Odra), around the Szczecin Bay, Œwina and Dziwna. Endangered by flooding are also urban areas of Szczecin (primarily D¹bie district), Œwinoujœcie, Trzebie¿ and other towns. Indirect effects encompass damage to sewerage and other infrastructure. Parts of the Ports of Szczecin, Œwinoujœcie and Police are also vulnerable. Because of the increasing flow velocities, hazards are posed to the stability of Œwinoujœcie wharves. Ship waves can enhance the instability of navigation channel banks.

In case of the anticipated sea level rise, thin barriers stretching from lakes and the sea can be vulnerable to erosion. As a consequence, the inner lagoon, lake and bay areas can strengthen their connections with the open sea, and their ecosystems can change their character. All the polders within the coastal zone are endangered with the sea level rise too. 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. Since it is low-lying, the S³owiñski

National Park can be menaced, and extensive erosion of the Hel Peninsula is expected in all the four scenarios of the sea level rise. The altitude above sea level of wharves, jetties, breakwaters, and other facilities in Gdañsk and Gdynia varies from port to port, but many locations are threatened with results of the sea level rise.

Basing on results of the research carried out it was stated that the whole Polish coast is threatened with results of climate changes. It was ascertained that 2200 km^2 of land and more than 230 000 people is endangered. In case of lack of activities the total cost of lost area in the scenario forecasting 100 cm rise amounts currently to about 30 billion USD (and about 18 billion USD on the areas endangered with periodical floods), whereas the cost of full protection reaches 6 billion USD. Those figures increase by some 50% if the year 2025 is taken for the starting one. This, in turn, is connected with postponement of decision making. It is also a result of rising prices. What is desired is quick making decisions and taking appropriate actions.

Scenarios of physical and socio-economic development were discussed in the context of climate changes taking place within the Polish coast. Simultaneously, added were elements of adjustment with other studies of climate changes for Poland. The *full protection* adaptation strategy is defined as the implementation of all feasible protection measures to minimise losses of any coastal land or values. The strategy anticipates:

- establishment of protective systems; total length of the new protective systems along the open coast equals 16.3 km of dikes, 21.7 km of seawalls, and 1 km of offshore breakwaters,
- full protection of the Odra estuary means preservation of the polders on peripheries of the estuary,
- construction from Gdynia to the eastern border from about 107 to 280 km of new dikes depending on the scenario and reconstruction of dikes of length equalling to 243 and 324 km,
- modernisation of the existing and construction of new polders. The new polders require new facilities such as pump stations, drainage and other infrastructure, while older polders in central coastline must be redesigned by rising the dikes, adding new pump stations, increasing the rate of pumping, and applying other measures to preserve, or even improve, the present condition of polders.

Cost of implementation of partial protection for the scenarios with 10 and 30 cm sea level rise in the year 2030 reaches respectively: 0.6 and 2 billion USD. Respectively, cost of implementation of full protection amounts to 0.9 and 2.3 billion USD. Cost of implementation of the full protection strategy includes also some additional expenditures on infrastructure and its modification. Protective investments should be designed mainly for areas of the eastern and western coast, where it is the most profitable basing on the cost-benefit analysis.

Due to limited means available for this purpose, there is a need to concentrate on small, particularly endangered areas. Cost analysis shows that actions should be first of all taken within Szczecin and Gdañsk—Elbl¹g coastline. In the strategy of limited protection the investments should be distributed more evenly. This should also be the case within the Hel Peninsula and central coastline. The future investment would go mostly into construction works, such as for seawalls and dikes, together with beach and bank nourishment, dune and cliff stabilisation, dredging operation and infrastructure.

Comparing respective strategies considered in the Study in question one can draw the following conclusions:

1. In all cases but central coast, the protection cost is substantially lower than the value potentially lost. The costs to protect area from £eba to Gdynia are much higher than the value potentially lost.
2. Within central coast, there are priority protective areas (such as the S³owiñski National Park) and these are only protected at a high cost relative to their capital value.
3. An important conclusion is constituted by a necessity to arise national awareness in the field of dangers connected with climate changes, and particularly with the sea level rise, long before occurrence of serious economic and ecological losses. Lack of such awareness can substantially limit economic development of coast regions.

7.4. ADAPTATION OF AGRICULTURE TO CLIMATE CHANGE

Agriculture is a branch of the economy which is the most vulnerable to climate changes effects. It results from the fact that growth and development of crops, being an basic element of primary agricultural and food production, depends heavily on changes of temperature, precipitation, and concentration of CO_2 in the atmosphere, which in turn, are the main factors of the anticipated climate changes of anthropogenic nature. The range of climate changes impact will reach 60% of the whole territory of the country (18.8 million ha of arable land areas). At the same time, due to poorer soil that is more vulnerable to water management changes, a scale of this impact will be higher than in the current European Union countries.

Agriculture adaptation to the climate changes has not yet been researched in detail. Such analysis will be carried out in the years 1996-1997. Evaluation presented below is a result of an earlier fragmentary research work performed by various scientific institutions within the country.

The following are exemplary adaptation processes of the Polish agriculture to the forecast climate changes depending on a course of those changes:

- 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 (SO_2) and ozone (O_3) 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.

It is foreseen that the projected climate changes will have a multi-directional impact on agricultural production in Poland. If the concentration of CO_2 doubles and temperature rises we can expect a growth of the yield of most of currently grown crops. Longer vegetation period will create conditions favouring 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.

8. STRATEGIES OF GHG EMISSION REDUCTION

8.1. POWER GENERATION SECTOR

Analysis on possibilities to reduce GHG emission in this sector was conducted by means of energy system models available on the Polish market, i.e. ENPEP (BALANCE, ELECTRIC/WASP), ELFIN, and the SDM–NE model elaborated in the FEWE.

Research has been carried out for three scenarios of the country economic growth: slow structural changes (stagnation), base-line and fast structural changes (chance).

The slow structural changes scenario (stagnation) was based on several general assumptions anticipating development of the country till 2000 according to the *Strategy for Poland*, completing economic transformations till the year 2010, increase of investments in services sectors, and a faster rate of export than import and GDP rise. By means of this scenario elaborated were two energy and capacity demand forecasts till 2030 considering actual assumptions regarding state energy policy suggested by the Ministry of Industry and Trade, assumptions regarding organisational/ownership changes within state power generation sector, presumed production costs, including investment needs, presumed changes in prices and tariffs. In this scenario GHG emission till 2030 will increase by 50-70% depending on kind of gas.

The base-line scenario is significantly lower in energy and capacity demand than stagnation scenario. Adopted was a number of assumptions verifying assumptions of the stagnation scenario evaluation within energy demand. It was also assumed that the economy will be changing to market economy with current adaptation capabilities (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. Capacity demand on the side of network energetics remains at the level of the stagnation scenario.

The following assumptions were made concerning calculations of optimal choice of energy sources:

- research work will be oriented towards variants of energy generation subsector development. The variants would take into account a group of small sources as dispersed energetics,
- development variants will be considered including, or excluding, nuclear energetics development after the year 2010 basing on safe technologies,
- making operational several new or modernised blocks in the existing power generation plants till 2000,
- fuel prices, available power, and energy generation in network power generation plants will remain at the level of the reference (base-line) scenario.

Calculations were done for the four following variants of further development of energy supply and demand programs in Poland:

- *reference variant (a)* – does not include small size units based on new gas technologies, represented in calculations by 50 MW units,
- *variant with dispersed power,* ER *(b)* – combined steam/gas blocks are substituted with dispersed power generation using small blocks and other assumptions as in *a*,
- *variant nuclear 1,* (discount rate 12%), EJ1 *(c)* – shortening construction time for nuclear candidate from 9 to 6 years and variants *a* and *b*
- *variant nuclear 2,* (discount rate 10%), EJ2 *(d)* – assumptions as in *c*.

Estimations for GHG emission changes are similar in all variants of this scenario till the end of the first decade of the XXI century. After initial decline of emission in the years 1992-1995, it increases to a level of some 102% of the emission from 1988 in 2010. Till 2030 there is a decrease of emission to a level of 93% of the emission from 1988 in variants *a* and *b*, to a level of 89% in variant *c*, and to a level of 78% in variant *d*.

In the **scenario of fast structural changes (chance)** a hypothesis was assumed 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 economisation of demand that will cause decrease of discount rates together with improving the openness of the economy. Optimal choice of energy sources was based on assumption of costs discount rate varying from 12 to 6%, and on the same remaining assumptions as in the base-line scenario.

In the chance scenario considered were four variants of power generation sector:

- *reference variant (a)* – as in the base-line scenario,
- *variant with dispersed power generation ER (b)* – as in the base-line scenario,
- *variant without nuclear power, without EJ (c)*,

variant without nuclear power assuming maximum renewable energy and fuels use (RENEW) (*d).*

In variants *a* and *b* there appears a substantial limitation of coal fuels share for the sake of natural gas (till the year 2015), and then nuclear fuel. In variant *c* assumed is a considerable increase in natural gas use. In variant *d*, in turn, assumed is a considerable increase in renewable energy use (more than 4%).

This scenario leads to GHG emission reduction by about 25% in the year 2030 as compared with the 1988 emission in variants *a* and *b*. It also leads to emission increase by about 10% and 13% in case of variants *c* and *d* respectively.

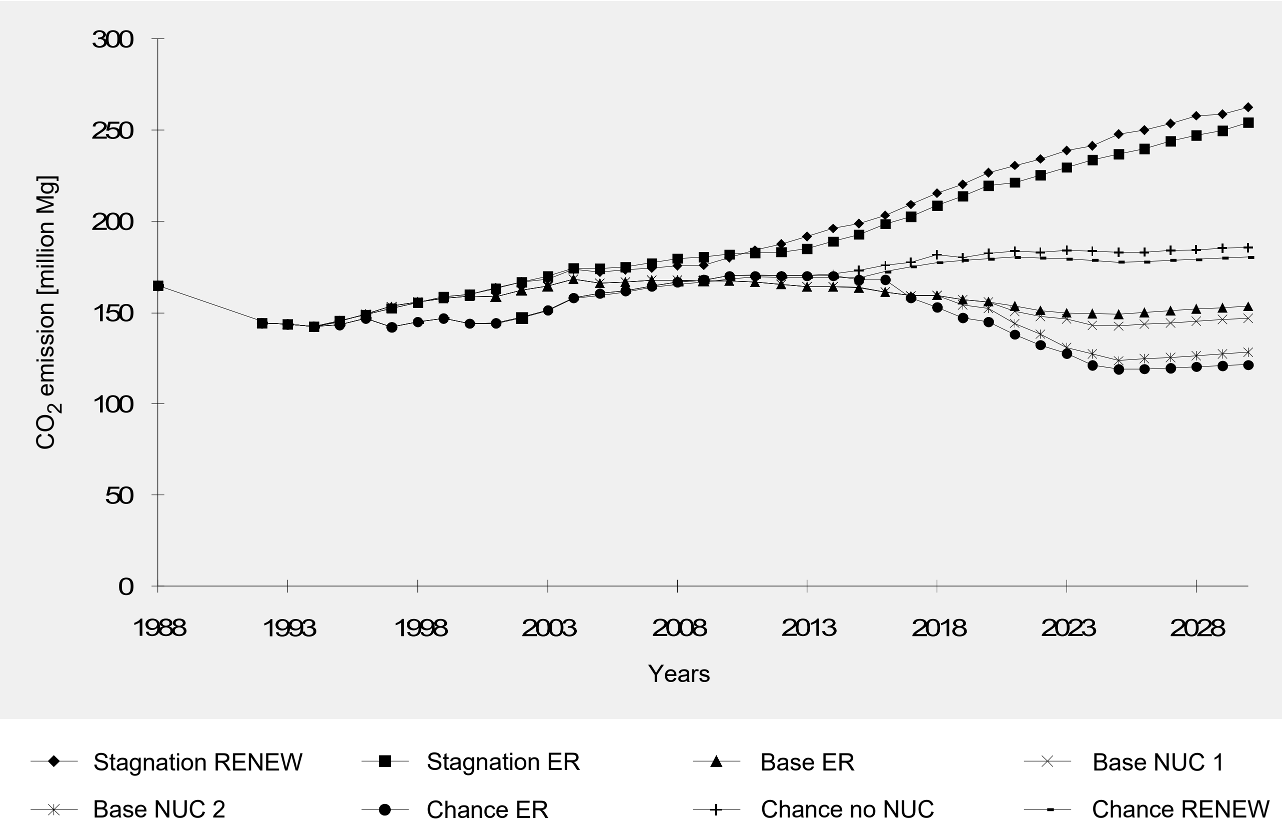

Figure 8.1. CO_2 emission for variants of energy sector development and accepted scenarios of economic development

Results of CO_2 emission changes for the above discussed scenarios (fig. 8.1) show that emission level below base year (1988) level may be assured only by implementation of the base-line scenario and chance scenario with nuclear energy variant. Stagnation scenarios will cause significant increase of emission.

Results of this sector analysis allow to formulate the following conclusions:

1. For quite long time the global effects coming from increasing the energy efficiency 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 its real current and future needs and elaborating long-term economic development strategies (including energy subsectors).
2. Accelerating the changes in economy over the tempo resulting from adaptation capabilities can bring negative medium and long-term results. Accelerating these changes has to be associated with increasing the adaptation capabilities of the society and economy to transformed economy.
3. It is necessary to conduct the analyses of appropriateness of instruments and incentives (e.g. carbon tax) to introduce in the moment when the economy restructuring rate is slower than adaptation capabilities of the society.
4. Chance scenario shows the method of getting together the need of realisation of current priorities with promotion of new priorities and development chances, and creating the possibilities of their realisation in the future. The policy suggested in this scenario enables the society and economy to react on existing incentives faster and with positive feedback effects.
5. Delaying the development decisions in power industry is possible as a result of market transformation effects and demand stabilisation. It is truth considering:

- very dynamic changes regarding power and heat production technologies,
- changes regarding the structural organisation of these economy branches,
- continuing 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 environment-friendly projects that are thrown away nowadays due to financial reasons. The number of alternatives grows resulting not only from technical development but also the possibilities of their acceptation in the economy.

6. In case of necessity to make 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 plants.
7. Decentralisation of the electro-power system favours increase of system efficiency. It is linked with an increase in share of small capacity facilities. However, dissemination of generators limit transmission losses and probability of simultaneous brake down of facilities. This could be eligible source of investment savings due to better system reliability. Consequently, competitiveness within the system is considerable. Higher elasticity of diversified system and more capacity for co-generation of electricity and heat (wider decision-making possibilities) while making energy economy the market one, and development uncertainties are very positive features.
8. Structure of the dispersed power generation is favourable for use of renewable energy sources. For increase of economical attractiveness of renewable fuels especially important are tariffs relay on value and marginal cost base as a function of localisation of energy user.
9. Enforced, in relation to economically optimal solutions proposed by the ENPEP model, intensification of utilisation of renewable energy up to level proposed in the Study (chapter 8.6) makes it possible to reduce emission by 3% for the chance scenario when cost are negligibly higher. Only 3% reduction of GHG emission with approx. 5% share of those sources in the power structure is due to limitation of time of those sources operation.
10. Introduction of nuclear energy sources in each case leads to apparent limitation of GHG emission. Nuclear sources force out mainly blocks powered by hard coal. In case of lack of society and political agreement to initiate nuclear power sources, increase of GHG emission seems inevitable to the range of 19-53% in the year 2030 with a little bit higher costs.
11. In the analysed scenarios, along with limitation of energy demand increase share of energy generation from industrial and network power generation plants increases.
12. In case of demand increase in the stagnation scenario one should expect GHG emission growth by ca. 60% in 2030 in comparison to emission of 1988. These effects are expected in spite of fuel structure changes, especially increase of natural gas share in power generation and associated heat up to 18% till 2030.
13. This study proposes likely directions of changes of energy supply that require further studies and analysis. Of special observation value should be local market attractiveness of different sources of heat as a function of new legislation rules and institutional statements for energy economy. In case supply from associated units especially important is conception of rates for two energy markets: electricity and heat.

14. Increase of demand under base-line scenario and related supply variants are the result of the following:

- during the period 2003-2011 2% absolute emission growth is observed as compared with 1988 for all variants of the scenario due to demand increase and hard coal dominated fuel structure of production,
- after 2011, as a result of fuel structures changes there will be increase brake, and then drop in GHG emission reduction level,
- till 2030, in variants including nuclear power generation, GHG emission reduction is lower than the emission in 1988 by 11% (variant EJ1) – 22% (EJ2). However, deterioration of nuclear variants goal function is remarkably slight as compared with the dispersed energy production variant,
- in reference and dispersed energy production variants after 2014 emission will not exceed the level from 1988, reaching in 2030 level lower by some 7% than in base year,
- in relation to 1988 relative emission related to GDP drops down doubly for base-line scenario for the year 2010, 3.1 times for the year 2020, and 4.3-5.1 times for the year 2030,
- in comparison with the stagnation scenario, relative emission related to GDP drops down in the base-line scenario by some 1.13 times in 2010, 1.5 times in 2020 and 1.8-2.1 times in 2030.

15. Increase of demand under chance scenario and researched changes of ways of its realisation cause the following:

- for variants allowing for nuclear power there is a strong decrease of GHG emission by some 25% in the year 2030 in relation to 1988, i.e. below emission of the base-line scenario despite higher energy production in the final phase of the forecast,
- for nuclear variants there is a temporary increase of emission up to a level of 3-4% over 1988 level in the period 2008-2015, reaching peak by some 19% higher than in 1992,
- for variants with restricted nuclear power development one can observe absolute increase of emission exceeding in 2030 the level of 1988 emission by about 139%,
- intensification of renewable energy sources (proposed in chapter 8.6) utilisation slightly worsens goal function value and limits emission to the level exceeding emission of the year 1988 by some 10%,
- in relation to state from the year 1988, relative emission related to GDP drops down for chance scenario 2 times in 2010, from 2.7 to 3.5 times in 2020, and from 3.7 to 5.8 times in 2030,
- in comparison with variants of the stagnation scenario, relative emission related to GDP, towards the end of the forecast drops respectively 2.3 times and 1.5 times for the *nuclear* and *non-nuclear* variants.

16. Each considered variant presents a tendency for a slight (2-4%) growth of emission of GHG until 2015 in comparison to the 1988 level. After then one can observe, depending mainly on nuclear management development and share of nuclear power generation in overall power production demand an possibility of absolute reduction of emission to the level of 25%. In case of lack of agreement to nuclear power variant the most optimistic situation is 7% drop in emission in 2030 in comparison to 1988 emission in case of wide natural gas use and with moderate (base-line) scenario of economic growth. Growth under a rate set by the chance scenario will signify an absolute emission increase by some 10%, even with remarkable preferences for renewable energy use.

8.2. INDUSTRY SECTOR

For the purposes of generation and evaluation of technological options of GHG emission reduction, analysis of energy intensity of the economy was carried out. In particular the analysis concerned industry and its most energy-intensive products and technologies. In 1988 share of industry together with power and heat generated for industry, in national emission of gases amounted to some 35%. Analysis of GHG emission from industry showed that some 74% of the overall emission comes from four most energy-intensive sectors, i.e. iron and steel metallurgy, non-iron metals metallurgy, mineral industry, as well as chemical, refinery, and petrochemical industries. The above-mentioned branches of industry make up a total of 46% of industry added value, and their share in direct energy consumption in industry amounts to some 76% (without petrol and petroleum, included in transportation sector). In less energy-intensive branches share of added value reaches some 45%, and share of direct energy consumption reaches some 24%. Unfavourable is also structure of directly utilised energy carriers. In connection with the above-mentioned, the detailed analysis was conducted for the four mentioned industry branches, in relation to the whole industry the analysis was restricted to the so called quasi-technology, i.e. universal energy technologies connected with changes and energy consumption.

In the analysis of respective technologies distinguished were three groups of measures, namely: autonomic, energy and GHG emission reduction measures.

Autonomic measures (au). They give energy effect and limiting emission *by the way* of modernisation and restructurisation of industry branches. Distinguishing those production technologies is also of decision-instrumental nature in formulating of strategy of GHG emission reduction, because producers/investors through competition on the market are forced to improve their technologies. In their long-term survival strategy, effect of GHG emission reduction is thus autonomous. An additional criterion of exploration area choice is constituted by amount of technical potential and possibilities of limiting energy consumption in industry production technologies. An example of potential of depleting energy intensity of products may be provided by a comparison of energy intensity of steel, ammonia, cement, and paper production in the European Union countries and in Poland. It would be feasible to reduce energy intensity in relation to the average of the best practically achieved energy intensity – for steel by over 40%, for ammonia by over 24%, for cement by over 49%, and paper by 28%. Average potential of energy intensity depletion for the four mentioned products amounts to over 38% in relation to already achieved best results in the above-mentioned countries' practice.

Energy measures (en). They include the so called quasi-technologies or universal cross-branch technologies, in which the main effect of improvements can be seen in reduction of energy costs (e.g. highly efficient boilers, pumps, electrical engines, ventilators, etc., refuse energy salvage, associated production of power and heat, improvement of energy management systems), or gas pollutants reduction, including GHG emission reduction (e.g. power generation in highly efficient gas-steam cycle);

GHG emission reduction measures (ec). They consist mainly in replacement of solid fuels with hydrocarbonate ones (*inter alia* conversion of carbon boilers into gas ones, production of power and heat in industrial power generation plants in associated cycles with an increased use of natural gas). Taking into account GHG emission, structure of direct energy consumption in industry is unfavourable. Solid fuels burning makes up some 47% of emission, fossil fuels burning constitutes some 7%, gases and refuse fuels burning adds 41% and 5% respectively. Change of this structure, i.e. increase of natural gas share, constitutes potential to decrease GHG emission reduction in this group of measures.

In the choice of options of reducing GHG emission reduction for further evaluation, of primary importance were rankings of size of the expected outputs. Apart from the choice made, there could also be other options, participation of which could contribute to reduction of emission by 20% in relation to the presented set of options (100%).

Formulation of GHG emission reduction strategy assumptions is based on:

- formulation of the base-line scenario defining what happens when future development historical and political trends will be left to continue; this scenario is also referred to as *non-intervention* scenario, which means that GHG emission will be changing in the future without any special actions of the adopted emission reduction policy;
- choice of goal i.e. level of GHG emission abatement, estimated beginning from the base-line scenario through respective periods till the year 2030; choice of goal is a political decision connected with:
  - Poland's commitments which may be made while signing international agreements on GHG emission reduction, concerning the United Nations Framework Convention on Climate Change,
  - comparison of cost-benefit relation of industry options with options of other economy branches, and choice of reduction goal for the whole Poland according to principle of greatest profit and realisation possibilities,
  - presentation of Poland's contribution to lessening the threat of global climate changes as an active action for the sake of society of the world;
- drawing up the options according to decreasing economically profitable order and increasing effect of reduction of GHG emission giving possibility of goal selection;
- evaluation of conditions, and based on it, choice of instruments for the goal realisation results from the following reasons:
  - the Polish Government is responsible for realisation of goals resulting from the signed international agreements,
  - hence, strategy will be a long-term, planned enterprise of the government,
  - Poland's economic regime will continue to develop towards market economy; thus, the choice of instruments of governments influence upon independent economic entities in industry will be adequate possibilities of the country's intervention on the market,
  - GHG emission reduction strategy should be integrated with industrial, ecological, and energetic policy of the country and create synergy of these policies' instruments.

GHG emission abatement scenarios were investigated with regard to the stagnation and base-line scenario. The stagnation scenario assumes economic growth with frozen production structure and energy intensity from the last year before the socio-economic regime was introduced (1988). The base-line scenario should be perceived as the one that provides economic growth with assumed changes of production structure of industry branches and frozen energy intensity (at the level from 1988), from which excluded were effects of emission reduction from respective groups of measures (*bottom-up* analysis), (fig. 8.2.). As a consequence of the above-mentioned factors, attainment of GHG emission reduction effects may be attributed to the initially-described technological options ordered from the smallest to the greatest unit (marginal) cost of reduction (fig. 8.3, tab. 8.1). After analysis all of twenty four measures, the GHG emission reduction in 2000 was estimated at 50 million tons of CO_2 equivalent, which, against the base-line scenario is about 25%; in 2010 at 90 million tons, i.e. about 30%; in 2020 at 100 million tons, i.e. about 25% and in 2030 at 107 million tons, i.e. about 24% (fig. 8.4).

The above-presented measures do not contain all opportunities of GHG emission reduction in industry. Not accurate estimation is a result of not considering in the analysis some 30% of technologies employed in industry, as well as an influence of implementation of non-, or low-investment measures resulting from better management of energy.

Implementation of measures limiting GHG emission requires outlays reaching a total of 95 milliard[2] USD'90 in the period between 1995 and 2030. The above figure is divided into the year 1999 (16%), 2000-2009 (28%), 2010-2019 (24%, and 2020-2030 (32%), (tab. 8.2).

The following general assumptions of strategy of GHG emission reduction in industry were adopted.

Until 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-organisational transformations. In the nearest years, i.e. in the period 1996-1997 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-organisational 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 to about 5-8% in the entire industry and proportional GHG emission reduction.

[2] 10^{12}

Within the years 2005-2020, i.e. in the period of middle-term horizon of technological changes, implemented will be *second wave* technologies which actually are technically viable but their effects are not feasible economically in the current relations between capital and energy prices, and other production factors (labour, materials, etc.). 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 is because of finalising of the process of energy carriers prices reflecting the costs (regarding the long-term marginal costs of development) between 2000-2005. The Polish industry will begin to integrate with the 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 within signed conventions. In this light, natural environmental protection policy and its instruments such as: *carbon tax*, *international emission trade* and *activities implemented jointly* policy will have stronger influence. The period till 2005 can be used by Poland to create an analysis of 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, hence in faster development of Polish industry.

After 2020, i.e. in long-term time horizon, technologies of the 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 a large extent, 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 earlier (starting possibly from now) participation in work of the international institution (OECD, IEA) which co-ordinate and co-finance research and development, at least regarding the access to information concerning advanced technologies, and create country centres of information and advising.

Realisation of the above-presented goals requires preparation and application of appropriate instruments in the field of industrial, ecological and energetic policy (tab. 8.3 – 8.5).

On the basis of analysis of the industry sector the following conclusions can be drawn:

1. In the years 1988-1993 industry reduced its final energy consumption from 1653 PJ/year in 1988 to 1123 PJ/year in 1993, i.e. by 32%. In the transition period from centrally-planned to market economy, i.e. in the years between 1989-1993 there was in industry depletion of GHG emission (CO_2 equivalent) from about 201 million in 1989 to some 149 million Mg in 1993, i.e. by about 26%. 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,
- small decrease as a result of energy carriers structure change.

   There was observed an increase of GHG emission by 3.4% as a result of worsening of effective use of energy. Only the years 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 sold production. By maintaining this trend, the Polish industry would have the chance to return to the highest sold production level (reached in 1989) with reduced by 23% final energy consumption.
2. The possibilities to reduce GHG emission from industry as a result of both industrial branches structure change to less energy-intensive, and implementation of technologies with better energy utilisation and more friendly for the environment (lower emission of pollutants, including GHG) technologies. GHG (CO_2 equivalent) emission reduction in 2010 can be brought about by:
- decrease by about 24 million tons as a result of technological reconstruction of production in energy-intensive industrial branches (iron and steel metallurgy, chemical, refinery, petrochemical, mineral, and non-iron metals industries),
- reduction by about 58 million tons as a result of energy efficiency increase in universal, cross-branches technologies (highly efficient electric engines, electronic adjustment of drives, heat salvage, improvement of machines and energy utilising facilities efficiency, improvement of steam management),
- decrease by about 6 million tons as a result of energy carriers structure change in industry, in other words of growing share of hydrocarbon fuels, especially natural gas.
3. Most of the evaluated technologies, i.e. about 67%, is characterised 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 to 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 tons. It is 26-29% of GHG emission reduction level of the 1988 or 20-22,5% with regard to the base-line scenario in 2010. The choice of this aim in industry which could be the subject of Poland's obligations within

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 the fact that about 30% of technologies in industry were not the subject of this analysis as well as because of the fact that the impact of implementation non- and low- investment measures which are a result of better management and energy economy it is not taken into account in the analysis.

