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Republic of Belarus

FIRST NATIONAL COMMUNICATION

in Response to Belarus' Commitments Under the UN Framework Convention on Climate Change

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ABSTRACT

NATIONAL COMMUNICATION, GREENHOUSE GASES, EMISSIONS (DISCHARGES) SINKS (REMOVALS), EMISSION FACTOR, ENERGY, INDUSTRIAL PROCESSES, SOLVENTS USE, AGRICULTURE, LAND USE, FORESTRY, WASTE, VULNERABILITY AND ADAPTATION, GHG EMISSIONS REDUCTION STRATEGY.

The objective of this work is to prepare the First National Communication in response to commitments of the Republic of Belarus under the UN Framework Convention on Climate Change for the Annex 1 Countries of the Convention; develop greenhouse gas (GHG) inventories for 1990, 1995, 1999, 2000 in accordance with the 1996 Methodology of the Intergovernmental Panel on Climate Change (IPCC) and estimate the contribution of each GHG into the total global warming effect (GWE); provide information on policies and activities aimed at reducing GHG emissions and make forecasts up to 2020; and prepare the detailed data to assess the potential climate change effect on agricultural, forest and aquatic ecosystems, social environment and to identify measures to adopt them to the climate change.

With due regard to the above objective, in the course of work the greenhouse gas emissions/removals inventories encompassing the following sectors have been prepared: energy; industrial processes; agriculture; land-use change and forestry; and waste; the policies and activities aimed at reducing GHG emissions and their projected indices, assessment of vulnerability and adaptation of the national economy to the climate change are presented herein.

The studies conducted allow the most critical spheres of mitigating the GHG emission impact on the climate be identified in the future.

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ABBREVIATIONS

IPCC	–	Intergovernmental Panel on Climate Change
NMHC	–	Non-methane hydrocarbons
GHG	–	Greenhouse gases
UNFCCC	–	United Nations Framework Convention on Climate Change
t. f.e.	–	Tonne of fuel equivalent
GWP	–	Global warming potential
GWE	–	Global warming effect
GDP	–	Gross domestic product
Cal.	–	Calories
J	–	Joule
EE	–	Energy economy
USSR	–	Union of Soviet Socialist Republics
BSSR	–	Byelorussian Soviet Socialist Republic
CIS	–	Commonwealth of Independent States
RF	–	Russian Federation
USA	–	United States of America
CM	–	Council of Ministers
MAF	–	Ministry of Agriculture and Food
ME	–	Ministry for Emergency
FC	–	Forestry Committee
MNREP	–	Ministry of Natural Resources and Environmental Protection
MOE	–	Ministry of Education
MPE	–	Ministry of Power Engineering
IHE	–	Institution of higher education
UN	–	Organization of United Nations
NAS	–	National Academy of Sciences
INRUE	–	Institute for Natural Resources Utilization and Ecology
IEB	–	Institute of Experimental Botany
BRC ECOLOGY	–	Belarusian Research Center “Ecology”
HPP	–	Hydropower plant
VOC	–	Volatile organic compounds
GCM	–	Global climatic models
NAR	–	Northern agroclimatic region
SDW	–	Solid domestic waste
CAR	–	Central agroclimatic region
SAR	–	Southern agroclimatic region
UNEP	–	United Nations Environment Program
HTF	–	Selyaninov hydrothermal factor
PI	–	Pathogenicity index
PIAH	–	Pathogenicity index of air humidity
PIICAP	–	Pathogenicity index of interdiurnal change in atmospheric pressure

PIWS – Pathogenicity index of wind speed
PIAT – Pathogenicity index of air temperature
CPI – Complex pathogenicity index
TBE – Tick-borne encephalitis
WNF – West Nile fever
LCZ – Landscape and climatic zone
O – Oblast
S – sanatorium
AREFS – Automated regional ecological forecast system
SFF – State forest fund
SSTP – State Scientific and Technical Program
RW – Research work
GWL – Ground water level

Prefixes and Multiplying Factors

Prefix	Symbol	Order
Kilo	**k**	10^3
Mega	**M**	10^6
Giga	**G**	10^9
Tera	**T**	10^{12}
Peta	**P**	10^{15}

INTRODUCTION

Signing and ratification of the UN Framework Convention on Climate Change (UNFCCC) by the Republic of Belarus (signed 11.06.1992, ratified 11.05.2000 and entered into effect 09.08.2000) demonstrate that Belarus is seriously concerned with the problem of greenhouse gases and their affect on climate change.

To efficiently plan and manage Belarus' national economy, a large number of economic, social and natural indicators needs to be analyzed and accounted. To this end, the database and a system for its efficient application for planning and managing different economic activities should be developed. The most critical component of the database is the climatic data.

An ultimate objective of the UNFCCC is to stabilize greenhouse gas concentration at such level that would prevent harmful man-made interference into the climatic system. This level needs to be maintained over the period of time long enough for ecosystems to naturally adapt to climate change. The UNFCCC appeals to all parties concerned for pulling their efforts to address the following three targets:

- developing, regularly revising, publishing and presenting National Inventories of anthropogenic emissions of all greenhouse gases not controlled by the Montreal Protocol to the Conference of the Parties;
- using comparable methodologies for developing inventories of greenhouse gas emissions from sources and removals by sinks;
- formulating, implementing, publishing and regularly revising national programs providing for actions to offset anthropogenic emissions-induced climate change to bring down anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol to the their levels.

The main commitment of the Republic of Belarus under the UNFCCC provisions are as follows: (i) to reduce anthropogenic GHG emissions, primarily, CO_2; to prepare, publish and systematically revise and submit the National Inventories of anthropogenic GHG emissions from sources and sinks (except ozone-depleting gases, Art. 4.1a, UNFCCC) to the Conference of the Parties. The Inventories should be prepared based on the IPCC methodologies approved by the Conference of the Parties and be provided in a transparent and verifiable manner.

With due regard to the above, preparing the National Inventories pursues an objective of estimating the current greenhouse gas emission levels to identify perspective program interventions and measures aimed at reducing the affect on the climate change.

The First National Communication of the Republic of Belarus has been prepared in accordance with the following methodical documents:

1) Guidelines for Preparing National Communications of Annex I Parties to UNFCCC, Part I: Guidelines for Presenting Reports on Annual Inventories (Document FCCC/CP/1999/7);

2) Guidelines for Preparing National Communications of Annex I Parties to UNFCCC, Part II: Guidelines for Presenting Reports on Annual Inventories (Document /CP/1999/7);

3) UFCCC Guidelines for Reporting on Global Climate Observing System (Document /CP/1999/7);

4) Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories;

5) Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, IPCC, 2000;

6) IPCC Synthesizing Report *Climate Change,* 2001;

7) IPCC Technical Guidelines for Assessment of Climate Change Impact and Adaptation, UNEP/WMO, 1994;

8) Guidelines on Methods of Assessment of Climate Change Impact and Adaptation Strategies, UNEP, 1998.

In addition to the above documents, national regulatory and methodical documents related to the inventories, specific emissions calculation, etc. have been used. The task force involved in preparing the inventories has also used a multi-year experience, data and findings of previous studies conducted within the framework of national tasks.

The provided data encompass the following six modules:

1) GHG emissions in the energy and raw-material processing sector (CO_2, CH_4, N_2O, NO_x, CO, NMHC, SO_2);

2) GHG emissions in the industrial processes sector (CO_2, CH_4, N_2O, NO_x, CO, NMHC, HFC, SO_2). Fluorocarbons are not produced in the Republic of Belarus. HFC 134 and 134a are used as a refrigerant, with HFC 134 accounting for less than 0.5% of the total volume. Therefore, only HFC 134a emissions have been calculated. The calculated HFC aggregate emissions are extremely low ~ 0.001 Gg, i.e. it may be actually neglected;

3) GHG emissions associated with solvent use (volatile non-methane organic compounds);

4) GHG emissions and removals in the agriculture (CH_4, N_2O);

5) Land-use change and forestry (removals «-« CO_2);

6) GHG emissions in the waste sector (CH_4, N_2O).

The inventories have been prepared for the following period: the base year of 1990; 1995 - the year of the maximum decline in output; and 1999 and 2000. This period encompasses all specific aspects in the Belarus' national economy development.

The National GHG Emissions Reduction Strategy has been developed based on experience of other countries in preparing the respective data, specifics of development of Belarus, as well as on the results of work on GHG inventories and assessment of vulnerability and adaptation of the social and economic system to the climate change, and also other data.

The document contains a detailed information on assessment of potential climate-change effect on as follows:

- agricultural, forest and aquatic ecosystems;
- climate-dependent sectors of economy (agriculture, forestry, water economy);
- social sphere; and

it also contains assessment of measures aimed at adapting them to the climate change.

The collected and analyzed data had to meet the following requirements: consistency, transparency, comparability, completeness and accuracy.

To compare the contribution of different greenhouse gases, their equivalent has been used: CO_2 – 1; CH_4 – 21; N_2O – 310.

The IPCC software was used for computation. Tables with summarized greenhouse-gas inventory data are prepared in a special IPCC-designed format.

The National Communication has been prepared with the financial support of the GEF and IBRD. The GEF Project Manager is Shevchenok V.N., MEM.

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- Ministry of Economy
- Land Resources, Geodesy and Cartography Committee
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- Ministry of Housing and Utilities
- Forestry Committee of the Council of Ministers of the Republic of Belarus
- Ministry of Agriculture and Food
- Belarusian State Petrol and Chemistry Concern *Belneftekhim*
- State Energy Efficiency Committee of the Council of Ministers of the Republic of Belarus
- Ministry of Power Engineering
- Ministry of Statistics and Analysis
- Ministry of Education
- Republican Hydrometeorological Center

Their comments were helpful in preparing the final version of the National Communication.

Summary

National Circumstances

Belarus, the USSR republic up to the end of 1991, is located in the Central East Europe and categorized as the economy in transition. The country's area is 207.6 thou km^2 (2.1% of the Europe area). The population size is 10.0 million as of the beginning of 2001. The capital of Belarus is Minsk.

Belarus is a landlocked country and borders Russia, Ukraine, Poland, Lithuania and Latvia. Its area stretches for 560 km from north to south (from 56°10′ to 51°16′ northerly latitude) and 650 km from west to east (from 23°11′ to 32°47′ easterly longitude). Belarus is administratively divided into 6 Oblasts comprising 118 Districts.

Belarus is located in the moderate climatic zone. Specifics of the country's climate are defined by its geographical location in middle latitudes, relative proximity to the Atlantic Ocean, prevailing western transport of air masses, and flat relief not impeding their propagation in any direction. These conditions define predominance of moderately continental climate in Belarus.

Supply of total solar radiation reduces from south to north from 4,100 to 3,500 MJ/m^2 a year, with 50% of solar heat influx accounting for May-July and 5% - for November-January.

Currently, Belarus is categorized as the economy in transition. Analysis of dynamics of major economic indicators and fuel consumption over the period in question allows for identifying two stages characterized by different trends of the GDP energy intensity and GHG emissions in Belarus.

The first stage covers 1990 – 1995. This period is characterized by slump in the GDP and fuel consumption, with the rate of fuel consumption reduction exceeding that of the GDP fall. The fuel consumption reduced by 44%, while GDP – by 35%. Thus, this reduced energy intensity of the economy. Naturally, the Belarusian energy sector reduced the GHG emissions over the given period. This has been conditioned mainly by lower fuel consumption and the change in the pattern of the fuel used to some extent.

The second stage covers 1996 – 2000. During that period, Belarus took important steps to manage the economic crisis and pursue the energy conservation policy which were provided for by *Main Guidelines of Socio-Economic Development of the Republic of Belarus for 1996–2000*, *Main Spheres of the Energy Policy of the Republic of Belarus for a Period up to 2010* and *Republican Energy Conservation Program up to 2000*. As a result, the GDP increased by 36% over the five-year period and fuel resources consumption stabilized. Hence, economy energy intensity further reduced.

Given the above, 1990 has been taken as the base year.

National Inventory of GHG Sources and Sinks

The conducted studies have demonstrated that greenhouse gas emissions from different national economy sectors are responsible for the global warming effect.

The major contributor is carbon dioxide, total emissions of which amounted to 72,888.15 Gg in 2000, or 58% of the base 1990 level and 91% of the level of 1995, that is the year of maximum decline in GDP and emissions.

CO_2 emissions accounted for about 63% in 2000 of the total global warming effect. Dynamics of change in CO_2 sinks over 1990-2000 is not so significant as that of emissions. In 2000, they amounted to 39,565.02 Gg, or 108.7% compared to 1990 and 1995.

CO_2 emissions are mainly provided by the *Energy* module – 51,026.74 Gg, or 70%, while the module *Land-Use Change and Forestry* is responsible for CO_2 sinks – 39,565 Gg, or 100%.

Methane emissions amount to 12,839.19 Gg of CO_2 equivalent, or 24.27% of the total GWE, while the energy provides 20%, agriculture – 34.6% and waste – 21% of the 2000 level. Compared to 1990 and 1995, energy and agriculture show most significant changes.

N_2O emissions in 2000 amounted to 6,748.8 Gg of CO_2 equivalent, or 12.75% of the total GWE.

In general, the global warming effect in 2000, with sinks being accounted, amounted to 52,911.13 Gg. Sinks reduced CO_2 emissions by 54.3% and GWE by 35%. In 1990, sinks reduced the GWE by 10% and in 1995 by 27.1%.

The rate of change in the GWE compared to that of the GDP over 1990-2000 is significantly higher, with the GWE continuously decreasing. GHG emissions in the *Energy* module are mainly responsible for the decreasing.

Carbon oxide emissions are defined by the transport-related emissions in the *Energy* module.

CO emissions reduced to 756.5 thousand tonnes in 2000 and accounted for 40% of the base 1990 level, or 54% compared to the 1995 level. The decreased freight and passenger traffic is mainly responsible for the CO emissions reduction.

Emissions of non-methane organic compounds are mainly defined by emissions from transport in the *Energy* module and partially in the *Solvents* module. The reduced transport-related emissions primarily resulted in the reduction due to the above-mentioned reasons.

Nitrogen oxide emissions, defined predominantly by energy processes, also reduced.

Sulfur dioxide emissions are defined mainly by emissions in the *Energy* module and reduced by 55% from 1990-1995 and by 74% by 2000 compared to 1990 and amounted to 213.15 thousand tonnes.

Decreasing fuel consumption combined with decreasing fuel oil fraction and increasing gas fraction contributed to the reduced emissions.

The uncertainty of activity data and emission factors have been determined primarily through expert appraisal and changed from 1 to 35% in different items. The activity data in the *Solvents* module are characterized by the highest uncertainty and in the agricultural sector it amounted to 20%, while in the main module – *Energy* – the uncertainty of the activity data and emission factors is not so significant. This actually determined the total combined uncertainty of inventory data at a level of 3.056%.

The projected increase in GHG emissions is conditioned by the output growth in all industrial sectors, while science-intensive production facilities are prioritized. Given this factor and prioritization of resource/energy saving technologies, the GHG emissions growth will be lower than that of the GDP.

National GHG Emissions Reduction Strategy for Economy of the Republic of Belarus

The following targets are to be addressed in the future by developing the energy economy (EC):

- meeting to the maximum requirements of domestic consumers in fuel and energy resources, predominantly by utilizing local resources;

- providing energy security of the country and enhancing its energy independence by optimizing the energy budget structure (increasing the share of secondary energy resources, local types of fuel, unconventional and renewable energy sources, namely, wind/solar/bio power engineering and midget hydropower plants), extensively introducing novel effective electric power generation technologies and implementing energy conservation measures in all sectors of the economy, including the social sphere;

- improving forms of interaction (impact) between EC and environment to mitigate adverse effect on the nature.

The structure of electricity-generating sources in the power engineering sector is to be optimized by introducing combined-cycle and turbine technologies, increasing electric power generation through heating cycle, converting boiler plants to mini-heating and power plants (HPP), thereby allowing the ever-growing demand for electric energy to be met to the maximum and efficiency of supplying heat to Belarusian settlements to be increased.

The priority spheres in the chemical and petrochemical industries include as follows:

- developing new generations of chemical products, primarily state-of-the-art chemical fibers and yarn, plastics, elastomers, advanced mineral fertilizers and chemical ingredients of feed mixtures, products of large-scale and small-scale chemical sector and also consumer goods;

- systematically implementing novel technologies to promote resources saving, production ecologization and rational nature management starting from 2006 (following the basic modernization of enterprises) as the sector's priority sphere;

- focusing on comprehensive raw materials processing and waste utilization. This would require development of basically new range of facilities for treating gaseous, liquid and solid substances capable of reducing anthropogenic impact on the environment; increasing the range of catalysts and initiators of new-generation reactions and processes based on them to increase the production of olefine polymers, organic synthesis products and other ecologically clean products.

The State Scientific and Engineering Program of *Developing and Implementing Novel Materials, Energy-Conservation Technologies and Resource-Saving Structural Systems of Dwelling Houses Reducing Resources and Energy Consumption in the Process of Housing Construction and Maintenance* is to be implemented in the construction sector.

The priority spheres of the transportation sector development in terms of main parameters are to be as follows:

- restructuring and modernizing most critical communications, facilities and systems to bring them into compliance with world standards;

- renovating and restoring the production potential, replacing depreciated and obsolete equipment and transportation facilities;

- creating enabling environment for attracting transit flows;

- improving and tightening the ecological control over operation of transportation facilities.

An integrated system of environmental measures is designed to reduce (decrease) the adverse effect of transportation facilities operation on the community and environment in the near future.

Accumulated scientific knowledge and experience allow for developing and implementing a range of institutional/economic and engineering measures reducing carbon dioxide emissions from disturbed bogs. These measures include as follows:

- ecologically restoring disturbed bogs by rebogging to resume peat-formation processes;

- bringing the structure of crop areas on reclaimed peat soils in compliance with melioration projects and scientifically substantiated recommendations;

– changing over to ecologically and economically substantiated methods of using degraded peat soils;

– preventing fires on peat lands.

In accordance with the developed GHG emissions forecast, the trend toward the increased GWE would be observed by 2020. In general, according to the optimistic scenario the GWE would amount to 76,512.72 Gg in 2020 that is actually 1.5 times higher than the aggregate GWE in 2000 and by 36.5 % lower compared to the base 1990 level (Table 3). However, the global warming effect would be growing significantly slower than the GDP. It would increase mainly through GHG emissions in the *Energy* sector which would account for 98% of the aggregate GWE by 2020. The contribution of the industry and *Waste* sector to the GWE would be minor – 2.37% and 2.97%, respectively, agriculture – 19.96%. The *Land-Use Change and Forestry* sector would remove about 24.17% of greenhouse gases due to sinks.

CO_2 emissions totaling 91,981.1 Gg by 2020 would mainly contribute to the GWE. CO_2 emissions would totally increase by 30% compared to 2000 and decrease by 25% compared to the base 1990 level.
In 2020, the CO_2 emissions would exceed 71% of the total global warming effect. According to the forecast, removals would reduce nearly by 5% in 2020 compared to 2000, while it would increase by 3% compared by 1990.

Among different national economy sectors the energy complex would provide main CO_2 emissions in 2020 – 71,821 Gg, or 78.1%, while the *Land-Use Change and Forestry* sector would provide CO_2 removals - 37,626 Gg or 100%.

In 2020, methane emissions of the CO_2 equivalent would amount to 13,235 Gg, or nearly 17% of the total GWE according to the optimistic scenario. The agriculture-induced emissions would provide the bulk of methane (>53%). In this case, the energy would account for 28%, waste - 15%. Compared to 2000, the contribution of energy to the methane emissions would increase by 40%, and decrease by 15% compared to 1990.

Table 1 Contribution of Source (Sink) Categories to Aggregate GWE in 1990

Categories of GHG sources and sinks	**Emissions, Gg**			**Emissions of CO_2 equivalent, Gg**				**Aggregate GWE percentage, %**
	CO_2	**CH_4**	**N_2O**	**CO_2**	**CH_4**	**N_2O**	**Aggregate GWE**	
Energy	100,615.2	321.04	0.77	100,615.2	6,741.84	238.7	107,595.74	89.08
Industrial processes	1,856.35	1.15	1.12	1,856.35	24.15	347.2	2,227.7	1.85
Solvents								
Agriculture	0	529.53	30.68	0	11,120.13	9,510.8	20,630.93	17.33
Land-use change and forestry	**-12,720.51*** * emissions 23,676.89	6.09	0.04	-12,720.51	127.89	12.4	-12,580.22	- 10.41

forestry	removals – 36,397.40							
Waste	0	111.83	0.77	0	2,348.43	238.7	2,587.13	2.15
TOTAL	89,751.04	969.64	33.38	89,751.04	20,362.44	10,347 .8	120,461.28	100
	Aggregate GWE percentage, %			74.51	16.90	8.59	100	

Table 2 Contribution of Source (Sink) Categories to Aggregate GWE in 2000

Categories of GHG sources and sinks	Emissions, Gg			Emissions of CO_2 equivalent, Gg				Aggregate GWE percentage, %
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	Aggregate GWE	
Energy	50,741.57	123.27	0.36	50,741.57	2,588.67	111.6	53,441.84	102.05
Industrial processes	1,277.78	1.61	1.01	1,277.78	33.81	313.1	1,624.64	3.10
Solvents								
Agriculture		333.94	18.76		7,012.74	5,815.6	12,828.34	24.50
Land-use change and forestry	**-18,981.38*** * emissions 20583.64 removals - 39565.02	22.90	0.04	-18,981.38	480.9	12.4	-18,488.08	- 35.30
Waste		129.67	0.76		2,723.07	235.6	2,958.67	5.65
TOTAL	33,037.97	611.39	20.93	33,037.97	12,839.19	6,488.3	52,365.86	100
	Aggregate GWE percentage, %			63.09	24.52	12.39	100	

Table 3 Contribution of Source (Sink) Categories to Aggregate GWE in 2020

Categories of GHG sources and sinks	Emissions, Gg			Emissions of CO_2 equivalent, Gg				Aggregate GWE percentage, %
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	Aggregate GWE	
Energy	71,821	175	0.49	71,821	3,675	152	75,648	98.87
Industrial processes	1,474	1.76	0.98	1,474	37.0	304	1,815.0	2.37
Solvents								
Agriculture	0	336	26.5	0	7,056	8,215	15,271	19.96
Land-use change and forestry	**– 18,940.5*** * emissions 18,686.1 removals – 37,626.6	20.85	0.02	– 18,940.5	437.85	6.2	– 18,496.45	– 24.17
Waste	0	96.65	0.791	0	2,029.65	245.52	2,275.17	2.97
TOTAL	54,354.5	630.26	28.78	54,354.5	13,235.5	8,922.72	76,512.72	100
	Aggregate GWE percentage			71.04	17.3	11.66	100	

According to forecast data, N_2O emissions would amount to 8,922 Gg of the CO_2 equivalent in 2020, or 11% of the total GWE.

The projected increase in GHG emissions in the energy sector is conditioned by the GDP growth and by higher fuel consumption, respectively. GHG emissions, however, are projected below the 1990 level.

Assessment of Vulnerability, Climate Change Impact and Adaptation Measures

Assessment of Vulnerability and Adaptation of Agriculture to Climate Change

The Belarusian climate is characterized by the following parameters:

maximum values: annual air temperature - 7.3 °C (Brest); July mean monthly air temperature - 18.5 °C (Gomel, Mozyr, Bragin); annual total precipitation - 769 mm (Novogrudok); July monthly total precipitation - 97 mm (Tolochin);

minimum values: annual air temperature – 4.7 °C (Ezerishche); January mean monthly air temperature – (-8.1) °C (Ezerishche); annual total precipitation – 566 mm (Bragin); February monthly total precipitation – 28 mm (Bobruisk, Bragin).

The agribusiness sector is a multi-sectoral nature-intensive sector exerting substantial multi-directional pressing on the environment. The area of agricultural land is 57.4% of the land resources, or 11,923 thousand ha, including 8.0% used by individuals. The number of employed population has been gradually decreasing over the last decade from 985.4 (1990), 843.5 (1995) to 625.1 (2000) thousand people.

Agroclimatic resources of the country are rather favorable. The most dangerous weather events in the warm period of the year are frosts and droughts; in the cold period – thaws, strong frosts, firm ice crust; in the early-spring periods – rotting-out, cold spells, etc. Climate-induced losses in yielding capacity of major cultivated crops are somewhat lower in Poozerie region and substantially higher in Polessie: they are minimum for potato (9.9%) and spring barley (16.7%), maximum for winter wheat (21.3%) and fiber flax (17.6%).

In Belarus, the climate contribution to the total yield dispersion is 22-38% for winter crops and from 35 to 81% for spring crops. The climate-induced drop in the yield occurred at the end of the 70s despite improvement of the farming technique. Climatic conditions from 1984 to 1990 promoted the yield growth supported by a high level of the farming technique. Since the beginning of the 90s, the yield drop conditioned by worsened climatic variables, as well as by the reduced level of the farming technique in the economic crisis environment was observed again.

The dynamics of the livestock and poultry population, except horses, is characterized by the downward trend over 15 years starting from 1985. As a result, the livestock reduced from 7,556 to 4,326 thousand heads, swine stock – from 5,012 to 3,566 thousand heads.

The period since 1989 is characterized by a substantial elevated temperature background (by ≈1 °C). Such lengthy and intensive warming had not been observed over the whole period of instrumental observations. Warming is characteristic of mainly winter months. In the last years, however, warming also occurred in summer months.

Warming resulted in the shift of dates of a stable air temperature transition through 0 °C, 5°C, 10°C and 15 °C and in the increased total temperature for the respective periods. This had resulted in the change of the term of various natural processes and shift of climatic phases, in particular, formation of the early protracted spring, extension of a warm postharvest period allowing the yield of afterharvesting cruciferous forage crops, etc to be increased. The risk of frosts in spring increased due to earlier vegetation (specifically in southern regions). The frequency of thaws, their duration and maximum temperatures increased, dry spells became more frequent and longer in summer.

The noted increase in the number of unfavorable climatic phenomena starting from the 70s resulted in the yield reduction in unfavorable years, the number of which increased both in Belarus and other countries. The secondary yield reduction since 1990, is related not only to unfavorable weather phenomena, but also to unfavorable economic environment. Winter rye and barley provide an example of these trends.

According to the obtained scenario estimates, the air temperature increase, proved actually by all authors and methods, which is projected to be 1 – 3 °C and higher in the mid of the XXI century is most probable. The precipitation estimates are less reliable – from a slight increase to reduction in the annual total by 10-20%. This changes (shifts in time) all agroclimatic indicators: dynamics of heat and moisture, transition dates, etc.

Climatic changes mainly effect the animal husbandry forage resources influencing the grazing period duration, quality and productivity of pastures and hayfields, fodder harvesting volume, etc. In specific abnormal years, the cattle grazing period may be by 20-25 days shorter or longer its mean duration. This affects economic indicators in the sector. Climate-induced deviations of the scenario-based yield of fodder crops are 10-15%.

Possible effect of climatic changeability on an optimum cattle population is assessed from the following ratio: changing the fodder harvesting volume by ±10-15 % (937-1406 thousand fodder units) changes the optimum cattle population by ±500-760 thousand animal units.

The country's fund of land resources is substantial, however, their areas have been gradually increasing in general over the recent period, primarily due to withdrawal of radionuclide-contaminated lands from agricultural use and also due to alienation of the land for non-agricultural use. For each resident of Belarus there are 0.9 ha of agricultural land on the average, of them, 0.6 ha of arable land. These indicators are higher than in European countries and 2-2.5 times exceed the minimum for providing food and agricultural raw materials. A significant portion of land, however, is in unsatisfactory reclamation condition.

The crisis in all spheres of the agricultural sector aggravates estimation of strategies and adaptation measures, therefore, only general forecasts may be made regarding two types of the impact response, namely, limitation and adaptation. The limitation strategy is aimed at preventing or slowing down the increase in greenhouse gas concentration in atmosphere. It led to some stabilization of the process, but it is not capable, in principle, of preventing climatic changes. The adaptation requires accounting of both negative and positive climate change-related effects. The actions of adaptation to emergencies should be primarily considered, since climatic changes mainly manifest themselves in the variation in frequency and intensity of abnormal events.

14 most hazardous for farming weather phenomena have been identified for Belarus which define the climatic yield variability being for spring barley 1-38 (an average of 20%), for winter rye 9-28 (15.9%), for potato 10-32 (16.4%) and increasing eastward and south-eastward. It is higher on light soils and expressed most for barley and is substantially dependent on the level of agrochemical indicators. Weather and climatic parameters effect differently at different crop vegetation phases. The yield losses may reach 50-60% and more due to unfavorable weather conditions and they are primarily induced by dry spells. The higher occurrence of mild winters changes the hibernation conditions of winter crops due to rotting and snow mold. Dry spells account for nearly 70% of losses. The effect of abnormally warm winters, the change in dates of reference temperature values, crop phenophases and terms of technological operations need to be studied.

Probable warming of climate and change in geographical precipitation distribution related to it would necessitate the revision of the land cadastral evaluation system, since agroclimatic conditions in Vitebsk Oblast would substantially change (improve) due to warming and lower wetting on medium and heavy soils. Such a trend of climatic processes would deteriorate the situation in the areas with sandy and reclaimed soils of the Polessie region. In general, Belarus will have to substantially restructure agricultural and arable lands. Area of arable lands is likely to reduce in the southern part of the country both on dominant mineral light-composition soils and on reclaimed peat soils, since it would be impossible to till them. The actions to adapt the agricultural sector to the climate change, which manifest itself in the increased frequency of extreme weather phenomena, would be needed as a whole.

Assessment of Vulnerability and Adaptation of Forestry to Climate Change. Lands of the State Forest Fund (SFF) of the Republic of Belarus amount to 9,247.5 thousand hectares as of 01.01.2001, or 44.55% of the total country's area, of which 7,851.1 thousand ha are forested (37.82%). Swamps accounting for a significant fraction (497.6 thousand ha, or 5.4%) of the SFF play an extremely important role in terms of biospheric functions.

Given the average increment rate of the stem wood of 6.3 m^3 per 1 ha of forested land and drain of 1.8 m^3/ha/year, the annual wood increment in Belarusian forests amounts to 35.3 million m^3. Accounting the forest utilization volume, which has been estimated at 10.2 million m^3 over recent years on the average, the total basic change in forest stock in Belarus is 25.1 million m^3 of wood a year.

Climate change impact and Belarusian forest/forestry vulnerability have been assessed for the following time frameworks: 1980-1990-2000 – base period and 2000-2030-2050 – forecast period.

Environmental forecasting for regions similar by their natural and climatic characteristics to those of Belarus has demonstrated a favorable effect of the global warming on the forestry as a whole.

The standing timber stock is expected to grow by more than 10% by 2050. The response of Belarusian forests located in the transition belt between the boreal taiga zone and broad-leaved forest zone will be defined by a complex interactive effect of precipitation and increased air temperature. The change in conditions will be relatively favorable for oak, pine, drooping birch, hornbeam and other broad-leaved (except ash) species predominantly negative for spruce, ash, white birch, spreckled and black alder.

A direct effect of the increased carbon dioxide concentration level combined with the climate change and air pollution effects may lead to an extensive range of responses, namely, from significant increase in the forest productivity to forest death.

Most significant effects of the climate change for the forestry and forest ecosystems are as follows.

Positive or mainly positive changes will be expressed in as follows:

a) increase (not less than 10%) in the base stand increment rate due to elevated active temperatures (up to 10%) and longer vegetation period increasing from 180-205 to 195-230 days in a year and higher carbon dioxide concentration in the atmosphere (up to 50% by 2050);

b) earlier ripening of ligneous plant fruits/seeds and also that of forest berries due to earlier vegetation by 10-15 days and even more in specific years compared to average long-term dates;

c) earlier thawing of soil resulting in 10-15-day shift of the silvicultural season, thereby somewhat extending forest planting (sowing) operations.

Actually all negative effects of the climate change would manifest themselves most in the southern region of Belarus (in Brest and Gomel Polessie), to a lesser extent in the subzone of hornbeam-spruce forests and to relatively minor extent, in Vitebsk Oblast, northern areas of Minsk, Mogilev and Grodno Oblasts.

Below are listed the effects being neutral or contradictory in ecological terms, but requiring adaptation measures:

a) active overgrowing of open swamps of all types of shrub and forest vegetation in connection with the groundwater recession and surface drying-up;

b) transfer of more land, which became unsuitable for agricultural use due to the increased zone of droughty phenomena occurrence, to the forest fund.

Adaptation of the forestry to new weather and climatic environmental conditions should be aimed at both overcoming negative effects of these changes and obtaining the highest benefit from them. The adaptation measures package should encompass the following major spheres: planning and regulatory; financial and economic; institutional and economic, educational and research.

Assessment of Vulnerability and Adaptation of Water Economy to Climate Change. The Republic of Belarus has a large number of aquatic ecosystems including rivers (20.8 thousand), lakes (10.8 thousand), water storage reservoirs (153) and ponds (1.5 thousand). The total river length is 90.6 thousand kilometers. They are within the catchment areas of the Black and Baltic Seas. The main rivers are Berezina, Neman, Sozh, Pripyat, West Dvina and Dnieper. Of 146 km^3 of the annual precipitation, almost 110 km^3 evaporate into the atmosphere and only 36.0 km^3 (25%) transform into the local river runoff. 22.2 km^3 of transit water annually flow from neighboring areas. Total resources of the local river runoff are 56.2 km^3/year. The largest lakes are Naroch (80 km^2), Osveiskoe (52.8 km^2), Chervonoe (43.6 km^2). The total storage capacity of water reservoirs is 3.1 km^3, active storage capacity – nearly 1.2 km^3.

A number of man-made water systems are available in Belarus. The Berezinskaya system 169 km in length and connecting the West Dvina with Dnieper is located in the northern part of the country. In the south, in Polessie, two water-dividing connecting canals are available, namely, Dnieper-Bug and Oginsky. The former is a part of the Dnieper-Bug waterway 735 km in length.

To assess climate-induced changes of water resources, two methods were applied: statistical and water-balance; while biomanipulation models were used for studying aquatic ecosystems of the Naroch lakes; and statistical methods were used to study ground water. The random component in the change in series of water discharge was analyzed by using tests of the number of rotary points and change in difference signs. Kendall and Spearman ***rho*** were also used.

Analysis of Climatic Change Effect on River Runoff and Water Level in Lakes. As geographical zones change latitudinally with resultant change of climatic factors, the average annual runoff also changes across the area. The total reduction in the annual runoff is observed from north to south.

The most important phase of the Belarusian rivers’ water regime is a spring flood. The height of the spring flood above the normal (low-water) level on large rivers reaches 8.6-12.8 m. The flood height is approximately 2 times lower on medium and small rivers. The flood continues 30-120 days.

The spring flood on the rivers is followed by the summer-fall low-water periods when water levels reach minimum values. Its duration on the rivers of the West Dvina watershed area is 120-140 days, that of Pripyat – 135-165 and on the remaining rivers – 190-205 days. In dry years (1939, 1951, 1952), drying was observed on rivers and canals with the watershed area over 1,000 km^2.

Rivers freeze up for 80-140 days from the second decade of November. During severe winters, some small rivers may freeze down to the bottom for a period up to 4.5 months. In mild winters, freeze-up is not observed on rivers.

The analysis of precipitation over the last century shows that a greater amount of precipitation was recorded at the beginning of the century, since G.Ya. Vangengeim western atmospheric circulation form dominated at that time. During the winter season, the Belarusian river runoff increased.

Warming in the 20s-30s of the last century was accompanied by the reduced precipitation specifically in the eastern part of the republic that led to the runoff reduction at that time and, hence, to negative differences in the Dnieper and West Dvina rivers' runoff during 1929-1945 and 1890-1902.

The discharge of rivers for periods with high-wind speeds appeared to be somewhat lower than for periods with low-wind speeds. This is related to the reduced evaporation during periods of low-wind speeds. Comparing the difference in river runoff for epochs with high and low-wind speeds allowed the contribution of this factor to be assessed – it amounted to about 10%, on the average.

Dynamics of extreme discharges over 100-year observation period in different months have been studied for the West Dvina and Pripyat rivers. Most frequently occurred abnormal years are as follows: with maximum discharge – 1931, 1932, 1933, 1958 and 1962, with minimum discharge – 1921, 1939, 1954, 1969, 1976 and 1984. The runoff formation is subject to wide-range fluctuations for rivers with small watershed areas compared to the rivers with a large watershed areas.

Analysis of climatic change effect on ground water in basins of the largest rivers has revealed that intra-annual variation in the GWL has a specific climate-related regularity. The spring GWL peak is observed, as a rule, in April when levels rise from 0.4 to 2.3 m. In the summer season, the GWL is defined by temperature and precipitation of the previous one-two months. In this case, an inverse relationship with temperature of previous months was revealed – increasing temperature decreases GWL. The analysis has demonstrated that there exists an annual cycle, as well as cycles lasting 3-4 and 6-7 years. The cycles of 2-3, 4-6 and 10-12 years are characterized by a higher occurrence. It is not possible to identify cycles of a longer duration because of short series of observations.

Increasing air temperature during the "warm" period (1988-1992) reduced the spring amplitude of the ground water level throughout Belarus. The "cold" period (1964-1968) was accompanied by significant spring GWL amplitudes.

Climate Impact on River Ecosystems. Asynchrony in variation of major runoff types (annual, maximum and minimum) is characteristic of large Belarusian rivers. Comparative assessment of the change in average annual runoff and quantiles of different probability, as well as maximum and minimum runoff from 1961 to 2000 has demonstrated that differences in annual runoff over the selected averaging periods are within the calculation accuracy both for average and assured values. The runoff of large rivers has not actually changed. The increased Pripyat runoff observed in 1965-1985 may be explained by climatic changes (fluctuations of dryness of years).

Changes in maximum runoff are beyond the calculation accuracy and its reduction is characteristic of all rivers. The changes are most significant on the Berezina, Neman and Dnieper rivers and less substantial changes are observed on the West Dvina and Pripyat rivers.

The minimum runoff on rivers changed differently, for instance, the minimum Pripyat runoff substantially increased, while the increase was less on the Dnieper river (Orsha) and the runoff had not changed on the remaining rivers.

All past and current changes in hydrochemical background are within the bicarbonate-calcium water type.

*Climate Impact on Lake Ecosystems and Water Storage Reservoirs***.** The analysis of spectral density of time series of lake levels has revealed availability of a long-period component of 20-30 years for majority of Belarusian lakes.

A single-humped curve of the annual variation of lake levels with the peak in April-May is characteristic of Belarusian natural lake reservoirs in dry years (1951, 1959, 1964). Humid years (1987, 1990, 1998) are characterized by the double-hump curve with the first peak in March-April and the second one in fall-early winter.

Warming, observed over the last thirteen years (1989-2001), effected the temperature and ice regime of rivers, lakes and water storage reservoirs.

The surface layer water temperature in water reservoirs significantly increased since 1989. The most significant deviations from normal are observed in the spring period. In summer months the deviation from the mean long-term data decreases, while it increases in fall months.

The maximum water temperature over the entire observation period has been recorded on most lakes and water storage reservoirs in 2001 and amounted to 28.8 ^{0}C for the Naroch, 29.4 ^{0}C for Neshcherdo and 26.4 ^{0}C for Vygonoshchanskoe lakes.

Over the 1989-2001 period, the transition of water temperature through 4 ^{0}C, 10 ^{0}C – a week earlier than usual and 4-8 days later than usual in the fall was observed at the Belarusian water reservoirs. The same tendency has been revealed for water temperature transition through 0.2 ^{0}C. The climate change resulted in the increased ice-free period duration. Rising temperature in the surface layer contributes to early active weed growth period and increases its duration (spring phytoplankton development).

Impact of Drainage Reclamation on River Hydrological Regime, Ground Water Levels and Climate. Up to date, nearly 1 million 400 thousand ha have been reclaimed in Polessie region. The drainage reclamation simultaneously resulted in ground water recession, substantial reduction in evaporation losses from ground water surface, reduced radiation balance and transpiration moisture flow. Reclaimed bog soils heat faster than unreclaimed ones, but they are characterized by lower thermal conductivity.