4. 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. Till 2005 achievement of GHG emission abatement by some 20% (as compared with the base-line scenario) should stimulate state industry policy instruments aiming to reconstruct Polish industry. This will affect both industry branches changes, increasing share of less energy-intensive branches, and technology reconstruction of the most energy-intensive branches of industry. After 2005 in realisation of strategy of GHG emission reduction should predominate new mechanisms of integrated energy and environmental policy. Part of them can be adapted within international co-operation regarding the climate protection.
5. Going out from technology positions, the so called *first wave* technologies (currently viable technically, commercialised and profitable for implementation) it is possible to construct the scenarios of GHG emission reduction in industry only to 30% emission according to base-line scenario, there is no possibility to construct reduction scenarios up to 50%. In the time horizon till 2030 it can be changed by faster economic progress s of the so called *second wave* technologies actually feasible but yet not profitable) or deeper changes of industry structure for the sake of modern, non-energy-intensive industrial branches and to some degree, further increase of natural gas consumption.
6. Taking into account the necessity of industrial reconstruction and its adaptation towards the requirements of international competition, 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 favourable to political and economic integration of Poland with the OECD-countries. Therefore, preparation and implementation of GHG emission mitigation strategy, including also the one in industry, within integrated energy and economic policy as well as active participation in climate protection international institutions can bring a number of profits to Poland, mainly because of:

- joint investment in Poland,
- receiving more favourable 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.

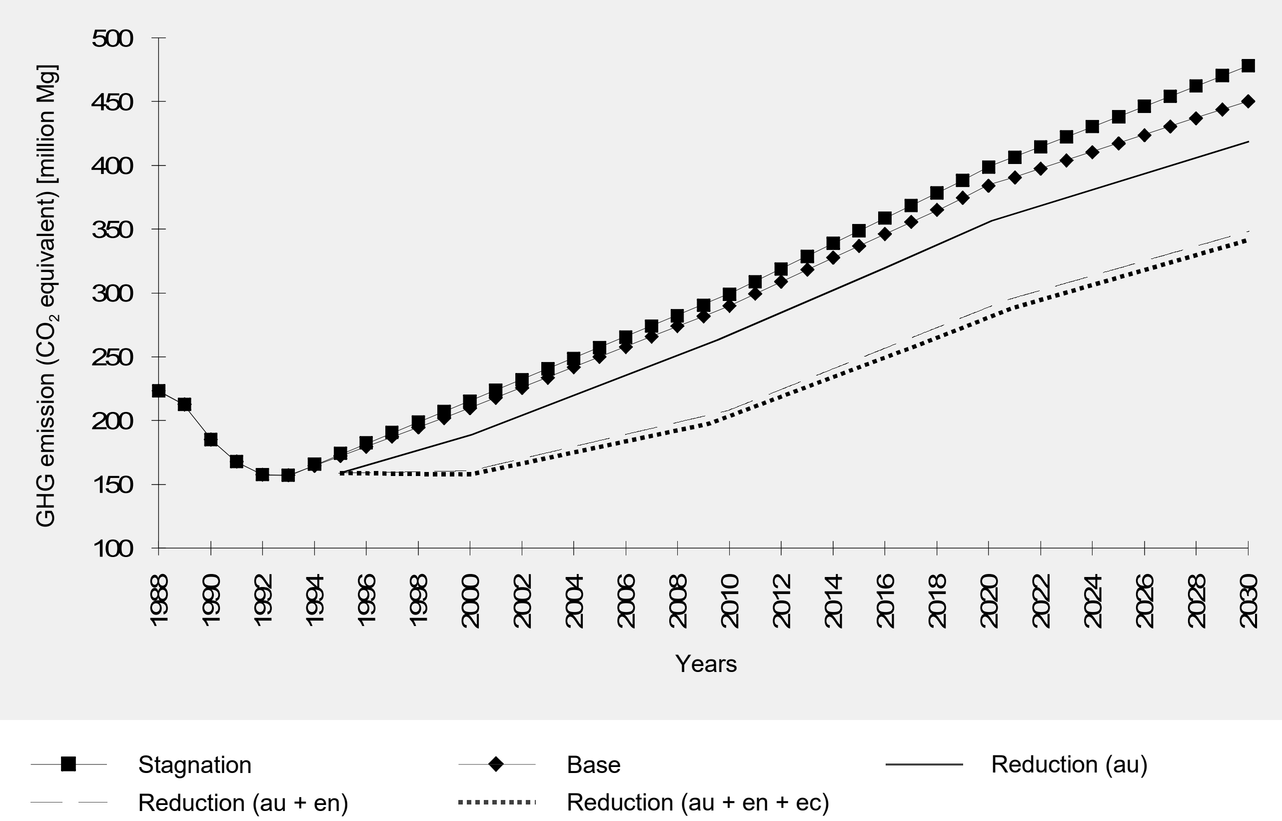

Figure 8.2. GHG emission from industry for various reduction scenarios and selected scenarios of economic growth in 1988-2030

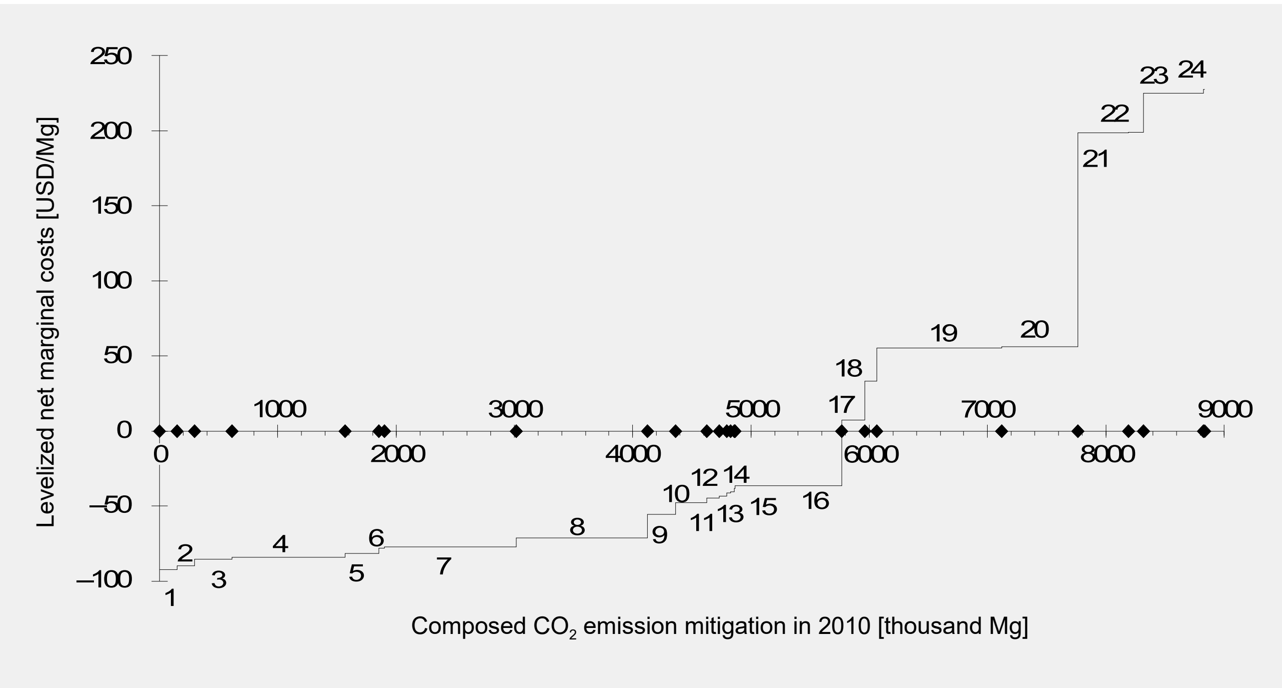

Figure 8.3. Energy measures of GHG emission mitigation according to reduction costs: 1, 2, 3, ... 24 – measures in order according to table 8.1

Table 8.1. GHG emission mitigation from industry according to groups of measures, specific investment cost (SIC) and internal return rate (IRR)

No	Measure type	Emission mitigation in years [Gg]				SIC	IRR
		2000	2010	2020	2030	[USD/t]	[%]
	Energy measures (en)						
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	Modernisation of heating furnaces	1535	2683	2683	2683	-47.67	42
11	Heating processes - heat recovery in the boilers and evaporated installations	1036	1036	1036	1036	-44.71	36
13	Utilisation 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	9 058	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	Modernisation of raw - material part of iron and 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 electrolyse	32	32	32	32	-38.02	18
20	Technological modernisation of chemical industry	4947	6472	8350	9764	56.36	*
23	Technological modernisation of refinery and petrochemical industry	2858	5109	6408	8313	224.77	*
24	Alumina electrolyse by using of agglomerated anodes	72	72	72	72	227.57	*
	Subtotal	19808	23773	27044	30488		
	GHG emission mitigation measures by fuel substitution (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 electricity 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**		

Table 8.2. Investment cost for GHG emission mitigation in industry in 1995-2030

No	Measure type	Investment cost in years [million USD]			
		1995-1999	2000-2009	2010-2019	2020-2030
	Energy measures (en)				
1	High-efficiency lighting	22	53	8	
2	Monitoring of production processes	17	67	12	
3	High-efficiency electric motors	103	832	152	
4	Improvement of steam economy	115	1082	714	
5	Electronic control of electric motors	9	439	71	
6	Blast furnance gas pressure turbines	61			
7	Improvement of energy management in industry	984			
9	Heating processes - heat recovery in the recuperators	160	53		
10	Modernization of heating furnaces	180	73		
11	Heating processes - heat recovery in the boilers and evaporated instalations	146	62		
13	Utilization of chemical energy of basic oxygen furnace gas	7			
16	Improvement of efficiency of energy using machines and divices	739	246		
18	Generation of electricity in industrial combined cycle power plants	325	50		
19	Generation of electricity from colbed methane in power plants - combined cycle	1302	2604		
22	Dry coke quenching installation	2125	820		
	Subtotal	6294	6382	958	
	Autonomous measures (au)				
8	Modernization of raw - material part of iron and steel metallurgy	1527			
12	Enlargement of cement production by dry method using	4	216		
14	Enlargement of lime production in Maerz furnaces	12	19	40	
15	Implementation of modern zinc electrolyze		19		
20	Technological modernization of chemical industry	2000	6300	9000	12000
23	Technological modernization of refinery and petrochemical industry	3000	9300	12500	18000
24	Alumina electrolyze by using of agglomerated anodes		240		
	Subtotal	6543	16094	21540	30022
	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	67	105		
21	Co-generation of elecricity and heat in industrial power plants by enlarged using of natural gas	2700	4515		
	Subtotal	2767	4620		
	Total	**15605**	**27096**	**22498**	**30022**

Table 8.3. Structural changes and technological reconstruction of industry

<table>
<tr><th>Błąd! Nie zdefiniowano zakładki.Causative forces</th><th>Programmatic activity</th><th>Way of realisation (instruments)*</th><th>Period of implementation (influence)</th></tr>
<tr><td rowspan="2">1. Adaptation to international competition and gaining competitiveness on internal and foreign markets.

2. Needs of reconstruction and modernisation of production potential

3. Adaptation of production capacity towards the rationalised market demand.

4. Necessity of employment rationalisation in heavy industry for less capital-intensive medium and small enterprise sector.</td><td>1. Macroeconomic market reforms</td><td>1. Organisational and ownership changes forcing greater economy efficiency and development capacity (demonopolisation, commercialisation and privatisation etc.)[E].
2. Setting prices of energy carriers at the real level regarding the marginal costs of energy sector development [E].</td><td>successively till 2000

1995-2005</td></tr>
<tr><td>2. Industrial policy</td><td>1. Planning
1.1. Updating, approval and implementation of the following reconstruction programs:
• metallurgy [E],
• fuel & energy sector[E],
• heavy chemical synthesis[E].
2. Financial
2.1. Creation of state financial guaranty system supporting reconstructing programs for heavy industry [N].
2.2. Stimulation of establishing of consortiums of banks for financing of reconstruction [N].
2.3. Construction of investment tax credit system according to state strategy of industry reconstruction [N].
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 [E].
2.5. Stimulating of development of non-energy-intensive and modern industry sectors, so called "high chance sectors" [N].
3. Organisation and information
3.1. Elaborating and implementation of monitoring system of structural changes and technological industry reconstruction (including impact on energy consumption changes and pollutants emission) [N].
3.2. Defining of research & development priorities directed towards modern, enviro-nmentally friendly, as well as material- and energy-saving production technologies and ensuring their financing [N].
3.3. Including of country research & develop ment base into process of organisational and ownership changes in industry N].</td><td>
1995-1997 (till 2005)

till 2002

till 2002

1996-2005

1995-1997 (till 2010)

till 2010

1996-1997

1996-1997

1996-1997</td></tr>
</table>

* E - existing, N - new.

Table 8.4. Technologies of energy efficiency increase (quasi-technologies – cross-branches technologies)

Błąd! Nie zdefiniowano zakładki. Causative forces	Programmatic activity	Way of realisation (instruments)*	Period of implementation (influence)
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.		1. Legal 1.1. Creating of new energy law which would regulate [N - under way] : • opportunity and investment profitability for producers and grid distributors of energy carriers for energy efficiency by energy users, • principles of construction 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.	1996-1997
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.		2. Financial 2.1. Implementation of accelerated amortisation system for devices with high energy efficiency. Implementation of amortisation duty of such devices into amortisation act within the period of 4 years, consequently, for enabling an earlier use of profit [N].	from 1997
	1. Energy policy	2.2. Stimulating innovative financing forms of measures, including pilotage additional capitalising (under commercial law) by state agencies of self-financing firms based on dividing of profit from energy cost-saving (firms of ESCO type) [N].	1996-1997
		2.3. Including into investment tax credit system preferences regarding the devices with high energy efficiency [N].	from 1997
4. Importance of natural resources, including energy exploitation efficiency for improvement of state of environment.		2.4. Supplementation of 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 [N].	1996-1997
		3. Information 3.1. Funding of auditing of energy efficiency increase in small and medium industrial enterprises [N].	from 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 [N].	from 1998
		3.3. Institutionalising and financing of professional data bases as well as guidance regarding energy-saving and environmentally friendly technologies, connected with international OECD/IEA systems as:GREENTIE, EPA etc. [N].	1996-1997

* E - existing, N - new.

Table 8.5. Technologies of substitution of coal fuels with hydrocarbon fuels and renewable energy carriers

Błąd! Nie zdefiniowano zakładki. Causative forces	Programmatic activity	Way of realisation (instruments)*	Period of implementation (influence)
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 (indirect significance): • national [E - to be modified], • international (European Union) [E]. 1.2. Implementation of principle of the lowest costs of attaining local standards of quality of air, including principle of integrated planning of energy resources, into the existing system of temporary permissible pollutions for regions [N]. 1.3. Implementation of programs of air pollutions reduction from the so called low emission sources in industry [N]. 2. Financial 2.1. Adaptation of payment system for the use of environment to marginal costs of pollutions mitigation [N]. 2.2. Progressive (educational) and later a significant increase of charges for CO_2 emission [N].	till 2000 from 2000 from 1998 (after 2005) till 2000 (after 2000) 1998-2000 till 2000 reasona-ble; after 2000 significant
	1. 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.	1996-1997
	3. Integrated energy and ecological policy	1. Co-ordination of energy and environmental policy instruments according to the least costs principle of energy sector and maximising of results of environmental pollution emission mitigation.	1996-1997

* E - existing, N - new.

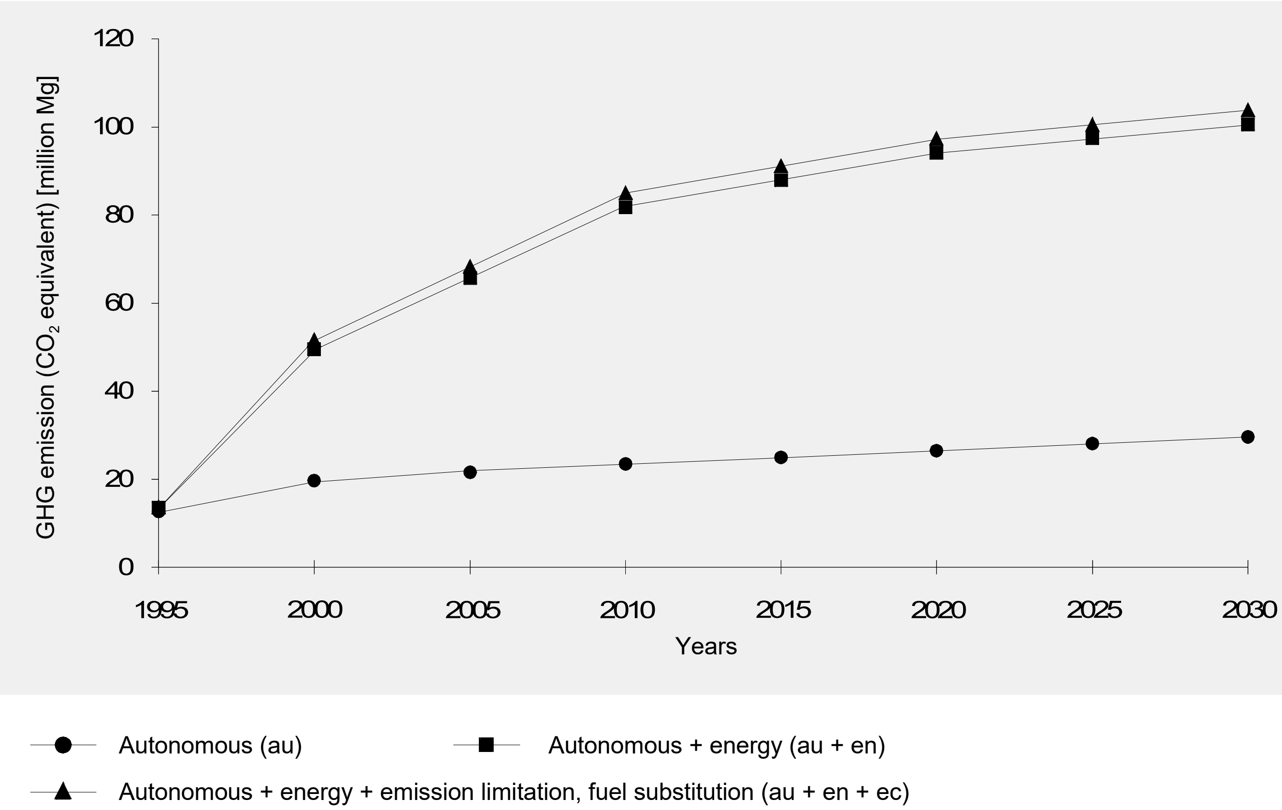

Figure 8.4. GHG emission mitigation from industry in 1995-2030 according to group of measures

8.3. MUNICIPAL SECTOR

Emission of greenhouse gases which results f~~o~~rom the use of energy ~~using~~ in municipal sector has been estimated on ~~a~~the -basis of a consumption of different energy carriers and applied technologies of energy conversion ~~for~~ to cover~~ing~~ identified energy needs in the sector. In particular stages of the project the following problems were considered:

- -basic, ~~defin~~identifiable~~able~~ aims of energy use and the final energy demand,
- ~~-nowadays~~current standards of energy receivers and their possible changes, ~~of them,~~
- currently -applied and possible to implement technologies of energy us~~ing~~e,
- -possibilities for~~of~~ changes of standards and methods of energy use resulting in the GHG emission,
- -proposed strategies for the emission reduction.

Several general assumptions were assumed that condition changes of energy demand in this sector. The assumptions are following:

- housing construction development will continue in line with the government forecasts,
- the worst-equipped flats will be liquidated,
- supply of flats with hot water will be better systematically,
- there will be a successive gasification of the country,
- there will be an increase in home electrical appliances and duration of their use,
- cubature of non-residential buildings will grow slower than cubature of residential buildings,
- newly constructed buildings will comply with heat isolation requirements, and
- there will be a drop in energy use to illuminate roads.

It was estimated that the power demand for space heating in residential buildings will ~~increase~~ grow ~~from~~ from about 90 GW in 1988 to almost 150 GW in 2030. The ratio of municipal heating systems and local boiler-houses will significantly increase from 28% in 1988 and 30% in 1995, to over 41% in 2030. The ratio of individual CH systems with gas fired boilers will also increase significantly from 4.4% in 1988 and 12% in 1995 to 25% in 2030. The demand for stove heating will decline from about 33 GW (of final power) in 1988 and 32 GW in 1995 to 20 GW in 2030.

Demand ~~of~~ for power and energy in warm sanitary water and applied hot water supply systems will increase more than the population as standards ~~o~~for sanitary water us~~ing~~e will be higher, particularly in rural areas. This will imply increased demand for electricity especially to the year 2020.

The energy demand for cooking will not change too much. The final energy demand will change proportionally to the population increase. The total consumption of usable energy will ~~be~~ remain almost ~~not~~ unchanged as average efficiency of energy carriers use will increase. The ratio of network gas will increase ~~what~~ which will ~~be~~ result~~ed~~ ~~by~~ from the assumed gasification of the country. ~~More rarely kitchen s~~Kitchen stoves fired with solid fuels will be in less use.

T~~t~~he elaborated prognosis assumed that the electricity consumption per capita in the households will increase significantly, i.e. by about 70% and reach about 58 TWh in 2030.

The estimation of the GHG emission is given in table 8.6. According to the ~~accepted~~ adopted base-line scenario the emission increases from 1995 till 2030 by about 37% in case of CO_2 and about 28% in the case of methane (CH_4). In relation to 1988 increase of those gases emission amount to respectively 41% and 29%. It is impossible to estimate nitrous oxide (N_2O) emission as the most of specific emission factors for this gas are unknown.~~necesary for this nitrogen monoxide gas emission technology most of specific emission factors are indicators are unkno.~~

Table 8.6. Greenhouse gases emission according to base-line scenario

Emission	Mean emission in years					
	1988	1995	2000	2010	2020	2030
CO_2 [million Mg]	158.29	162.25	169.04	183.99	200.40	222.92
CH_4 [thousand Mg]	3.34	3.29	3.42	3.61	3.89	4.33

As reduction options of energy consumption and the GHG emission some measures were considered in the following areas:

- within improvement of thermal insulation and sealing buildings (option *external isolation of walls and flat roofs of residential and non-residential buildings*, option *sealing up window woodwork and controlling ventilation*, option *change for energy-saving windows*),
- within lighting end energy devices (option *change for lighting systems in flats, non-residential buildings, as well as road lighting system*, option *exchange of energy devices – energy receivers – for more efficient ones*),
- within more energy efficient buildings heating (option *exchange of boilers in network heating sources*, option *substitution of hard coal with solar energy, gas, wood,* option *payment for network heating on the basis of measuring of consumption and* option *modernisation of CH installation supplied by network heat*, option *modernisation of individual internal heating systems, including weather automatics*).

As a result of gradual implementation of ~~the~~ enterprises ~~affairs~~ favouring ~~which are sound for the~~ emission reduction, it is possible to, according to adopted assumptions, limit energy consumption for residential space heating, depending on energy carrier, from 19% to over 30%, on the ~~an~~ average by about 29%, and to limit energy consumption for non-residential space heating from 6% to 18%, ~~an~~ on the ~~an~~ average by about 17.6%. An improvement of efficiency of devices for warm sanitary water supply can ~~let~~cause ~~to~~ reduction of demand for energy by 6%. Particularly ~~big~~ large savings can results from an~~n~~ ~~advancement~~ improvement of operation of municipal heating systems. However, in relation to utilisation of energy carriers to prepare hot sanitary water in 1992, after improvement of generation efficiency, consumption in 2030 is 25% higher. Against the year of 1988 this increase amounts to 27%. It will be possible to reduce ~~yearly~~ demand for electricity for supply of appliances in households by about 4.9 TWh. Wider use of energy saving light-sources~~,~~ than ~~it was assumed~~ assumed in the base-line scenario, allows~~lets~~ ~~to obtain notable~~ for a significant decrease of electricity consumption for lighting. A~~A~~ccord~~ing~~ing~~to~~ to the considered reduction scenarios the demand for energy for lighting is to be ~~lessened~~ reduced by several percent to 2030.

As a result of implementation of the chosen reduction scenario, the CO_2 emission will be higher in 2030 than in 1988 by 12%. Emission of CH_4, in turn, will be in 2030 higher by 6% as compared with 1988. The anticipated limited emission of CO_2 against emission being in line with the base development scenario are presented in figure 8.5.

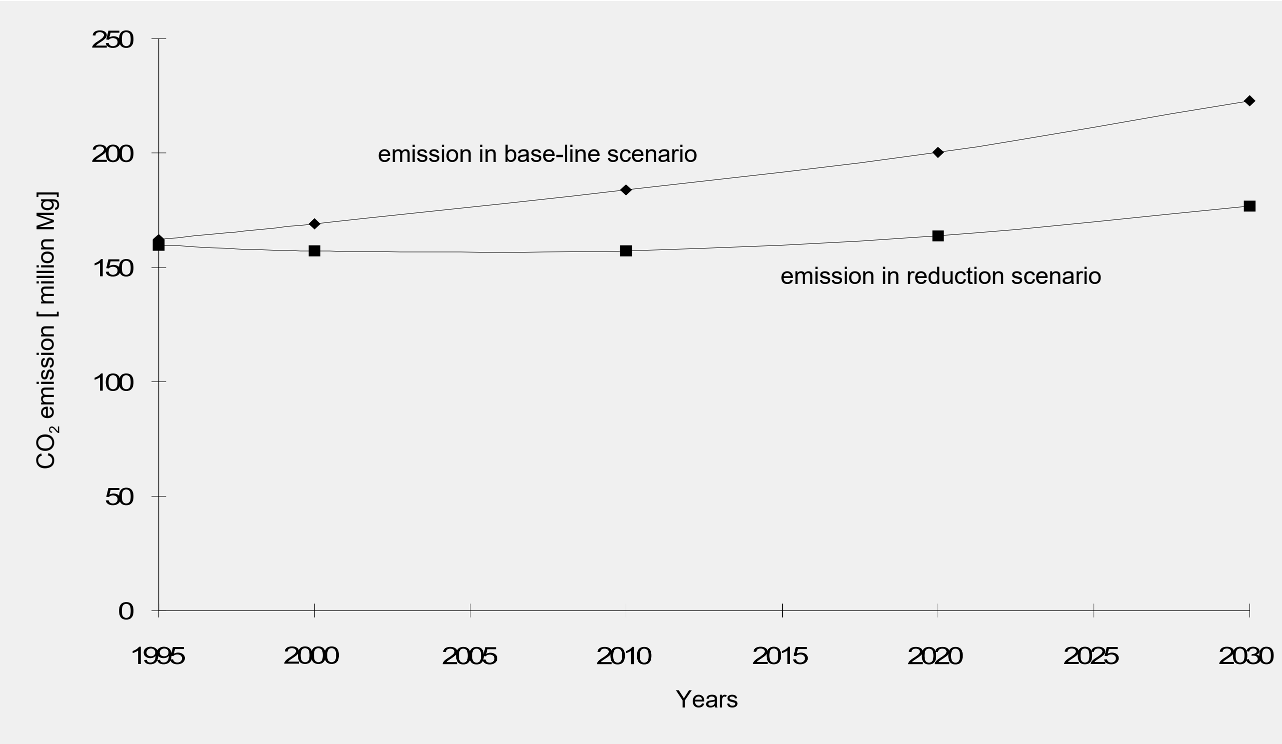

Figure 8.5. CO_2 emission according to base-line and reduction scenarios in municipal sector

Carried out analysis allows to formulate following conclusions:

1. The economy development and related to it changes of ~~live~~ standards of living will cause significant increase of final energy demand for various living needs and other purposes in the municipal sector. As it was stated above, if no wider program of modernisation of systems of energy use is undertaken, the ~~yearly~~ annual emission of GHG will rise ~~since~~ between 1995 ~~to~~ and 2030 by about 37% in case of CO_2 and about 28% in case of CH_4.
2. It is potentially possible to implement such changes in methods of ~~covering~~ meeting the energy needs in municipal sector that the annual GHG emission will be stabilised in relation to ~~on~~the 1988 emission level and reduced by over 20% in ~~the~~ relation to ~~foreseen~~ 2030 emission ~~in 2030 according~~ foreseen in the bas-line scenario~~to basic scenario~~.
3. T~~T~~he lowest unit ~~specific~~ costs of GHG emission reduction among the considered options are ~~are~~ characteristic of programs of ~~the lowest between the considered reduction options in the case~~ modernisation of heating systems:

- ~~–~~application of weather control systems and temperature control 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 networks,
- ~~–~~assembling of network heating systems and internal CH systems with measurement and control devices which enable accounting systems based on consumed energy according to measurements, not ~~in~~ on the lump sum as it is now.