Irrigating reclaimed bog soils increases the radiation balance and reduces their maximum surface temperature by 6-10 ^{0}C.

The drainage reclamation that changed the water-air soil regime significantly effected the regime of many small and medium rivers. After the drainage reclamation, the hydrographic network density increased 2.5-4.9 times, thereby creating more favorable runoff conditions for floodwater discharge.

After the drainage reclamation, of 50 surveyed watersheds the annual runoff increased on 26. Drainage most significantly effected small watersheds up to 2,000-3,000 km^2 in area in the first years (due to the reduced total evaporation and drawdown of ground water storage). In the first years, the annual runoff increased by 20-30% and base runoff by 50-70% and even more. No significant changes were observed on the other watershed areas.

The predicted climate warming would cause further negative response of both aquatic systems as a whole and its individual components and the river floodplains would be effected most as most sensitive landscapes.

The forecast of water resources change demonstrates the need of taking preliminary measures to mitigate possible climate change-related unfavorable effects.

In water resources management terms, the most significant factor is accounting possible transformation of the dry-year hydrograph specifically if the overall volume of the projected reduction in the annual runoff would fall within the summer/fall runoff low period. The water management would encounter the following negative effects:

1) decrease in actual design supply of economy units using surface water;
2) drop in minimum water levels in rivers, thereby effecting the operation of water intakes not provided with a dam, water transport and recreation;
3) ground water recession, specifically in riverain zones;
4) lower river water quality related to a lower degree of dilution of effluents and other pollution sources;
5) transformation of the rivers' hydrobiological regime caused by the change in the river level and speed regimes, increase in air temperature leading to deterioration of the oxygen regime and reduction in self-cleaning intensity.

Considering in more detail the climate change-related effects, the following aspects need to be noted.

Forecast of Climate Change Impact on River and Lake Ecosystems. Increasing "thermal load" on rivers and water reservoirs may accelerate eutrophication processes, thereby shifting the equilibrium in the species composition (in groups) of phytoplankton toward species (groups) with higher temperature optimum (for example, cyanobacteria) and posing a substantial risk for drinking water quality.

Warming would effect fish resources. Uniform increase in water temperature in shallow water reservoirs would results in the weight loss of fish inhabiting cold water and cause lethal outcome in multiple bions.

The disruption of fish biocycle, peter-out of stenobiont fish from the fish fauna, change in species diversity and fish number and biomass are to be expected.

The experts believe that currently systematized hydrobiological data are not available, therefore it is not possible to statistically credibly verify changes in structural parameters of aquatic organism communities in response to the effect of specific environmental factors and to identify in particular climatic change impact. There is a need to commence long-term "high-frequency" hydrobiological parameters observations of most characteristic water bodies within the framework of research monitoring..

Decreasing water levels in rivers and lakes is likely to increase ^{137}Cs and ^{90}Sr radionuclide concentrations in surface water of the Dnieper and Pripyat basins located in Gomel and Mogilev Oblasts.

Forecast of climate change effect on ground water level has demonstrated that if the annual temperature increases in Belarus by about 0.2 °C in the beginning of the XXI century, this may result in the ground water recession by 0.02 m relative to the normal. If the temperature increases by 1.5 °C by 2025, this would lead to GWL recession by approximately 0.03-0.04 m relative to the normal. Spring GWL amplitudes would decrease like it was in late 80s-early 90s during the five-year warming, the low-water levels would become even lower.

Risk of Inundation of Areas by Floods. The analysis of data on 1845 and 1931 floods shows that more catastrophic floods and high water may form in Belarus in the future. Such a situation is possible with a higher anthropogenic load on the watershed leading to substantial change of conditions of runoff formation in hydrological terms.

The adaptation of the water economy and aquatic ecosystems should pursue the objective of mitigating negative effects related to warming and contribute to the sustainable development of the Republic of Belarus.

Implementing water supply actions is time-consuming, therefore large water management measures need to be planned 25 years in advance and implemented 10-15 years ahead of the water demand.

The long-term planning of the economic activity should take into account vulnerability of surface water and specific limitations of adaptation measures without reference being made to specific dates on the change onset. The adaptation of the economic activity should first of all include water conservation, extensive use of low water-consumption processes, and more extensive use of agricultural land irrigation.

Assessment of Vulnerability and Adaptation of Social and Economic Systems to Climate Change

To date, only some papers on assessment of social and economic effects of the forecast climate change are available, therefore, the proposed conclusions are based primarily on the expert estimates that need to be further refined.

There exists a clear-cut relationship between integral hydrometeorological indicators and economic indicators. It is much more pronounced in grain production. Over the last decade, the change in the annual grain harvest in Belarus in the best and worst climatic years is about 2.5 million tonnes. Given that the climatic component of the change in the grain harvest is about 30-40% and a minimum price of one tonne of grain is USD 80, minimum economic losses would be estimated at USD 80-100 million as a result of the reduced grain harvest in Belarus. Expert estimates demonstrate that weather and climatic conditions lead to the change in the gross farm product by 15-20% as minimum.

Potential loss induced by unfavorable weather and climatic conditions is the largest in the agricultural sector (nearly 70%) for countries in the moderate zone. It may be reduced by 35-40%, provided countermeasures are taken. The potential loss in the aviation, construction, power engineering, heating, manufacturing industry, transportation and other sectors is within the range from 0.1 to 2% of the gross national income, and avoidable loss varies from 20 to 40% of the total loss.

Reduction in the solar radiation due to the projected thicker cloud cover and lower atmosphere transparency reduces possibility of using solar energy, while lower wind speed observed over the last 20-25 years reduces possibility of using wind energy.

The most significant implications of the climate change are expected in highly urbanized areas. Such effects may manifest themselves in lower water supply, increased thermal loads and unfavorable conditions contributing to emergence of various infections.

Saving fuel and energy resources is one of the most important socio-economic effects related to climate warming.

Lower severity of climatic conditions currently determining the cost of maintaining the economic activity would be most positive factor of climate warming for Belarus. Fuel and energy saving resulting from shorter and less severe cold season and, hence, lower energy costs for heating buildings may be one of the most substantial socio-economic effects for our region due to expected anthropogenic climate warming.

Over the last decade, the heating period reduced by 6-9 days mainly due to its earlier termination. An average temperature of the heating season increased by 1-1.5 ^{0}C (more in the north). All this resulted in the decrease in the degree-day total by 9-11%. That appropriately effected the heating fuel consumption.

Calculations have demonstrated that if mean annual air temperature rises from 0.5 ^{0}C to 3 ^{0}C, the heating period will reduce by 6 days and 36 days, if the temperature rises by 3 ^{0}C.

Temperature inside the premises is an important parameter for heat calculation.

The reduction in heat loss and, hence, saving fuel with the temperature increase by 0.5 ^{0}C would be 3.5%, and with the temperature increase by 3 ^{0}C – 15.3%.

The total fuel saving with temperature rise by 0.5 ^{0}C would be 6.6%, and by 3 ^{0}C – 33.8%.

The obtained results rather well agree with the results obtained for countries of the Western Europe and European part of Russia.

The assessment of change in pathogenicity indices of temperature, humidity, wind speed, interdiurnal pressure drop, as well as of the annual variation in the complex pathogenicity index over the last 40 years has demonstrated the multidirectional character of trend changes in the above pathogenicity indices. Pathogenicity indices of air humidity and that of interdiurnal variability of atmospheric pressure increase, thereby adversely effecting the community's health. At the same time, wind speed decreases and temperature rises, thereby contributing to positive dynamics of the pathogenicity index of wind speed and temperature.

The annual variation in the complex pathogenicity index is favorable for human health in the cold season and unfavorable in the second half of summer over the last decade. This is related to the increased occurrence of maximum summer temperatures creating additional load on the organism, specifically for people with cardiovascular diseases. Increased frequency of thaws with a maximum temperature > 4 ^{0}C and subsequent cold spells result in a number of chill cases.

Climate warming will allow people to spend more time in recreational zones (in forests, at the rivers, lakes, water reservoirs) and, thus, a higher anthropogenic load on these ecosystems may be expected and, hence, lower water quality and aggravation of the epidemiological situation.

Therefore, the projected climatic changes will entail significant changes of human health.

In conclusion, it has to be underlined that ecosystems (aquatic, forest, agricultural) should not be considered separately, as they are integrated in the nature. The state of environment mainly defines human health, that is why it is of critical importance to make integrated assessments of the climate impact on ecosystems, economy and community's health. This would allow for not only selecting more beneficial adaptation actions at the national level, but also disseminating them to the intergovernmental (regional) levels.

Research and Systematic Monitoring

Climate condition is systematically monitored in the Republic of Belarus. Precipitation substantially changed within a year and in specific years over the instrumental observation period. This is specifically characteristic of August, when monthly precipitation values reduced by one fifth. A significant deficiency of precipitation was observed in April-May, while precipitation began to increase in February, June and September in the last years. Extremely humid years were recorded (1998, first half of 1991 summer, second half of 1993 summer, etc.). Precipitation fluctuation has increased in July over the recent decade.

Regression dependencies of different agroclimatic indices on average monthly temperatures have been established by processing base period data. Among such indices are the dates of a stable air transition through 0º, 5º, 10º and 15 ºC in the spring and fall, duration of periods with the temperature above these limits, as well as respective total active temperature. Forecasts made for 2010-2039 show the increase in mean air temperature by 1 ºC, with the mean annual day-time temperature increasing by 0.92, and night-time by 1.15 ºC. Increments of total temperature above 0º, 5º and 10 °C are expected to be approximately equal and are nearly 200–220 C°, increment of total temperature for 15 °C is substantially greater - higher in Minsk (387 °C) than in Vasilevichy (294 ºC).

Therefore, conducted numerical experiments provide evidence of a high rate of change in mean annual night-time temperatures compared with day-time ones. This conclusion is supported by the current meteorological observation data. The forecast estimates of agroclimatic indices are as follows: the onset of periods with a temperature above 10 °C may be expected in spring 3–7 days earlier and in fall 2–6 days later that would increase the vegetation period duration almost by two weeks in 2010 – 2039 period.

Public Education and Awareness Enhancement

The country's ecological education system is developing. To form a community being conscious of the environment and its problems, the Council of Ministers of the Republic of Belarus approved the Republican Program of Ecological Education for 1991-1995 by adopting Resolution No. 85 on

March 14th 1991. That first Republican Program formulated specific targets of each form of the education system:

- preschool, general secondary, out-of-school education and learning;
- vocational and technical education;
- higher and secondary special education;
- retraining and advanced training.

In addition, some regions of the republic take the initiative to develop *Comprehensive Programs of Continuous Ecological Education and Teaching Preschool and School-Age Children.* The Program prepared in 1996 by a large team of teachers and tutors of Grodno institutions of higher education may serve as an example, and it is based on the principle of succession of ecological education of preschool children and students of primary, secondary and higher forms.

Currently, it is getting more evident that global problems of environmental protection and ecological security cannot be successfully solved by efforts of only governmental institutions. One of the critical conditions of pursuing the national policy is to involve general public into the process of taking ecologically informed decisions. It has been noted in many intergovernmental documents, in particular, in decisions of the UN Conference On Environment and Development (UNCED, Brazil, 1992), Conference of Environmental Ministers of Europe in Lucerne (1993), Sophia (1995) and Aarhus Conference of Ministers, that ecological problems may be efficiently addressed, provided that all citizens concerned are involved.

The Ministry of Natural Resources and Environmental Protection of the Republic of Belarus is implementing provisions of the Aarhus Convention, in particular, by strengthening collaboration with non-governmental ecological organizations and involving them into joint activities aimed at environment enhancement and protection.

In July 2001, to implement provisions of the Aarhus Convention and coordinate activities of the MNREP structural divisions with non-governmental environmental organizations and associations, the Ministry set up the Public Coordinating Ecological Council incorporating 17 non-governmental organizations and associations.

Setting up the Council allowed the non-governmental organizations to take part in making ecologically informed decisions, and participate in formulating the ecological policy (National Plans of Actions, Bills, regulatory and legal acts, etc.).

PART I. NATIONAL CIRCUMSTANCES

The Republic of Belarus, the USSR republic up to the end of 1991, is located in the Central East Europe and categorized as the economy in transition. The country's area is 207.6 thou km^2 (2.1% of the Europe area). The population size is 10.0 million as of the beginning of 2001. The capital of Belarus is Minsk.

Belarus is a landlocked country and borders Russia, Ukraine, Poland, Lithuania and Latvia. Its area stretches for 560 km from north to south (from 56°10′ to 51°16′ northerly latitude) and 650 km from west to east (from 23°11′ to 32°47′ easterly longitude). Belarus is administratively divided into 6 Oblasts comprising 118 Districts.

Table 1.1. National circumstances of the Republic of Belarus

Index	1990	1995	2000
Area, thou km^2	207.6	207.6	207.6
Forests and other forest plantations, % of country area	35.6	39.9	40.6
Agricultural lands, % of country area	45.3	45.0	44.6
Population, mln. people (as of year beginning)	10.2	10.2	10.0
Urban population, % of total population	66.1	67.9	69.7
Labor force, % of total population	53.2[a]	44.4	45.3
Employment structure:			
Agriculture and forestry, % of total employed	19.5	19.7	14.8
Industry and construction, % of total employed	42.0	34.5	34.6
Services spheres, % of total employed	38.5	45.8	50.6
GDP, % against 1990	100.0	65.2	88.6
GDP structure:			
Commodity producing sectors, % of GDP	68.9	49.2	45.6
of them:			
Agriculture and forestry, % of GDP	23.0	15.8	12.1
Industry and construction, % of GDP	45.6	33.0	32.9
Services-providing sectors, % of GDP	28.5	41.1	39.9
Net taxes, % of GDP	2.6	9.7	14.5
Per capita GDP according to PPP, USD	6,125	4,981	7,824

1.1 National Administration

In accordance with the Constitution, the Republic of Belarus is a unitary democratic social legal state. The Head of the state is the President of the Republic of Belarus. The Parliament, Government, Presidential Administration, Judicial Bodies, Public Prosecutor's Office and State Control Committee are the bodies of state administration. The Parliament – National Assembly of the Republic of Belarus – is the representative and legislative body of the country comprising two Chambers – the House of Representatives and the Council of the Republic. The Government – the Council of Ministers of the Republic of Belarus - is the executive body performing national administration functions.

The national administration system is built on functional/sectoral and territorial principles and includes 24 Ministries, 12 Sectoral Committees, 6 Oblast and 118 District Executive Committees, as well as municipal, rural and village Executive Committees.

The Belarusian environmental legislation is being developed based on the experience of industrially developed countries and, in general, is in compliance with international standards. The Constitution of the Republic of Belarus declares the right of each citizen for healthy environment and damages for violation of that right. The *Law On Environment Protection of the Republic of Belarus* was the first of environmental laws adopted by independent Belarus in 1992. It regulates environmental relations in the whole environment sphere and serves as a basis for the following sectoral laws: *On State Ecological Assessment* (1993, revised in 2000), *On Sanitary and Epidemic Welfare of Population* (1993, revised in 2000*), On Special Natural Areas and Sites of Protection* (1994, revised in 2000), *On Fauna Conservancy* (1996*), On Atmospheric Air Protection* (1997), *On Radiation Safety* (1998), *On Hydrometeorological Activity* (1999) and *On Waste* (2000). The relations in the nature management sphere are regulated by Codes of the Republic of Belarus, including the Code of the Republic of Belarus On Subsoil Assets (1997), Water Resources Code of the Republic of Belarus (1998), Land Code of the Republic of Belarus (1999), Forest Code of the Republic of Belarus (20000 and others.

The system of environment protection authorities comprises the President of the Republic of Belarus, National Assembly, Council of Ministers and also Local Governments. Local Governments directly manage implementation of the national and regional nature conservation programs. A special competence body is the Ministry of Natural Resources and Environmental Protection reporting to the Council of Ministers. In addition to it, the Ministry for Emergency, Ministry of

Health Care and Land Resources, Geodesy and Cartography Committee are authorized to control the state of environment. The Forestry Committee, Ministry of Internal Affairs, State Customs Committee, and Administration of Affairs of the President of the Republic of Belarus perform specific environmental functions.

1.2 Natural Resources

In terms of nature Belarus is located in the west of the East-European Plain in the mixed forest zone. Mean absolute elevation above seal level is 160 m. The highest elevation is Dzerzhinskaya mount on the Minsk upland (345 m). The lowest elevation is the river Neman valley on the border with Lithuania (80 m). The area of Belarus is divided into 5 physiographic provinces: Poozerie, Belarusian ridge with adjacent plains, East-Belarusian (Upper Dnieper province –Pridneprovie -, Sub-Polessie and Polessie.

Poozerie (46.7 thou km^2) is the northern province – the area of glacial lakes, undulating and morainal land and glaciolacustrine planes formed during the Wurm glaciation epoch. The Belarusian ridge with adjacent plains (50.3 thou km^2) covers the western and central part of Belarus. It is a hilly, most elevated part of the country. Pridneprovie (15.1 thou km^2) is characterized by a flat land relief and most fertile soils. Polessie (58.1 thou km^2), the largest province, covers the southern part of the country and is characterized by a low landscape predominantly of alluvial origin and is the main area of marsh occurrence. Sub-Polessie (37.4 thou km^2) – a flat area with prevailing morainal-sandr and fluvioglacial landscapes – is located between the four said provinces.

Land Resources.

The land fund of the Republic of Belarus is 20,759.6 thou ha. Its structure was as follows as of 1 January 2001:

- Land of farms and individuals 10,763 thou ha (51.9%)
- Land of forestry organizations 7,754 thou ha (37.3%)
- Land of reserve, conservation areas, national parks and spas 10,035 thou ha (5.0%)
- Land of other land users 1,208 thou ha (5.8%)

The following trends have been observed in the land-use structure over the last 20 years: reduction in area of farms, increase in area of forestry enterprises, increase in the area of nature conservation, recreation, historical and cultural land and community land in settlements.

In 2000, natural areas of protection amounted to 1,562.2 thou ha, or 7.5% area of Belarus. Natural areas of protection comprise Berezinsky Biosphere Reserve, four National parks (Belovezhskaya Pushcha, Braslav Lakes, Pripyatsky and Narochansky), wildlife reserves and monuments of nature.

Belarus is characterized by abundance of bog and forest-bog complexes (2,379 thou ha, or 11.5% of the country area). Of them, forest bogs represent 48.3%, shrub bogs –12.1% and open bogs – 39.6%. Drainage reclamation of bogs to transform agricultural land was intensively conducted in the second half of the XX century. That process reached its peak in the 1960s-1970s. The reclamation mainly affected open bogs the area of which reduced from 1,514 thou ha in 1954 to 985 thou ha in 1988 and 940 thou ha in 1994. Since the mid 1990s, however, the rebogging of open bogs resulted in the increase in area and it amounted to 964 thou ha in 2000. It should be noted that mainly lowland bogs were drained through reclamation.

Mineral Resources

Explored reserves of mineral and raw material resources allow for meeting perspective needs of Belarus in potash and rock salts, lime and cement raw materials, refractory and ceramic clays, construction and molding sands, sand and gravel material and construction stone. Potash salts serve as the feed for producing potash fertilizers being a critical export potential of Belarus.

Belarus is not rich in fuel and energy resources, although it has some reserves of oil, oil gas, peat, brown coal and slate coal. Oil, oil gas and brown coal deposits are mainly located in Gomel Oblast. Current recoverable oil reserves amount to 65 mln tonnes, and possible reserves – 189 mln tonnes. To date, over 100 million tonnes of oil have been extracted. Explored reserves of oil gas are estimated at 8 billion m^3. Brown coal is not mined, however possible reserves are estimated at 1,351 million tonnes. Deposits are perspective for open-cut mining to fully meet the needs of the population in household fuel, however, they are not currently mined due to ecological reasons. Peat-fields are located in many areas of Belarus, but they are most abundant in Polessie. To date, over 1 billion tonnes of peat was extracted. Usable resources are estimated at 3 billion tonnes. Slate coal is characterized by a high ash content and currently its use is economically inefficient.