4. The program of windows sealing in residential and non-residential buildings is relatively easy to ~~realize~~ implement and important for the GHG emission reduction.
5. Potentially significant possibilities of ~~decreasing~~ reduction of the energy demand and, as a consequence,~~the~~ GHG emission result from possible improvement of the building thermal insulation, especially of ~~the~~ residential buildings. These enterprises are profitable only when applied to a limited group of buildings characterised by especially bad condition of thermal insulation of external full walls and buildings, in which elevation repairs are necessary for other technical reasons than heating losses. Profitable is also improvement of thermal insulation of walls with air gap through filling them with porous material. In case of the majority of buildings with average heating losses, external walls heating is still not profitable and needs ~~big~~ high capital investments. ~~It is similar~~ Similar situation applies in case of windows ~~revision (~~replacement~~)~~ and energy carriers substitution option.
6. If the GHG emission reduction program is to be implemented in municipal sector it will be necessary to find financial means for this purpose, to change some legal regulations and to undertake some organisational activities. In particular the following problems should be considered:

- changes of standards for devices and other objects – energy receivers ~~standards~~ resulting in a decrease of energy demand, i.e. ~~decreasing~~ bringing down permissible ~~values~~ levels of heat transmission factors through the walls and windows, closing or limiting availability of the market for energy-intensive devices (systematic changes of norms and other legal regulations concerning conditions allowing for use of technical devices),
- taxes for use of less ~~noble~~ pure fuels – coal, heavy oils, etc. and/or support for gas system and nuclear energy development,
- breaking social fears as for consequences of ~~development of nuclear~~ nuclear power industry development, and realising of a wide variety of scientific research projects on the use of nuclear energy sources in electricity and heating systems,
- support~~ing~~ for a development of small energy systems based on renewable energy sources through subsid~~inges~~, taxes reductions, etc., and legal preferences for operation of these sources in a national electrical system and local electrical or heating subsystems,
- legal regulations allowing for and facilitating investing in enterprises resulting in energy consumption decrease, realised on the basis of capital of other users, particularly enabling to include in costs and correct rate of profit of generation and distribution of energy carriers, costs of energy-saving investments made at energy receiver,
- tax reductions for purchas~~inge~~ of less energy-intensive devices provided that they substitute old and technologically out-dated ones,
- ~~a~~ supplementing of ~~of~~ primary and secondary school curricula with subjects concerning use, and not only protection, of the environment~~use and protection~~, promotion of behaviour and formation of sound habits ~~sound~~ for energy savings and rational use of environment,
- publication ~~propaganda~~ and education actions oriented towards the adult part of the society ~~part of the society~~, promoting ~~necessity~~energy and materials savings,
- reorganisation of public services to ensure proper ~~realization~~ implementation of assumed legal changes, educational programs and efficient use of results of social behaviour changes.

8.4. TRANSPORT SECTOR

After a period of extensive quantitative development which lasted till the end of the 80's, the Polish transport system has been undergoing structural transformation. Its main reason is a transition to market economy with all the consequences related to this fact. The most visible features of the transition process include: a reduction of the amount of goods carried; rapid increase of international traffic, mostly by road; shift from rail to road in both passenger and goods transport; shift from collective to individual means of passenger transport in urban areas; rapid growth of motorisation causing fast increase of road traffic volumes; slow changes in vehicle fleet towards more energy-efficient and environment friendly vehicles. The occurring changes have both positive (reduced transport intensity of the economy) and negative (quickly growing motorisation) influence on the GHG emission level.

For the needs of forecasting the GHG emission from the transport sector and testing alternative mitigation strategies, mathematical computer model (GHG–AW) has been built within the Study relating demographic and economic variables with transport demand, energy and fuels demands, and emission of GHG. The model was calibrated on the basis of data for the past years. The model was used to forecast volumes of passenger and freight traffic, energy consumption and the GHG emission for the period up to 2030. As reference scenario adopted was a variant of the most probable course of development processes with anticipated progress in transport technology and operation, and no intervention to reduce the GHG emission. With these assumptions, it can be expected that the total emission from the transport sector will be increasing till the years 2020-2025, and will stabilise at the level of about 200% of the present emission (1990). Adopting transport of the year 1990 in analysis concerning transport as a base year was caused by a lack of full statistical data concerning traffic volumes in 1988. It is estimated that emission from the transport sector in 1990 made up some 90% of the 1988 emission.

Effectiveness of a number of strategies leading to slowing down of the process of increase of GHG emission was analysed. The strategies can be classified in 5 categories:

- strategies leading to the reduction of transport demand,
- strategies supporting shift to cleaner means of transport,
- strategies of technological improvements of the vehicles,
- strategies inducing shift to lower emission fuels,

- strategies promoting better operation.

The starting point for estimating GHG emission was transport volumes (passenger-kilometres and ton-kilometres), and energy consumption rates per one unit of transport volume. These rates were determined on the basis of results of research of the Transport Economics Research Centre and Automotive Research Institute in Warsaw.

The base-line scenario was elaborated on the basis of assumption that the current trends will continue, and as a consequence, the transport sector will develop without intervention aiming at reducing GHG emission. Degree of development will be adjusted to the general state of the national economy.

The main features of the base-line scenario refer to:

- transport demand – the most probable trends were assumed, forecasts are based on the latest official forecasts till 2010 with extrapolation to the year 2030,
- transport technology – assumed were moderate improvements in automobiles technology and shift to lower emission fuels,
- mobility conditions – such as at the present moment (without additional traffic volumes, distribution of speed as at the present moment).

The GHG abatement scenarios were formulated with regard to five categories of actions:

- impeding transport demand increase,
- supporting shift to environment friendly means of transport,
- improvement in vehicle technology,
- shift to lower emission fuel systems,
- improvements in transport operation.

Quantitative analysis of alternative elementary variants lead to the formulation of four combined variants:

I – stimulation of uniform municipal structures accompanied by impediment of mobility and automobile use,

II – limitation of transport increase and improvement of transport efficiency,

III – technological progress (means of transportation, energy sources),

IV – sum of all elementary variants.

Forecasts of emission for basic and IV variant, and for three macroeconomic scenarios (base-line, stagnation, and chance) are presented in figures 8.6. and 8.7.

Identified were also policy instruments which seem to be possible to apply in Polish conditions. They are enumerated in table 8.7. together with brief explanations. This table includes also two additional pieces of information. The first concerns a probability of application in short, medium, and long-term perspective. It is shown by use of capital letters S, M and L. The second piece of information concerns means which are most effective. In the table they are put in bold typeface.

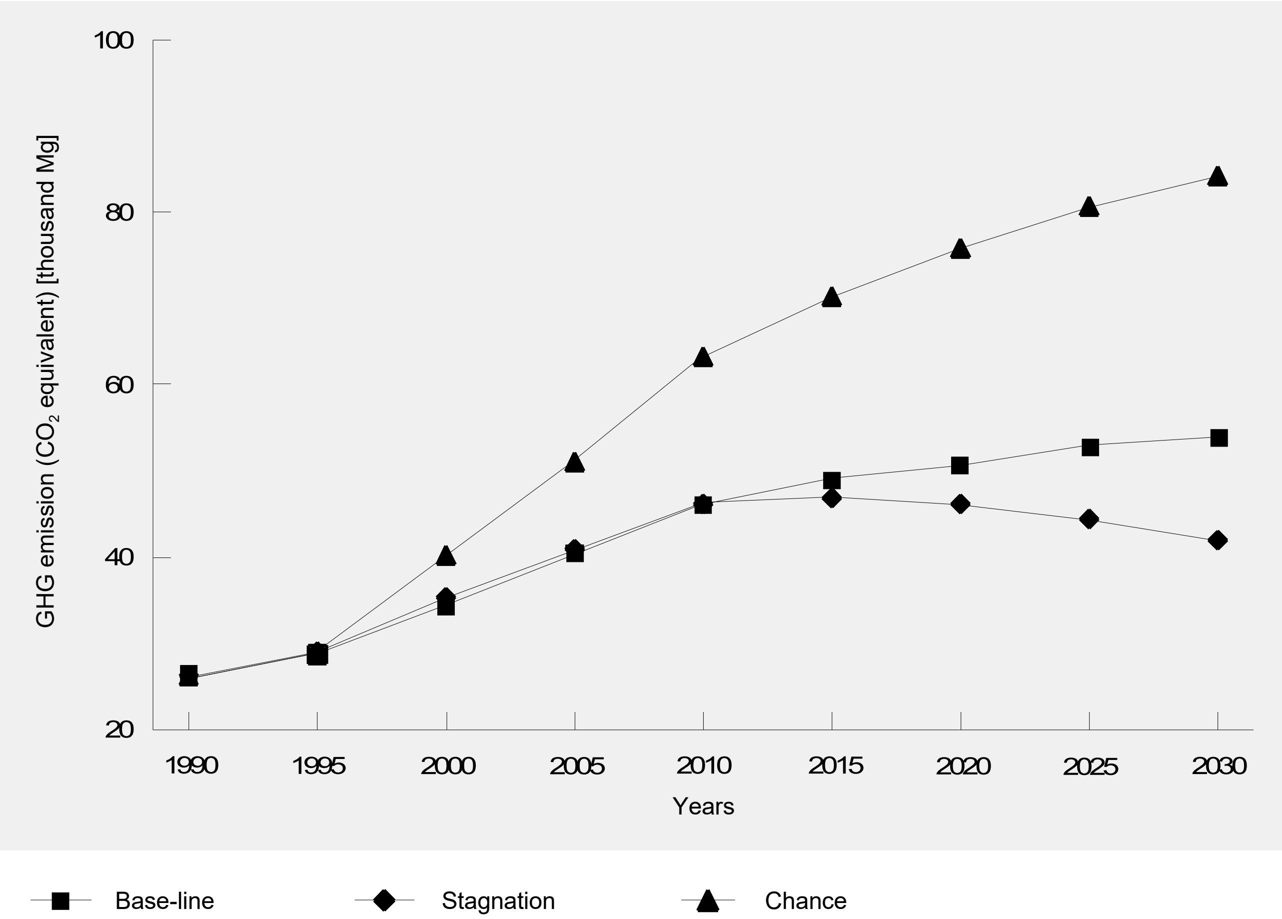

Figure 8.6. CO_2 equivalent emission in transport according to basic variant (no reduction measures) of selected scenarios of economic growth

Table 8.7. Policy instruments for combined strategies in transport and their applicability in Polish conditions

Policy measure	Strategy			
	I	II	III	IV
Urban planning	L			L
Mixed use of land	ML			ML
Density standards	ML			ML
Promoting city-centre development	ML			ML
Promoting transport-effective development of national economy		SML		SML
Development of telecom./telematics	ML	ML		ML
Vehicle purchase tax/annual license fee	ML	ML		ML
Fuel (carbon) tax/duty	**ML**	**ML**	**ML**	**ML**
Parking charges	SML		SML	SML
Road pricing	**ML**	**ML**	**ML**	**ML**
Modernisation/development of railways	SML	SML		SML
Public transport fares (subsidy policy)	**SML**			**SML**
Public transport and HOV priorities in traffic	**SML**		**SML**	**SML**
Parking standards	**ML**			**ML**
Car-free zones	ML			ML
Promoting bicycles	SML			SML
Vehicle energy consumption standards			**ML**	**ML**
Vehicle emission standards			**SML**	**SML**
Lowering speed limits and enforcement			SML	SML
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, **L -** the most effective measure.

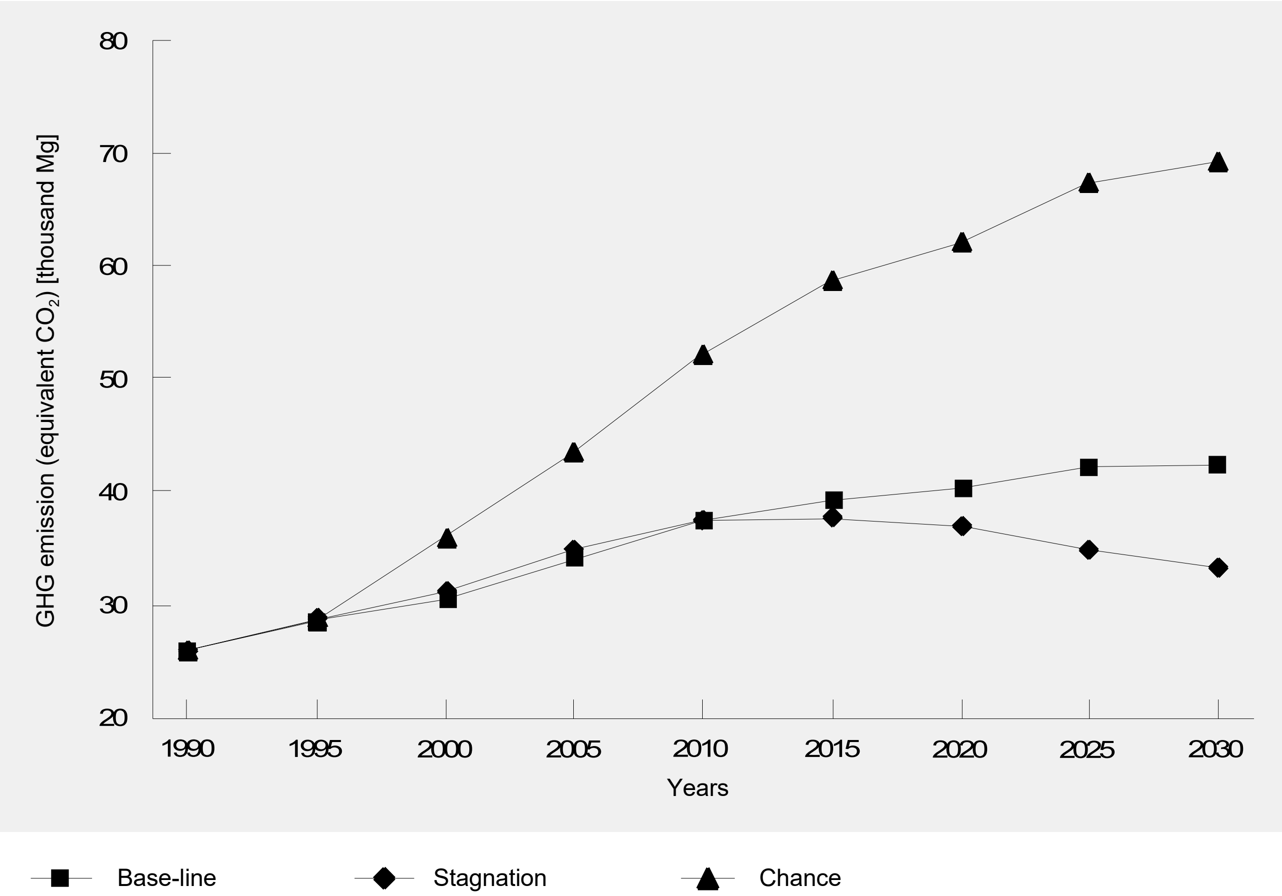

Figure 8.7. CO_2 equivalent emission in transport according to variant IV (reduction measures) of selected scenarios of economic growth

The following conclusions were formulated on the basis of this analysis:

1. In the base-line scenario, based on the assumption of the most probable trends, if there is no intervention aiming at the reduction of GHG emission, total emission from the transport sector will be growing up to the years 2020-2025, and then will stabilise at the level of about 206% of the 1995 emission.
2. Analysis of different elementary variants led to the conclusion, that the most effective could be:
- reducing personal mobility,
- technological progress in the construction of road vehicles leading to better fuel efficiency and shift to better fuels, better use of means of transportation, first of all through increasing occupancy rates.
3. All these variants could allow for reduction of the emission by about 5-10% in relation to the base-line scenario.
4. Combination of strategies can reduce the GHG emission by 8-15% below the level expected in the base-line scenario. Realisation of the best variant IV would, in the long-term perspective, lead to decrease of total emission from the transport sector by 21% and stabilisation of the emission at the level of about 163% of the 1990 emission level.
5. Analysis of macroeconomic scenarios (stagnation and chance) leads to the conclusion that accelerated economic growth, without preventive measures undertaken, could bring about growth of the GHG emission in the year 2030 to the level of about 320% of the 1990 emission level. With the most effective abatement variant (variant IV) this growth would be lower (total emission in 2030 at the level of 265% of the 1990 emission level).
6. The most effective policy measures are fiscal measures, such as: increased fuel tax/duty and general road pricing; as well as restrictive measures, such as: energy intensity standards or restrictive parking standards. However, it is very unlikely that these measures will be accepted in the nearest future. They should be considered as the most important in the medium – and long-term policies.
7. In the first stage, application of incentives for purchasing energy-saving vehicles, and promotion of public transport (fares policies and priority in traffic) deserve special attention.

8. Results of completed studies should be treated as preliminary ones since various elements of the transport/emission model drawn up in the course of the study, require further research.

8.5. AGRICULTURE SECTOR

As opposed to other economy branches, agriculture is characterised by specific GHG balance, particularly CO_2 balance. At the present level of crop production in Poland, they absorb from the atmosphere annually over 200 million tons of this gas through the photosynthesis process. It constitutes half of the CO_2 global emission by non-agricultural sectors of the economy. Despite the fact that more than 90% of absorbed CO_2 returns to the atmosphere as a result of biological oxygenating and combustion of agricultural products, the process of CO_2 circulation in the biosphere itself creates a buffering system against excessive accumulation of CO_2 in the atmosphere. This system is regulated by the amount of crops. For instance, increase of annual cereals crop by 1 million tons brings about increase of absorption and circulation of CO_2 in the biosphere by 3.2 million tons. A significant part of CO_2 absorbed by plants may undergo retention (about 11 million Mg a year) in a form of solid organic compounds of soil.

Diversity of crop and livestock production allows for a choice and use of many options aiming at reducing global GHG emission. At present, 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. Among feasible options chosen were those in which 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 fertilisers 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 fallow 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 experience of many developed countries of the world in introduction of new technologies into the production of renewable energy sources, such as diesel oil from rape, ethanol from triticale and solid fuel from miscanthus.

Each of the options was considered in each of four climatic scenarios (see chapter 8.1) and ranked according to climate changes and atmospheric CO_2 concentration changes, as well as possibilities of adapting of specific options to those changes. 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 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 realisation when the available area of land under cultivation is defined and different for each scenario. For the humid and hot climate scenario, the relation of GHG emission reduction in 2030 to the emission

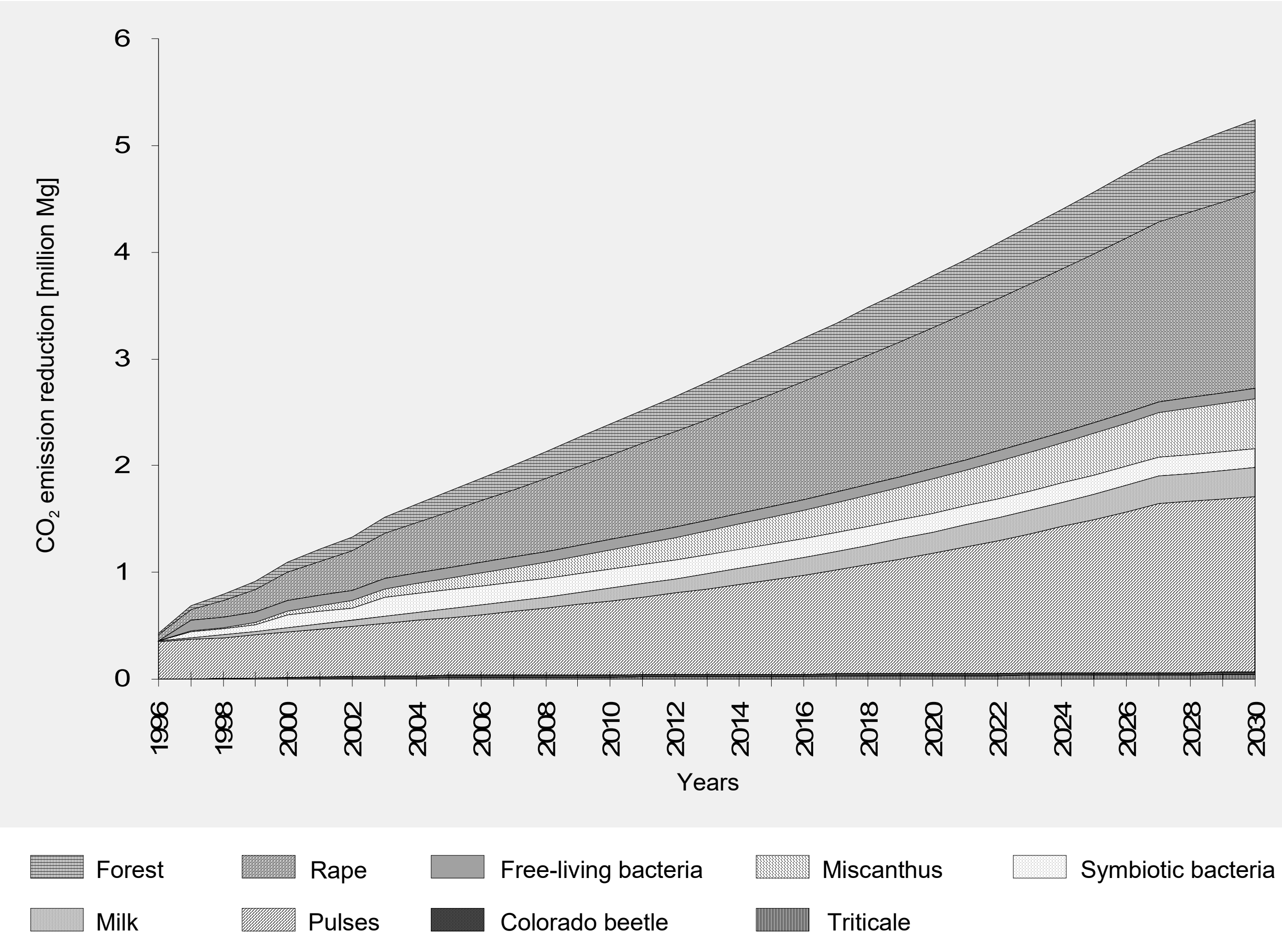

Figure 8.8. CO_2 emission reduction till 2030 in agriculture according to dry and warm climate scenario

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.

Extent of emission reduction for respective options for the two chosen climatic scenarios is shown in figures 8.8. and 8.9. In relation to other options, reduction potential of options: *triticale* and *Colorado beetle* is minimal and slightly affects CO_2 emission reduction.

In the basic version of the set of 9 options to reduce GHG emission, the highest reduction can be obtained through the option *rape*. It reaches in 2030 the level of about 2.8 million tons (the option *rape*) and 1.5 million tons (the option *pulses*). Other options bring much lower abatement of GHG emission. However, while three options (*pulses*, *miscanthus* and *forest*) increase the possibilities for reduction with time, the three biotechnological options (*Colorado beetle*, *symbiotic bacteria*, and *free-living bacteria*), after the completion of laboratories and implementation of inocula or transgenic plants, i.e. since 2004, provide stable annual GHG emission reduction. Employment of those options in practice must be, however, preceded by detailed analysis of natural factors, economic conditions as well as factual state of danger caused by climatic changes.

Scope and speed of implementation of tasks aimed at GHG emission reduction in agriculture will to a large extent depend on many factors, among which the most important include:

- social awareness of producers and agricultural administration as for the necessity of implementing technologies for GHG emission reduction in agriculture,
- changes in the structure of farms and character of their production (larger farms specialised in plant production will implement GHG emission reduction technologies quicker than small farms with no specialisation defined),

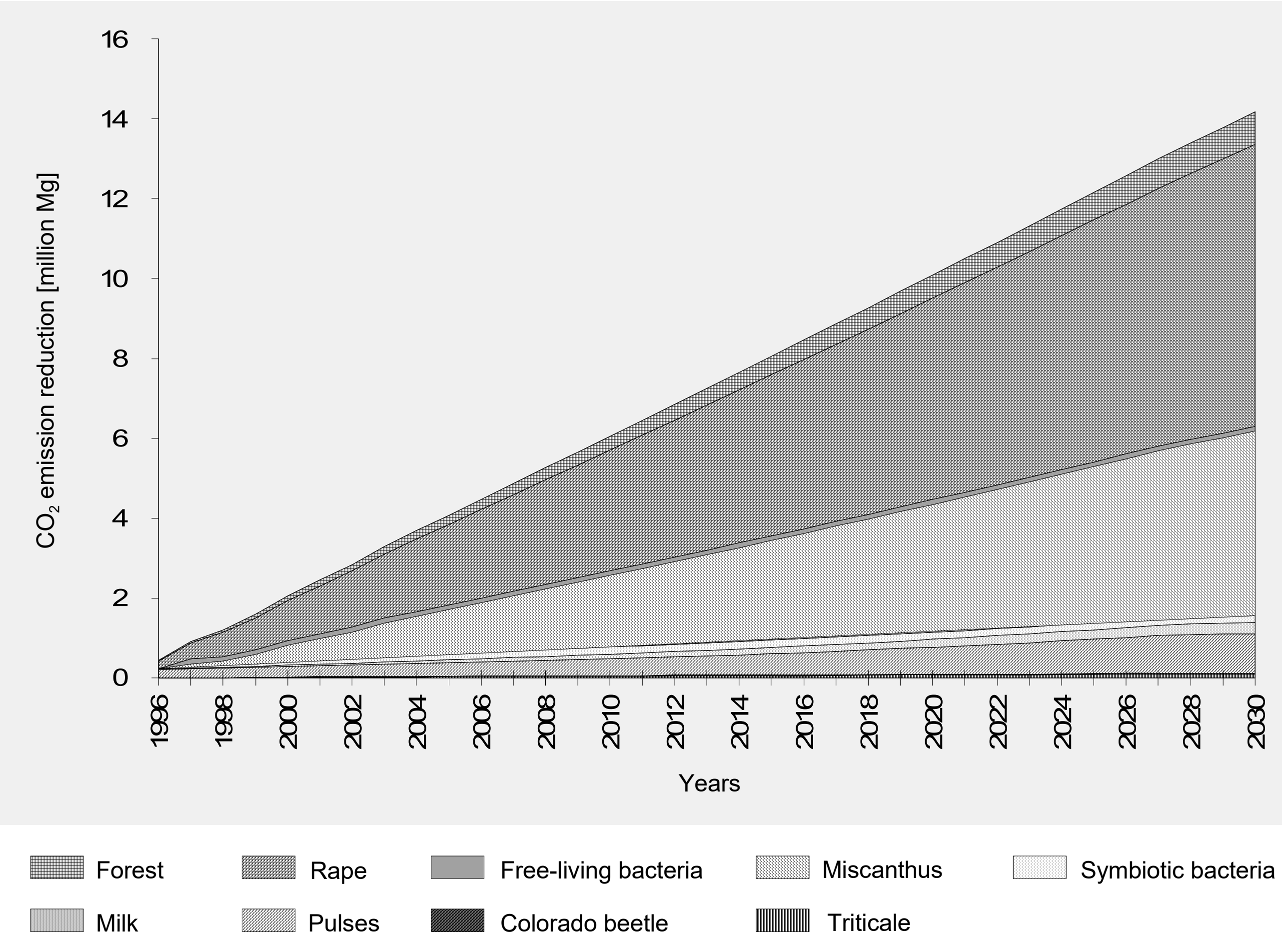

Figure 8.9. CO_2 emission reduction till 2030 in agriculture according to humid and warm climate scenario

- fiscal policy that favours 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.,
- construction 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 be accompanied by formal and legal activities allowing for:

- identification of standards of permissible levels of GHG emission in agriculture,
- introduction into the food market of transgenic varieties of potato resistant to Colorado beetle and other transgenic plants resistant to biological and environmental stress,
- obtaining a license (national and EU) for production of environmentally safe food by producers that implement GHG emission reduction options through a change in fertilisation from mineral to biological nitrogen fixing and abandoning pesticide use,
- application of legal regulations for transfer and use of GHG emission reduction technologies in agricultural sector.