Water Resources

Surface water resources of the Republic of Belarus are estimated at 57.9 km^3 a year. Larger portion of the river runoff forms within Belarus (34 km^3/year), while exogenous inflow from Russia and Ukraine makes up 41%. Belarusian rivers are within the catchment areas of the Black and Baltic Seas. The river system of the Dnieper river with large tributaries of Pripyat, Berezina and Sozh (52% of the country area) is within the Black Sea basin, while the Baltic Sea basin comprises the river systems of the West Dvina, Neman and West Bug (42%). Belarus has over 10 thousand lakes which are mainly located in the Poozerie region (over 4 thousand) and in Polessie (nearly 6 thousand). 75% of lakes have the surface area of less than 0.1 km^2 and are categorized as small lakes. The majority of large lakes are of glacial origin and are located in the northern part of the country. The largest is the lake Naroch (80 km^2). 153 water storage reservoirs were built in Belarus.

Natural ground water resources are estimated at 16 km^3 a year and are the main source of household water supply. Approved usable ground water resources are estimated at over 2.3 km^3 a year.

Biological Resources

The Belarusian flora comprises nearly 2,100 higher and 9,400 inferior plants. Of ligneous plants, 107 wild-growing local species are known, of them, 28 are tree species and the remaining are shrub, semishrub and dwarf shrub vegetation. The fauna includes 453 species of vertebrates and over 30 species of invertebrates. Of the mammal species there are a roe deer, a wild boar, an elk, a red deer, a fox, a hare, a squirrel, a wolf and others. The rare species comprise European bison, a lynx, a badger and a brown bear. There are 298 bird species in Belarus, of them, 225 nest in the country.

1.3 Climate

Belarus is located in the moderate climatic zone. Specifics of the country’s climate are defined by its geographical location in middle latitudes, relative proximity to the Atlantic Ocean, prevailing western transport of air masses, and flat relief not impeding their propagation in any direction. These conditions define predominance of moderately continental climate in Belarus.

Supply of total solar radiation reduces from south to north from 4,100 to 3,500 MJ/m^2 a year, with 50% of solar heat influx accounting for May-July and 5% - for November-January.

The most important climate-forming process above the country’s area is the western transport of air masses allowing weakly transformed sea air masses from the Atlantic Ocean to reach Belarus. As a result, warm advection is observed in winter and, hence, increased air temperature. In summer, the western transport cools hot weather. Thus, specifics of the atmospheric circulation contribute to smoothing intra-annual differences in solar radiation-related heat supply.

The regularity of solar radiation supply and global atmospheric circulation condition mean air temperatures distribution throughout Belarus. A mean annual air temperature is positive and changes from +7.0 °C in the south-west to +4.5 °C in the north-east in Belarus. The warmest month is July, and during that time a mean annual temperature is from +17.0 °C to +18.5 °C increasing from the north-east to south-west. Given the long-term observations, the coldest month is January. A mean air temperature in January is from –4.5 °C to –8.0 °C decreasing from the south-west to north-east. An absolute temperature maximum was recorded in the south-east of Belarus in Gomel Oblast (+38 °C), while an absolute minimum was recorded in the north-east in Vitebsk District (-44 °C). The shift of the coldest winter period from January to December has been observed in the last decade and that fact is considered to be a characteristic feature of the current warming period.

Amount of precipitation a year is, on average, 600 – 700 mm. Approximately 60% of precipitation account for the warm half-year, while 40% for the cold half-year. The distribution of precipitation in Belarus is somewhat non-uniform, which is conditioned by specifics of the atmospheric circulation and relief. Lowland is characterized by the lowest precipitation - 600 – 650 mm/year. More precipitation is observed in the elevated area of Belarus (Minskaya Upland - 650 – 700 mm) and specifically its western areas (Novogrudskaya Upland - 750 mm). In dry years, the precipitation may reduce to 300 mm, while in humid years it may reach 1,000 mm. The total precipitation month-wise is minimum in February-March and maximum in summer months. Annually, Belarus encounters 3 – 4 rainless periods lasting 10 days at a time. Every two years Belarus does not receive rainfall for 20-25 days at a time, and every 10 years – for 30-35 days. Dry spells occur during eastern winds and anticyclones. Snow falls over the whole Belarusian territory in winter. The snow cover duration is from 70 days in the south-west to 125 days in the north-east of the country. The duration of a stable snow cover in Belarus started to decrease in the last decade.

Duration of the vegetation period with mean diurnal temperatures over +5 °C changes from 209 days in the south-west to 180 days in the north-east of the country.

1.4 Population

The population size was 10.0 million people as of 1 January 2001, an average population density is 48.1 people/km^2, the urban population size is 70.2%. Dynamics of demographic indicators is provided in Table 1.2.

Table 1.2. Demographic Indicators (as of 1 January each year)

Indicator	1990	1995	1998	1999	2000
Population size, mln people	10.2	10.2	10.1	10.0	10.0
Urban population, mln people	6.7	6.9	6.9	6.9	7.0
(%)	(66.1)	(67.9)	(68.8)	(69.3)	(69.7)
Natural movement, ‰	+3.2	-3.2	-4.4	-4.9	-4.1
Balance of migration, ‘000 people	-19.6	-0.2	+19.9	+17.6	+12.1

The population life activity results in formation of solid domestic waste and residential water, decomposition and disinfection of which lead to GHG generation. The Belarusian population forms demand for goods and services the production of which requires fuel resources, wood and agricultural raw materials, thereby leading to GHG emissions. Thus, the population explicitly and implicitly influences the GHG emissions. The population dynamics over 1990 – 2000 period relatively favorably influenced the given processes. The population reduced by 0.2 million people, that is considered as an extensive restraint of consumer demand in the country. That impeded, to some extent, the increase in domestic waste and also growth of production for local needs, thereby contributing to the reduction in GHG emissions.

The natural decline in population is conditioned by two factors, namely, aggravation of the social and economic crisis by the mid 1990s and deterioration of reproductive properties of the population age structure which resulted in the lower birth-rate and higher mortality. This tendency is characteristic both of the rural and urban population. However, the urban population increases due to migration inflow. The urban population is characterized by high concentration. 1.7 million people reside in Minsk (24.2% of the urban population). 25.6% of urban residents are concentrated in five Oblast centers (cities with 250,000-500,000 residents). There are 9 cities with a number of residents from 100 thousand to 250 thousand making up 17.6% of the urban population. 197 small and medium urban settlements numbering less than 100 thousand residents in each are available in Belarus.

It is difficult to unambiguously assess the urbanization influence on the change in GHG emissions. On the one hand, the Belarusian rural population is the only consumer of fuel wood, peat briquettes and other stove fuel the use of which in individual households is characterized by lower efficiency compared to that of urban heat power plants. In addition, the production of domestic fuel for the rural population adversely effects the condition of GHG sinks (forests and peat bogs). On the other hand, urban residents more intensively use public transport services and have higher incomes and in the economic terms the urban population-formed demand stronger stimulates the consumption of fuel resources and agricultural produces in Belarus and, hence, results in the increased GHG emissions.

In 2000, the size of the employed population amounted to 4,441 thousand people compared to 5,151 thousand people in 1990, i.e. the number of employed reduced by 13.8 %. The occupational pattern changed. In the first half of the 1990s, the services sector increased in the occupational pattern, while the share of industry and construction reduced and in the second half of the 1990s, the increased share of the employed in the services sector was accompanied by employment level stabilization in the industry and lower employment in the agricultural sector.

1.5 Economy

Currently, Belarus is categorized as the economy in transition. Prior to the beginning of the 1990s, Belarus was one of the most industrially developed republics of the former Soviet Union. Given the share of industry in the occupational structure (35 %) and national income production (47%), Belarus was among three leading republics alongside with Russia and Latvia. The Belarusian industry used more advanced equipment than, on average, in the FSU republics. In the late 1980s, the economic development slowed down, socio-economic contradictions which manifested themselves in high inflation rate, shortage of final consumption of goods and services and overproduction of capital goods. The USSR collapsed in 1991 disrupting established economic relations of Belarus with other FSU republics. A high level of specialization in the FSU in machine-building, chemical, petrochemical and consumer goods industries and a strong dependence on Russia's raw material sources and sales markets, political, social and economic upheavals in 1991 formed prerequisites for severe economic crisis in the first half of the 1990s. In that period, the dynamics of economic indicators was characterized by a substantial fall (Table 1.3).

Table 1.3. Dynamics of Main Economic Development Indicators, % against 1990

Indicator	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Gross domestic product	99	89	83	73	65	67	75	81	84	89
Industrial products	99	90	81	70	61	64	75	85	93	101
Agricultural produces	95	87	90	77	74	75	72	71	65	71
Investments in fixed assets	104	74	63	56	39	37	44	55	51	52
Retail turnover	92	72	62	56	43	56	66	84	93	103
Paid services for population	84	63	45	38	36	38	41	46	52	54

The Program of Priority Measures for Managing the Economic Crisis was adopted in 1994, and Major Guidelines of Socio-Economic Development of the Republic of Belarus for 1996-2000, National Strategy of Stable Development of the Republic of Belarus up to 2010, General Scheme of Managing the National Economy of the Republic of Belarus for 1996-2000 and other strategic documents were developed in 1996. They stipulated the framework of the Belarusian socially-oriented market economy model providing for an active leverage effect. Development of the effective agribusiness sector, intensive housing construction and building up the export potential were identified as economic priorities. Implementing this economic model made it possible not only to check the decline in production, but also reach positive dynamics of major macroeconomic processes, annually increase the GDP and industrial output and stabilize the situation in the domestic consumer market. The Belarusian economy will develop further within the framework of the Program of Social and Economic Development of the Republic of Belarus for 2001-2005 adopted by the Government and approved by the President.

In general, the experts stated that economic situation stabilized in 1996–2000. However, dynamics of investments in the fixed assets arises concern, since they reduced more than 2-fold in 2000 compared 1990. An active part of fixed assets depreciated by 70 – 75 %.

The agriculture experiences severe crisis since reforms of economic relations are needed in the agribusiness sector. Nevertheless, the Belarusian population is better supplied with meat and dairy products, eggs and potato compared to big CIS countries (Russia, Ukraine, Kazakhstan). Pursuing the national policy of supporting the agricultural sector by subsidizing it maintained a relatively high level of food products consumption. Currently, this is of critical social significance.

The Belarusian economy is strongly dependent on external economic processes which is conditioned by its high level of openness. While the economy openness level of the countries worldwide is about 40% as a whole (external turnover-GDP ratio), this indicator for Belarus is over 130 %. In 2000, the external turnover was at the level of USD 15,904.9 million. The export amounted to USD 7,330.7 million, import – USD 8,574.2 million, with the negative external trade balance of USD 1,243.5 million. The major foreign partner of Belarus is Russia. In 2000, it accounted for 65% of import and 51% of export of Belarusian commodities. Machine-building products (26.3%); mineral products (20.1%), among which potash fertilizers account for larger share (2.8 million tonnes); and chemical products (19.7%) dominate in the export structure. The major imported items include mineral products (31.2%), primarily oil (12.0 million tonnes) and natural gas (17.1 billion m^3); machines, equipment and transportation facilities (18.3%) and also chemical products (15.3%).

1.6 Power Engineering

Burning carbonaceous fuel provides the main GHG source. In the process of fuel combustion, carbon dioxide (CO_2), carbon oxide (CO), nitric oxides (NO_x), water (H_2O) and other substances producing direct and indirect greenhouse effect form. Prior to 1995, gross consumption of fuel and energy resources was steadily decreasing and then stabilized at the level of 35–37 million t.f.e. Strong dependence on imported energy resources and building up non-payments for fuel and energy by domestic consumers pose major problems for the power engineering sector development. Increasing raw-materials import prices increases energy tariffs, thereby aggravating the non-payment problem. As a result, there exists acute shortage of intraindustry investments in fixed assets of the energy economy. Local energy production have been reducing from 1990 to 2000: oil – from 2.1 to 1.9 million tonnes, natural gas – from 297 million m^3 to 257 million m^3, fuel peat – from 3.5 to 2.0 million tonnes.

The Belarusian economy is characterized by high GDP energy intensity. The energy equivalent-GDP ratio in comparable prices accounting actual price proportions between production and consumption most objectively characterizes the energy intensity. The given indicator (Table 1.4) dropped in the 1990s. By 1995, the GDP energy intensity dropped by 14% compared to 1990 due to the reduced consumption of energy resources caused by the economic crisis. The second half of the 1990s saw further reduction in energy intensity by 28% compared to the 1995 level due to economic turnaround and pursuance of the national energy-conservation policy.

Reviewing the behavior of main economic indicators and fuel resources consumption over the period in question allows two stages to be identified which are characterized by different tendencies of the GDP energy intensity and GHG emissions in Belarus.

The first stage covers 1990 – 1995. This period is characterized by slump in the GDP and fuel consumption, with the rate of fuel consumption reduction exceeding that of the GDP fall. The fuel consumption reduced by 44%, while GDP – by 35%. Thus, this reduced energy intensity of the economy. Naturally, the Belarusian energy sector reduced the GHG emissions over the given period. This has been conditioned mainly by lower fuel consumption and the change in the pattern of the fuel used to some extent.

Table 1.4 Belarus GDP Energy Intensity

Indicators	Years						
	1990	1995	1996	1997	1998	1999	2000
Gross energy consumption, million t.f.e.	63.1	35.3	35.5	36.8	36.6	34.3	34.9
GDP, USD billion:							
In comparable prices [a]	34.9	22.7	23.4	26.2	28.3	29.3	31.1
At average-weighted exchange rate	25.8	10.5	14.1	14.7	16.1	10.9	11.4
according to PPP	62.6	51.5	55.4	62.9	69.1	72.5	78.3
GDP energy intensity, kg f.e./USD:							
In comparable prices	1.81	1.56	1.52	1.41	1.29	1.17	1.12
At average-weighted exchange rate	2.45	3.36	2.52	2.51	2.27	3.13	3.06
according to PPP	1.01	0.69	0.64	0.59	0.53	0.47	0.44
GDP energy intensity, PJ/USD billion:							
In comparable prices	53.0	45.6	44.5	41.2	37.9	34.3	32.9
At average-weighted exchange rate	71.8	98.3	73.8	73.5	66.6	91.9	89.6
according to PPP	29.5	20.1	18.8	17.2	15.5	13.9	13.1

[a] 1990 GDP is given according to WB data

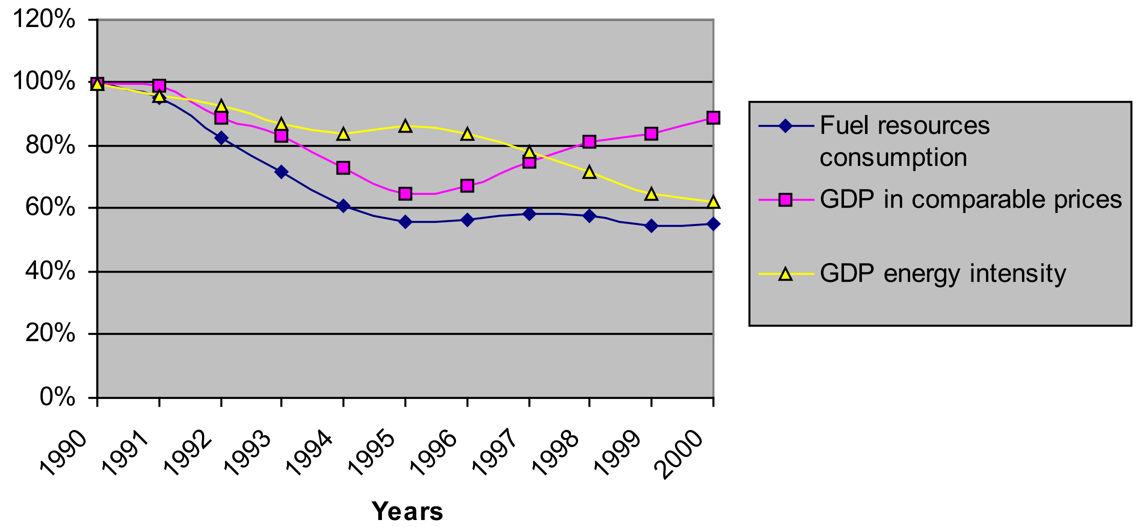


Fig. 1.1 Dynamics of energy and economic indicators, % against 1990

The second stage covers 1996 – 2000. During that period, Belarus took important steps to manage the economic crisis and pursue the energy conservation policy which were provided for by *Main Guidelines of Socio-Economic Development of the Republic of Belarus for 1996–2000*, *Main Spheres of the Energy Policy of the Republic of Belarus for a Period up to 2010* and *Republican Energy Conservation Program up to 2000*. As a result, the GDP increased by 36% over the five-year period and fuel resources consumption stabilized. Hence, economy energy intensity further reduced. Energy-related GHG emissions reduced from 1995 to 2000, although the reduction was less substantial than in 1990 – 1995. The reduction in energy-related GHG emissions are, firstly, conditioned by 1.1% decrease in fuel consumption and, secondly, by the increased natural gas consumption in the fuel use pattern.

The pattern of energy resources used to meet energy needs has changed over the decade (Fig. 1.2). Natural gas has become the dominant energy source to “squeeze out”, first of all, fuel oil. The share of coal used to generate heat has reduced. Belarus, in particular, uses large amount of peat and briquette peat as energy sources (totally about 2 million tonnes of fuel equivalent). The other characteristic feature of Belarus is inadequate availability of water-power resources which accounted only for 0.01% in 1990 and 0.02% in 2000 in the consumption pattern of primary energy sources.

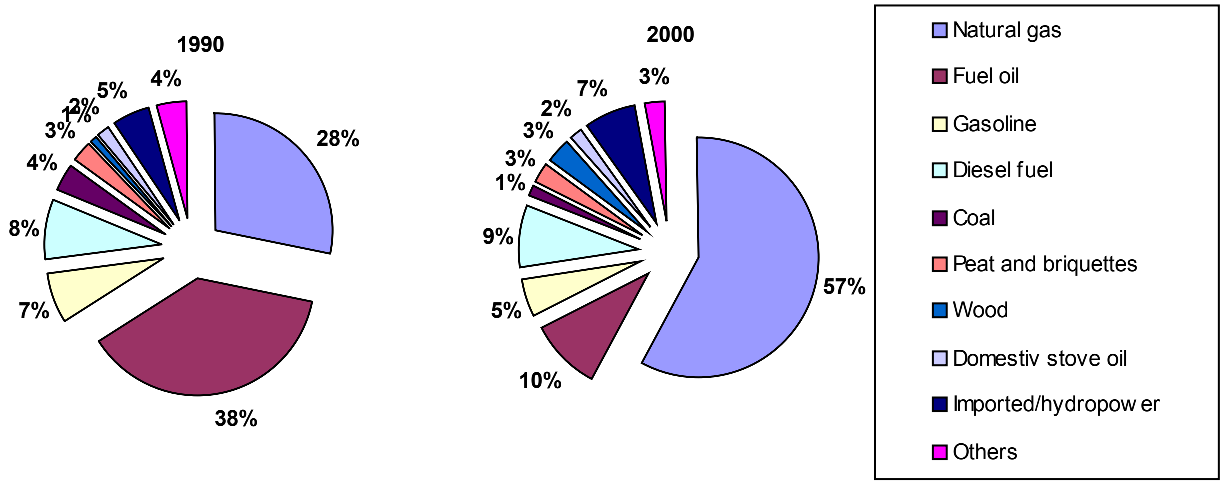


Fig. 1.2 Consumption pattern of primary energy sources

The fuel consumption pattern mainly remained unchanged. (Table 1.5). Fuel resources are primarily used to generate heat and electric energy, and also as the process fuel in the industrial sector. The households began to use substantially more fuel as the fleet of private cars increased and housing expanded.

The Belarusian energy economy includes fuel mining, transportation, storage and primary processing, generation and transmission of electric power and heat. Burning fuel to generate heat and electric power is the main GHG source. Belarus uses mainly natural gas and fuel oil for this purpose, but all possible fuel types are fired at small-scale boiler plants. 22 central heat power plants (CHPP) and public district power plants (PDPP), *Belenergo* company’s 25 district boiler plants, 8 isolated generating plants and 22,100 small boiler plants (with capacity less than 10 Gcal/h) generate heat and electric energy. The change in indicators of the Belarusian energy system performance is provided in Table 1.6.