Progress in implementation of all options aimed at GHG emission reduction in Polish agriculture will depend on a co-ordinated action of technological, economic, social, formal and legal (legislative) factors. Such co-ordination should be centralised in the Ministry of Food and Agriculture.

8.6. RENEWABLE ENERGY SECTOR

In Poland, climatic and water conditions as well as geographical configuration are not creating especially favourable circumstances for energy use from renewable sources (renewable energy). Nevertheless, in some regions of our country there are chances for utilisation of renewable energy sources, and consequently, for GHG emission reduction. The following renewable energy 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 as a result of methane fermentation of manure and organic waste.

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 utilisation was done. All mentioned above renewable energy sources have very large energetic potential. Technical possibilities of use of this potential up to 2030 are assessed for 337.2 PJ.

Annual possibilities of solar energy utilisation 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.

Similarly as in case of solar energy, in case of wind energy the biggest potential is in coastal zone and in the north-eastern Poland. Mazovian Plain, Middle Beskid, ¯ywiec Beskid as well as the eastern part of Sandomierz Valley with average annual wind velocity not exceeding 4 m/s were recognised 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^{o}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 £ódŸ with area ca. 67 thousand km^2 as well as Grudzi¹dz–Warsaw region with area ca. 70 thousand km^2 should be distinguished. Total geothermal waters potential in Poland is relatively large, but because of high mineralisation, 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 the point of view of water use for energy purposes are rivers of Vistula and Odra Basins and rivers of Baltic Przymorze district. Total country technical hydropower resources equal 13 650 GWh/per annum. The larger part of national resources (ca. 68%) is situated in the Vistula Basin region, half of which is from the lower part of the Vistula, some 500 GWh is constituted by small hydroplants .

Biomass, with respect to its utilisation for energy purposes has the biggest share in renewable energy. Wood chips resources occur almost in all regions of the country. Their sources are to be found in forests, wood industry, afforestations, and orchards. Forests are the biggest source of wood. It was estimated that 5.2 million m^3 of chips per year can be obtained additionally for energy purposes, next 1.1 million m^3 can be generated from industrial wood plants, 1 million m^3 – from orchards and 26.5 thousand m^3 from afforestation. Altogether ca. 7 336.5 thousand m^3 of wood fuels can be obtained per annum.

For combustion, especially in local heating plants straw can be utilised. Annual straw production in Poland equals 28-29 million 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, profitably for the economy, deliver raw materials for increasing alcohol production by approx. 250 million l and more for energy purposes. Alcohol is produced from potatoes and cereals. Before utilisation (as additive to gasoline) alcohol should be dehydrated.

Vegetable oil can be utilised in diesel engines instead of actually commonly used universal oil. In Poland, the best for that purpose is rape oil, because of rape traditional cultivation and acreage. Esterified rape oil can be used as a substitute of diesel oil, which gives the most significant ecological effects, or in different ratio mixtures with diesel oil.

Husbandry animals in the countryside are kept on a litter or without it. In both cases large quantities of manure are produced, which must be managed in a rational way in order not to be harmful for the environment and serve as fertiliser.

Methane fermentation of manure, especially dung, allows for reduction of unpleasant odour, improvement of fertiliser properties and production of combustible gas, which can be used for heating purposes in farms and farmers' houses and households. Current manure production equals 50 million m^3. Results of research showed that from 1 m^3 of manure about 20 m^3 (gross) of biogas can be produced, which is equivalent of 46 MJ of energy. For insurance of proper conditions for CH_4 fermentation manure or liquid wastes should be heated, which consumes about 40% of energy.

Utilisation of renewable energy, except for, fire-wood and electricity from hydroplants, is in the initial phase of development. Currently exploited are several hundred solar installations (to dry agricultural products, heat water), scores of wind power stations, three geothermal heating plants, dozens of plants combusting straw, experimental rape biorefinery, several installations dehydrating alcohol and providing ethanol, and dozens of biogas installations (methane fermentation of manure and landfills). Share of energy production of the above-mentioned installations has not yet reached 1 per mille share in the primary energy consumption balance of the country. Assuming the year 1988 as a reference year, except for electricity from hydroplants (about 3 900 GWh) and fire-wood (some 3.6 million m^3) renewable energy utilisation equalled zero this year. In Poland, the biggest possibilities of renewable energy utilisation are in agriculture, except for geothermal energy used for municipal heating and ethyl alcohol added to gasoline used commonly in cars. Energy demand of agriculture in 1993 reached 422.6 PJ per annum. According to the experts' opinions, the figure will remain similar in 2030 and will reach 419.0 PJ per annum.

It is assumed that renewable energy from wood and straw combustion, solar energy from air solar 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 in 2030. Energy supply 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 localisation 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, which is equal to 5.9 PJ. The remaining amount of ethanol will be used in transport sector. It is connected with ratio (1/3) of vehicles used in agriculture (gasoline-powered ones) to vehicles used in other sectors. Only part of thermal energy from water solar collectors i.e. 15.6 PJ will be used directly in agriculture. Remaining potential of water solar collectors in 2030 i.e. 11.4 PJ will be used in processes of hot water preparation in housing within urban areas.

Analysing technical possibilities of utilisation of potential renewable energy sources it was estimated that in 2030 it will be possible to obtain 161 PJ, which in relation to primary energy carriers utilisation in the whole economy, will constitute about 5%, and on the countryside about 24%. The biggest reduction of CO_2 equivalent emission is assured on the side of geothermal energy, solar collectors and water energy from big electric power stations. The least beneficial, in this aspect, is wind energy (autonomous systems) – table 8.8. Analysis showed the necessity of introduction of direct financial incentives (non-returnable subsidies, preferential credits) for actualisation of renewable energy utilisation. 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 modernisation, further improvement and development of actually used furnaces is needed. System of fossil fuels taxation (increase of traditional fuel prices) connected with environment contamination, excise and VAT tax will have significant influence on development of renewable energy usage. Energy produced from renewable sources should be, at least till the moment of reaching the significant level of energy production, tax-free (excise and VAT).

Table 8.8. Technical potential of renewable energy sources (RES), its predicted use up to 2030 and limitation of CO_2 equivalent emission

Renewable energy sources (RES)	Assessed RES technical potential [PJ]	Degree of RES use in 1988 [%]	Predicted RES use in 2030 (increase since 1988) [PJ]	Predicted CO_2 eq. emission reduction in 2030 [Mg/year]
1. Hydropower stations				
• large	43.0	30.14	15.8	4 389 385
• medium	4.3	3.25	1.8	503 000
• small	1.8	0.22	0.2	50 778
2. Windpower stations				
• autonomous	0.5	0.00	0.1	34 795
• grid	3.6	0.00	1.8	500 258
3. Geothermal energy	100.0	0.00	40.0	5 045 508
4. Solar collectors				
• air	21.6	0.00	14.2	1 155 123
• water	33.7	0.00	27.0	5 152 979
5. Biomass				
• wood burning	52.0	20.00	18.8	2 647 469
• straw burning	24.2	0.00	3.2	456 064
• rape biofuel	24.0	0.00	17.0	1 146 514
• ethanol	20.0	0.00	16.9	1 003 743
• biogas	8.5	0.00	4.2	289 401
Total	337.2	-	161.0	22 375 017

Besides economic measures social and political activities will play important role, especially in the field of overcoming institutional and information barriers. In this case the simplest and most effective measure is wide information provided 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 the result of minimal presence or shortage of adequate equipment on the market. For example, at that moment we have scanty supply of boilers for wood and wood refuses combustion on the market, as well as solar collectors for air heating (currently used are built in self-made system) etc. Informational and educational programs as well as advertising campaign can be effective methods popularisation of these equipment. Difficulties in creation of demand for given technology are, in this case, connected with shortage of knowledge about the technology itself and its possibilities.

It is proposed to use the 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. CAAs (Centres of Agricultural Advisement), energetic enterprises, technical schools (particularly agricultural ones), consulting firms,
- link of renewable energy sources utilisation programs with energy saving programs, especially in housing construction,
- inclusion of private sector (by incentives in tax reduction) into forming the market of renewable energy sources usage,
- introduction into 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 their own purposes and possibility of disposing energy surplus produced besides grid. In the area of centralised heating systems using renewable energy sources it is necessary to introduce a duty of energy purchase by distributing firms on priority principles (within electric energy there exist appropriate regulations),
- elaboration and acceptance by the Economic Committee attached to the Cabinet a comprehensive program of renewable energetics development in Poland with all elements i.e. economic, social and legal instruments.

The Study in question is the first to try to appraise possibilities of using renewable energy sources not just to improve energetic potential, but also to reduce GHG emission connected with production and utilisation of energy carriers. As every first attempt, this study requires further research specifying assumptions adopted and conclusions drawn. In particular, it would be purposeful in the future to expand this analysis over new, not included in the current stage technologies, provided that there will be available reliable technical and economic data about them, related to factual conditions of the country.

8.7. STRATEGIES OF CO_2 EMISSION REDUCTION IN FUELS PROCESSING

AND USE TILL 2010

This chapter is different from the remaining part of the Study in the way it covers the methodology and scope of the work issues. The research was extended over the whole CO_2 emission resulting from processing and utilising fuels, which constituted over 97% of the overall economic emission of this gas in Poland in 1992, and over 82% of all the GHG (after conversion into the so called G*lobal Warming Potential*). The adopted methodology is in line with the one used while drawing up *Polish Energetic Law till the year 2010*, which allows for a comparison of results presented in the two documents.

Calculations done within the Study were based on the assumptions of one scenario of the macroeconomic development of the country and related to it forecast on the energy needs. The reference scenario is characterised 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 changes in favour of less energy-consuming branches. Increase in production of energy-consuming goods is small .

In all calculations performed, one version forecast of the energy and fuel prices in Polish foreign trade was assumed, being in line with energy forecast price assumptions presented in accepted by the Sejm *Assumptions of Energetic Policy of Poland till the year 2010.*

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 in Poland. Since it is still uncertain how much natural gas will be available from import and what 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	Access to imported natural gas	Nuclear energetics
Scenario I	Not limited	Possible after 2005
Scenario II	Not limited	No
Scenario III	Limited (Max ca. 13 billion m^3 in 2010)	No

For each of the scenarios the following cases were analysed:

- *reference case* – the solution for this case includes no CO_2 emission limitations,
- *energy saving case* – like the reference case; however, it includes the whole variety of cost-effective energy saving measures,
- *5%, 10% etc. reduction cases* – these are cases with constrained CO_2 emission reduction; they assume stabilisation of CO_2 emission reduction after 2000 at the level of respectively 5%, 10% etc. lower than emission level from the year 1988 (see tab. 8.9).

Table 8.9. CO_2 emission in reference and reduction cases

Scenario	Case	Emission in year [million Mg]					
		1988	1993	1995	2000	2005	2010
Cases without CO_2 emission reduction							
I, II, III	reference	454	369	376	397	416	425
	save	454	369	376	392	409	417
Cases with constrained CO_2 emission reduction							
I, II, III	5% reduction	454	369	376	392	409	417
	10% reduction	454	369	376	393	409	409
	15% reduction	454	369	376	386	386	386
	20% reduction	454	369	376	363	363	363

In all the calculations conducted the same set of technologies and measures was assumed, implementation or realisation of which may contribute to CO_2 emission abatement in Poland. Below are the most important kinds of the above-mentioned measures:

Supply side

- increase of natural gas supply on the national market,
- modernisation and improvement of efficiency of existing technologies,
- utilisation of new technologies of electricity and heat production,
- growth of energetic renewable sources use.

Demand side

- measures of saving electricity,
- thermal renovation of buildings,
- variant technologies of hot-rolled articles production,
- technologies of single-family buildings premises heating.

Each of the above-enumerated points includes from several to dozens of options, e.g. measures of electricity saving include over 50 technologies, and possibilities of reconstruction of existing objects are described by technologies of modernisation of grid power generation plants, municipal heating plants, heating networks, development of existing heating plants, as well as modernisation and development of electricity transmission and distribution networks.

Emission for every case and scenario are given in table 8.9. Extent of reference emission from 1988 was assumed at the level of 454 million Mg. The year 1993 is a base year for calculations, and CO_2 emission calculated for that year are based on amounts of production and energy consumption synonymous with statistical data. Emission amounts for the *reference* case were calculated with consideration of the latest forecast of energy demand in the country and optimal way of meeting the demand. In the energy – saving case emission are a little bit lower due to assumed full utilisation of profitable energy – saving potential. Beginning from the year 2000 emission for reduction cases are exogenously assumed, and the obtained solution includes an optimal set of measures and technologies which satisfies demand for energy, not exceeding those quantities of emission.

Results obtained show that in the reference case limited natural gas access and lack of nuclear power do not cause an increase of emission till the year 2015. Those limitations begin to be seen only in CO_2 emission reduction cases, in which they cause increase of reduction costs in relation to the scenario without limitations (see tab. 8.10).

Table 8.10. Total discounted costs of CO_2 emission reduction according to scenarios I, II, III

Scenario	CO_2 emission reduction cases in reference to 1988 emission [million USD'90]					
	5%	10%	15%	20%	25%	30%
I	6	147	1 790	5 790	13 684	38 526
II	15	253	2 105	6 526	15 053	-
III	42	653	3 579	-	-	-

In the reduction cases, sector CO_2 emission generally decrease, but the scale of emission reduction from particular sectors is not regular and reflects the emission reduction costs. The greatest and considerably cheapest possibilities of CO_2 emission reduction occur in electricity and industry sector, as well as in households. Abatement of CO_2 emission in reduction cases results in changes in extent and structure of primary fuels utilisation. With the maximal

CO_2 emission reduction in the scenario I, energy consumption drops by some 9% in comparison with the reference case. Share of natural gas increases nearly doubly at the cost of coal utilisation reduction.

Abatement of emission in reduction cases is done through application of technologies with lower CO_2 emission, which are however more expensive. With lower levels of reduction applied are cheaper reduction options, and then, also the more expensive ones. Figure 8.10 shows order of application of the most important measures of CO_2 emission reduction as well as effect of their realisation in a form of CO_2 emission reduction (in comparison with emission from reference case).

Total reduction costs, presented in table 8.10, are relatively small, even with 5% reduction, but they rise quickly with further emission limitation. Reduction costs in the scenario III with limited gas access to natural gas and without nuclear power are significantly higher as compared with the scenario I without such limitations. Also the maximal possible reduction degree is lower (about 16%).

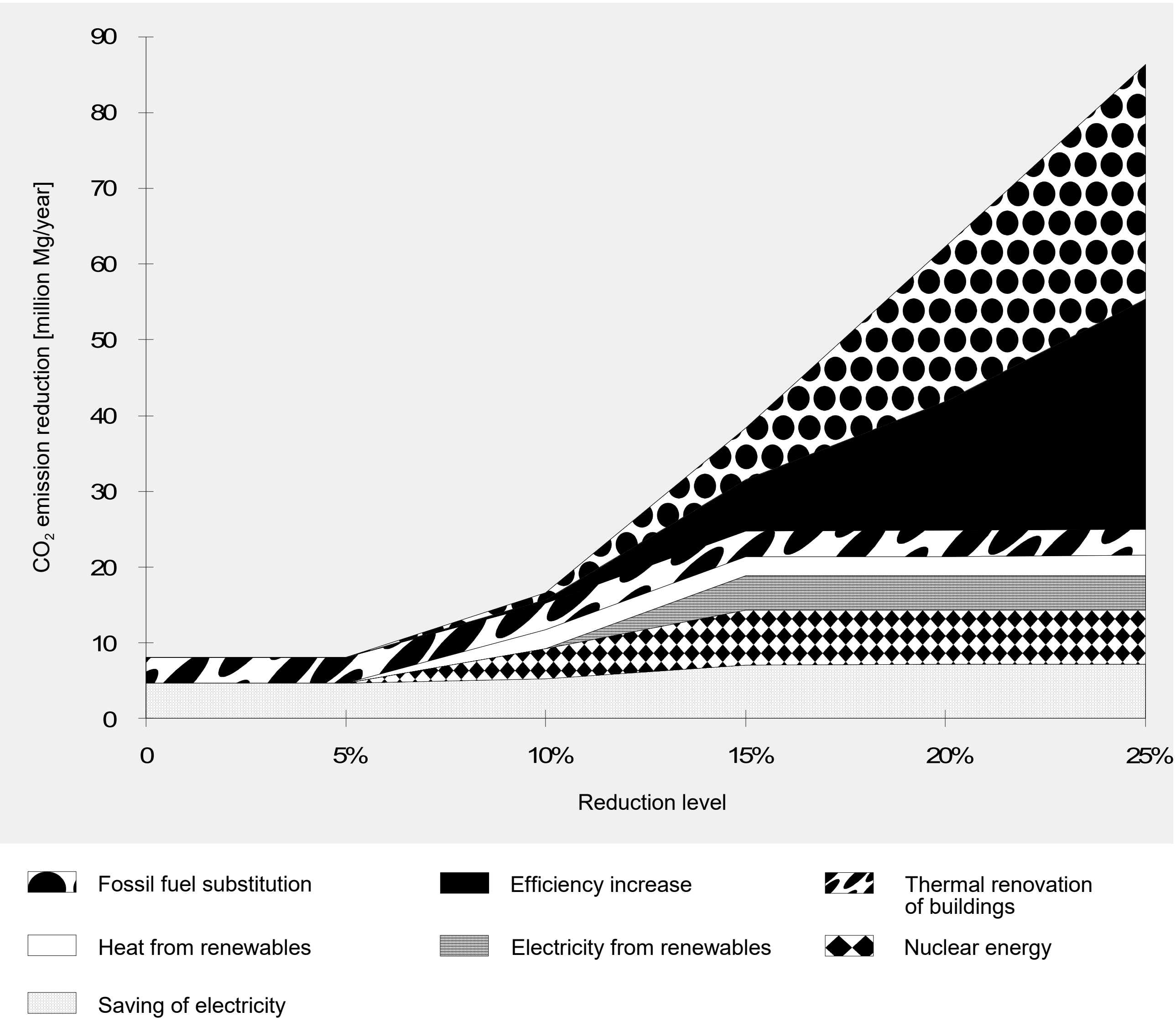

Figure 8.10. CO_2 emission reduction by reduction measures in different variants of scenario I

Below are presented total costs of reduction for the case with 10% reduction of CO_2 emission till the year 2015 (tab. 8.11).

Table 8.11. Total reduction costs with 10% CO_2 emission reduction in period 1996-2015

Scenario	Cost in years [million USD'90]				
	1996-2000	2001-2005	2006-2010	2011-2015	1996-2015
I	0	1	221	568	789
II	0	38	221	1 084	1 337
III	0	50	263	3 326	3 642

Unit costs of CO_2 emission reduction (see tab. 8.12) rise together with increasing degree of reduction, and also in successive years, because the increasing energy consumption makes emission reduction difficult. Marginal costs indicate how much should be paid to reduce emission by another unit, e.g. ton of CO_2 per annum. Marginal costs may be simply interpreted as amount of emission payment which should be introduced in order to achieve a given level of emission.

Influence of limited supplies of natural gas and lack of nuclear power plants on CO_2 emission reduction costs are presented in table 8.13. These limitations, particularly in the case of natural gas, bring about an increase of costs and drop in maximal potential of emission reduction.

Table 8.12. Unit CO_2 emission reduction costs according to reduction degree for Scenario I

Year	CO_2 emission reduction case in reference to 1988 emission [USD'90/Mg CO_2]					
	5%	10%	15%	20%	25%	30%
Average CO_2 emission reduction costs						
2000	0	0	7	19	34	77
2005	0	0	19	26	36	70
2010	0	9	19	27	37	68
Marginal CO_2 emission reduction costs						
2000	0	0	13	31	138	952
2005	0	2	28	43	47	145
2010	0	13	31	46	55	106

Table 8.13. Effects of various assumptions in CO_2 emission reduction costs in 2010

Scenario	CO_2 emission reduction case in reference to 1988 emission [USD'90/Mg CO_2]					
	5%	10%	15%	20%	25%	30%
Average CO_2 emission reduction costs						
I	0	9	19	27	37	68
II	0	8	22	31	40	-
III	0	10	38	-	-	-
Marginal CO_2 emission reduction costs						
I	0	13	31	46	55	106
II	0	15	31	53	61	-
III	0	18	65	-	-	-

Analysis of fuels processing and utilisation processes till the year 2010 leads to the following conclusions:

1. Maintenance of the present positive trends of energy intensity decreasing, market reforms, structural changes in the economy, and modernisation of energy sector will restrict rate of growth of CO_2 emission. It will enable, with GDP increase rate of 4% per annum, maintenance of CO_2 emission till the year 2010 below the level of 115% of the 1990 emission. It means emission reduction in this period by some 5% as compared with the 1988 emission. Faster rate of economic development or decline of the above-mentioned positive trends may, however, rise CO_2 emission extent.
2. In the period till 2010 it is possible to further decrease CO_2 emission and achieve greater than 5% level of emission reduction, calculated in relation to the 1988 emission. Decrease of emission causes fast rise of costs. Amount of those additional costs depends, to a large extent, on amount and price of available imported natural gas. Limited access to imported natural gas brings about remarkable increase of reduction outlays.

3. The greatest, considering potentials, and the cheapest possibilities of CO_2 emission reduction are in electricity sector, industry and households. Among the analysed possibilities, the most cost efficient measures of considerable CO_2 emission reduction potentials are the following:
- electricity and heat saving measures,
- construction of new gas power stations,
- increase of combined production in existing public CHP plants and heat plants,
- larger utilisation of gas in industry and public heat plants as well as in single-family buildings for heating purposes,
- utilisation of renewable energy, particularly biomass, hydroenergy, and solar energy,
- construction of nuclear power plants.
4. Energy saving measures, found and included in calculations, constitute a particularly important option because a number of them is cheaper than respective supply options, and therefore, their realisation causes an decrease of total costs of energy requirements satisfaction. These measures are generally related to electricity saving and buildings thermal renovation.
5. Comparison of results obtained for Poland with results of similar studies for the European Community countries shows that maximal possible reductions as well as reduction costs in Poland approach costs in countries like Germany and the United Kingdom. Only Denmark has cheaper reduction possibilities, in other countries, reduction costs are higher and reduction possibilities fewer.

9. MACROECONOMIC SCENARIOS OF GHG EMISSION REDUCTION

9.1. MAIN ASSUMPTIONS OF SCENARIOS

Analysis of macroeconomic GHG abatement scenarios were based upon Macroeconomic Reference Scenario (MERS). The very term MERS – reference scenario – was created in connection with analytic work on GHG emission reduction. This is a hypothetical scenario of the country development on the macro scale, which does not include measures specially oriented to GHG emission reduction, adaptation of the economy and the society to expected climate changes. This scenario includes long-term vision of the country, in our case the horizon is the year 2030. It constitutes a *reference* within macroeconomic costs and GHG emission reductions for the reduction development scenarios defining long-term strategies of GHG emission reduction. The MERS scenarios were the basis for creation of reduction scenarios. It was agreed to employ three reference scenarios, thus reflecting uncertainty concerning strategies of the future economic development of the country:

- *base-line scenario* – based on political assumptions currently declared by state authorities,
- *chance scenario* – based on the assumption that faster and more thorough structural changes will be possible in the economy and social than it was assumed within the base-line scenario, and
- *stagnation scenario* – based on the assumption of lack of social acceptance for structural changes in the economy and connected with them costs; it is a scenario with a lower rate of changes as compared with the base-line scenario.

The base-line reference scenario made up a leading strategy of economic development presented in the Study in question. Reference, stagnation, and chance scenarios present strategies of economic development that are symmetrical to the base-line reference scenario.

For all the scenarios assumed were two variants of climate change:

- moderate warming – 0.05^0C per annum, and
- rapid warming – 0.10^0C per annum.

In the stagnation scenario the variants are SPst1 and SPst2, in the base-line scenario – SOb1 and SOb2, and in the chance scenario – SOsz1 and SOsz2. Reference scenarios: base-line and chance ones were treated as a base for the creation of macroeconomic reduction scenarios, using climatic policy in a form of carbon tax in two options (50 and 100 USD'90/MgC), and additionally introducing investing subsidies in variants characterised by higher carbon tax (i.e. strong climatic policy). Altogether, obtained were eight reduction scenarios (4 scenarios in the base-line and chance scenarios each. Table 9.1. shows ordered paths of macroeconomic development for the distinguished scenarios according to the above-mentioned assumptions.

Table 9.1. Scheme of the Country GHG emission 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	
climate warming		climate warming		climate warming		climate warming		climate warming		climate warming		climate warming	
moderate	rapid	moderate	rapid	moderate	rapid	moderate	rapid	moderate	rapid	moderate	rapid	moderate	rapid
SPst1	SPst2	SOb1	SOb2	SRb1	SRb2	SRb3	SRb4	SOsz1	SOsz2	SRsz1	SRsz2	SRsz3	SRsz4

Abbreviations used in table 9.1:

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,

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,

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,

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,

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,

1,2..4 – N^0 of a given scenario.

9.2. MACROECONOMIC REFERENCE SCENARIOS

The MERS base-line scenario is centrally-situated among the considered set of reference scenarios. It was specially treated in the Study because this scenario made up a starting point for the creation of scenario cases of *chance* and *stagnation*, and was politically verified. The scenario is based on specific documents including declarations of state authorities as far as the realised path of the state economic development is concerned. Considering the above, the following assumptions were adopted while elaborating the scenario:

- change of the economy structure towards decrease of share of heavy and material-intensive industries (metallurgy, coal industries), and increase of share of processing industries with advanced technologies, and services; change of production and employment structure in agriculture,
- translocation of labour force according to structural changes in the economy,
- changes in ownership of production centres towards increasing of share of private property;
- strengthening of market principles operation as a basic self-regulation mechanism in the economy;
- opening of the economy through realising of currency exchange rates, gradual liquidation of duty barriers, influx of foreign capital, increase of foreign trade exchange, adjustment of national legal regulations to the ones being in force in the European Community,
- admission to the European Community on the turn of the centuries;
- changes in the energetic economy within rationalisation of fuels and energy utilisation, decrease of energy intensity, changes of energy utilisation structure,
- decrease of the environment pollution through pro-ecological investments in the energy sector and in the remaining sectors and branches of the economy.

The final and the most important result of the base-line reference scenario is a forecast of GHG emission. The elaborated base-line reference scenario together with elementary macroeconomic changes till 2030 was passed an opinion by the members of Commission for Sustainable Development.

The following conclusions, resulting from base-line scenario, were concidered in elaboration of GHG emission reduction strategies:

- ◊ The economy transformation period disturbs the hitherto trends and makes the estimation of coefficients in the model equations difficult. At least several years have to pass by before such attempts will be feasible to undertake. Before 1989 there were in the economy excess of employment (hidden unemployment), which makes estimation of coefficients in the model equations still more difficult.
- ◊ The qualitative analysis should be given particular significance in the carried out scenarios analysis. The qualitative analysis are a preliminary stage for the next stage, i.e. calculations with the use of formalised models giving solutions in numbers.
- ◊ In the long-term forecasting, the Polish economy has to take into consideration two dilemmas: on the one hand, impeding increase of the unemployment, and on the other hand, necessity of the economy restructuring (especially energy, heavy industry, and agriculture modernisation).
- ◊ Reduction of unemployment could delay the rate of the economy restructuring. In order to enable them on a wider scale, a very high economic growth (high value of GDP) would be necessary, which, in turn, requires high expenditures of money.
- ◊ The above dilemmas and approaching them will in the near future determine development of the country, simultaneously creating possibilities of slower or faster GHG emission reduction, as well as a possibility for better or worse adaptation of the socio-economic system to global warming effects.
- ◊ The results of macroeconomic forecasting should provide a grasp of scale of the necessary changes in the economy in order to achieve desired effects in GHG emission reduction. Evidence in this matter will be provided by level and structure of GDP, its structure, capital expenditures and their structure, energy carriers consumption level and its structure, employment and rate of unemployment, expected losses in GDP due to use of e.g. tax on carbon concentration in fuels.
- ◊ The above results confronted with results of the sectoral scenario analysis should enable appraisal of feasibility of the considered long-term strategies of the country development in the context of forecast climate changes. Those results should also enable elaboration of possible, to be accepted by decision-makers, ultimate development strategy to be realised in practice taking into account international commitments, including the ones within GHG emission reduction.
- ◊ Elaborated and implemented into economic practice long-term development strategy of the country has got to undergo actual control and evaluation in a special, continuous process of verification As a result of this process, there follows a correction of a given development strategy.