Table 1.5 Pattern of Fuel Resources Consumption for Energy Purposes, %[a]

Main spheres of use	1990	2000
Electric power generation	20.8	20.9
Heat generation	34.4	39.2
Use as fuel in:		
Industry	10.6	10.3
Construction	0.9	0.4
Transportation	9.8	8.9
Agriculture	3.7	3.5
Housing/utilities	3.2	1.3
Other sectors	0.3	0.2
Household use	7.7	12.3
Loss and other distribution	8.6	3.0
T o t a l	100.0	100.0

[a] Fuel resources are considered without accounting fuel processed as raw materials to produce other fuels, chemical, petrochemical and other non-fuel products.

Table 1.6 Power Engineering System Indicators

Indicators	1990	2000
Power plant installed capacity, MW	6,939	7,838
Electric power generation, billion kWh	39.5	26.1
Heat energy generation, mln Gcal	111.3	69.1
Electric power import, billion kWh	9.6	7.3

Methane and volatile non-methane organic compounds (VNMOC) leakages and emissions during transportation and storage of gaseous and liquid fuel and in the process of oil refining provide an additional GHG source in the energy economy. Gas pipelines (total length – 6,400 km), oil pipelines (3,007 km), and oil product pipelines are mainly used for transportation. Main pipeline sections have been operated for 30 years and are worn out in some places. Oil products are produced by two refineries. Oil products are delivered to intermediate tank farms by railway and to final gasoline stations – by vehicles.

1.7 Transport

As the GHG source, the transport ranks next to heat and power engineering. Transport sector operation produces CO_2, CO, CH_4, N_2O, NO_x and VNMOC emissions. The Belarusian transport sector includes railway, motor, inland water and aviation transport. The main modes of transport are railway and motor transport. In 1990–2000, the road network expanded 1.5-fold, while the length of railways actually remained unchanged.

Table 1.7 Public Transport Characteristic in Belarus

Indicators	1990	1995	2000
Railways, km	5,569	5,564	5,533
Motor roads, km	48,902	51,547	74,385
Passenger turnover, mln passenger-kilometer	42,179	25,861	32,358

Freight turnover, mln tonne-kilometers	97,829	35,109	40,425

Since 1990, the passenger and freight turnover by all modes of transport reduced by 23% and 59%, respectively. The structure of passenger traffic by all modes of transport substantially changed. As a result, the share of the railway transport of the total passenger turnover increased from 40.0% in 1990 to 64.5% in 2000, while the share of the bus and air transport reduced from 46.9% and 13.1% to 33.6% and 1.9%, respectively, over the same period. The structure of freight turnover by all modes of transport remained actually unchanged. The railway (73–78 %) and motor transport (22 – 27%) are dominant modes.

The size and structure of the public and private fleet changed over the period in question. The total number of vehicles increased 2.5-fold: from 650.8 thou units in 1990 to 1,002.3 thou in 1995 and 1,533.4 thou in 2000. The sky-rocketing of private vehicle use contributed to the growth. As a result, the private transport share in the Belarusian fleet structure increased from 89.1% in 1990 to 96.2% in 2000.

It should be noted that notwithstanding high rate of the Belarusian fleet growth, the total fuel consumption in the transport sector reduced from 5.6 mln t.f.e. in 1990 to 3.0 mln t.f.e. in 2000.

1.8 Industry

The industry generates greenhouse gases as by-products of specific technological energy and production cycles. The following industrial sectors generate process-related greenhouse gases: metallurgy, machine-building and metal-working (electric smelting, rolling, pipe manufacturing, metal casting, refrigerating equipment, manufacture and repair), petrochemical industry (production of ammonia, nitric acid, caprolactam, ethylene), construction material industry (cement, lime production), woodworking and pulp-and-paper industry and glass works). Greenhouse gases form both through burning fuel in process furnaces to produce high-temperature heat and chemically and thermally processing raw materials. As a result, CO_2, CO, N_2O, NO_x, VNMOC, and HFC_s.

Machine-building (34.2% of the industrial product cost), consumer goods (17.2%), food (14.9%), and also chemical and petrochemical (9%) sectors were leading sectors in 1990. A substantial growth in the share of power engineering (from 2.6% to 13.8 %), chemical and petrochemical industries (from 9.0% to 14.3 %), as well as ferrous metallurgy (from 0.9% to 2.4 %) was observed in the industrial products pattern by 1995 caused by the rise in import prices for raw materials for the above sectors. In 2000, proportions in the industrial products structure remained approximately at the 1995 level. The only exception is the power engineering, the share of which reduced from 13.8% to 8.4 %.

Since the mid of the 1990s, the industrial production began to increase and that growth is related to the governmental crediting of current assets and more effective utilization of the industries' capacities, and in the late 1990s, Belarusian ruble devaluation and labor cheapening further promoted it. Stabilization of or increase in physical indicators was observed with respect to major industrial products since the second half of the 1990s. The industry's major problems include depreciation of fixed assets, technological lagging of products at external markets and shortage of investments in the sector.

1.9 Agriculture and Forestry

The agricultural sector is the main source of non-energy-related greenhouse gases. Enteric fermentation and manure decomposition produce GHG (mainly methane) in livestock breeding. Application of organic and mineral fertilizers, biologically fixed nitrogen, field waste water and afterharvesting crop residue, greenhouses and reclaimed land tillage are the main sources of GHG emissions. They generate N_2O, CO_2, CH_4.

Table 1.8 Agriculture Performance Indicators

Indicators	Years		
	1990	**1995**	**2000**
Agricultural produces production, % against 1990	100.0	73.6	71.4
Produces cost structure, sector-wise, %:			
Plant growing	36.0	57.0	54.0
Livestock breeding	64.0	43.0	46.0
Sown areas, thou ha	6,126	6,150	6,155
Application of mineral fertilizers in active ingredient, thou tonnes	2,011	512	1,022
Application of organic fertilizers, mln tonnes	79.2	49.2	35.9
Livestock population, thou heads:			
Cattle	6,975	5,054	4,221
Swine	5,051	3,895	3,431
Sheep and goat	445	262	154
Horse	217	229	217
poultry, mln heads	50.6	29.8	30.1
Peat production for agriculture, thou tonnes	12,304	961	188

Production of agricultural produces reduced in 1990–2000. The sown area structure has not substantially changed over that period. Cereal crops (41.2%) and fodder crops (42.3%) dominated in it. The yielding capacity of cereal crops reduced from 26.6 cwt/ha of sown area in 1990 to 19.1 cwt/ha in 2000. The yielding capacity of other crops is also below the 1990 level. The reduced application of fertilizers greatly contributed to that decline. The agricultural animal population substantially reduced: cattle - by 39.5%, swine - by 32.1%, and goats/sheep - by 65.4%. In general, a steady tendency of reducing main GHG sources in agricultural sector was observed.

Major carbon dioxide sinks in Belarus are forests. Forest management, species composition of stands and forest age influence the volume and efficiency of carbon removals.

The Forest Fund area amounted to 9,247.5 thousand hectares as of 1 January 2001, of which 7,851.1 thousand ha are forested, or 37.8% of the Belarusian area. All Belarusian forests are state-owned. The major part of forests is under the authority of the Forestry Committee of the Council of Ministers of the Republic of Belarus. Part of forest area is managed by conservation areas, national parks and other departments. The dynamics of forest resources is characterized by steady increment (Table 1.10). Approaches to stable forestry management are stipulated in the Strategic Forestry

Development Plan formulated in 1997. It is planned to increase the percentage of forest land to 40% by 2015. In this case, new large forest areas are to be created on lands withdrawn from the agricultural use because of low productivity and Chernobyl nuclear disaster-induced contamination.

Forest resources management improved over the 1990–2000 period. The final harvest area reduced by 27.9%. The forest harvesting volume including all types of cutting in 2000 was at the 1990 level: 10,738 and 10,787 thou m^3. The forest cutting structure changed: principal (final) harvest prevailed in 1990 – 52.2% of harvested wood, while in 2000 60.1% of wood was produced by selective felling (thinning and sanitary cuttings) and other cuttings. Forest planting and sowing increased by 23.7% compared to 1990.

Table 1.9 Forest Resources of Republic of Belarus (by years of governmental accounting as of 1 January)

Indicator	Years					
	1973	1978	1983	1988	1994	2001
Forest land total area, thou ha	8,225	8,242	8,265	8,055	8,676	9,248
Forested area, thou ha	7,063	7,168	7,192	7,028	7,372	7,851
Total forest stand stock, mln m^3	640	738	843	921	1,093	1,340
Percentage of forest land, %	34.0	34.5	34.6	33.9	35.5	37.8

1.10 Waste

In 1990–2000, the economy-related negative impact on the environment reduced.

Main water use indicators drastically reduced in 1991–1997, while they have stabilized in the recent years. In general, water withdrawal from natural sources reduced 1.6 times over the decade. As a result, industrial water consumption reduced more than 2-fold, and agricultural water supply and irrigation – 2.5-fold, public water and safe water supply increased by 13% making up 758, 160 and 782 mln m^3, respectively, in 2000. Waste water is treated by anaerobic bacteria in special plants. This process produces methane, some quantity of nitrous oxides and VNMOC.

Solid waste generated in Belarus are subdivided into three groups: solid industrial waste, solid municipal waste and sewage sludge. Decomposing solid waste organic components release methane and also carbon oxides and VMNOC.

Annually, 20 mln tonnes of solid industrial waste are generated. Nonrecycled industrial waste is accumulated at 80 industrial waste disposal sites. Enterprises of different industrial sectors accumulated 684.6 mln tonnes of production and consumption waste as of the beginning of 2001. Halite waste (86.3%) and halite sludge (10.1%) prevail in the bulk of accumulated waste. Currently, the level of waste utilization is low (16%) due to low content of valuable components in waste, shortage of processing capacities and necessary technologies.

Annually, 2 mln tonnes of solid municipal waste is generated. Almost all of them are disposed at 202 solid municipal waste dump sites. Only 4% of solid municipal waste is processed (composted). Additionally, 1 million tonnes of solid industrial waste is disposed annually at solid municipal waste disposal sites.

Sewage sludge is accumulated at sludge drying beds of treatment facilities in the amount of about 80 thou tonnes of dry residue. High toxicity level makes sewage sludge utilization difficult.

PART II. NATIONAL INVENTORIES OF GREENHOUSE GAS EMISSIONS AND SINKS

1. ENERGY

In its broad sense, the energy comprising all processes of energy activity related to the organic fuel extraction, storage, transportation and utilization (combustion) is the main anthropogenic source of emissions most of which are categorized as greenhouse gas emissions.

A larger share of industrial energy is generated by burning carbon fuel. In the process of its combustion, carbon is oxidized and carbon dioxide is emitted into the atmosphere. Since the carbon content in different types of fuel significantly differs, anthropogenic greenhouse gas emissions depend on the volume and type of the fuel used.

In the *Energy* module, greenhouse gas emissions have been estimated as a result of the following energy activities: fuel combustion, production, transportation, storage and distribution of fuel products. Greenhouse gas emissions were estimated based on quantitative data on fuel used sector-wise in the Belarusian economy.

Greenhouse gas emissions estimation in the module is subdivided into two main components:
- fuel combustion-related emissions; and
- gas leak-related emissions.

Emissions of the following greenhouse gases were estimated in the module:

- gases with direct greenhouse effect: carbon dioxide (CO_2,), nitrous oxide (N_2O) and methane (CH_4,);
- ozone precursors or gases with indirect greenhouse effect: carbon oxide (CO), nitrogen oxides (NOx) and non-methane hydrocarbons (NMHC);
- aerosol precursors: sulfur dioxide (SO_2,).

Following the 1996 IPCC Guidelines, the greenhouse gas emissions in the *Energy* module were estimated by using two methods.

According to the first method, carbon dioxide emissions (CO_2) (the most dominant of GHG emitted in terms of tonnes) are calculated based on the balance of different fuels supplied to the Republic of Belarus and carbon content in them - the so-called reference approach.

Estimation of the consumption by fuel types serves as the basis of calculation using the reference method, with the following variables being accounted:

- volume of extraction of primary fuels (production of secondary fuels is not taken into account);

- volume of primary and secondary fuels imported to Belarus;
- volume of exported primary and secondary fuels;
- volume of fuel used for the international maritime and air transport (“international bunker”);
- change in fuel stock.

The expected consumption of each fuel is determined by the following formula:

Consumption = *extraction + import - export – international bunker – change in stock.*

Not the total quantity of fuel supplied is burnt to generate energy and a portion of it is used as a feed stock, with the hydrocarbon raw material being not burnt and the carbon it contains being stored in the manufactured product pool or generated waste. Such “stored” carbon is estimated by the volume and types of fuel used as a raw material and excluded from emission calculations.

The reference method allows the upper CO_2 emissions level to be obtained.

In the second method, the estimation of greenhouse gas emissions through major activities related to fuel combustion by ***categories of sources*** is based on quantitative data on fuels used sector-wise in the Belarusian economy.

Categories of sources the activity of which is related to fuel combustion are subdivided as follows in accordance with the 1996 IPCC methodology:

- ***Energy sector – fuel processing, energy generation and transmission*** – emissions produced by burning fuel in the power generation sector and converting the primary energy raw materials into the secondary ones and also their further processing.
- ***Industry*** - emissions produced by using a process fuel in industrial furnaces and plants of industrial sectors.
- ***Transport*** - emissions produced by using fuel to operate all modes of transport, namely, road, railway, air (excluding factory conveyance and hoisting facilities).
- ***Commercial and administrative buildings*** (non-residential sector) - emissions produced by burning fuel in commercial and administrative buildings.
- ***Residential buildings*** - emissions produced by burning fuel in residential buildings.
- ***Agriculture/forestry*** – emissions produced by burning fuel in agriculture and forestry: skidders, pumps, grain dryers, glasshouses, etc.
- ***Others.***

Accounting the quantity and types of fuel consumed in each sector is an item of governmental statistical reporting of enterprises and organizations, including as follows: quarterly Forms 4-CH “Report on Fuel Balance, Supply and Consumption, and Collection and Utilization of Waste Petroleum Products”; monthly Form 1-TER “Report on Fuel-and-Power Resources Consumption”; and Form 1-TEB for 2000 – “Energy Budget of the Republic of Belarus” which are aggregated by the Ministry of Statistics and Analysis up to the republican level as a whole.

Calorific values of all fuel types have been determined with consideration for indicators (factors) relative to heat value of 1 tonne of fuel equivalent (1 tonne of fuel equivalent has a heat value of 7 Gcal, or 29.3 GJ).

IPCC Guidelines-recommended greenhouse gas emission factors for all fuel types have been mainly used.

1.1. Fuel Consumption Structure

In 2000, all sectors burning fuel consumed 29.01 million t.f.e. in Belarus. The volume of fuel consumed in terms of energy units made up 850,288 TJ (including the biomass fuel and "international bunker") (Table1.1.).

Table 1.1 Fuel Consumption Structure in 2000

Fuel	Consumption, TJ
Fuel oil	82,755
Household stove oil	4,603
Diesel fuel	70,363
Liquefied gas	12,976
Motor gasoline	43,015
Aviation kerosene	2,386
Lamp oil	86
Aircraft motor gasoline	17
Coal	13,958
Peat	5,183
Briquette peat	21,718
Natural gas fuel	540,459
Refinery gas	12,785
Biomass fuel	28,331
Others	11,653

The fuel consumption structure includes 14 fuel items. Natural gas and fuel oil account for a major share ~ 63.6% and ~ 9.7%, respectively, and these fuels were mainly consumed for electric power and heat generation (Fig. 1.1.).

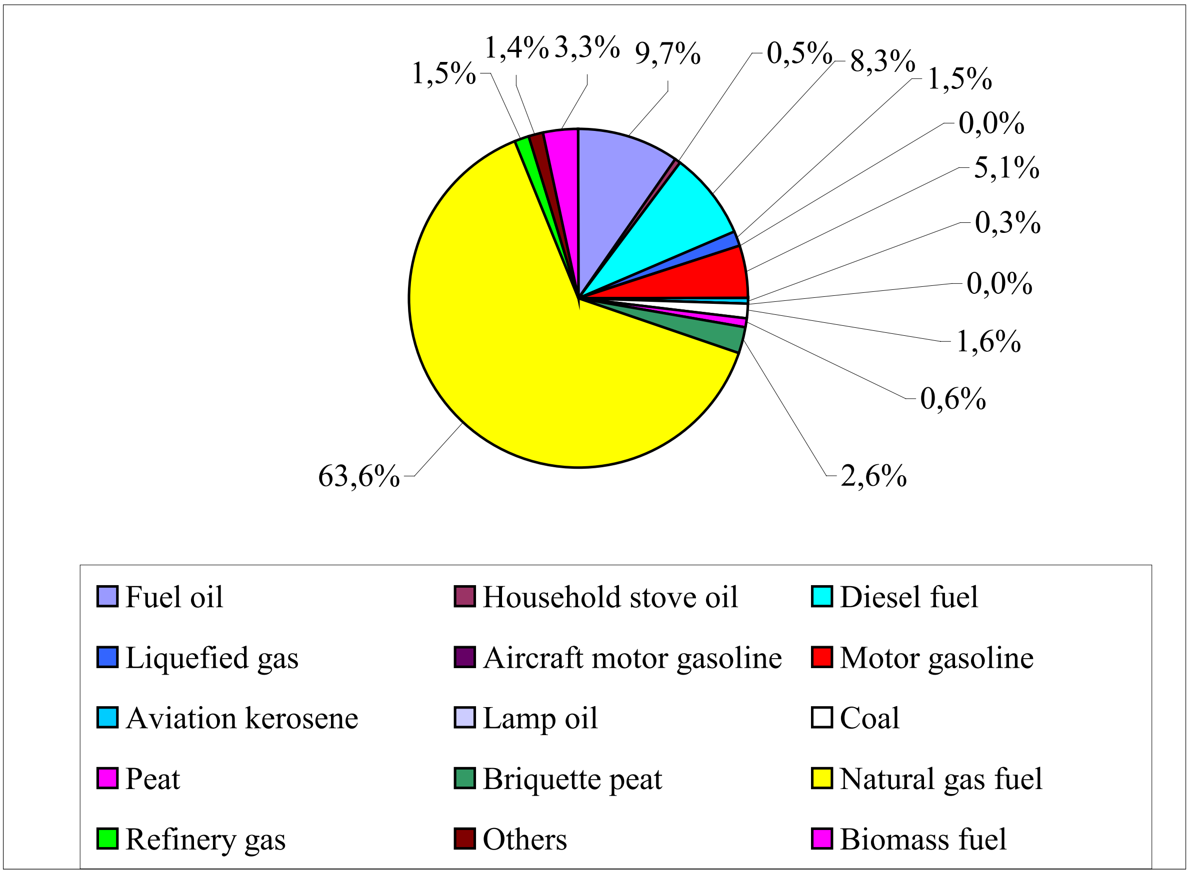


Fig. 1.1. Fuel Consumption Structure in 2000

The gaseous fuel accounts for 65.1%, liquid fuel - 25.4%, and solid fuel – 3.3% in the fuel consumption (Fig. 1.2.).

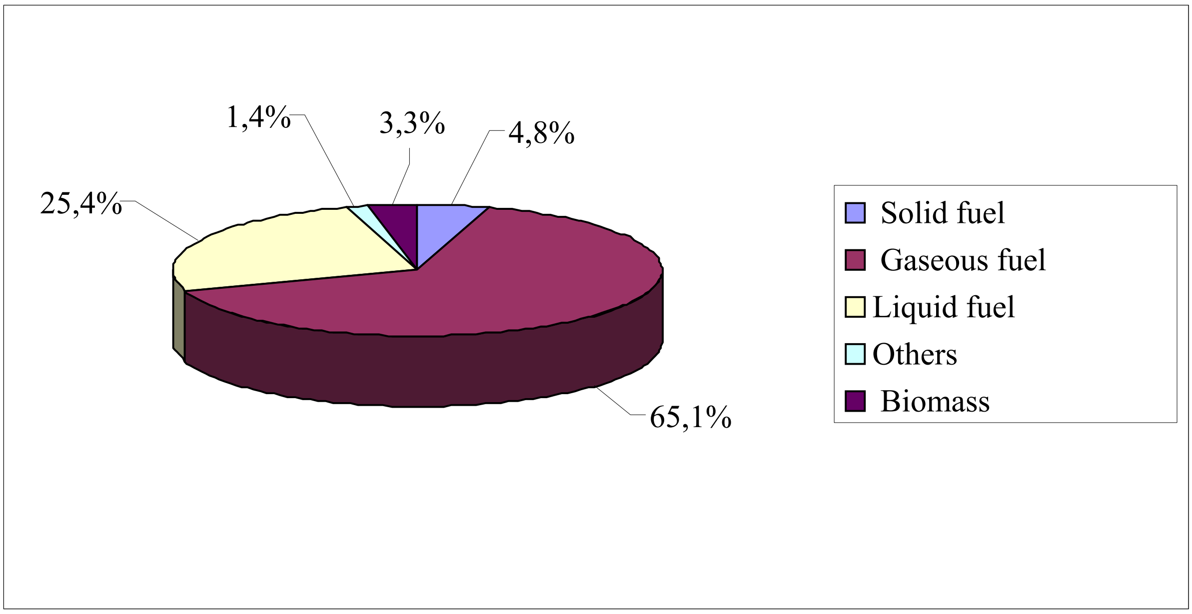


Fig. 1.2. Fuel Consumption

Following the IPCC Guidelines, estimating national GHG emissions excludes emissions related to the international air transport fuel consumption ("international bunker") from the total national emissions. The reference to the “international bunker”-related quantity and fuels and respective emissions is given for the information purpose only.

Biomass fuel and CO_2 emissions produced by burning the biomass fuel are included into the module reporting for information purpose only.

According to the national statistical reporting and data provided by the National Aviation Committee of the Republic of Belarus, the “international bunker” amounted to 81.98 thousand t.f.e. of aviation kerosene and gasoline in 2000, while biomass fuel consumption – 0.967 million t.f.e.

The category *Energy sector – fuel processing, energy generation and transmission* was the most fuel-intensive source category as before - 65.5% of the overall fuel consumption in the module - accounting for 81.5% of natural gas and 92 % of fuel oil of the total fuel consumption in the module. Nearly 95% of fuel in the category *Energy sector – fuel processing, energy generation and transmission* was consumed for energy generation, namely by public district power plants (PDPP) and central heat power plants (CHPP) and by boiler plants for generating power/heat.

In the *Transport* category (road and railway), 9.4% of fuel was consumed of the total quantity and ~ 47% of diesel fuel and ~ 92% of motor gasoline were consumed of the total amount of those fuels in the module.

The residential sector fuel consumption amounted to 10.8% of the total fuel consumed in the module. The consumption structure included the following seven fuels: natural gas ~ 45%, wood fuel – 21.6 %, briquette peat – 19.4%, liquefied gas - 12%, with remaining share being covered by household stove oil, coal, and lamp oil.

The categories *Industry* and *Agriculture/Forestry* consumed 6.7% and 3.6%, respectively, in 2000 of the total fuel consumed in the module *Energy* (Table 1.2, Fig.1.3.).

Table 1.2 Fuel Consumption by Source Categories in 2000

Source category	**Fuel consumption, TJ**
Energy sector – fuel processing, energy generation and transmission	555,133.5
Industry	57,105.6
Transport	79,762.4
Commercial sector	11,178.5
Residential sector	91,189.4
Agriculture/Forestry	30,295.8
Others	23,220.7

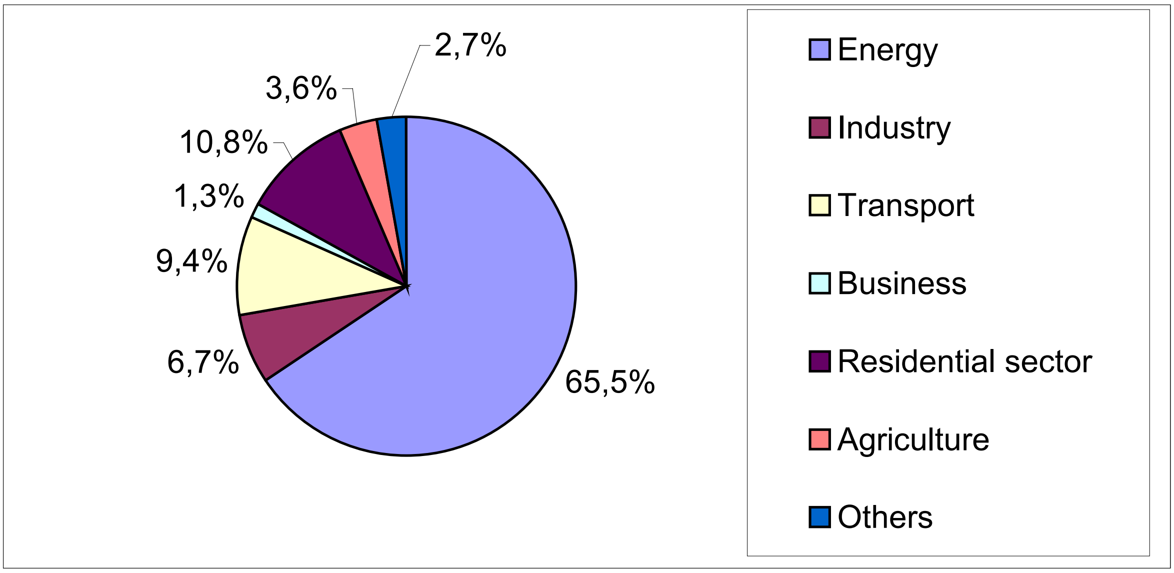


Fig. 1.3. Fuel Consumption (%) by Source Categories in 2000

1.2. Greenhouse Gas Emissions Estimation

1.2.1. Carbon Dioxide Emissions

In the general form, the greenhouse gas emissions from energy sources are calculated by the formula:

$$Emissions = \sum (EF_{ab} \times Activity_{ab}), \qquad (1.1)$$

where EF – emission factor, kG/GJ; a – fuel type, b – source category, Activity – fuel consumption in energy units (GJ).

In estimating GHG emissions in the module, emission factors for fuels were mainly used from the IPCC Guidelines.

Using characteristics of fuels being used in Belarus, natural gas/fuel oil CO_2 emission factors were calculated and used both in terms of Terajoule (TJ) and a tonne of fuel equivalent (t.f.e.) (Table 1.3).

Table 1.3 Emission Factors Comparison

Fuel	Regional (t C/TJ)	IPCC (t C/TJ)
Gas	15.0	15.3
Fuel oil	21.2	21.1

To calculate the factors, the following general equation was used:

$$EF^{CO2} = f\,(\text{carbon content, fuel calorific value, underburning})$$

For gas and fuel oil, the following formula was used:

$$EF^{CO2}\ (\text{t } CO_2/\text{t.f.e.}) = (44/12) * C^{daf} * (7000/Q^{daf}) * f\,\Gamma_{УН,} \qquad (1.2)$$

where 44/12 – factor of conversion from carbon emissions to CO_2 emissions (t CO_2/t C) , 7000 – factor of conversion from tonnes of fuel equivalent to kilocalories (kcal/kg f.e.; 1 kg f.e. = 7000 kcal), C^{daf} – carbon content in fuel in dry state (%), Q^{daf} – low heat value of fuel in dry state, i.e. fuel calorific value (kcal/kg), $f\,\Gamma_{УН}$ – unoxidized carbon function (%) which is calculated based on the data on combustibles in the carryover.

Table 1.4 CO_2 Emissions from Burning Fuel by Source Categories, Gg

Source category	**CO_2 emissions**
Energy sector – fuel processing, energy generation and transmission	32642,24
Industry	3,456.23
Transport	5,545.65
Commercial sector	686.25
Residential sector	4,717.52
Agriculture	2,158.36
Others	1,535.32
Total	**50,741.57**

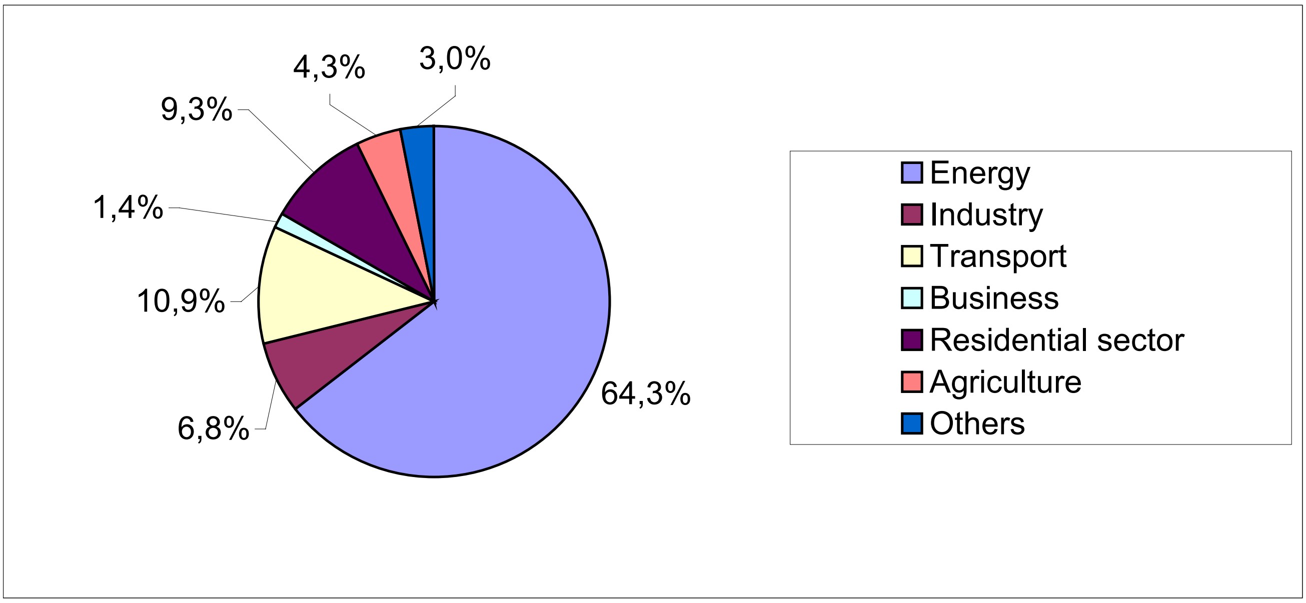


Fig. 1.4. CO_2 Emissions by Source Categories in 2000

In 2000, total CO_2 emissions in the *Energy* module amounted to 50,741.57 Gg (Table 1.4.). The following source categories contribute most to the CO_2 emissions: *Energy* – fuel processing – 64.3%, *Transport* – 10.9%, *Residential sector* – 9.3%, *Industry* – 6.8% (Fig. 1.4.).

1.2.2. Emissions of Other Fuel Combustion-Related Greenhouse Gases, Except Carbon Dioxide

In 2000, burning fuel produced trace greenhouse gases differing from CO_2 and accounting for 2.5% of aggregate GHG emissions in terms of Gg in the *Energy* module.

Methane and nitrous oxide are direct gases, with the proportion of emissions of CO_2 equivalent in the GWE accounting for 4.8% and 0.2%, respectively. In estimating emissions of these gases, the IPCC defaults were used.

The fuel burning-related **methane emissions** contribution to the overall methane emissions in the module is insignificant (~14%). Fuel burning produces small quantity of methane due to incomplete combustion. The methane emissions are dependent on temperature in a boiler plant or a furnace unit - the lower efficiency of the plant, the higher the methane emissions. Therefore, the highest CH_4 emissions are typical for household stoves and outdoor burning. The sources of the *Residential Buildings* category contribute most to the methane emissions from fuel burning (~69.0%): the bulk of emissions is produced from burning briquette peat, coal and fuel wood.

The transport facilities-produced methane emissions (5.7% of CH_4 emissions in the module) depend on the methane content in fuel, combustion efficiency, engine type and control system availability.

Oil and gas systems are an additional methane emission source in the module. This category includes all emissions produced in the process of crude oil/natural gas extraction, processing, transportation and consumption. Factors of emissions of methane during oil refining and storage and gas transportation and storage are taken from Table 1-6 of the IPCC Guidelines. Methane emissions from oil and gas systems accounted for ~86% of total methane emissions in the module in 2000. The methane emissions in 2000 amounted to 123.26 Gg.

Nitrous oxide produced during fuel combustion is a minor contributor to the total emissions. Nitrous oxide forms directly in the fuel combustion process. It has been found that the lower combustion temperature, the higher N_2O emissions. The N_2O formation mechanism is rather well studied, but experimental data are incomplete, therefore a new “fuel/sector” approach is most appropriate for calculating nitrous oxide emissions.

IPCC Guidelines-based nitrous oxide emission factors were used for different modules of fuel consumption in power plants, as well as for the transport sector.

In the N_2O emissions structure in the *Energy* module, the emissions from sources of the category "Energy sector – fuel processing, energy generation and transmission" accounts for 36.6%; in the residential sector ~31%. N_2O emissions in the module totaled 0.36 Gg in 2000.

1.2.3. Emissions of Precursors of Ozone and Sulfur Dioxide

Nitric oxides are indirect greenhouse gases, while they play an important role in forming atmospheric ozone and may be in the focus of the environmental policies. This report reviews NO_x from the point of the greenhouse effect, i.e. their oxidizing capacity is considered.

Energy processes form the most critical anthropogenic source of nitric oxides. There exist two main mechanisms of NO_x formation in power plants:

1) formation of "fuel NO_x" during chemical processes of conversion of N contained in fuel;
2) formation of "thermal NO_x" by binding atmospheric nitrogen in the combustion process.

"Fuel emissions" account for nearly 80% of nitric oxides, while "thermal emissions" - about 20% and are combustion temperature-dependent.

In the N_2O emissions structure in the module, emissions from sources of the category "Energy sector – fuel processing, energy generation and transmission" account for 54%; emissions from mobile sources - ~33%.

Totally, NO_x emissions in 2000 amounted to 165.62 Gg in the module.

Like NO_x**, carbon oxide** is an indirect greenhouse gas. Carbon oxide forms as an intermediate product as a result of underburning during fuel combustion.

The carbon oxide emissions from mobile sources in the *Transport* category are significant and represent ~63%.

CO emissions in the module amounted to 692.76 Gg in 2000.

The road transport CO and NO_x emission factors are used according to the national data (Table 1.5).

Table 1.5 Road Transport CO and NO_x Emission Factors

Fuel	***CO***		**NO_x**	
	T/t	g/GJ	T/t	g/GJ
Gasoline	0.440	10,075	0.025	572
Diesel fuel	0.125	2,941	0.035	824
Liquefied gas	0.440	9,562	0.025	543

NMHC are indirect greenhouse gases. Non-methane hydrocarbons (olefins, ketones, aldehydes, etc.) are underburning products. NMHC emissions significantly depend on the fuel, plant type and burning technique. Mobile sources and burning fuel in dwellings (specifically biomass burning) are responsible for a significant NMHC emissions.

NMHC emissions from mobile sources depend on the engine type, fuel, exhaust gas control system available (for example, catalytic converters) and transport traffic condition. Engines running idle, at low speed, as well as engines in bad repair produce the highest NMHC emissions. In 2000, NMHC emissions from mobile sources – mainly from burning gasoline and diesel fuel – accounted for 73% of the total NMHC emissions in the module, from burning fuel wood in dwellings - 17.8%. In 2000, NMHC emissions amounted to 97.76 Gg.

IPCC Guidelines NMHC emission factors are used.

Sulfur dioxide is not a greenhouse gas, but its presence in the atmosphere affects climate. Reacting with oxidants, SO_2 forms sulfate aerosols.

Energy processes involving sulfur-containing fuel combustion lead to the increased SO_2 concentrations and, hence, to the elevated aerosol concentrations in the atmosphere.

The fuel composition, but not burning technique is responsible for the sulfur dioxide emissions, therefore, to calculate sulfur dioxide emissions, annual fuel consumption values (in energy units), SO_2 emission factors (kg/TJ) and sulfur content in fuel and ash are used.

The annual sulfur oxides emissions (SO_2 and SO_3) on SO_2 basis from energy processes are calculated by the formula:

$$M_{SO2} = 0.02 \times B \times S^P \times (1-\eta^I) \times (1-\eta^{II}), \qquad (1.3)$$

where B – fuel consumption, t/year, S^P – sulfur content per fuel as-received, %, η^I – fraction of sulfur oxides carried over with ash, η^{II} – fraction of sulfur oxides trapped in an ash collector with particulates.

In 2000, sulfur dioxide emissions amounted to 202.36 Gg in the module as a whole.

1.2.4. International Aviation Bunker

Aircraft-produced greenhouse gas emissions are related to aviation kerosene and gasoline burning. Aircraft motor gasoline is used to run low-capacity aircraft and typically accounts for less than 1% of the total fuel used in the aviation. The methodology for calculating greenhouse gas emissions from aircraft is applied only to fuel used in turbojet engines.

The National Aviation Committee of the Republic of Belarus reports that turbojet aircraft made 9,041 landing-takeoff cycles in the territory of the republic in 2000. The aviation kerosene consumption amounted to 55.374 thousand tonnes, and for all landing-takeoff cycles - 14.5 thousand tonnes. The overall carbon dioxide emissions amounted to 168.22 Gg.

Fuel consumption and GHG emissions for landing-takeoff cycles and in-flight have been estimated based on the total number of landings-takeoffs and GHG emission factors provided in Section 1.5.3.5 of the IPCC Guidelines.

1.2.5. Conventional Biomass Fuels

In Belarus, this fuel category comprises fuel wood for heating, logging waste, logs of disassembled old buildings, and sleepers. The quantity of each wood fuel is subject to statistical reporting. According to it, 0.967 million t.f.e. of biomass fuel was consumed in 2000.

Greenhouse gas emissions (CH_4, CO and N_2O) have been estimated for biomass fuel by using defaults. In addition, the total quantity of the fuel consumed needs to be converted into weight units of dry matter. To convert biomass volume into the dry matter mass, the default equaling 0.5 was used.

Wood fuel-produced carbon dioxide emissions were considered separately from other fuels. The reason is that in accordance with methodical recommendations, CO_2 emissions from burning biomass fuels are included for information purpose only, but not included into the summary column of the national CO_2 emissions from energy sources.

1.3. Dynamics of Fuel Consumption and Greenhouse Gas Emissions

Greenhouse gas emissions are defined by the volume and structure of fuels used. In 2000, the fuel structure included 14 fuel types, with carbon emission factors ranging from 28.9 (peat) to 15.0 (natural gas) t C/TJ.

Over the period from 1990 to 2000, Belarus reduced fuel consumption in all activities involving fuel burning, extraction, storage and transportation (*Energy* module) by 41.8 %, and by 8.9% and 6.3% in 2000 compared to 1995 and 1999, respectively (Table 1.6.).