Two other reference scenarios – *chance and stagnation* – were elaborated assuming as follows.

The reference scenario of chance was created with an assumption of possible deeper and faster changes than in case of the base-line reference scenario, i.e.:

- accelerated, in relation to presently declared by the state authorities, changes of economic structures towards more energy and material saving structures with a high degree of processing,
- full openness of the economy towards international environment,
- significant increase of share of hydrocarbon fuels (mainly natural gas) in the energy structure supplying the economy.

The reference scenario of stagnation was formulated with the assumption of barriers remarkably restricting development of the economy adopted in the base-line reference scenario through:

- freezing of technological and organisational structures of production,
- conservation of the material and energy-intensive nature of the economy,
- very limited opening the economy to the international surroundings,
- protection and development of hard coal mining,
- slow restructuring of the national economy.

The reference scenario of stagnation was introduced into the Study in order to compare it with reference scenario of chance and base-line reference scenario.

The given reference scenarios as a guiding path of development were submitted to teams elaborating sectoral reduction scenarios. The basic macroeconomic parameters of all the elaborated scenarios (stagnation, base-line, and chance) are presented in figures 9.1-9.8.

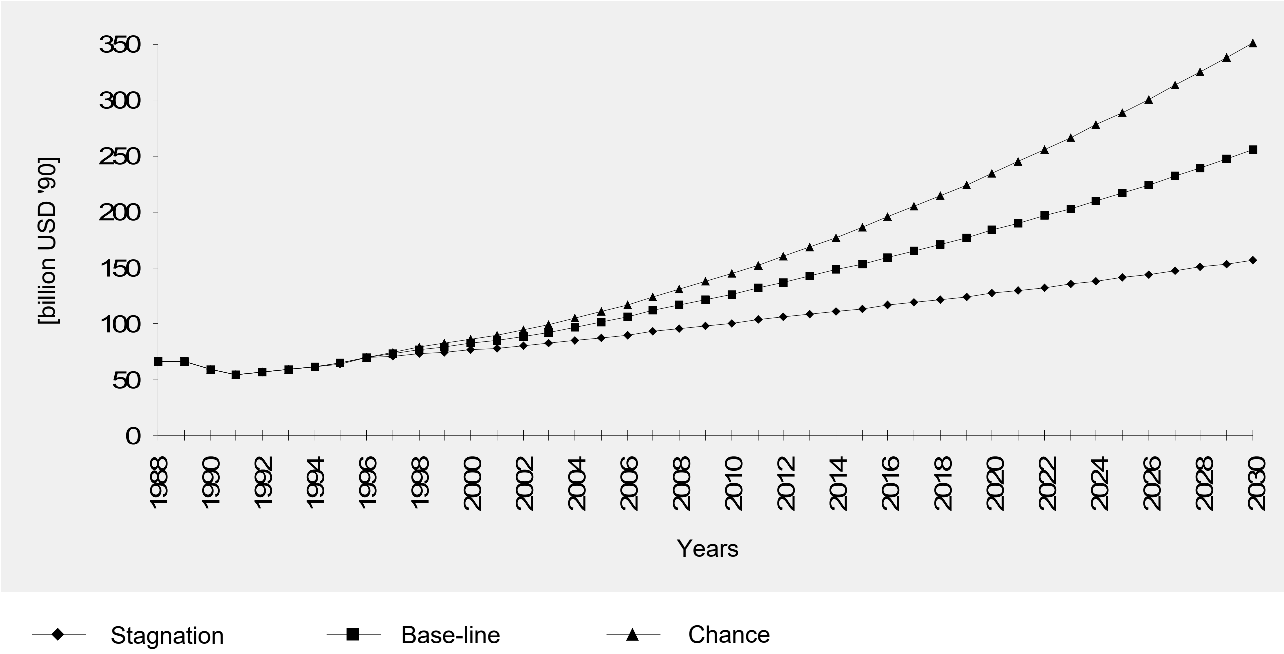

Figure 9.1. GDP – alternative paths of economic development for different scenarios

On the basis of parameters of the set of macroeconomic scenarios of the country development the following conclusions can be drawn:

- GDP is significantly higher in the chance scenario than in case of the stagnation and base-line scenarios,
- course of change of unemployment rate in the base-line scenario is almost steadily decreasing, the stagnation scenario does not assure drop of the rate, and in the chance scenario the rate significantly decreases only in the year 2005, reaching the lowest value of all the scenarios in the year 2030,
- energy consumption supplying the economy towards the end of the considered period (2030) has similar values in the chance and base-line scenario. However, course of that consumption is more advantageous in the chance scenario. The stagnation scenario is characterised by a very slow rise and reaches in the year 2030 lower value as compared to the rest of scenarios,
- the lowest energy intensity of GDP is represented in the chance scenario, the highest is presented in the stagnation scenario, while in the base-line scenario course of energy intensity of GDP reaches values between the two above-mentioned scenarios.

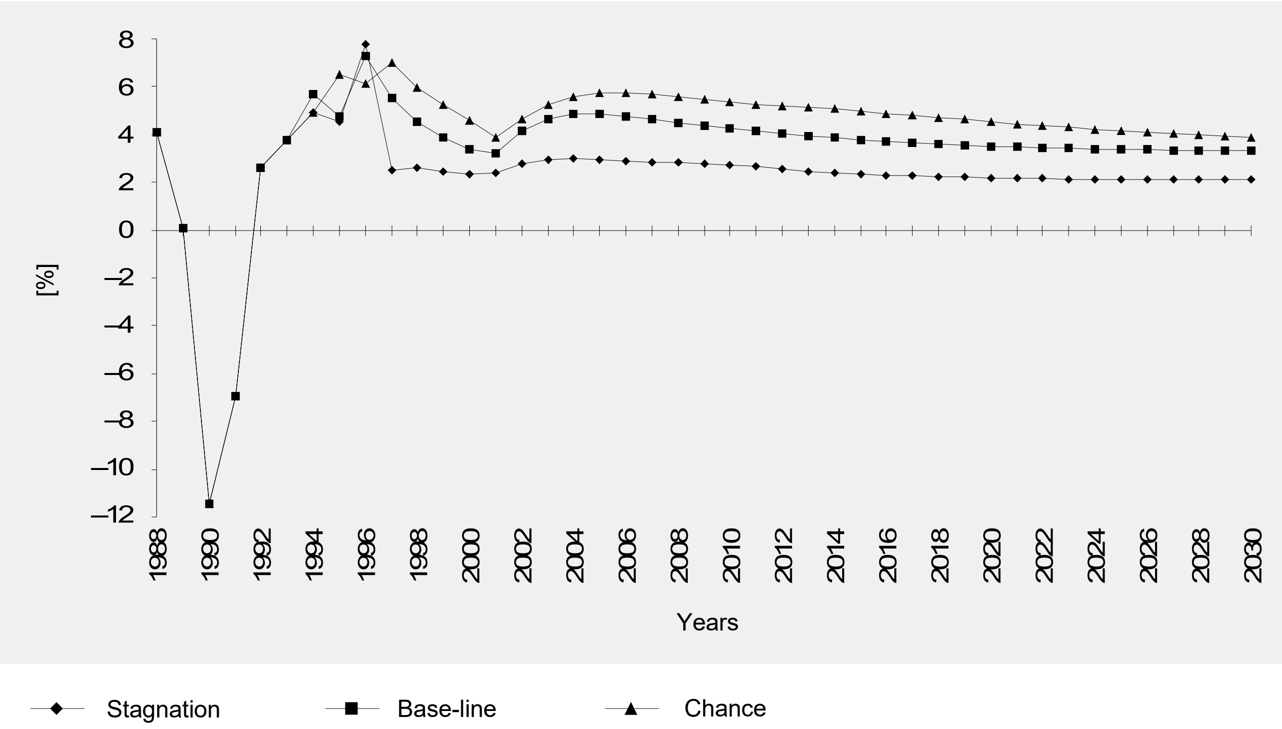

Figure 9.2. GDP rate for alternative paths of economic development for different scenarios

The analysis of CO_2 emission course shows that in 2030 the relation of CO_2 emission in reference scenarios to emission in 1988 is as follows:

- base-line scenario 1.22,
- chance scenario 1.02,
- stagnation scenario 1.11.

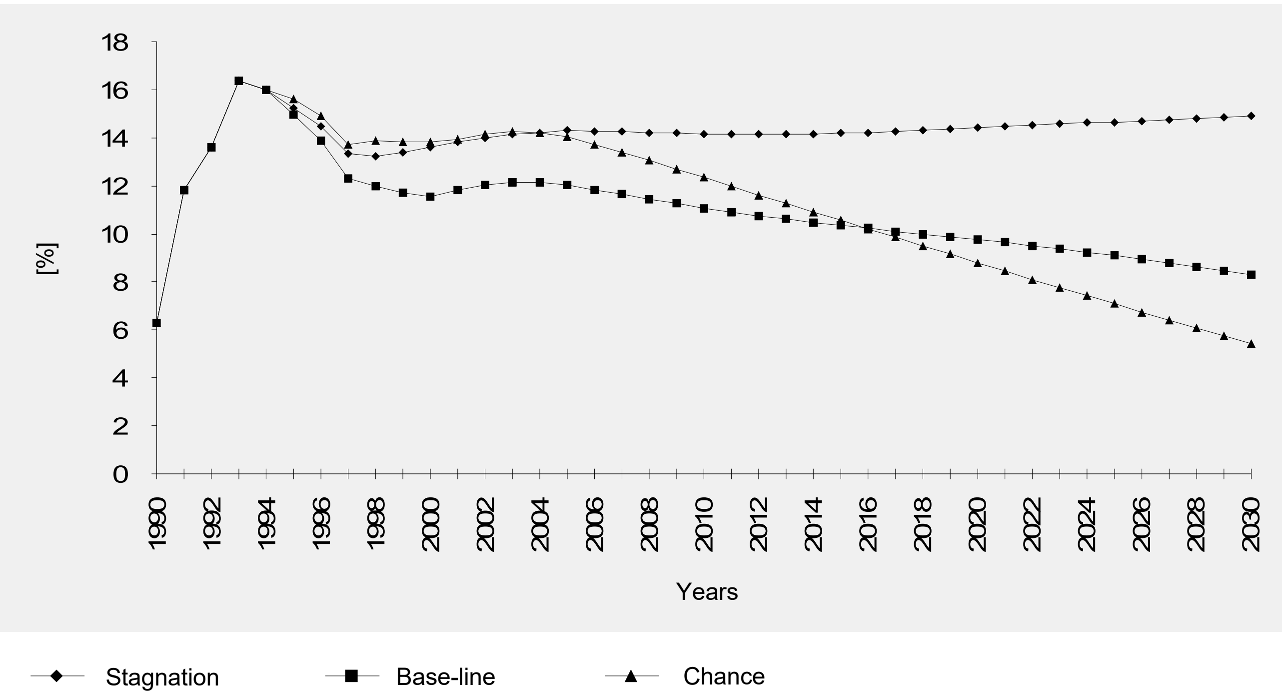

Figure 9.3. Rate of unemployment for alternative paths of economic development for different scenarios

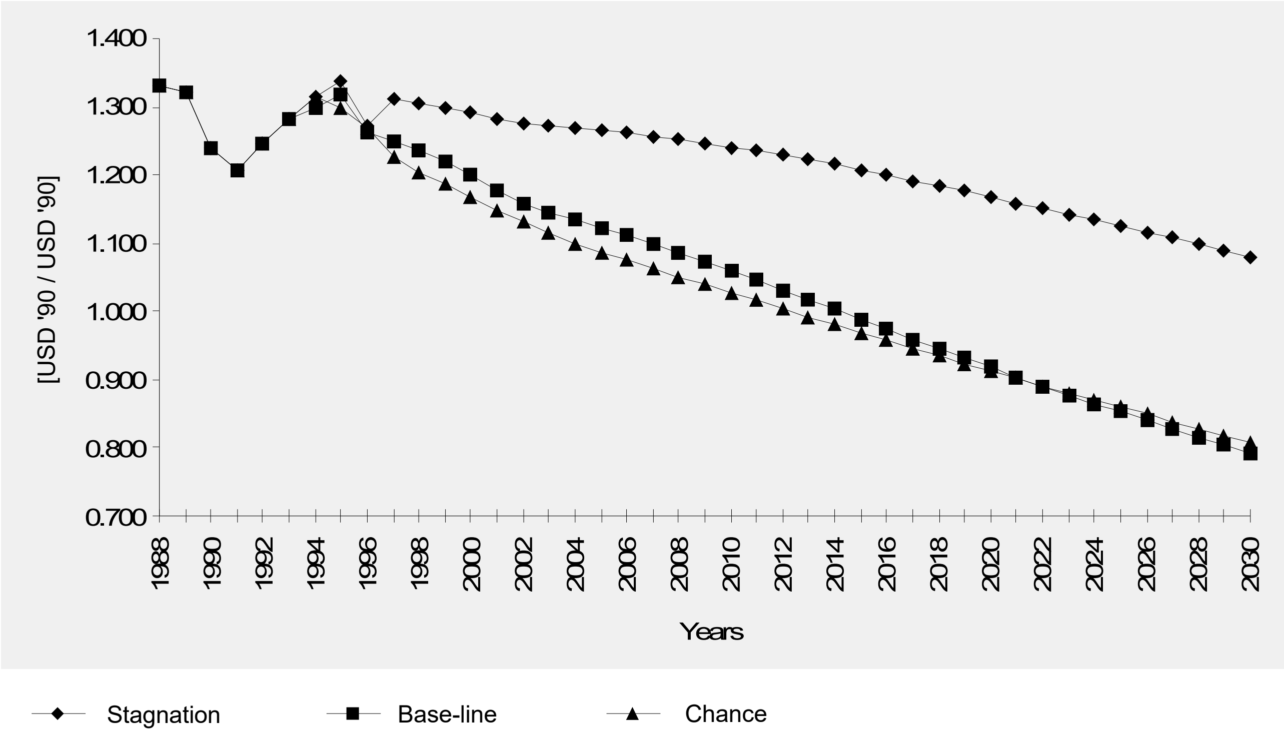

Figure 9.4. Material intensity of GDP – alternative paths of economic development for different scenarios

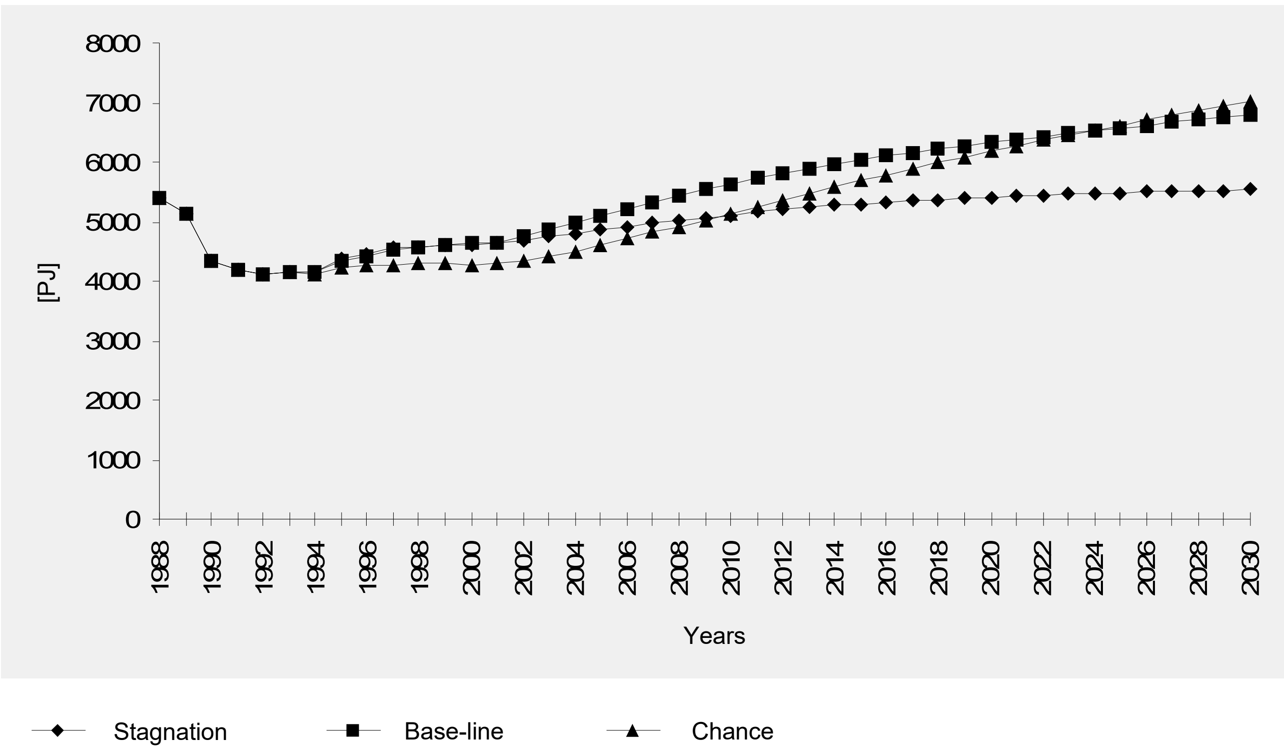

Figure 9.5. Domestic energy consumption – alternative paths of economic development for different scenarios

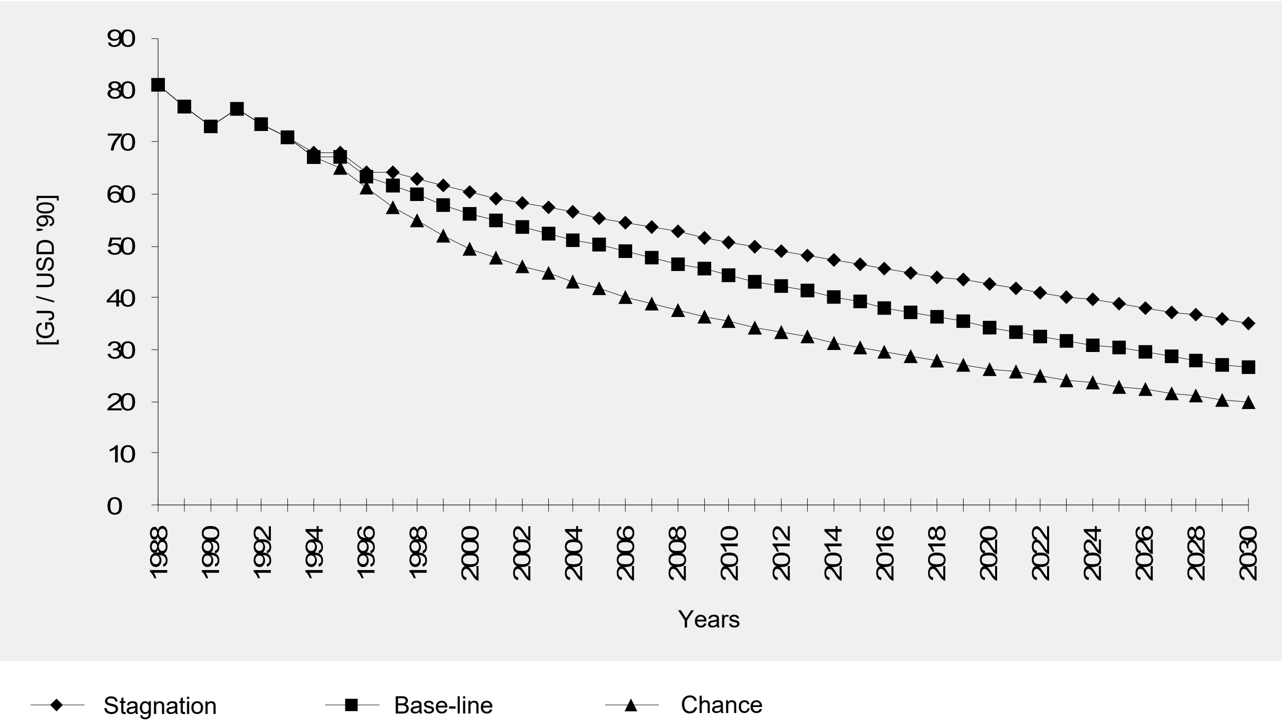

Figure 9.6. Energy intensity of GDP – alternative paths of economic development for different scenarios

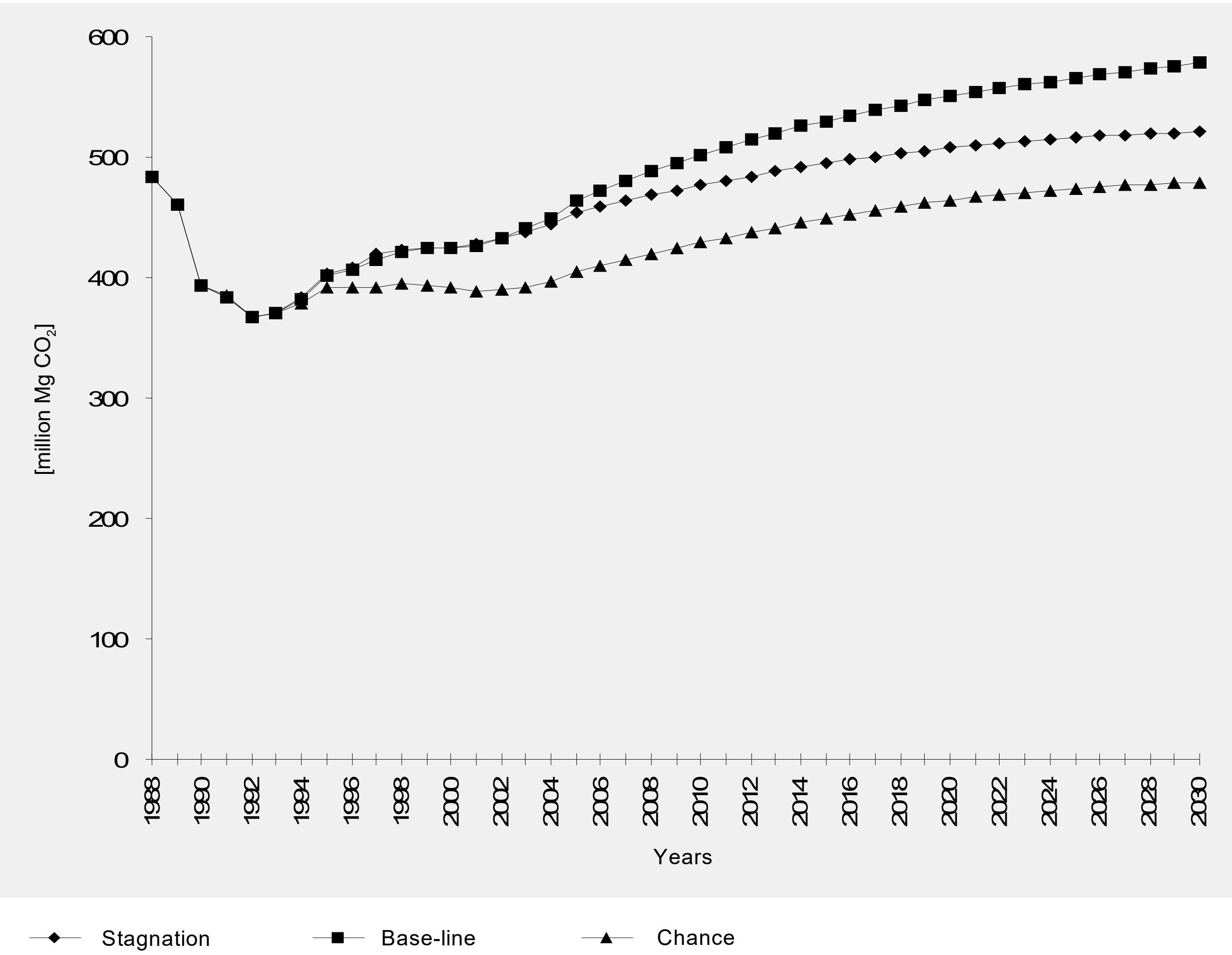

Figure 9.7. Domestic CO_2 emission – alternative paths of economic development for different scenarios

The economy energy emission intensity (relation of CO_2 emission to energy supply) is determined by structure of energy and technologies of processing energy, as well as resulting from it structure of direct energy. Influence of these factors on the economy energy supply emission results in changes of its value for scenarios in the year 2030 respectively:

- base-line scenario 85.1 [kg/GJ],
- chance scenario 68.6 [kg/GJ],
- stagnation scenario 93.6 [kg/GJ].

Analysis of CO_2 emission intensity in relation to GDP in 2030 with regard to emission intensity in 1990 shows its decrease:

- base-line scenario by up to 32%
- chance scenario by up to 20%.
- stagnation scenario by up to 47% of the 1988 value.

Taking into consideration emission intensity analysis of macroeconomic reference scenarios, the following conclusions can be drawn:

- the lowest CO_2 emission and emission intensity factors are achieved by the chance scenario thanks to the assumed high technology development, high efficiency of investments, suitable structure of energy supply (increase of 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 the base-line scenario with the indirect (between the 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 simultaneous slower implementation of hydrocarbon fuels into fuels and energy structure, and slower decrease of coal share in energy production,
- in the stagnation scenario CO_2 emission is lower than in the base-line scenario and higher than in the 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 the economy development paths including the greenhouse gases emission reduction, show variety of possibilities to make 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 ratified United Nations Framework Convention on Climate Change. Its realisation needs maintenance of the current unemployment rate (about 14%) till the year 2005. After that year, can occur a continuous and remarkable decrease of unemployment rate reaching in some 6% in 2030, and occurrence of significant increase of consumption per capita only around the year 2005. Reason of these occurrences should looked for in the need for structural and technological reconstruction of the national economy (fuel and heavy industries, and agriculture).

◊ Probably the country economic development will be realised according to the base-line reference scenario (especially in the initial period) due to already made political decisions and other governmental documents, which present the economy and sectoral development forecasting. The corrections of the base-line scenario, according to the main assumptions in the chance scenario, can be profitable (especially for energy intensity of GDP and greenhouse gases emission reduction).

◊ Realisation of the stagnation scenario is not very much probable due to governmental decisions already made, accepted development forecasts, and the society's lack of acceptance of low living standards.