Table 1.6 Fuel Consumption Dynamics

Energy	**Fuel Consumption, PJ**			
	1990	**1995**	**1999**	**2000**
1. Solid fuel	103,713	46,415	37,859	40,857
2. Gaseous fuel	479,642	436,480	578,412	553,244
3. Liquid fuel	848,537	424,359	255,799	213,799
4. Other fuels	3,078	--	3,915	11,653
Total	**1,434,970**	**907,254**	**875,985**	**819,555**
Biomass	20,831	23,443	28,994	28,331

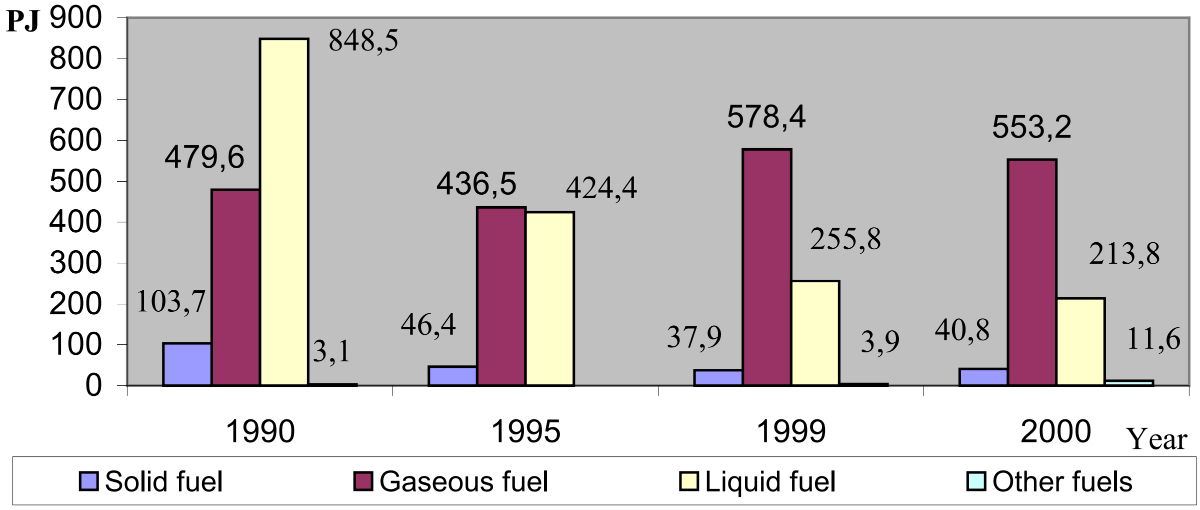


Fig. 1.5. Fuel Consumption Dynamics

Emissions of all greenhouse gases resulting from the energy activity, namely, fuel burning, and production, transportation, storage and distribution of fuel products amounted to 52,023.7 Gg in 2000.

Carbon dioxide (CO_2) emissions accounted for 97.5% in the GHG emissions. The share of the remaining six greenhouse gases accounts for only 2.5%, of them, CO emissions – 1.33%, SO_2 – 0.39%, methane – 0.24% , NO_x – 0.32%, NMHC – 0.19% (Table 1.7.).

Table 1.7 GHG Emissions Dynamics

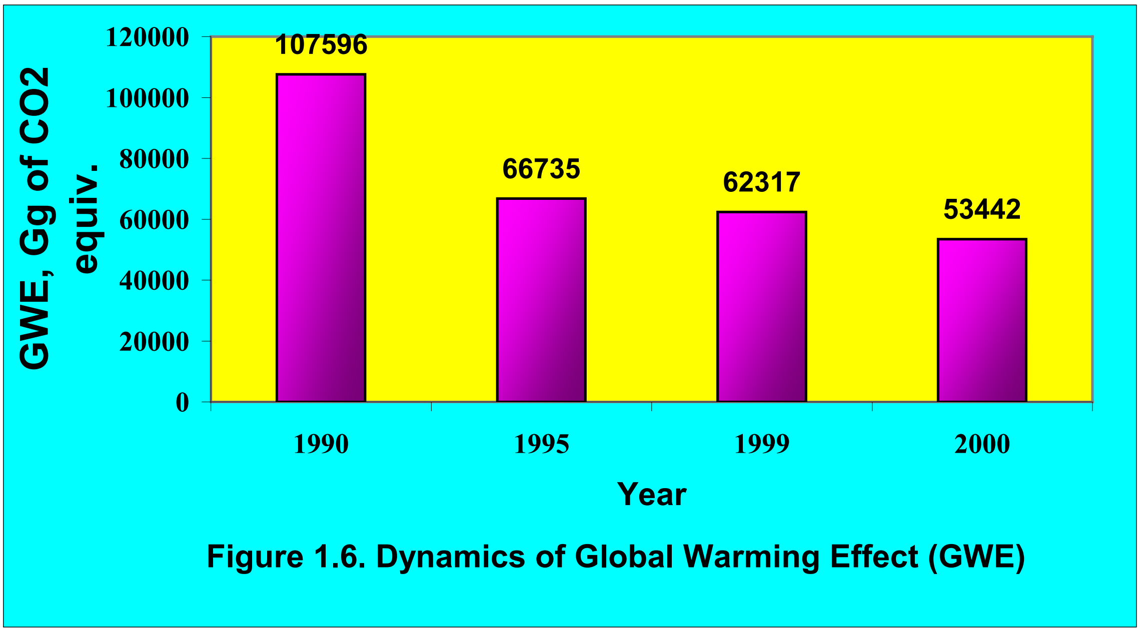
Year	**Consumption,** *TJ*	**Emissions, Gg**						
		CO_2	**CH_4**	**N_2O**	**Nox**	**CO**	**NMHC**	**SO_2**
1990	1,455,801	100,615	321.04	0.77	318.68	1,798.8	383.82	811.74
1995	930,697	60,552.1	288.05	0.43	216.274	1,356.8	296.115	365.81
1999	904,979	55,185	332.5	0.48	137.66	985.1	202.96	208.78
2000	847,886	50,741.57	123.26	0.36	165.62	692.76	97.76	202.36

Decline in oil refining has led to the reduced methane emissions and, hence, reduced emissions from oil and gas systems. Declining fuel consumption in the energy sector has explicitly resulted in the reduced N_2O, SO_2 emissions. Falling freight and passenger turnover has resulted in the reduced NOx, CO, and NMHC emissions.

Table 1.8 Greenhouse Gas Emissions Dynamics from Fuel Burning

Year	Fuel consumption, PJ	CO_2, CO_2 equivalent	CH_4, CO_2 equivalent	N_2O, CO_2 equivalent	Global warming effect
1990	1,455.801	100,615.3	6,741.6	238.7	107,596
1995	930.697	60,552.1	6,049.3	133.6	66,735
1999	904.979	55,185.45	6,982.5	148.8	62,317
2000	847.886	50,741.57	2,588.5	111.6	53,442

Figure 1.6. Dynamics of Global Warming Effect (GWE)



847.886 PJ were used for all activities related to organic fuel extraction, storage, transportation and consumption (combustion) in 2000 (not accounting the "international bunker").

This fuel quantity resulted in emissions of all greenhouse gases amounting to 52,023.7 Gg. Emissions of carbon dioxide – the most dominant of GHG emitted - amounted to 50,741.5 Gg (97.5%).

A relative effect of greenhouse gases may be compared by using such an indicator as the global warming effect (GWE) when GHG emissions are estimated based on the greenhouse gas exposure over 100-year period of the CO_2 equivalent. Thus, the methane GWE is 21, and that of nitrous oxide is 310.

In 2000, the direct GHG-induced GWE from burning fuel in the module amounted to 53,442 Gg of the CO_2 equivalent (Table 1.8.). CO_2 emissions are the largest contributor (95%) to the GWE. In 2000, the GWE from burning fuel in the module reduced by 54,154 Gg (50.3%) compared to 1990, by 13,293 Gg (19.9%) - 1995, and by 8,875 Gg (14.2%) - 1999.

Over the ten-year period (1990-2000), fuel consumption reduced by 41.3% and emissions of all greenhouse gases - by 50.3 %. The energy/resource-saving policy being pursued and the change in fuel consumption over 1990-2000 mainly resulted in higher rates of GHG emissions reduction. Fuel oil and coal have been efficiently replaced by natural gas and biomass fuel. Therefore, the share of coal reduced from 3.7% to 1.6% in the fuel consumption over the period in question, that of fuel oil - from 37.5% to 9.7%, while the share of natural gas increased from 30.3% to 63.6% and that of biomass fuel - from 1.4% to 3.3%.

Over the recent years (1995-2000), Belarus managed to reduce the GDP energy intensity by 28%, while the GDP has grown by 36%, by implementing state-of-the-art technologies and pursuing efficient energy conservation policies.

In the course of developing the inventories, the data on fuel consumption and GHG emission factors were subject to an expert appraisal. The uncertainty of data on fuel consumption by types is minimum and amounts to 1-5%, since the data on consumption is an item of the national statistical reporting of the Belarusian enterprises and organizations. The emission factors uncertainty is 1-10%.

2. INDUSTRIAL PROCESSES

The major GHG emission sources in this module are the construction industry, metallurgy, chemical and petrochemical industries.

GHG emissions with respect to each industrial process have been estimated based on output and emission factors in accordance with the method presented in the Revised Guidelines for National Greenhouse Gas Inventories: Workbook (IPCC, 1996), with consideration being given for national specifics of the Republic of Belarus.

The following data have been used as initial data on output in physical terms:

- data of the Ministry of Statistics and Analysis both published [6] and compiled by the task force responsible for the Report;
- data of ministries and departments;
- data of individual enterprises;
- data obtained through own research.

GHG emission factors have been used by the following sources depending on the data available:

- Revised Guidelines for National Greenhouse Gas Inventories (IPCC, 1996): Workbook;
- Specific Indicators of Pollutant Emissions by Sectors of Industry, 1991 [7];
- Handbook of Specific Indicators of Pollutant Atmospheric Emissions for Some Industries – Main Sources of Atmospheric Pollution, (Saint-Petersburg, 2001) [8];
- Ecological Certificates of Enterprises, Research Work Report of BRC ECOLOGY and other organizations.

Greenhouse gases produced by industrial processes in Belarus include as follows: CO_2, CH_4, N_2O, NO_x, CO, NMHC, HFC, SO_2.

2.1. Carbon Dioxide Emissions

Since CO_2 is not subject to national statistical reporting in 2-oc Form (air), its emissions are calculated based on the output and respective emission factors.

Two sources contribute to the carbon dioxide emissions, namely, cement and lime industries.

The cement technology produces CO_2 at the stage of clinker production – an intermediate product. The cement output stated in the Statistical Handbook [6] and adjusted for the clinker output was used in calculations. The adjustment was made since, in addition to clinker, cement contains 5 – 20% of mineral additives [9]. An average additive content of 13% is used.

The IPCC Guidelines-recommended CO_2 emission factor is used, since the national data are not available.

Table 2.1 CO_2 Emissions, Gg

Source	1990	1995	1999	2000
Cement production (clinker-adjusted)	996.20	544.63	881.64	814.76
Lime production	860.15	358.03	524.01	463.02
Total:	**1,856.35**	**902.66**	**1,405.65**	**1,277.78**

Over the 1990-2000 period, the contribution of the cement production to total emissions increased from 53.7% to 64.8% (Table 2.1).

On the contrary, the lime production contribution to emissions reduced as a result of the declined lime production. In calculating the CO_2 emissions in the lime production, the IPCC Guidelines factor is also used – 0.79 t CO_2/t of lime produced from calcite raw materials, since lime is not produced from dolomite in Belarus.

Decreasing output resulted in 31% reduction in CO_2 emissions from these sources throughout the industry from 1990 to 2000.

For the ammonia production, carbon dioxide emissions have not been calculated, since the Grodno Production Association *Azot* – the only ammonia manufacturer in Belarus – fully uses CO_2 as the raw material at all 4 production lines producing carbamide.

2.2. Sulfur Dioxide Emissions

The major sources of SO_2 emissions are cement, ammonia and sulfuric acid industries, with the sulfuric acid technology being the major contributor accounting for 94-96% of emissions (Table 2.2).

Table 2.2 SO_2 Emissions, Gg

Source	1990	1995	1999	2000
Cement production	0.68	0.37	0.60	0.55
Ammonia production	0.04	0.02	0.03	0.03
H_2SO_4 production	18.32	7.28	9.56	10.21
Total	**19.04**	**7.67**	**10.19**	**10.79**

To calculate SO_2 emissions, ammonia and sulfuric acid outputs were based on the enterprise-wise data received from the Belarusian National Oil and Chemistry Concern. The specified compounds are intermediate products at the chemical industries, thus the data regarding them are not available in Statistical Handbooks. IPCC Guidelines SO_2 emission factors are used.

2.3. Carbon Oxide Emissions

Carbon oxide emissions were calculated for ammonia, ethylene/propylene, caprolactam and production of some metals (Table 2.3).

Table 2.3 CO Emissions, Gg

Source	1990	1995	1999	2000
Ammonia production	0.60	0.38	0.44	0.42
Ethylene/propylene production	0.15	0.11	0.11	0.11
Caprolactam production	2.67	2.23	2.16	2.49
Metal production, total, including:	4.59	2.43	4.60	5.01
Electric steel	1.56	1.04	2.03	2.27
Rolled ferrous metals	1.1	0.98	2.08	2.24
Steel/cast iron pipes	0.45	0.05	0.12	0.11
Iron casting	1.14	0.26	0.27	0.28
Steel casting	0.28	0.08	0.08	0.09
Non-ferrous casting	0.06	0.01	0.02	0.02
Total	**8.01**	**5.15**	**7.31**	**8.03**

Chemical industry's output data have been collected at the sector's enterprises. The data on the iron and steel industry's output have been received from the Ministry of Statistics and Analysis of the Republic of Belarus.

CO emission factors in calculations have been used based on the national data: for ammonia and caprolactam from the reference [10], for ethylene and propylene and electric steel from [8], rolled metal and pipe production from [7], iron casting from [11], steel casting from [7], non-ferrous metal casting from [11].

It should be noted that for steel casting produced without using fuel, emissions forming during operation of electric arc steel melting furnaces served as a basis for calculations. Cast iron is smelted predominantly in fuel-fired cupola furnaces. An industrial component, which is small, may be separated out only with a high error. Therefore, carbon oxide and nitrogen emissions from cast iron smelting were accounted in the *Energy* module. In the *Industrial Processes* module, the aggregate specific emissions from processes of tapping cast iron from cupola furnaces to hot-metal ladles and casting iron into moulds were used for calculations.

Belarusian machine-building enterprises predominantly smelt non-ferrous metal in induction crucible and channel electric resistance furnaces and in electric-arc furnaces with an output of 0.15 – 2 t/hour. Average specific values of nitric and carbon oxides emissions were used specifically for them.

The iron and steel industry is the main CO emissions contributor accounting for ~ 60%. It may be noted that among the industries the caprolactam production accounts for the largest fraction of CO emissions exceeding 30% of the total emissions.

2.4. Nitric Oxide Emissions

Nitric oxide emissions are characteristic of a number of processes of the chemical and metallurgical industries (Tables 2.4, 2.5).

Table 2.4 NO_x Emissions, Gg

Source	1990	1995	1999	2000
Nitric acid production	0.18	0.13	0.16	0.16
Ethylene/propylene production	0.05	0.04	0.04	0.04
Caprolactam production	0.06	0.05	0.05	0.05
Metal production, total, including:	0.67	0.42	0.84	0.92
Electric steel	0.31	0.21	0.41	0.45
Rolled ferrous metals	0.21	0.18	0.39	0.42
Steel and cast iron pipes	0.05	0.01	0.01	0.01
Steel casting	0.06	0.02	0.02	0.02
Non-ferrous metal casting	0.05	0.01	0.01	0.02
Total	**0.96**	**0.64**	**1.09**	**1.17**

Table 2.5 NO_2 Emissions, Gg

Source	1990	1995	1999	2000
Weak nitric acid production	1.12	0.84	0.99	1.01

For weak nitric acid, nitric oxides emission factors are used based on the data provided by the Grodno PA *Azot* producing it, for other industries – based on [8].

Metallurgy accounts for 70-78% of emissions of nitric oxides, with electric steel and rolled ferrous metal industries being the main contributors.

2.5. Methane Emissions

Methane emissions have been calculated for chemical industries (ethylene and methanol) and electric steel industry (Table 2.6).

Table 2.6 CH_4 Emissions, Gg

Source	1990	1995	1999	2000
Chemical industry (ethylene, methanol)	0.15	0.11	0.12	0.15
Electric steel industry	1.0	0.67	1.3	1.46
Total	**1.15**	**0.78**	**1.42**	**1.61**

Methane emission factors in calculations are used based on [8]. Steelmaking accounts for nearly 90% of aggregate methane emissions.

2.6. Emissions of Non-Methane Hydrocarbons

The NMHC hydrocarbon emissions are characteristic of asphalt making, glass making and a number of chemical industries (Table 2.7).

Table 2.7 NMHC Emissions, Gg

Source	1990	1995	1999	2000
Asphalt making	0.26	0.12	0.14	0.11
Glass making	0.03	0.02	0.03	0.03
Ammonia production	6.04	3.82	4.38	4.17
Chemical industries (ethylene, propylene, polyethylene, phthalic anhydride, acrylonitrile)	0.99	0.69	0.72	0.72
Total	**7.32**	**4.65**	**5.27**	**5.03**

The data on chemical products output have been received at the industry's enterprises, while IPCC Guidelines emission factors are used for them.

Glass output data for calculations have been received from enterprises of the Belarusian Ministry of Construction and Architecture, and emission factors are used from [8].

As regards asphalt, NMHC are emitted during asphalt making, road paving and then from road pavement during operation in accordance with the IPCC Guidelines. We have calculated only NMHC emissions for asphalt making. The output data were provided by the BELAVTODOROGI Department. The emission factor is used based on the national data, that is, the data on NMHC emission analysis at 19 Belarusian asphalt plants [12].

Unavailability of national data rules out the possibility of calculating NMHC emissions during road paving and operation. The IPCC Guidelines-recommended NMHC emission factor of 320 kg of NMHC per 1 tonne of road pavement cannot be accepted, since 1/3 part by weight of asphalt cannot volatilize into atmosphere.

Ammonia process is the main contributor to the NMHC emissions exceeding 80%.

2.7. Fluorocarbon Emissions

Fluorocarbons are not produced in Belarus.

HFC 134 and 134a are used as a refrigerant, with HFC 134 accounting for less than 0.5% of the total volume. Therefore, emissions are calculated specifically for HFC 134a.

In making calculations, emissions related to replacement of ozone-depleting refrigerants with HFC 134a and emissions induced by operating refrigerating equipment were taken into account. In 1998 and 2000, Grodno PA *Khimvolokno* replaced refrigerant 12 with HFC 134a.

Data on the HFC 134a consumption for making calculations were received from the Belarusian enterprises, and the IPCC Guidelines emission factors were used.

The calculated aggregate HFC emissions are very low amounting to ~ 0.001 Gg, i.e. it may be actually neglected.

Reviewing the tendencies of greenhouse gas emissions in the *Industrial Processes* module as a whole, it should be noted that they are defined by the output of respective products. A nose-diving decline in production in 1995 compared to 1990 also effected emissions of all greenhouse gases (Figs. 2.1, 2.2).

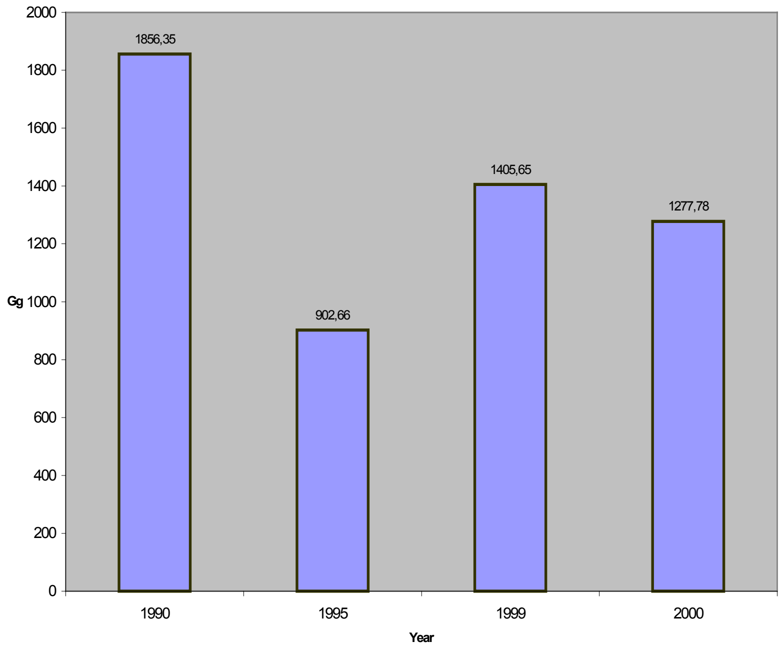


Figure 2.1 Dynamics of CO_2 Emissions

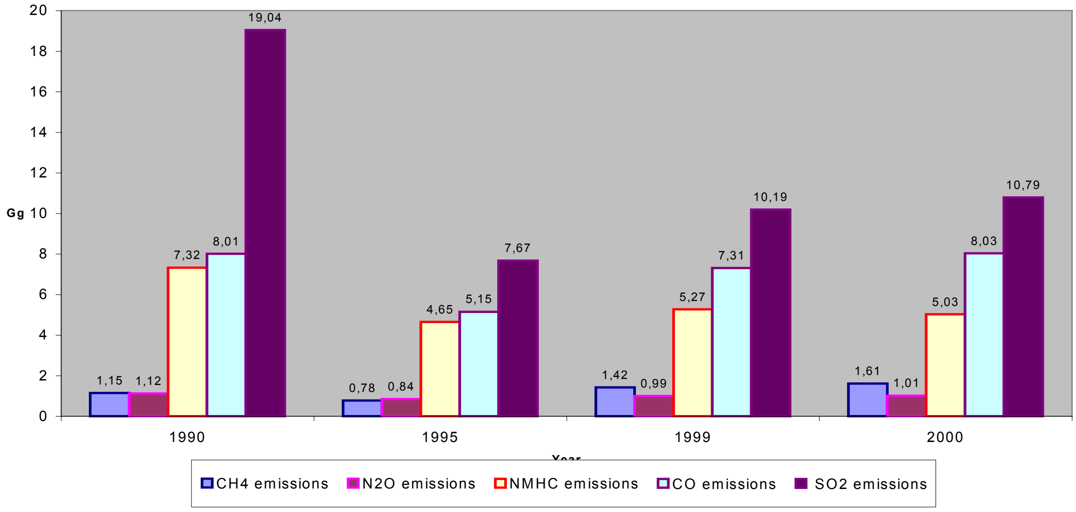


Figure 2.2 Dynamics of Greenhouse Gas Emissions (except CO_2)

During the years which followed, the output growth also resulted in greenhouse gas emissions.