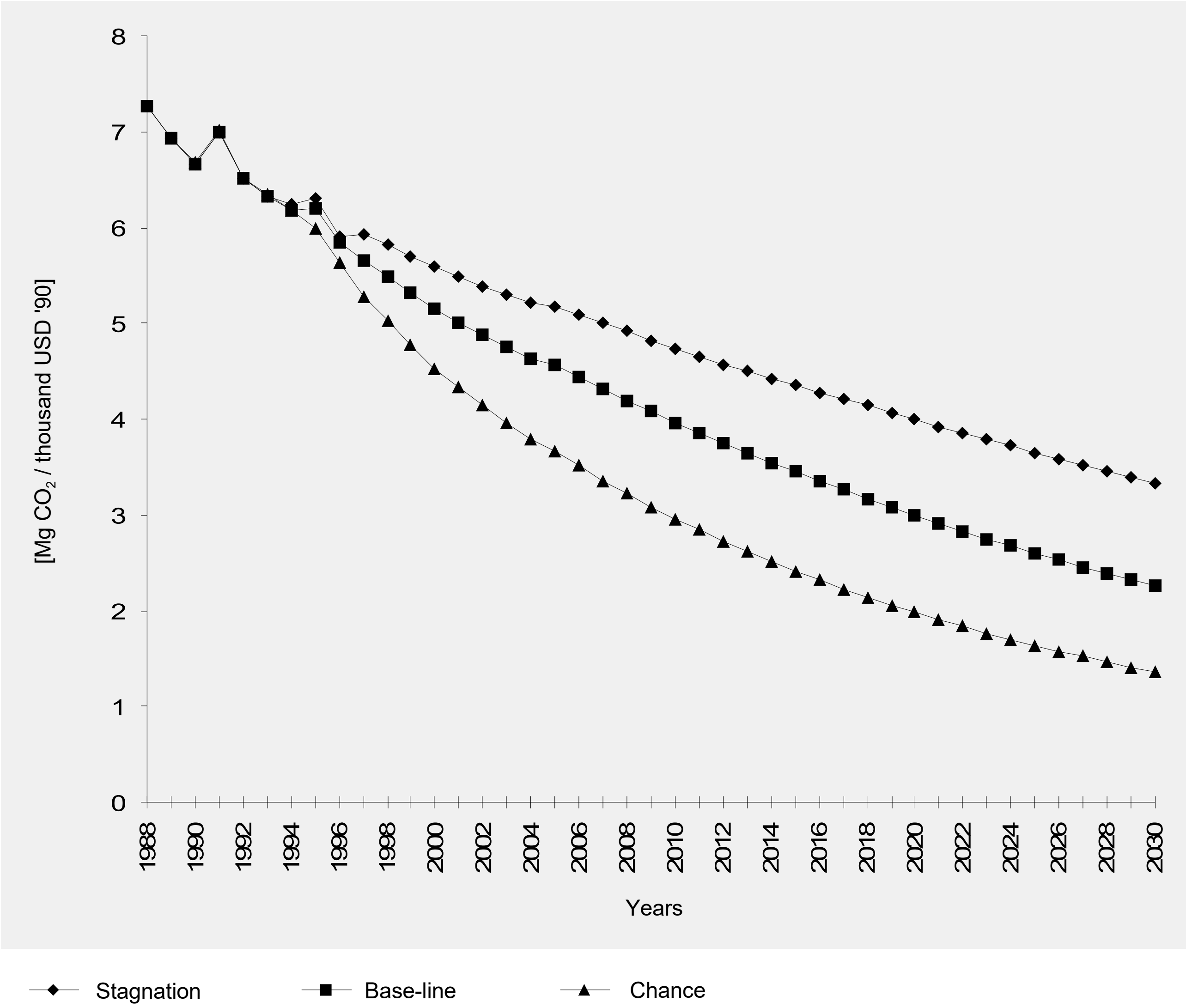

Figure 9.8. GHG emission intensity of GDP – alternative paths of economic development for different scenarios

9.3. COUNTRY GHG EMISSION REDUCTION SCENARIOS AND THEIR MACROECONOMIC IMPLICATIONS

GHG emission reduction scenarios were elaborated basing on the adopted assumptions for industrial sector (without power generation sector), municipal, public, commercial, services, households, and for development of renewable energy sources. Scope of GHG emission reduction and costs related to realisation of reduction options in sectors was adopted on the basis of submitted GACS spreadsheets (see chapter 6) and included to analysis of macroeconomic strategies of GHG emission reduction.

For the power sector, the results of sectoral optimising calculations containing investment programs and operating and maintenance costs were taken as the source of data. Wide spectrum of variants considered in this sector enabled quite precise assignment of proper power sector development variants to different macroeconomic scenarios.

For the transport sector economic parameters of GHG emission reduction scenarios were not estimated at the sectoral level (investment costs, variable costs). That is why streams of investments and other economic parameters were estimated at the level of macroeconomic modelling controlling compatibility of the resulting economic and technical parameters (GHG emission, fuels consumption, transport, transport intensity of GDP) with sectoral analysis results.

Agriculture was treated in a similar way as transport sector considering that structural changes in the economy will govern much stronger behaviours of the sector than any GHG reduction actions in the sector. Agreement between the sectoral and macroeconomic results in this area was controlled at the level of final results.

Sensitivity of the economy to GHG emission reduction stimulation through carbon tax was initially tested by investigating influence of the tax on economic effectiveness of technological GHG emission reduction options for industrial, household, municipal, commercial, services and renewable energy sources. Weak influence of carbon tax on economic effectiveness of GHG emission reduction options was stated. That is why for the chosen options, implementation of which is required because of general needs of the economy (e.g. modernisation of chemical and pertochemical industries), direct investment subventions were applied in order to activate the options. Investment subventions were assumed in base reduction scenarios (SRb3 and SRb4) at the level of 80 million USD'90/year, and in chance reduction scenarios at the level of 53 million USD'90/year. Their share in total investment costs of the country oscillates around 0.3%. Relations between investment costs for realisation of GHG emission reduction option (including subventions), and investment outlays of the whole national economy are presented in table 9.2 On the basis of technical analysis of GHG emission reduction options, defined was potential, technically-conditioned GHG emission reduction in respective sectors and after consideration of carbon tax and investment subventions enforcement, summary GHG emission reduction of the considered options for particular macroeconomic scenarios (fig. 9.9–9.12).

Figure 9.9 shows technical potential for GHG emission reduction in a form of three integrated reduction options (enumerated in tab. 8.1 in chapter 8.2.):

- energetic,
- autonomous,
- restricting emission of greenhouse gases

Figure 9.10 presents technical potential for GHG emission reduction in households, public buildings, commerce, and services, as well as municipal economy ordered in three sets of reduction options (described in chapter 8.3.):

- isolation and sealing buildings,
- lighting and electrical appliances,
- operational sources of heating of buildings

Figure 9.12 presents technical potential for GHG emission reduction through utilisation of renewable energy, aggregated in five groups of reduction options (presented in chapter 8.6.):

- hydroplants,
- wind power plants,
- biofuels,
- solar collectors,
- geothermy

Changes of the country CO_2 emission, reduction and macroeconomic cost of CO_2 emission reduction was presented in the following figures:

- figures 9.13-14 for the base reduction scenarios SRb1 and SRb3 (moderate warming),
- figures 9.15-16 for the base reduction scenarios SRb2 and SRb4 (rapid warming),
- figures 9.17-18 for the reduction scenarios of chance SRsz1 and SRsz3 (moderate warming),
- figures 9.19-20 for the reduction scenarios of chance SRsz2 and SRsz4 (rapid warming),

Table 9.2. presents the main parameters of the elaborated macroeconomic scenarios.

Analysis of course of the base-line reduction scenarios leads to a conclusion that scenarios SRb1-SRb4 can achieve CO_2 emission in 2030 similar to those of the year 1988, with a mean annual macroeconomic cost of CO_2 emission reduction in 2030 oscillating from 84 to 147 USD'90/Mg CO_2. Reduction scenarios of chance SRsz1-SRsz4 lower CO_2 emission in 2030 below the level of 1988 CO_2 emission, however, with higher, than in base-line scenarios, mean economic cost of CO_2 emission reduction in 2030 between about 210 USD'90/Mg CO_2 for scenarios SRsz1 and SRsz2, to about 358 USD'90/Mg CO_2 for scenarios SRsz3 and SRsz4.

Table 9.2. Main parameters of the economic scenarios

Scenarios	GDP [bln USD'90]			Energy use [PJ]			Energy intensity of GDP [GJ/USD'90]			Total investments in the economy [billion USD'90]			Investments for the GHG emission reduction options [million USD'90]			Domestic GHG emission [million Mg CO_2]			GHG emission reduction [million Mg CO_2]			Average macro-economic cost of GHG emission reduction [USD'90/Mg CO_2]
	1990	2010	2030	1990	2010	2030	1990	2010	2030	1990	2010	2030	1990	2010	2030	1990	2010	2030	1990	2010	2030	1995 - 2030
SPst1	59	101	157	4323	5112	5529	73.3	50.8	35.2	11.9	23.5	43.5	125	596	809	393	476	521	-	-	-	-
SPst2	59	101	158	4323	5044	5340	73.3	49.9	33.7	11.9	23.5	43.5	125	596	809	393	471	505	-	-	-	-
SOb1	59	127	256	4323	5629	6795	73.3	44.4	26.5	11.9	26.6	56.4	250	1192	1618	393	502	578	-	-	-	-
SOb2	59	128	258	4323	5551	6560	73.3	43.5	25.4	11.9	26.6	56.4	250	1192	1618	393	496	560	-	-	-	-
SRb1	59	125	246	4319	5289	5990	73.3	42.4	24.4	11.9	26.6	56.4	250	1229	1645	393	469	501	0	33	77	55
SRb2	59	125	248	4319	5219	5802	73.3	41.6	23.4	11.9	26.6	56.4	250	1229	1645	393	464	487	0	32	73	55
SRb3	59	126	249	4182	5256	5803	73.3	41.6	23.3	11.9	26.9	56.5	250	1460	1767	393	470	495	0	32	83	4
SRb4	59	127	251	4182	5187	5619	73.3	40.8	22.4	11.9	26.9	56.5	250	1460	1767	393	465	480	0	32	79	3
SOsz1	59	145	352	4323	5121	7003	73.3	35.3	19.9	11.9	32.0	87.9	400	1907	2589	394	429	479	-	-	-	-
SOsz2	59	146	356	4323	5065	6819	73.3	34.7	19.2	11.9	32.0	87.9	400	1907	2589	394	425	467	-	-	-	-
SRsz1	59	141	321	4323	4663	5827	73.3	33.0	18.2	11.9	32.4	88.0	400	2300	2679	393	389	393	0	40	87	111
SRsz2	59	143	325	4323	4618	5693	73.3	32.4	17.5	11.9	32.4	88.0	400	2300	2679	393	385	384	0	40	83	112
SRsz3	59	145	333	4323	4627	5387	73.3	31.9	16.2	11.9	32.4	88.1	400	2336	2828	393	389	389	0	40	91	26
SRsz4	59	146	337	4323	4581	5259	73.3	31.3	15.6	11.9	32.4	88.1	400	2336	2828	393	385	380	0	40	87	25

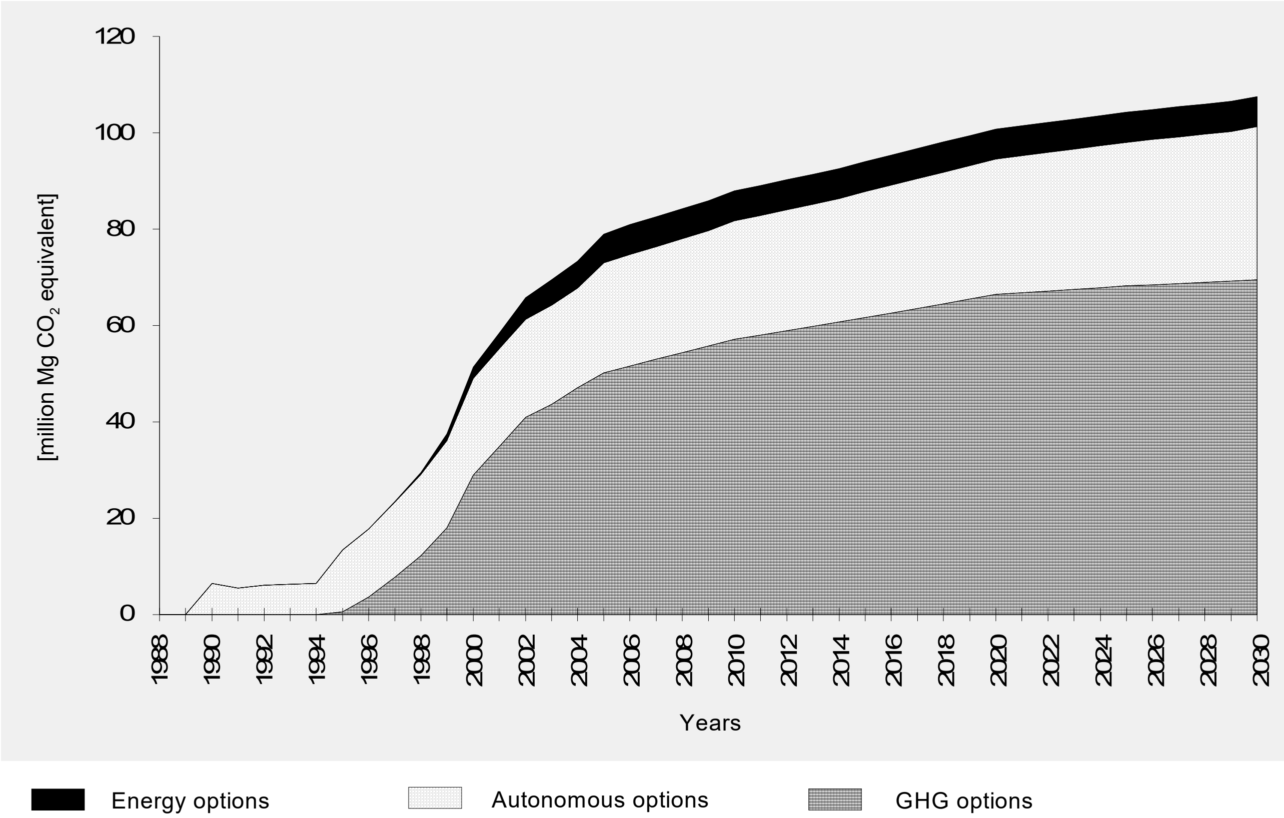

Figure 9.9. Technical potential of GHG emission reduction in industrial sector

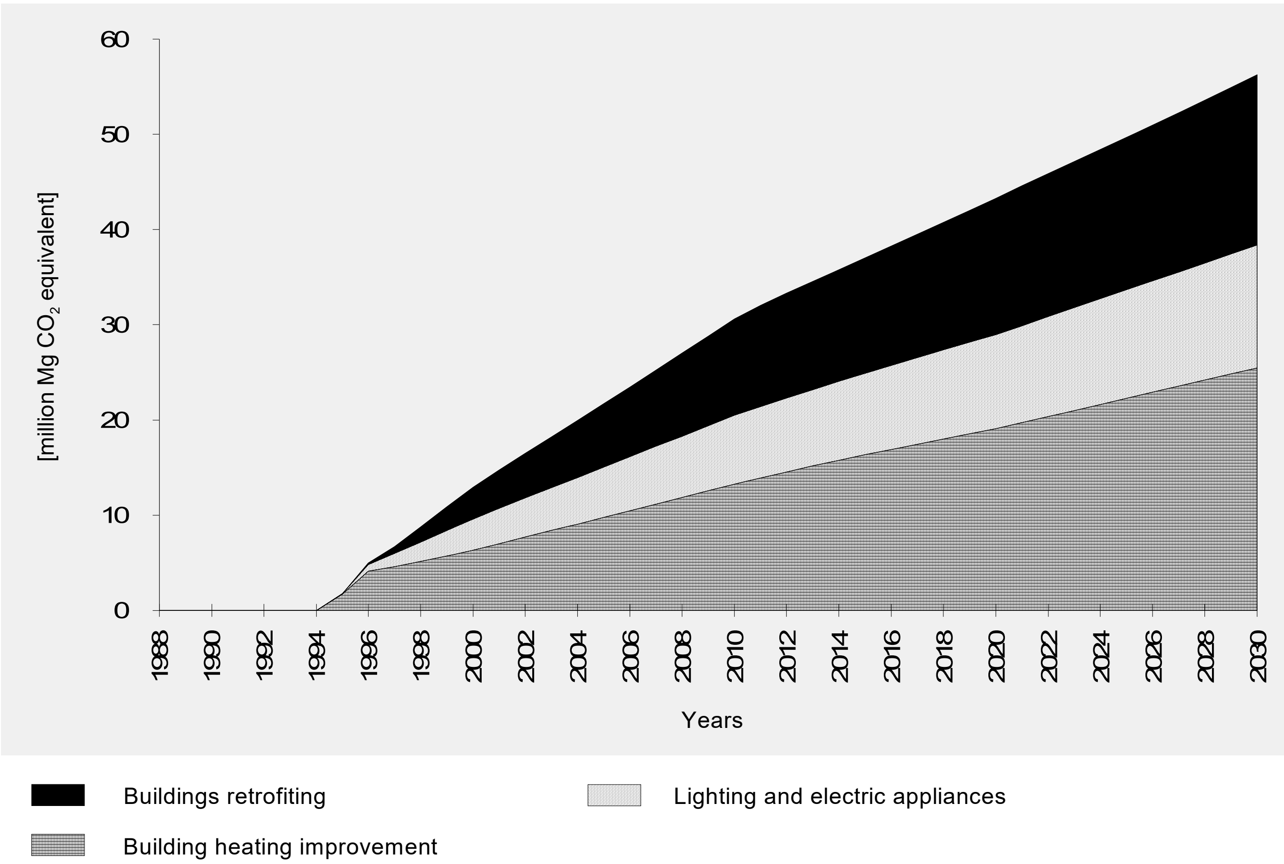

Figure 9.10. Technical potential of GHG emission reduction in house holds, services, municipal and commercial sectors

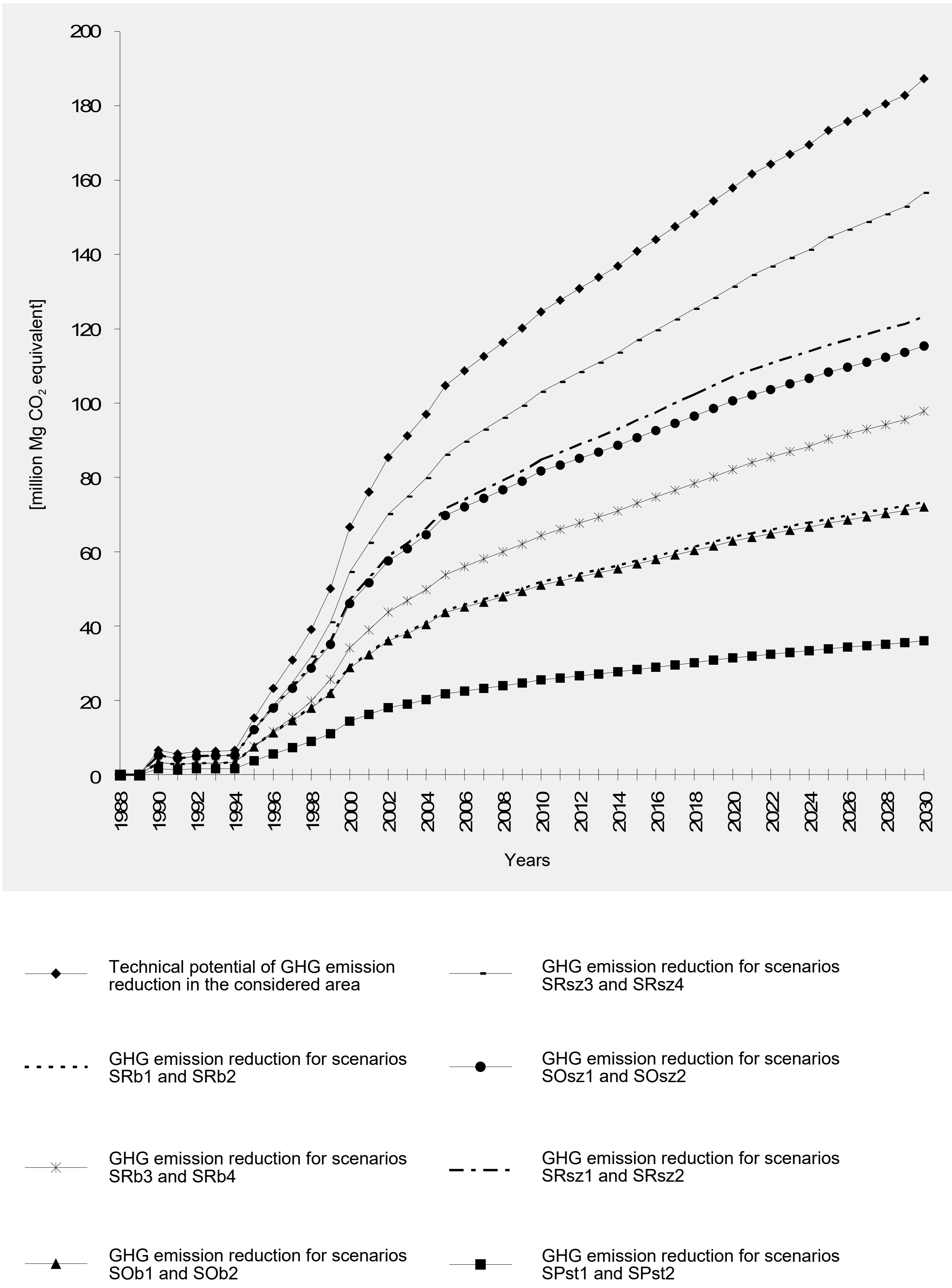

Figure 9.11. GHG emission reduction for sectors: industrial, house holds, municipal, commercial, in services and due to renewable energy development (90% of total GHG emission – *bottom up* results, discount rate r = 0.1)

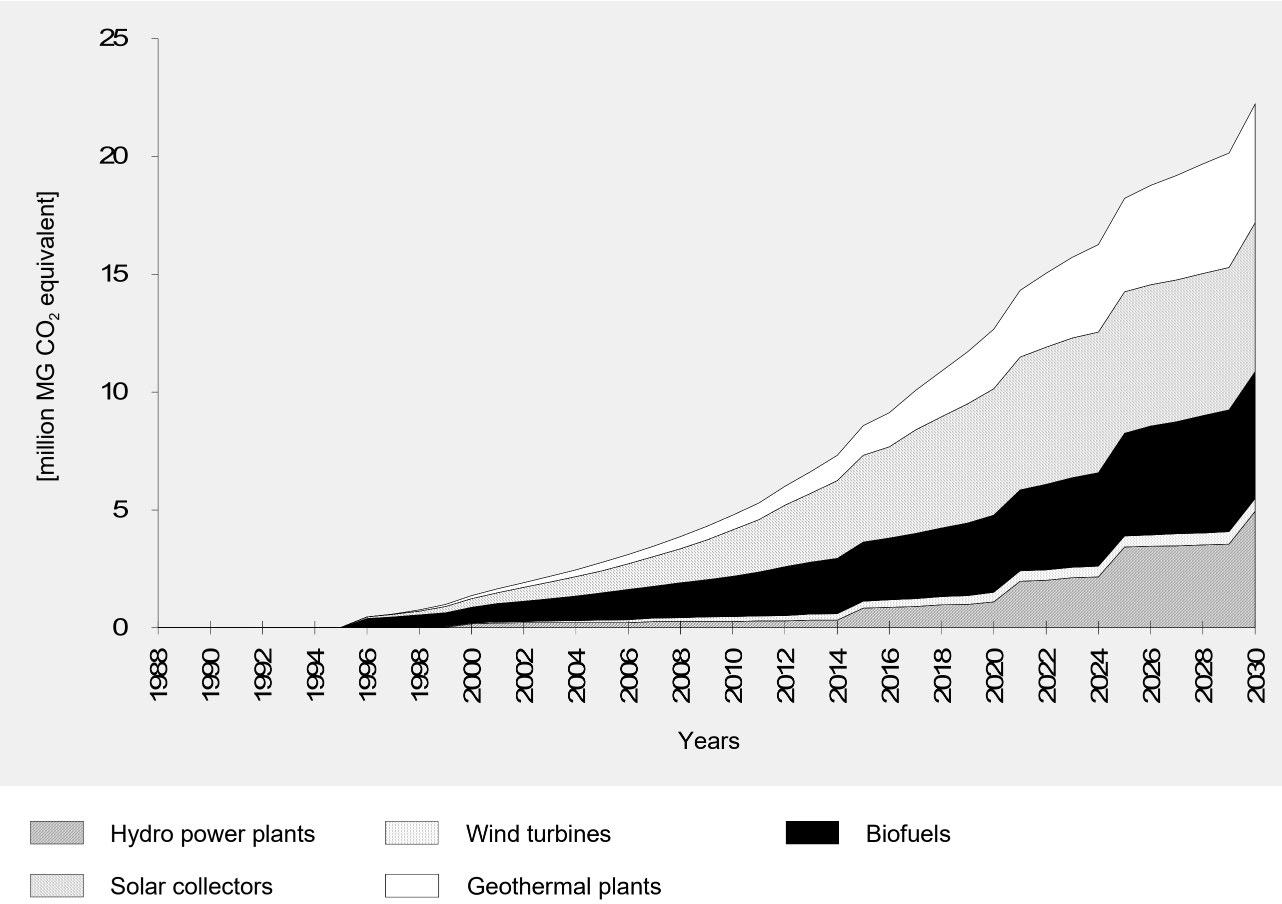

Figure 9.12. Technical potential of GHG emission reduction by renewable energy sources development

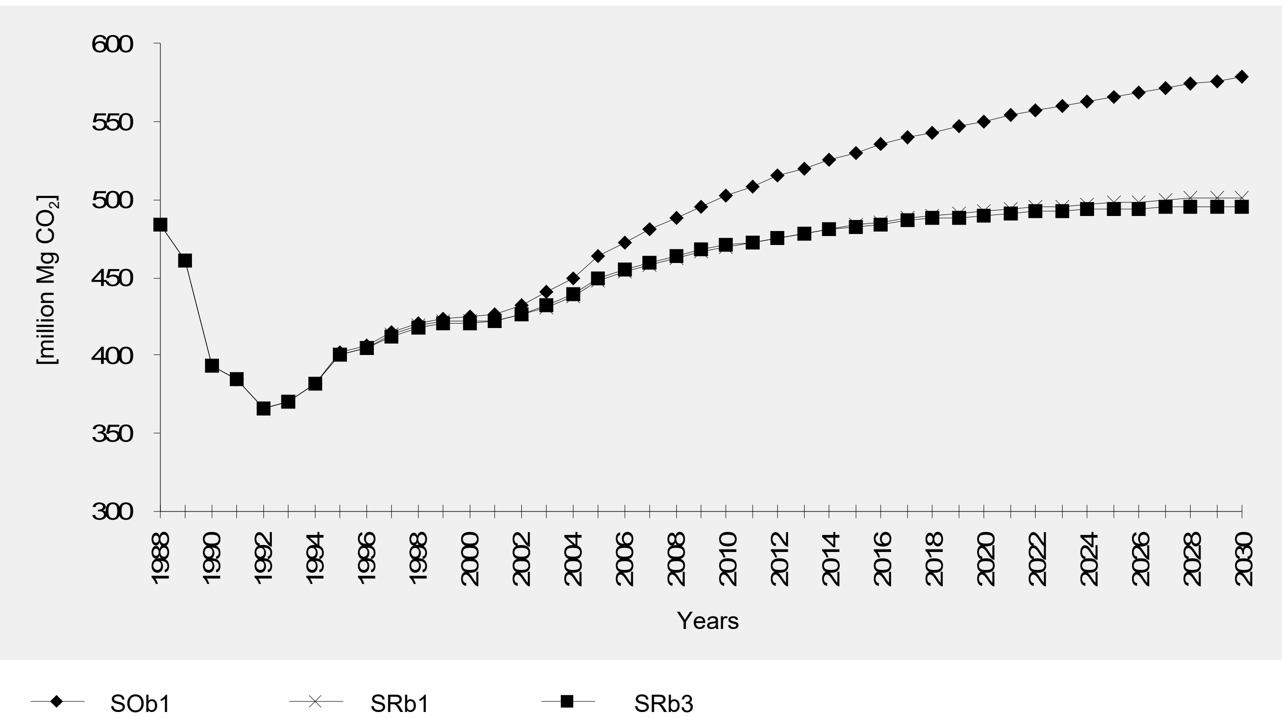

Figure 9.13. Domestic CO_2 emission – SRb1and SRb3 variants (base)

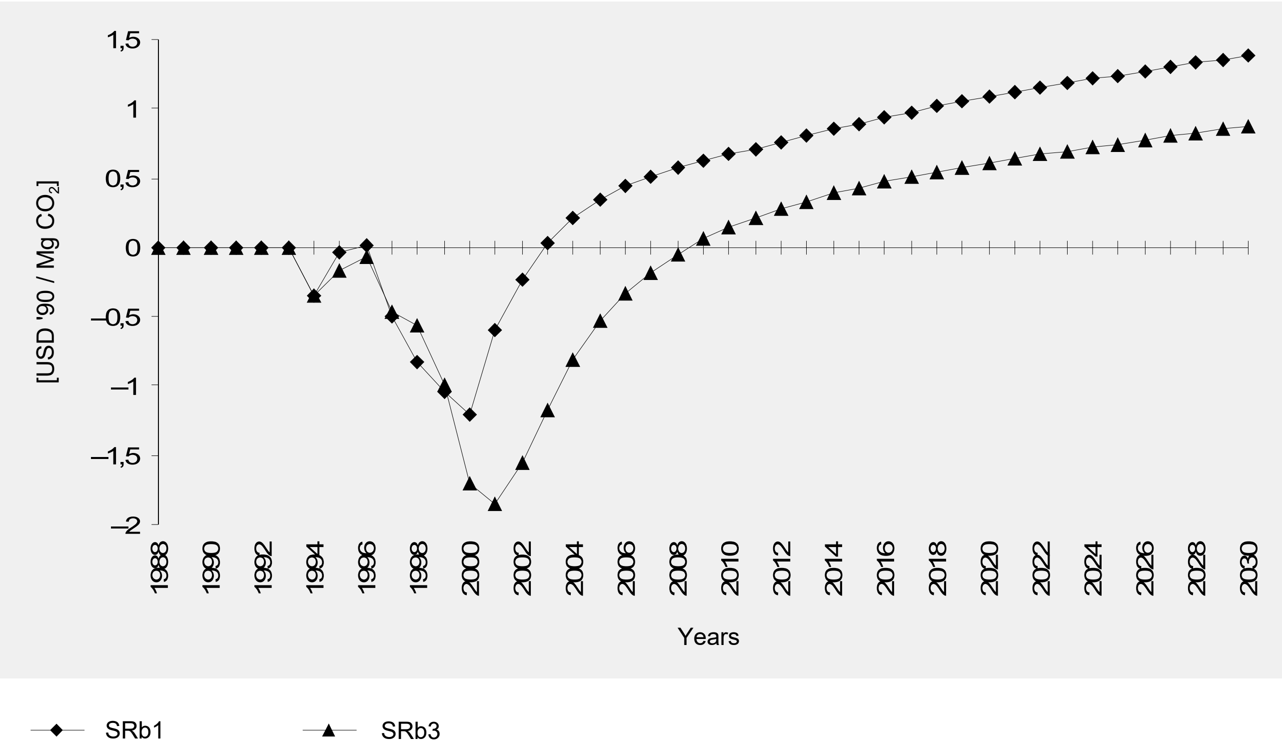

Figure 9.14. Macroeconomic cost of CO_2 emission reduction – SRb1 and SRb3 (base)

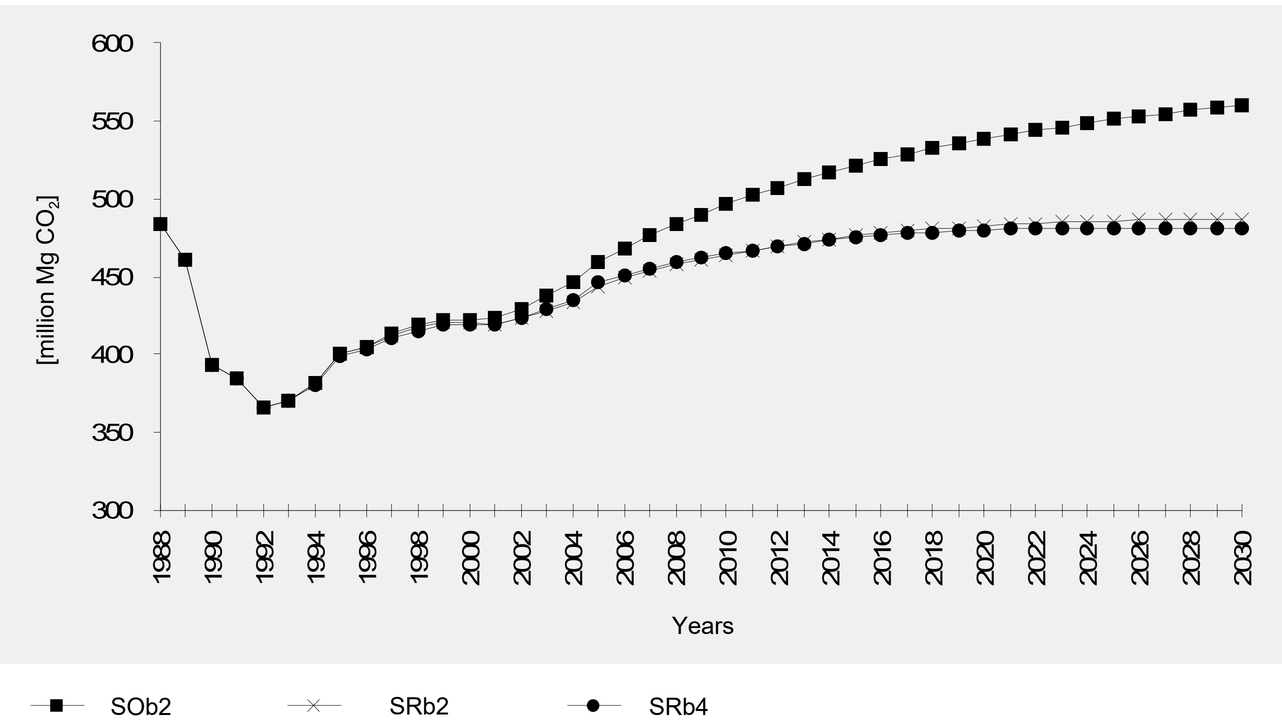

Figure 9.15. Domestic CO_2 emission – SRb2 and SRb4 variants (base)

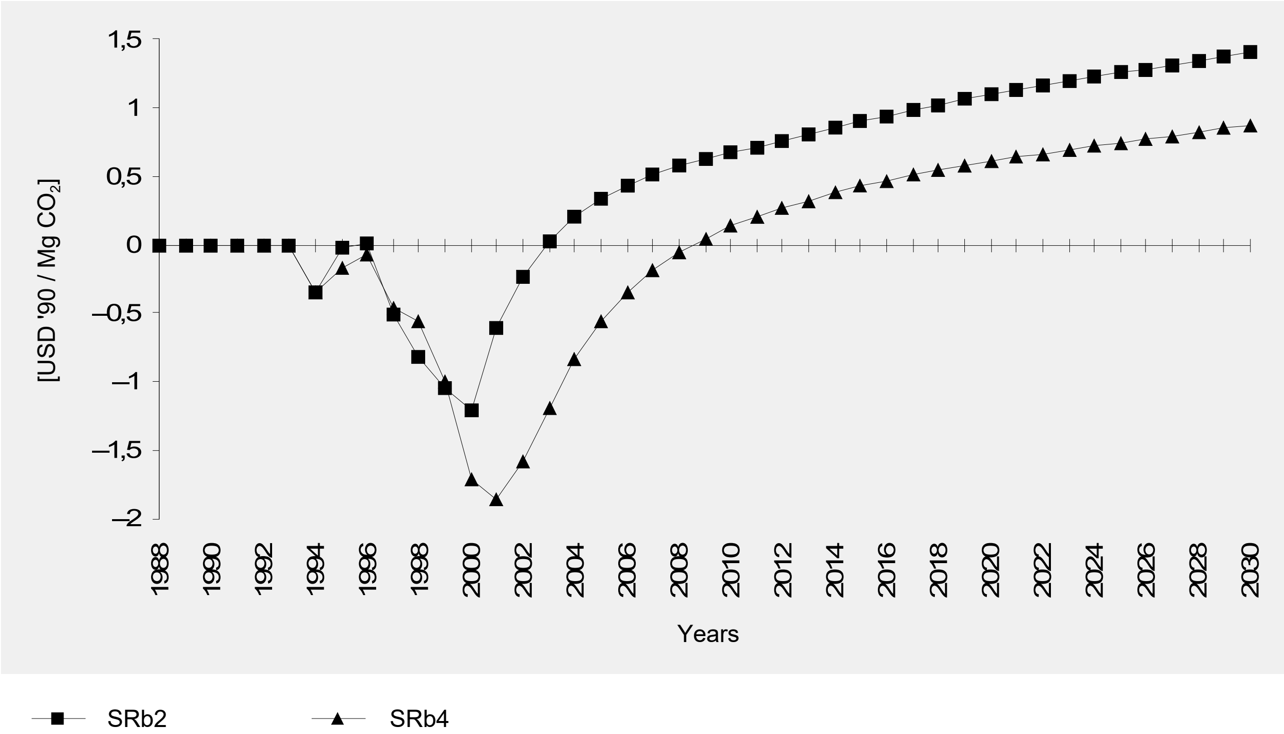

Figure 9.16. Macroeconomic cost of CO_2 emission reduction – SRb2 and SRb4 (base)

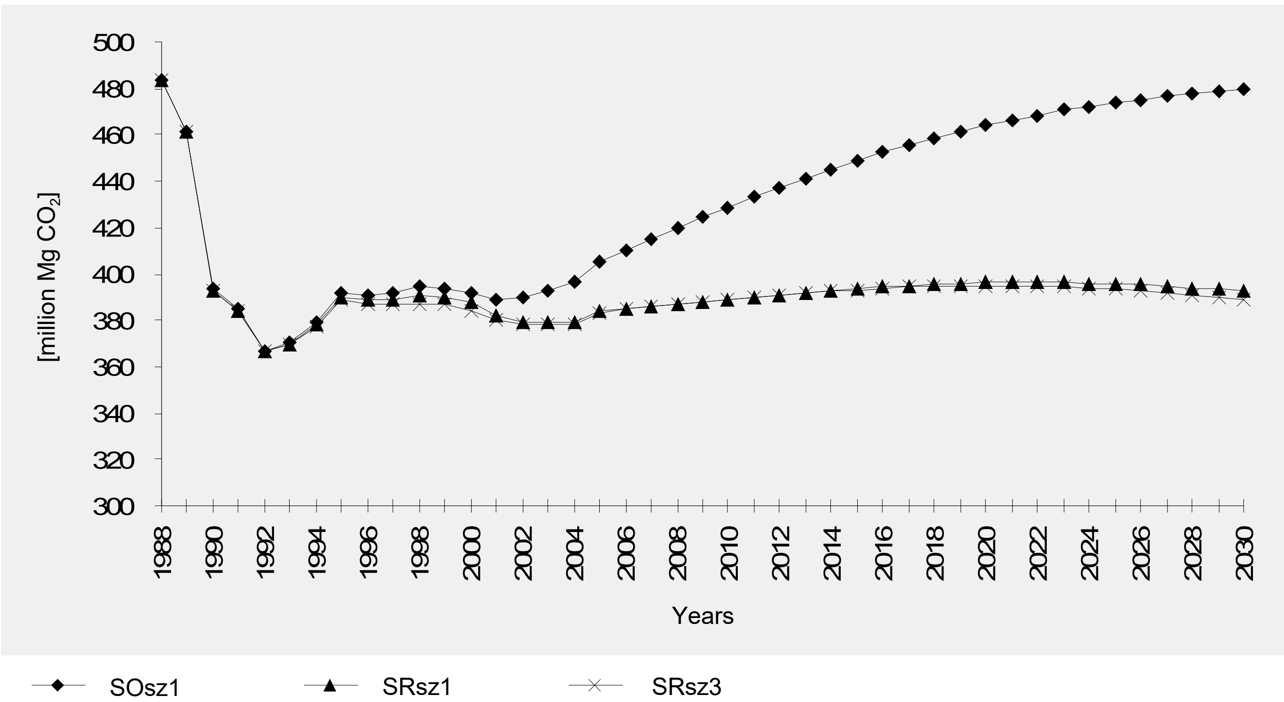

Figure 9.17. Domestic CO_2 emission – SRsz1 and SRsz3 variants (chance)

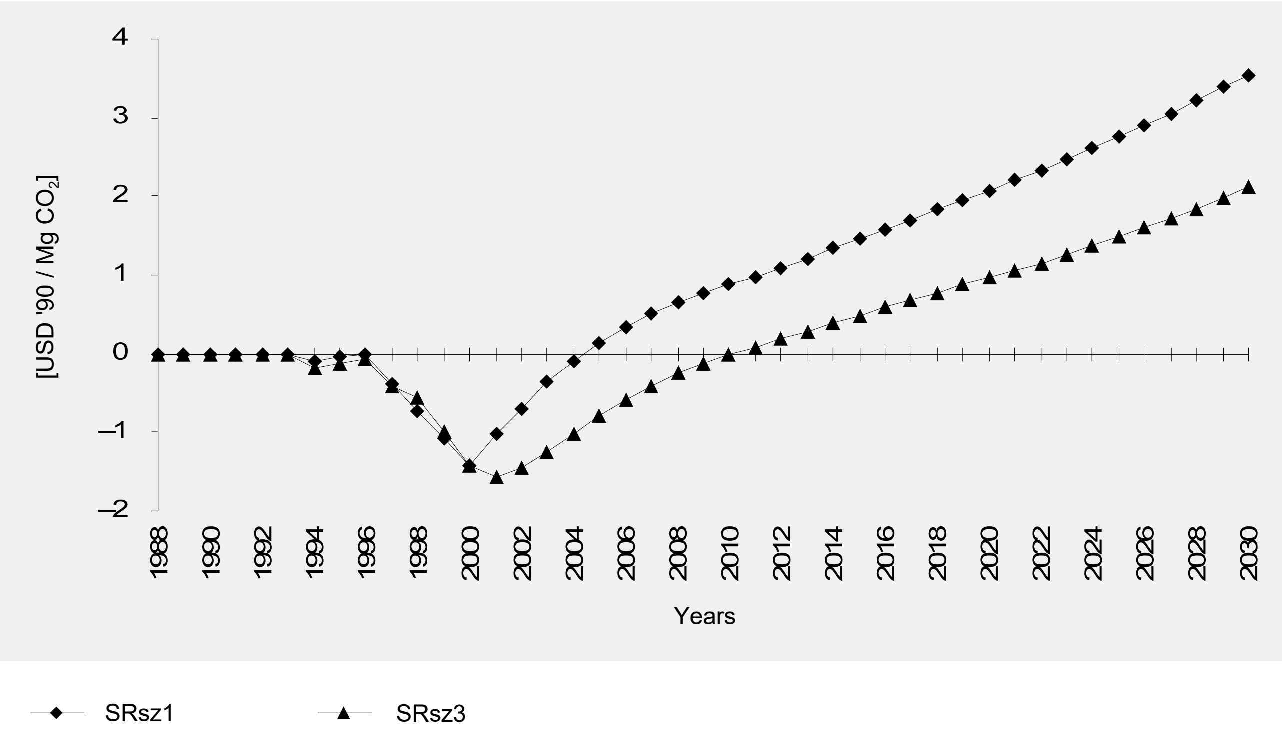

Figure 9.18. Macroeconomic cost of CO_2 emission reduction – SRsz1 and SRsz3 (chance)

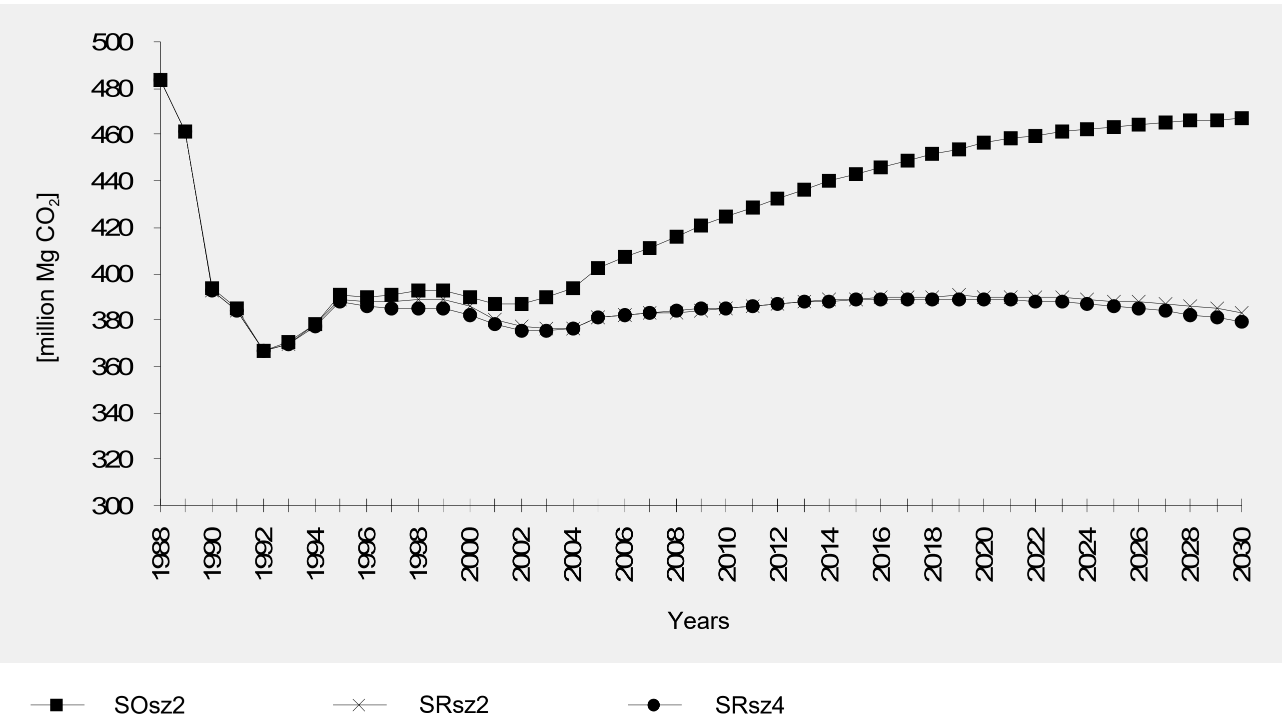

Figure 9.19. Domestic CO_2 emission – SRsz2 and SRsz4 variants (chance)

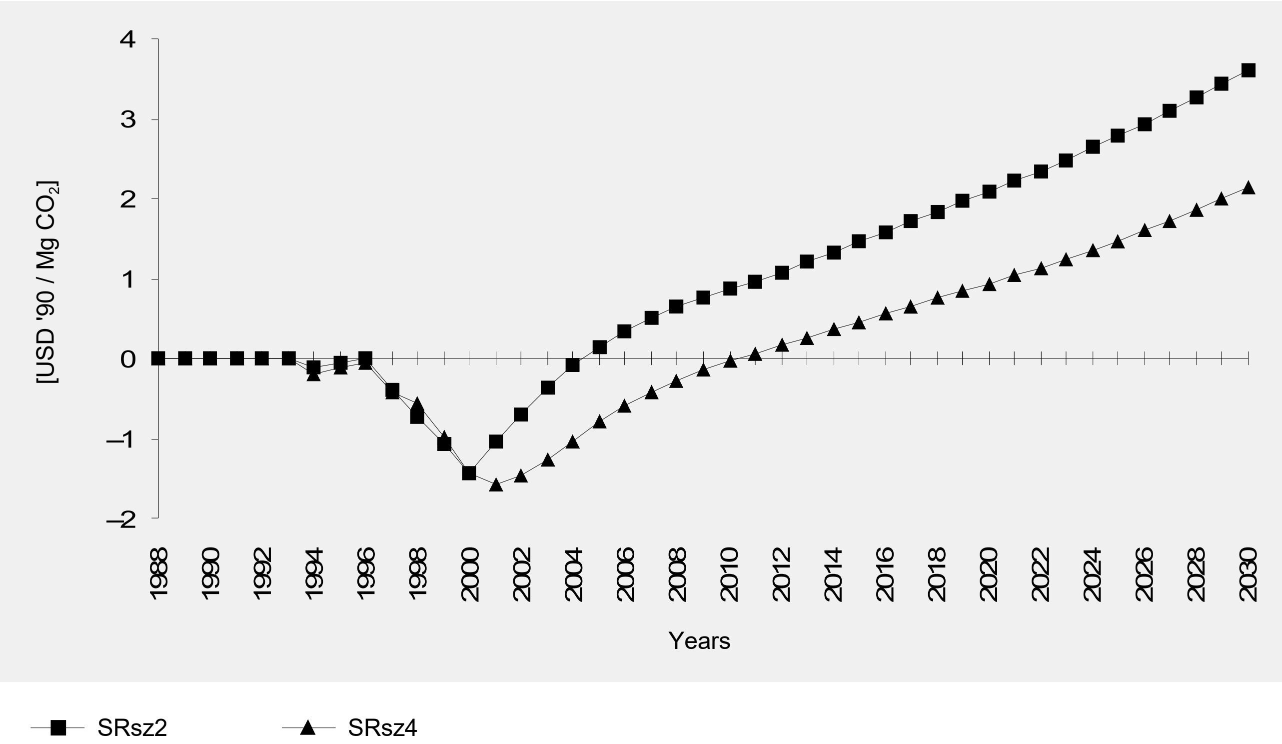

Figure 9.20. Macroeconomic cost of CO_2 emission reduction – SRsz2 and SRsz4 (chance)

9.4. TEMPERATURE CHANGE IMPACT

Studies on influence of temperature growth was done for all the reference and reduction scenarios. Rate of growth of temperature was assumed in two variants of climate warming growth rate:

- 0.05 ^{0}C per annum,
- 0.10 ^{0}C per annum.

The research was extended over all the reference scenarios. The calculated results of CO_2 emission for the climatic scenarios and all macroeconomic reference scenarios are given in table 9.3.

Table 9.3. CO_2 emission for climatic scenarios [million Mg]

Base scenario			Chance scenario			Stagnation scenario		
SOb (base)	–	597	SOsz	–	492	SOst	–	537
SOb1 (0.05^{o}C/year)	–	578	SOsz1	–	479	SOst	–	521
SOb2 (0.1^{o}C/year)	–	560	SOsz2	–	467	SOst	–	505

Table 9.4. Climate change impact on macroeconomic parameters modification in reference scenarios [%]

Increase of GDP			Decrease of energy supply			Decrease of energy intensity of GDP		
SOb1	–	0.7%	SOb1	–	3.4%	SOb1	–	3.8%
SOb2	–	1.5%	SOb2	–	6.8%	SOb2	–	7.2%
SOsz1	–	1.1%	SOsz1	–	2.6%	SOsz1	–	4.2%
SOsz1	–	2.1%	SOsz2	–	5.2%	SOsz2	–	7.8%
SPst1	–	0.9%	SPst1	–	3.4%	SPst1	–	4.6%
SPst2	–	1.9%	SPst2	–	6.7%	SPst2	–	7.2%

The results of climate warming are parameters changes in the considered scenarios, calculated with the support of the computer model of the national economy SDM–NE. Their absolute values (in %) for the year 2030 are presented in table 9.4.

The results presented in tables 9.3 and 9.4 confirm the thesis that climate warming decreases the energy supply demand (mainly for space heating) and therefore, result is GDP growth. It must be emphasised that in macroeconomic analysis the cost of adaptation to climate changes has not been taken into consideration due to lack of data (estimation of costs was done only in research on coastal zone adaptation).

9.5. CONCLUSIONS RESULTING FROM MACROECONOMIC EMISSION REDUCTION SCENARIOS

The obtained results of investigation of the reference scenarios and reductions of greenhouse gases emission as well as their analysis within the macroeconomic aspect in relation to the economy development, energy problems and emission, and relation between them, allow to formulate the following statements, postulates, and conclusions:

1. Three elementary scenarios have been considered: base-line, chance and stagnation scenario, which create a basis for wide analysis of the national economy development. The leading scenario is the base-line one. The chance and stagnation scenarios delimit the border of possibilities of Polish economy development: progressive and preservative one. Modified versions of the scenarios, especially of base-line and chance scenarios, 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 creation of governmental climate policy.
2. Chance scenario is the most profitable for economy development and fulfilling the commitment within the United Nations Framework Convention on Climate Change. This scenario realisation needs agreement of the society as far as the relinquishment of life standard in the first several years is concerned. This scenario gives a basis for implementation of climate policy aiming at, *inter alia*, climate protection. It is anticipated that a rapid grow of economy will not suffer from the unavoidable impulse of recession caused by financial regulators of that policy (carbon tax and financial investment subventions). Apart from it, the chance scenario has the best rates of emission intensity (without climate protection policy). However, one should be able to spot numerous barriers on the way to realisation of the chance scenario. There may emerge a conflict between realisation of short- and long-term goals. The conflict consists in a possibility of occurrence of social pressure on political decision-makers to gain a quick growth of consumption, necessity to diminish unemployment and limiting of the economic stratification of the society. Progress of the chance scenario attained by means of simulation reveals a possibility of growth of prosperity, and limitation of unemployment only after the year 2005. Furthermore, the chance scenario realisation depends on increased supply of natural gas to the national economy, and development of fuels and energy free market which can rise costs of the society maintenance through adaptation of fuels and energy prices to the European market. The above barriers restricting the possibility of the chance scenario realisation are also confirmed by results of analysis carried out by means of events interaction done by CIA model. According to them, the chance scenario has lower probability value than the base-line scenario.
3. Definitely disadvantageous is the stagnation scenario due to the highest material intensity of GDP, the highest energy intensity of GDP, the highest emission intensity of GDP, the highest increase rate of unemployment and the lowest consumption per capita.
4. The most probable is realisation of the base-line scenario. According to the HIPRE3+ model results, it has the next, after the chance scenario, value of political preferences and the highest probability of realisation. The base-line scenario has been created taking into account current government programs, and therefore, its development creates conditions for continuation. Unfortunately, this scenario presents a development path with the highest emission, although it has more advantageous macroeconomic factors, especially in relation to the 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 the chance scenario after 2015,
- energy intensity of GDP has a decreasing character (it is higher by 25% than in the chance scenario),
- unfortunately higher by over 50% emission intensity of GDP in relation to the chance scenario.

Apart from it, the base-line scenario can be susceptible to correction of development assumptions (which has not been 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 income growth.

Implemented scale of constraints within climate policy (carbon tax 50-100 USD'90/MgC) 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 greenhouse gases emission reduction amounted to 0.2-0.3% of total financial subventions. Implementation of the above-mentioned economic regulators caused, as simulation showed, a slight decrease of the national growth reflected in GDP drop at the end of considered period by about 5-10% depending on the scenario.

6. The influence of the climate policy regulators caused extreme greenhouse gases emission reduction (presented in CO_2 emission reduction) to about 79-90 million Mg, which gives the possibility not to exceed the emission of 1988 up to the year 2030. It is a good prognostic for Poland of meeting a potential and negotiable future commitments within the United Nations Framework Convention on Climate Change.

10. LEGAL AND ECONOMIC MECHANISMS OF GHG EMISSION REDUCTION

The implementation of the GHG emission reduction controlling system should be accompanied by general 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 system. The following changes and amendments to general legal regulations should take place:

- introduction into the Constitution of the provision on the duty of environment and climate protection, and adoption of the sustainable development principle,
- passing of consulted project of Civil Code, which includes Article on offences against environment; it would be purposeful to stress clearly that not undertaking actions for the sake of GHG emission reduction is an offence,
- 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 discontinuation of actions meant to limit GHG emission, 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).

In curbing GHG emission reduction the greatest significance is assigned to charges for pollution emission and the so-called product charges. Charges for removing trees and bushes play important role in GHG emission abatement. Also subsidies are one of possible form of financial support for implementation of environmentally sound technologies.

Charges for emission depend on the volume and (or) the quality of pollutants emitted into the environment. In Poland, applied are the charge for CO_2 emission (0.04 USD'90/Mg CO_2), the charge for the emission of chlorofluorocarbons (25,750 USD'90/Mg CFCs), and the charge for methane emission (0.04 USD'90/Mg CH_4)[3]. The means received as a result of introduction of the above described charges are allocated to environmental funds. According to the currently binding legal regulations these means may be used for preferential credits for investments aimed at production technology, technical change, scientific research, or environmental education of the society, in order to reduce greenhouse gases emission.

Product charges are financial encumbrance included into the prices of products which constitute the source of pollution, both in the processes of their production and consumption (utilisation). They are characterised by a relatively high administrative effectiveness of product charges resulting from very simple procedure of calculating and enforcing. In Poland, introduction of product charges is at the stage of consideration.

Charges for removing trees and bushes, which to some extent reduce tree and bushes removal and, what follows, increase the level of CO_2 absorption. The receipts from such charges are allocated to local (communal) environmental protection funds and may be used only for the purposes connected with the reduction of greenhouse gases emission (e.g. additional financing of afforestation costs and afforestion of land being the property of a commune).

[3] According to rates as of 1996.

Charges for waste storage in Poland do not depend on potential methagenity of wastes. Part of means gained through this kind of charge can be allotted to additionally finance construction of installations for collecting and utilising CH_4 from landfills.

Subventions is a form 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 (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, and relevant voivodeship and commune 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 amortisation, if the environmental friendly tasks and assumed ecological 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 in virtue of implementation of new technological solutions in the national economy.

It is proposed to introduce subvention of cost afforestation and plant species with high ratio of CO_2 absorption.

Forest subventions would help expand 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. In the 90's some 3 thousand ha of farmland was afforested every year. Assuming that some 10% of receipts from carbon tax (charge) will be allotted to forest subvention, then, in the case of analysed variant, income in this virtue would amount to some 80 million USD'90. Such amount should assure subsidising afforestation costs of about 100 thousand of farmland per annum.

Subsidising of cultivation with a high rate of CO_2 absorption would expand areas of these plants resulting in increasing CO_2 absorption. Extent of subvention would be defined by difference between mean income from cultivating four basic cereals, and income from cultivating plants with a high rate of CO_2 absorption, calculated separately for each voivodeship. For this purpose not more than 10% of receipts of carbon tax (charge) could be allotted.

Economic instruments currently applied in Poland have to undergo serious changes since none of our instruments proved really effective with regard to control over GHG emission.

Carbon tax (charge) should be the most important instrument implemented as a part of the GHG emission reduction strategy. In Poland, already employed is charge for CO_2 emission at the level of 0.04 USD'90 per 1 Mg CO_2. This charge is, in fact, of implementing and educating character. It does not serve a function of stimulus because there have not yet been elaborated possible for application methods of CO_2 emission reduction on the output. Numerous attempts are being made all over the world to tackle this problem. Therefore, more rational seems to be introduction of charge for fuels. It can take the form of the product charge fuels (imposed on the input product in the process) in a form of: charge on energy volume of fuel, charge on pure carbon content in fuel, or mixed carbon-energy tax (charge). Out of the three aforementioned forms of charges, the most effective solution would be the mixed carbon-energy tax (charge), which is determined on the basis of carbon content in one energy unit of a given fuel. It is this variant that we recommend that should be introduced in Poland. The charge should include the following types of fuel: hard coal, brown coal (lignite), furnace oil, natural gas, and petrol. The aim of introduction of the carbon-energy tax (charge) includes the following:

- within the economy:
  - restructuring of energy carriers consumption in Polish economy in favour of liquid and gas fuels,
  - reduction of material and energy intensity of production processes in Polish economy; and
  - increase of the efficiency of energy consumption and utilisation.
- within environmental protection:
  - reduction of pollution emission in general, and reduction of CO_2 emission in particular.

The European Commission suggests introducing the carbon tax (charge) at the level of 22 USD'90/Mg CO_2. The simulation calculations indicate that introduction of carbon tax (charge) at such level in Poland is impossible for social and economic reasons. It may be treated as a sum proposed for the years 2020-2030. In the performed calculations assumption was adopted that charge rate should not cause an increase of expenditures for energy and fuels in households higher than 0.5%. It means that in the current social and economic situation it is possible to introduce a charge rate which will not exceed 5 USD’90/Mg CO_2. Introduction of this rate would result in 4.8% increase of the hard coal prices for households, 6.2% increase of the furnace oil prices, and 2.0% increase of gas prices as compared to fuel prices as of the I quarter of 1995. The charge rate would cause gas become the relatively cheaper heating fuel and as such it would become more and more popular for house heating. Results of research done by B. Fiedor’s team in Chorzów indicate that application of such rate will make cost of space heating with coal approach cost of heating with gas. The highest increase of expenses for energy and fuels as a result of introduction of carbon tax (charge) will occur in pensioners’ and the retired people’s households and will amount to 0.74%.

The results of the introduction of carbon tax (charge) in industry are dependent upon the branch and the sector of industry it affects. Date from hard coal and furnace oil balance show that putting tax on those energy carriers will bring about more remarkable increase of costs of energy production (power industry utilises 54% of hard coal and 50% of furnace oils). Simulation analysis showed that introduction of carbon tax (charge) reaching 5 USD’90/Mg CO_2 will cause rise of production and services costs in the most energy-intensive industries by about 2%. After a few-year binding period of the proposed rate, charge could rise smoothly every year or rapidly every several years.

Controlling the methane emission by means of economic instrument. In Poland introduced was a charge for CH_4 emission. Its rate amounts to 0.04 USD’90/Mg CH_4 and it is enforced in case of industrial plants. It is a symbolic payment and plays only an informational role as a forecast of introduction of motivational charge. Proposed in the elaboration in question realisation of this rate and expansion of its scope is in line with the state energy policy. Apart from industrial plants the tax should be extended over large breeding farms, (local and municipal) landfills, and filling stations.

Unit charge for methane emitted by breeding farms would refer to amount of CH_4 generated in breeding of 50 big head of cattle, which constitutes a basic *animal unit*. The charge would be extended over those farms which have more head of cattle than one animal unit and its multiplication. It was assumed that the charge should be proportionate to the price of natural gas. For the rates of 10%, 25%, 33%, and 50% of the price of natural gas, charge for animal unit would amount to 306, 765, 1010, 1530 USD’90 per annum respectively. Social acceptance can be granted to the variant I (charge equal to 10% of gas price). It would safeguard income reaching 16 million USD’90 per annum in the country scale.

The charge for methane emitted by landfills should only be imposed on large landfills, which collect over 10 000 tons of wastes per annum and are exploited for at least 10 years. The unit price can be set in the range between 10 % to 50% of natural gas price, which will cause strain on wastes disposal costs by 0.2% and 1.0% respectively, as well as increase of maintenance costs of households by 0.002% to 0.009%. Therefore, charge rate of 50% is acceptable for price of 1 m^3 of natural gas. The estimated receipts generated by such charge would amount to 77.4 million USD’90.

Functioning in Poland **the charge for methane emitted by coal mines** equalling 0.04 USD’90/Mg CH_4 performs an informational and educational role. There is a need of introducing a stimulus charge. Simulation analysis were carried out consisting in increase of charge to the level of 10%, 25%, 33%, and 50% of the price of natural gas in industry (natural gas price – 100 USD’90/Mg). The introduction of new rate of the charge for CH_4 emission in coal mines will increase the costs of extraction of 1 ton of coal by 0.16-0.80%. From the point of view of the society acceptable is variant which will increase the costs of coal extraction by 0.16% per one ton of coal. The introduction of the charge reaching 10% of price of 1 m^3 of natural gas will cause increase of the costs of extraction of coal in CH_4 polluted coal mines will weaken their position on the market until the equipment for CH_4 collection is installed. Then, the mines will recover their position since they will no longer have to pay the charges for CH_4 emission and, what is more, there will be some profit from the sale of this gas.

Introduction of the charge for CH_4 emitted by breeding farms and landfills, as well as the increase of the charge for coal mines in case of the analysed variants would bring about annual receipts of 96 million USD’90 per annum. Economic entities which start the construction of special equipment for collecting and utilisation of CH_4 should be exempted of the obligation to pay such charges.

Analysis of costs of implementation and functioning of system includes costs of preparation of changes, i.e. preparation of system’s conception and legal acts projects, but also, system implementation costs, system functioning costs, research costs, and emergency costs. System will also generate significant income. The main source of income will be income from carbon tax (charge) and charges for CH_4 emission. Sum of 800 million USD’90 per annum should be viewed as a feasible one. System functioning costs will amount to some 56 million USD’90, so they will constitute 7% of incomes generated by system. Making these means support GHG emission reduction enterprises should assure achievement of the main strategy goals.

The proposed set of instruments in each variant of the analysed strategy will result in hampering down of increase of emission of CO_2 and CH4, and partly also other greenhouse gases due to vast potential of energy saving in Poland. The GHG emission reduction system will cause reduction of pollution (of heavy metals, sulphur dioxide, nitric oxides). Should the necessity to implement the GHG system be ignored, the transfer process of Polish economy toward sustainable development 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.

Social approval will be determined by the scope and methods of teaching the social group (economic groups included) affected by a particular instrument about the objectives and financial consequences connected with that instrument. It will be necessary to make people aware of the idea, goal of implementation, financial consequences, technical possibilities of adopting to the changed 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.

Administrative enforceability means actual possibilities of the implementation of a particular instrument within the system. The designed system does not show any new institutions, which facilitates its implementation.

The proposed system meets criteria of efficiency. Its implementation will only depend on sufficiently strong political willingness and involvement of state services of environmental protection in preparation and implementation of the project.

11. RECOMMENDATIONS

In order to adapt the Polish economy to climate change and achieve the GHG emission reduction defined by the United Nations Framework Convention on Climate Change, it is recommended that the following enterprises should be undertaken in the analysed sectors of the economy:

11.1. GENERAL

1. It is essential to elaborate and continuously update 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. There is no need to distinguish any of the scenarios as the so called reference scenario assuming certain *pattern* development of the economy. Scale, time horizon, and interdisciplinary character of the problem of defining development strategy of the country in the light of variable and uncertain internal and external conditions, cause that the so called reference scenario may an agreed category. In the light of significant economic and social transformations starting from the economic level characterised by low efficiency, the lion's share of GHG emission reduction should be connected with improvement of efficiency.
3. Work aiming to elaborate the strategy of GHG emission reduction should continue. The Study in question is the first elaboration of this kind, and a number of factors as well as assumptions requires additional research and appraisal.
4. 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.

11.2. PARTICULAR

11.2.1. ADAPTATIONS TO CLIMATE CHANGE

Water resources

1. The following should be counted among the main kinds of activities aiming at preventing from negative results of climate changes:
   - new economic and legal means oriented towards cost-effective use of water by the population and industry,
   - periodical limitations in water in-taking by industry and agriculture during drought periods,
   - effective management of the existing water resources,

- development of the technical infrastructure of the water management, i.e. construction of new storage reservoirs, transfer of water between river 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 improvement 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 vulnerability of the national agriculture to climate changes, particularly investigating irrigation strategies.
6. As it is shown in experience of several European countries, improvement of water use in the municipal 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 rise 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

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 means for smoothening 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 not so long perspective, i.e. till 2030, it is necessary to immediately undertake research aiming to prepare Polish agriculture to effective functioning in the conditions of the changing climate. Research of this type is already under way on the large scale in many countries world-wide.

11.2.2. EMISSION REDUCTION

Electricity 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 extending 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 able to adjust.
4. The following are suggested within domain of the implementation of the above-mentioned principles:
   - implementation of principles allowing for introduction of modernisation enterprises at energy users, financed or stimulated by energetic companies,
   - 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,
   - consistent preference, in the legal and financial systems, of enterprises improving efficiency of energy use,
   - further division of energetic systems through consistent implementation of the access principles *of the third party* in network,
   - arising interest at end users through tax allowances, labelling, informational programmes, educational programmes for children and youngsters,
   - establishment of local investment funds for acceleration of the energy economy restructuring towards improvement of its economic efficiency and fulfilling ecological conditions.
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. Choice 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. In steering the GHG emission reduction an important role will be played by macroeconomic regulations, such as budget, employment, income of families. The use of positive mechanisms (prices, tax allowances) are seen as the most efficient for they encourage to desired, but free choices making the economy more dynamic. 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.
7. Mechanisms of financial incentives should be established for producers and purchasers of devices compliant with the defined energetic and ecological standards.
8. It is recommended to undertake preparations for implementation of the carbon tax or charge considering the following:
   - 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 carbon tax (charge) is 50-100 USD'90/Mg C, and investment subsidies – 0.2-0.3% of total investment. Making use of the carbon tax (charge) 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 carbon tax (charge) 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 (charge) 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 (charge) before the year 2000.

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 reduction of 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 Company in order to gain the gas from other countries.
10. 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.
11. Owing to ecological and economic potential attractiveness of the nuclear energy, 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, 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.
12. 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 should be continued on their microeconomic 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.
13. Intensified should be the activities aiming at use of the following:
    - geothermal energy,
    - biomass,
    - water energy.
14. 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 intense undertake 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 concerning the economic instruments leading to demand reduction, 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 import energy (as a result of the European energetic treaty) from 2002 at the latest.
17. It is recommended that during international negotiations the 1988 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 CO_2 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.
18. 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 CO_2 emission reduction level for all countries, additional obligations

in virtue of such commitment would be for Poland comparable with commitments of such countries like Germany or the United Kingdom. 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 (FCCC, IPCC, IEA, OECD).
2. Reduction of the GHG emission in industry (together with emission reduction in the power sector connected with electricity and heat consumption by industry) in 2030 by approx. 40% in comparison with the year 1988 (about 90 million Mg of CO_2 equivalent), 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. It means that instead of the expected emission according to the base-line scenario at the level of approx. 450 million tons, emission would reach some 360 million tons (about 160% of 1988 emission).
3. Period till 2000 should be used for preparing instruments of energetic and environmental 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-line scenario) should be stimulated by instruments of the state industrial policy aiming at reconstruction of Polish industry. After 2005, 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 were discussed in chapter 9.4. They include nation-wide and local activities. In the first stage, the following are recommended as the most promising:
   - industrial and fiscal policy promoting vehicles with low energy consumption,
   - sharpening standards of fuel 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 above-mentioned 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

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.

Taking into account specific structure of the Polish agriculture (over 2 million farms with various acreage, production profile, and methods of cultivation and breeding) it is necessary to make a choice of particular options for given kinds of farms. Realisation of these options in the nearest future requires, among other things, the following:

- elaboration of bio-technological method of gaining seedling of *Miscanthus giganteus* plants *in vitro* as well as setting off their mass-production,
- drawing up new technologies of growing and harvesting plant biomass with destining in to renewable sources of energy,
- gaining transgenic varieties of resistant plants to diseases and pests,
- increase of activity and effectiveness of assimilating atmospheric nitrogen by symbiotic and free-living soil bacteria,
- elaborating new technologies of production of plant protein confection for food production,
- accelerating the rate of afforestation up to 30 000 hectares 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 triticale,
   - biogas.
3. It is suggested to make use, as an economic instrument, of the 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.
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 Government 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 appliances, 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 of subsiding thermal renovation of buildings for all groups of buildings owners.
4. Stimulating development of advisory bodies in the sphere of energy consumption in buildings and households, in order to facilitate identification of possible, economically grounded energy-saving enterprises.

5. 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.

11.2.3. 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 United Nations Framework Convention on Climate Change, Convention on Ozone Layer Protection as well as specific social, economic and ecological situation of Poland. In order to ensure a competent implementation and functioning of the GHG emission reduction system the following should be undertaken:

In the sphere of political and organisational activities

1. A statement should be introduced in the draft of the new constitution on:
   - sustainable development as a basis for activities in the sphere of economic, social, policy activities,
   - statement that would safeguard equal rights for using the goods and assets of the environment for economic entities and physical persons.
   - introducing duty to protect the environment (including climate).
2. In existing legal acts the following amendments should be introduced:
   - 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,
   - in the civil proceedings code there should be introduced a release from registration fees for civil issues within the environment protection and extent of claims in virtue of violation of the environment and a method of proceeding.
3. 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 sustainable 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,
   - adopting a principle that the basic criterion in defining unit rates of charges should be marginal costs of pollution reduction,
   - define principles of carbon tax (charge) implementation with consideration of the European Union requirements.
4. In the new drafting of the energetic policy the following issues should be highlighted:
   - necessity to introduce measuring of energetic facilities,
   - 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,
   - defining a principle of prices and tariffs of energy carriers stimulating effective use of energy,
   - defining standards and implementing a requirement of labelling energy effectiveness of facilities offered on the market,
   - defining a principle of amortising of energetic facilities, with a particular emphasis placed on high efficiency facilities,
   - need to introduce a system of agreements between energy suppliers and plants for long-term improvement of energy use efficiency and emission reduction.
5. 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.
6. In the industrial policy the following should be stressed:
   - implementation of programmes of metallurgy, fuel-energy sector, and heavy chemical synthesis restructuring,
   - creation of conditions favouring the development of small and medium enterprises, including amendments to law, particularly civil and commercial one, in the context of influencing on establishing and functioning small and medium enterprises according to solutions of the European Union,
   - stimulating development of non-energy-intensive and modern sectors of industry, the so called *high chance*,

- elaboration and implementation of system of monitoring of structural changes and technological reconstruction of industry,
- defining of priorities of research and development work oriented towards modern, pro-ecological, material-, and energy-saving technologies of production, and ensuring financing them.

7. While formulating the state agricultural policy, the following should be introduced:
   - preferring cultivation with a high ratio of CO_2 sink,
   - 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 CH_4 emission in cattle growing.

In the sphere of the environment protection law

General legal regulations of implementation of the system of strategies of the GHG emission reduction.

1. In the new drafting or amendment to the Statute on Environment Protection and Shaping the following activities should be undertaken:
   - to introduce new instruments: carbon tax (charge), charge for CH_4 emission from farms and municipal landfills as well as forest subvention, and subvention for cultivation with a high ratio of CO_2 absorption,
   - 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 carbon tax (charge) is destined for the forest subvention. The remaining part should be devoted for: subsidising cultivation with a high ratio of absorption, supporting and organising the environmental auditing, granting the credits guarantees risen in connection with realisation of investments affecting the GHG emission reduction and ecological education.
   - 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 and functioning costs. The term *available technology* means technology which is used at least by one producer in the world.
2. In the Statute on Forests, another source of Forest Fund should be pointed at, i.e. 10% of income from the carbon tax (charge). Also the statement should be provided with stipulation of use of that income for forest subventions.
3. 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 newly introduced 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,
   - calling 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,

   Basing on the draft of the Energetic Law, whose legislative process is under way in the Sejm 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,
   - identification of programs of activities for their realisation,
   - meeting the condition of defining the needs for fuels and energy in relation to the GDP, taking into account protection of the environment and rationalisation of the use of fuels and energy,
   - defining the price and tariffs policy,
   - defining the ownership 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,
   - obligation to produce and import facilities and installations compliant with the defined requirements,

- energetic labelling of products,
- defining fuel quality requirements.

Despite many positive legal regulations in the energetic economy, included in the Statute project, emphasised should be a low number of resolutions referring to direct use of fuels and energy by dispersed receivers.

Detailed legal regulations of implementation of the GHG emission reduction system

1. Decree of the Council of Ministers on the carbon tax (charge). The decree can be brought into life on the basis of the amendment to the Statute on Environment Protection and Shaping , 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 sub-account 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 Charges for CH_4 Emission from Farms and Communal Landfills. The decree can be brought into life on the basis of the amendment to the Statute on Environment Protection and Shaping, 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: CH_4 emission,
   - economic entities: owners of farms with more than 50 head of cattle, 150 head of pigs, 6000 head of poultry as well as administrators of communal dumping sites which are exploited for more than 10 years and collecting at least 10 thousand tons of wastes per annum,
   - way of calculating and amount of the unit sum of payment: payment would be calculated on the basis of every m^3 of communal waste materials (also from the agricultural and food industries) taken to landfills, amount of charge would be set by units exploiting the landfills on the basis of vouchers for accumulating wastes, charge for CH_4 emission from breeding farms would be paid in on the basis of administrative decision granted by commune organs,

- ways of paying in: charges would be paid in to an account of voivodeship funds of the environment protection and water management, and means disposed according to scheme adopted in case of charges for disposing of waste materials,
- entity easements: owners of farms and administrators of landfills who pull out CH_4 and use it.

3. Change of the Decree on Charges for Economic Use of the Environment and Introducing Changes to It. A new rate of charge for CH_4 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 Environment Protection and Shaping, 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 carbon tax (charge). Subsidies should be granted on the basis of competition of quality certificates granted by the State Committee of Normalisation of Measures and Quality, and the Agency of Technique and Technology.
5. Decree of the Minister of Environmental Protection, Natural Resources and Forestry on Principles of Granting Forest Subvention. The Decree can be brought into life on the basis of the amendment to the Statute on Forests. The Decree should concern principles of entering a contract on subvention among owners of land, Regional Directorate of State Forests and the Forest Fund. In an appendix to the Decree: pattern of a contract on subvention.
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: standards of energy consumption for respective kinds of household facilities and equipment.
   - entity: designers, producers, importers of household facilities and equipment.
7. Decree of the Council of Ministers on Negotiating Conditions of Implementation of Programs of Pro-ecological Restructuring of Enterprises. The Decree should concern:
   - subject: defining a scope of the pro-ecological restructuring of enterprises, constituting the subject of negotiations, defining a scope of duties of the State Inspectorate of Environment Protection and Departments of Environment Protection of the Voivodeship Offices in inspiring pro-ecological restructuring, defining a content of agreements made between enterprises and State Inspectorate of Environment Protection, which would make up a basis for gaining financial assistance by enterprises from special funds means,
   - Entity: economic units, organs of territorial self-government, state administration organs.

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,
- educating in the field of *energetic auditor*,
- program of development of publications addressed to energy users taking into consideration problems of climate protection.

12. GENERAL CONCLUSIONS

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 United Nations Framework Convention 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 and 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 carbon tax (charge) 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 consumption 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.**

13. ISSUES RESULTING FROM COUNTRY STUDY ELABORATION THAT REQUIRE FURTHER RESEARCH

Realisation of the Study allowed to formulate topics of further scientific work, analysis, as well as technical, economic, and social expertise. The list provided below includes tasks which are currently considered to be the most important, and does positively not exhaust all the issues**.**

Among the most urgent tasks in the years 1996-1997 is elaboration of strategy of reduction and absorption of GHG emission in forestry and agriculture. Apart from the aforementioned subject, out of already elaborated partial strategies there is a need emerging of supplementing the following issues:

Scope of needs

Within adaptation to climate change

- Society adaptation to climate change and their consequences
- Water demand of agriculture and forestry in changed climate conditions.
- Changes of coastal ecosystems resulting from climate changes and quantitative assessment of potential ecological losses.
- Adaptation of water and land systems resulting from climate changes.
- Economic appraisal of influence of climate changes upon regional and local ecosystems as well as water resources.
- Changes of dangers on the side of river floods in conditions of potential rise of the sea level.
- Influence of soil salinity on water supply and activities of agricultural and food sector.
- Endanger of water ecosystems in conditions of rise of water temperature.
- Cultivation of new basic varieties of crops characterised by enhanced resistance to drought and higher temperatures, as well as more effectively utilising CO_2 from the atmosphere.

Within the emission abatement activities

- Elaboration of methodology for formulation of strategy of generation and utilisation of energy, taking into account non-energy socio-economic goals.
- Evaluation of possibility to utilise nuclear energy with consideration of modern safeguarding techniques, and utilisation and disposal of used fuel.
- Research to create conditions of acceptance by the society of nuclear technologies in energy sector.
- Research of accepting of increase of costs of living resulting from activities for the good of depleting influence of the economy and human living upon climate changes.
- Estimation of profits and losses while using alternative transport strategies basing on long-term forecasts of transport.
- Drawing up reliable long-term forecast of transportation
- Appraisal of effectiveness of modernisation in municipal sector within thermal renovation and heating systems automatics.
- Drawing up of legal and economic principles of utilisation of renewable fuels with evaluation of a possibility of their growth.
- Assessment of possibilities of reduction or stabilisation of GHG emission in respective sectors, basing on long-term strategies of development of particular branches and enterprises, especially in sectors not included in the carried out analysis.
- Drawing up of principles of improving gas management in industry
- Verification of analysis conducted for the chemical and petrochemical industry in which preliminary analysis show inefficency of the technological reconstruction option
- Estimation of technical potential of industrial technologies which now are unprofitable or are in the process of research and development
- Elaboration of basis of modification and legal changes, as well as concepts of the energetic economy regime, creation of instruments shaping long-term needs of the society within energy demand
- Elaboration of long-term strategies of enterprises development
- Verification of ratios and estimation of the forecast demand for energy in non-residential construction and transport.
- Verification of energy consumption and GHG emission indicators for various means of transportation
- Elaboration and implementation of monitoring system of GHG emission changes from communal and industrial dumping sites, as well as gas piping and piping.
- Establishment of financial incentives to implement energy-saving and environmentally sound actions in industry, transport and municipal sector
- Elaboration of a national, widely-available system of information on technical, technological, economic, and statistical problems within data and advising, connected with similar international systems.
- Analysis of possibilities and eventual elaboration of *emission trade* system for greenhouse gases.
- Assessment of possibilities and choice of instruments of energetic and ecological policy according to the lowest costs with maximal effects on the national, regional, and local scale.
- Drawing up of directions for improving efficiency of actions in agriculture aiming to implement emission reduction options
- Elaboration of technologies improving efficiency of fodder use and milk efficiency cows , as well as intensification of cultivation of new varieties of rape seed and triticale for energetic purposes
- Evaluation of market needs and conditions of commercialisation of development of devices using renewable energy
- Assessment of pilot solutions using renewable energy sources
- Assessment of strategy of stabilisation/reduction of GHG emission against the background of strategies employed in European Union countries.
- Appraisal of impact of GHG emission reduction strategies upon rate and scope of the Polish economy’s adjusting to the requirements of the European Union
- Education of the society for understanding and accepting activities for the sake of limiting reasons and potential effects of climate changes, including:
    - ⇒ recommendations and guidelines with regard to programmes of formal education,
    - ⇒ forms, methods, and content of informal education,
    - ⇒ universally available training materials, also within co-operation with mass-media.

Within international aspects of climate protection policy

- Elaboration of regional scenarios of climate change
- Estimation of potential enhancement ecosystems role as sources and sinks of carbon dioxide and methane
- Climate sensitivity on GHG concentration changes in the atmosphere
- Set up regional centres for collection, analysis and distribution of climate system data
- Research on ocean circulation patterns
- Research on vulnerability of climate to changes of greenhouse gases concentration with scenarios of changes of frequency of occurrence of extreme values of meteorological elements.
- Analysis of chemical processes occurring in the atmosphere resulting from an increase of CFC compounds, their substitutes, methane and aerosols emission.
- Climate change detection
- Estimation of climate change influence on regional and local ecosystems and natural resources
- Social and economic consequences of climate change
- Elaboration and implementation of quantitative methodology of evaluation of risk of climate changes.

Moreover, the constant verification of the proposed reduction instruments and the elaborated long-term GHG emission strategy, against the background of the emerging socio-economic strategies of the country is necessary. It seems purposeful in the future to include GHG emission strategies as an integral part of such strategies.

ABBREVIATIONS

BALANCE	module of ENPEP package for simulation of energy economy development
CIA	Cross-Impact Analysis
CHP	Combined Heat and Power
CLIRUN3	Climate/Runoff model, 3rd version
CS–DB	Country Study Data Base
CSMT	Country Study Management Team
CSP	Country Study Program
EBRD	European Bank of Reconstruction and Development
EFOM	Energy Flows Optimisation Model
EIB	European Investment Bank
ELECTRIC/WASP	module of ENPEP package for optimization power sector development
ELFIN	model for power system simulation
ENPEP	Energy and Power Evaluation Program
FCCC	Framework Convention on Climate Change
FEWE	Polish Foundation for Energy Efficiency
GACS	GHG's Abatement Costs Spreadsheet
GHG	Greenhouse Gases
GFDL	Geophisical Fluid Dynamics Laboratory
GHG-AW	model for forcasting of GHG emission reduction strategies in transport sector
GISS	Goddard Institute for Space Studies
GDP	Gross Domestic Product
HIPRE3+	Hierarchical Preferences Decision Analysis
IBMER	Institute for Housing, Mechanization and Elecrification in Agriculture
IBW	Institute of Hydroengineering
IEA	International Energy Agency
IGeof	Geophisical Institute
IPCC	Intergovernmental Panel on Climate Change
IPPT	Institute of Fundamental Technological Research
IRR	Internal ReturnRate
LNPC	Levelized Net Present Cost
MERS	Macroeconomic Reference Scenario
OECD	Organization for Economic Co-operation and Development
O&M costs	Operating and Maintenance costs
SDM–NE	Simulating Dynamic Model of National Economy
toe	tons of equivalent oil
USEPA	United States Environmental Protection Agency