The structure of greenhouse gas emissions of the CO_2 equivalent in 2000 is presented in Fig. 2.3. It changed insignificantly over the period in question.

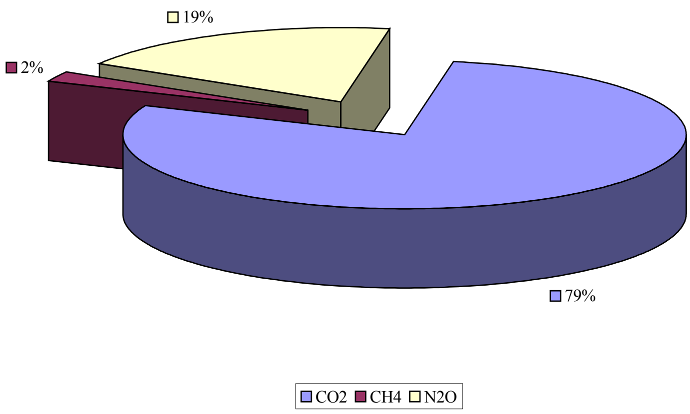


Fig. 2.3 Structure of Greenhouse Gas Emissions

The estimation of the uncertainty of calculation results is defined by the uncertainty of initial data, that is, by output and emission factors.

Output for a number of industries is based on the data provided by the Ministry of Statistics and Analysis of the Republic of Belarus, that of other industries were received from sectoral ministries and enterprises. The uncertainty of statistical data is evaluated within 3-10%, i.e. 6% on the average. The uncertainty of data received from the sectoral ministries and enterprises is lower, being up to 3%, in cases when the products in question are manufactured at a number of enterprises and is ~ 1%, if 1-2 Belarusian enterprises are involved in the production.

The uncertainty of IPCC Guidelines GHG emission factors may be estimated at the level of ~ 10%, while the national data uncertainty may be accepted within the range of 5%.

3. SOLVENTS AND OTHER PRODUCTS USE

Solvents are categorized as substances the use of which involves emissions of non-methane hydrocarbons.

Solvents are used in the following three spheres:

1) thinning paints;
2) degreasing and dry cleaning;
3) chemicals products manufacture/processing.

The first group in which solvents are applied includes processes related to the use of paints, lacquers, enamels, sealants, base coatings/primers. The main users are woodworking, machine-building and consumer goods industries, as well as construction and repair companies. As a rule, emissions comprise solvents contained in paints, enamels, lacquers and so forth being their volatile components: xylene, toluene, acetone, isopropyl alcohol, white spirit, ethyl cellosolve, etc.

The second group comprises processes using solvents for degreasing surfaces and dry cleaning. These types of solvents are used by enterprises of electronic and radio engineering industries, as well as by dry cleaning companies. In this case, acetone, gasoline, ethanol, carbon tetrachloride, trichloroethylene, and perchloroethylene prevail in emissions.

The third and the largest group comprises production and processing of chemical products:

- oil refineries;
- petrochemical enterprises (ethylene, propylene, acryclonitrile, methacrylate);
- chemical fibers enterprises: polyester fiber and yarn and raw materials for their production (dimethyl terephthalate, terephthalic acid), capron threads for tire fabric and industrial products, acrylic, carbon and modacrylic fiber;
- glass fiber and glass-fiber materials enterprises;
- paintwork materials enterprises (condensation resin/polymerization-based lacquers and enamels, polymerization resin-based primers) and raw materials for them (phthalic anhydride);
- tires for cars, trucks and agricultural machinery;
- general mechanical rubber goods;
- plastics production and processing (polyethylene, polypropylene, polystyrene).

Since a large number of chemical enterprises and crude oil refineries operates in Belarus, NMHC emissions are high (petrobenzene, cyclohexane, acetone, cyclohexanone, etc.).

In accordance with the IPCC Guidelines, emissions related to use of solvents and other products are estimated based on the products used (paints, enamels, solvents, etc.) and the aggregated emission factor.

Since currently the use of paints, solvents, primers and so forth are not accounted in Belarus, the NMHC emissions were estimated through the expert appraisal, with the analyses for 1990 and subsequent years being given consideration for. The specific pollutant emission per unit of paint (lacquer, etc.) used has been determined based on quantitative and qualitative analysis of the composition of a volatile component of different types of paints, enamels, primers, etc. by using research data and estimated at 0.5 t of NMHC/t paint. The specific pollutant emission during the degreasing process was taken to be 1.0 t NMHC/t solvent.

It has been noted above that the largest contributor to the NMHC emissions is the group of solvents used for chemicals production and processing (Table 3.1), as well as the oil refining process emitting a significant quantity of oil gasoline. Analyzing ecological certificates of enterprises manufacturing the respective products provided aggregated emission factors. Emission calculation results with respect to all groups of solvents/other products use are given in Annex 2, module *Solvents and Other Products Use*.

In the course of preparing the inventories, the expert appraisal of data on chemicals consumption and production has been given. Inasmuch as the national statistical reporting on paintwork products consumption and use of solvents for surface degreasing and dry cleaning is not available, the uncertainty of the activity data has been estimated at 35%, while that of data on emission factors - 5%.

Table 3.1 NMHC Emissions from Using Solvents and Other Products in Chemicals Production and Processing

Submodule	**NMHC emissions from using solvents in chemicals production and processing**		
Product	**A Quantity of product, t**	**B Aggregated emission factor, t NMHC/t**	**C NMHC emissions, Gg**
			C = AxB/1000
Oil refining	13,528,300	0.00147 for oil gasoline	19.886
Xylenes	38,006	0.0145 for xylene	0.551
Benzene	51,719	0.006 – benzene	0.310
Condensation resin-based lacquers	24,172	0.01 - aggregate for xylene, acetone, white spirit	0.242
Condensation resin-based enamels, primers and sealants	28,335		0.283
Polymerization resin-based lacquers, enamels, primers and sealants	6,109		0.061
Caprolactam	113,250	0.005 - aggregate for benzene, cyclohexane cyclohexanone	0.566
Dimethyl terephthalate	190,050	0.0013 - aggregate for methanol and xylene	0.247
Continuous glass fiber	19,975	0.03 for ethanol	0.599
Tires	231,050	0.00024 for gasoline	0.055
Rubber footwear (thousand pairs)	3,348	0.018 t/thousand pairs - aggregate for gasoline and alcohol	0.060
General mechanical rubber goods (molded and unmolded)	2,865	0.03 for gasoline and ethyl acetate	0.086
Total	**14,213,759**		**22.946**

Table 3.2 Dynamics of Non-Methane Hydrocarbon Emissions

Solvent use	NMHC emissions, Gg			
	1990	1995	1999	2000
Paints use	25.6	12.8	31.935	29.4
Production/processing of chemicals	65.28	21.42	19.042	22.946
Degreasing and dry cleaning	3.97	1.98	3.49	1.75
Total	**94.85**	**36.20**	**54.467**	**54.096**

In 2000, NMHC emissions produced by using solvents and other products reduced by 43% compared to those of 1990, while they increased by 33% compared to 1995 and reduced by 0.7% compared to 1999 (Table 3.2) resulting from the output growth in the Republic of Belarus over the period of 1995-2000 (Fig. 3.1).

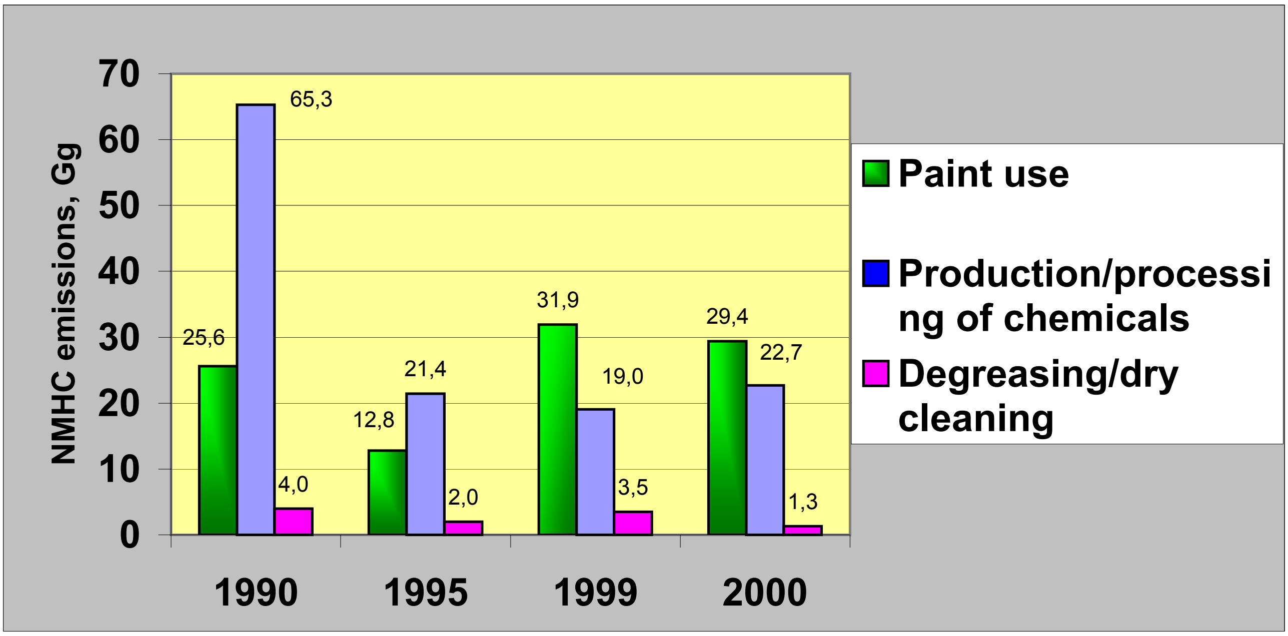


Figure 3.1 Dynamics of NMHC Emissions

4. AGRICULTURE

Main greenhouse gases emitted in this category of sources are CH_4 and N_2O supplemented by lower emissions of CO, NOx and CO_2.

In the category of sources *Agriculture*, the following sources are available in the Republic of Belarus:

- livestock (emissions from enteric fermentation and manure management are considered separately);
- burning agricultural residue on fields;
- agricultural soil emissions.

This sector includes as follows:

- direct emissions of nitrous oxide from agricultural soils caused by nitrogen fertilizer application;
- direct emissions of nitrous oxide caused by application of manure as fertilizer and cattle grazing;
- indirect emissions of nitrous oxide caused by application of nitrogen-containing substances in agriculture. It includes emissions induced by using reclaimed peat soils, emissions caused by atmospheric precipitation of nitrogen compounds and emissions due to leaching of nitrogen compounds from soils.

Such categories of sources as rice cultivation and slash-and-burn cultivation specified in the IPCC Guidelines and included into the agricultural sector are not available in the Republic of Belarus.

Of the sources available, the most dominant are the livestock (methane emissions) and direct emissions from arable soils and livestock breeding (nitrous oxide).

The following year-wise data were used for preparing the GHG inventories in the given sector:

- livestock population by animal species;
- manure storage and distribution systems by types;
- production of plant growing produces by crops;
- production of legumes by types of crops;
- fraction of biomass burnt on fields (by types of crops);
- level of nitrogen fertilizer usage;
- area of arable peat lands.

The data on livestock population, crop production output, including legumes, level of nitrogen fertilizer usage have been collected in the ministries and departments in full and covered all years required.

The data covering specific years in terms of areas of arable peat lands and agricultural burns have been obtained..

Therefore, the bulk of the statistical data required to calculate greenhouse gas emissions have been acquired.

The manure storage and distribution systems, as well as the fraction of crop residue burnt have been estimated through consultations with specialists.

The statistics provide the livestock population data for a specific year as of 1 January of the next year, therefore, an average of two successive years, that is, the average of 1990 and 1991 livestock data have been taken as the 1990 livestock data and so forth to characterize the current year.

The IPCC methodology of greenhouse gas inventories is based on the so-called top-down approach, when aggregated emission factors and production and statistical data are used..

The main calculation algorithm:

$$E = E\text{ф} \times P,$$

where E – volume of emissions of one or another gas from a specific source category, Eф- specific emission factor for the given category, P – statistical indicator characterizing intensity of a source (livestock population, fertilizer application, arable soil area, etc.).

This general algorithm is transformed to be applied to specific sources.

The main reference regarding emission factors is the IPCC Guidelines for GHG Inventories. The additional information has been obtained from the literature and archives and agricultural experts.

4.1. Calculation of Greenhouse Gas Emissions

Livestock breeding-related methane emissions have been calculated using livestock population statistical data and emission factors. The IPCC Guidelines factors were used (Table 4.1).

Unavailability of direct accounting of the biomass burnt on fields makes the estimation of emissions of gases with indirect greenhouse effect difficult. The basic initial data include the data on the burn area the arable land comprises provided by the Ministry of Natural Resources and Environmental Protection, as well as the expert appraisals. In general, burning crop residue is not characteristic of Belarus, and the public sector, in particular. The fraction of burnt agricultural crop residue is relatively higher in the private sector. In general, based on the data available it is presumed that 1% of crop residue of cereal crops and legumes and 5% of potato plant residue are burnt annually. The uncertainty of estimates is rather high which is primarily explained by the absence of direct accounting of burning crop residue.

Table 4.1 Basic Greenhouse Emission Factors in the *Livestock* Sector, Source Category *Agriculture*

	CH_4 emissions from enteric fermentation, kg/head	CH_4 emissions from manure, kg/head	N_2O emissions from manure, kg/kg of nitrogen emitted*
Non-dairy cattle	56	4	0.001-0.02
Diary cattle	81	6	0.001-0.02
Horses	18	1.39	0.001-0.02
Goats	5	0.12	0.001-0.02
Sheep	8	0.19	0.001-0.02
Swine	1.5	4	0.001-0.02
Poultry	-	0.078	0.001-0.02

* - depending on the storage system

Table 4.2 Methane Emissions from Enteric Fermentation and Manure Management Systems, Gg

	1990			1995				1999		2000		
GHG source	Enteric fermentation	Manure	Total	Enteric fermentation	Manure	Total	Enteric fermentation	Manure	Total	Enteric fermentation	Manure	Total
Animals, total	471.30	57.90	529.20	358.73	44.720	403.45	310.80	39.10	349.90	296.16	37.51	333.67
Cows	194.449	14.404	208.85	174.826	12.950	187.78	155.176	11.495	166.67	151.081	11.191	162.27
Other cattle	261.531	18.681	280.21	171. 934	12.281	184.22	145.046	10.360	155.41	134.856	9.633	144.49
Sheep	3.478	0.083	3.56	1.734	0.041	1.78	0.792	0.019	0.81	0.724	0.017	0.74
Goats	0.222	0.005	0.23	0.281	0.007	0.29	0.287	0.007	0.29	0.307	0.007	0.31
Horses	3.929	0.303	4.23	4.034	0.312	4.35	4.051	0.313	4.36	3.941	0.304	4.25
Swine	7.691	20.509	28.20	5.924	15.798	21.72	5.448	14.529	19.98	5.248	13.994	19.24
Poultry	0.00	3.915	3.91	0.00	3.331	3.33	0.00	2.378	2.38	0.00	2.368	2.37
Others												

Table 4.3 GHG (Nitrous Oxide) Emissions from Manure Storage and Distribution Systems, Gg N_2O

GHG Source	1990	1995	1999	2000
Manure	0.016	0.013	0.011	0.010

This category comprises a number of source sectors, namely, direct emissions of nitrous oxide from soils, emissions related to utilization of livestock waste and indirect emissions:

$$N_2O = N_2O_{DIRECT} + N_2O_{ANIMALS} + N_2O_{INDIRECT}$$

The calculation of N_2O emissions is based on the calculation of nitrogen flux into the soil and subsequent release in the form of N_2O.

Table 4.4 Emissions of Indirect Greenhouse Gases from Burning Crop Residue on Fields, Gg

	1990	1995	1999	2000
CH_4	0.332	0.310	0.218	0.268
CO	8.720	8.131	5.733	7.036
N_2O	0.000	0.000	0.000	0.003
NO_x	0.009	0.010	0.016	0.097

Emissions from Agricultural Soil

Direct Emissions Of Nitrous Oxide From Agricultural Soils From Nitrogen Fertilizer Application

The calculation was made based on mineral nitrogen fertilizer application data.

Direct Emissions Of Nitrous Oxide From Using Manure As Fertilizer

The basic input indicators include livestock and a fraction of manure used as a fertilizer. The fraction of manure remained on pastures and enclosed grazing land and also used as fuel (not available in Belarus) is taken into account.

Direct Emissions From Growing Nitrogen-Fixing Crops

The nitrogen release is calculated by the formula

$$F_{BN} = 2xCrop_{BF}xFrac_{NCRBF}$$

The calculation has been made using leguminous plants production indicators and nitrogen fraction (0.03) on the total biomass basis (indicator 2).

Direct Emissions Of Nitrous Oxide From Crop Residue

Emissions from nitrogen-fixing and non-nitrogen-fixing crops are included, with the fraction of burnt and removed residue being accounted.

The main statistical data used included the cereal crop production, with the dry matter fraction (0.85) and produces-to-biomass ratio being accounted (0.5).

The summary Table 4.5 provides direct emissions of nitrous oxide from soils.

The main emission source in the given group is arable reclaimed peat soils. Emissions from this source category were calculated based on the reclaimed arable peat land area and nitrous oxide emission factor (5 kg N/ha).

Table 4.5 N_2O Direct Emissions from Soils (apart from Organogenic Soils), N_2O Gg

N flux into soil	1990	1995	1999	2000
Nitrogen fertilizers	12.087	3.313	5.657	5.893
Manure (F_{AW})	0.011	0.008	0.006	0.006
Nitrogen-fixing crops (F_{BN})	0.251	0.187	0.002	0.292
Crop residue (F_{CR})	1.988	1.551	1.058	1.403
Total	**14.337**	**5.06**	**6.723**	**7.594**

Emissions Of Nitrous Oxide From Arable Reclaimed Peat Soils

The IPCC Guidelines for GHG Inventories recommend that the soils with organic depth of not less than 40 cm be accounted. Given the statistical data structure (*Belgiprovodkhoz* data), soils with the peat depth of 30 cm and greater were accounted.

The data on the area of reclaimed peat land is not annually summarized. The 1992 (for 1990) and 1996 (for 1995, 1999 and 2000) data were used.

Table 4.6 N_2O Emissions from Arable Peat Soils, N_2O Gg

	1990	1995	1999	2000
N_2O emissions (thousand tonnes N_2O/year)	7.181	6.691	6.691	6.691

Nitrous Oxide Emissions From Cattle Grazing

Emissions from pastures and enclosed grazing lands are accounted in this category. The major indicator is livestock population and a fraction of manure remaining on pastures.

Table 4.7 Nitrous Oxide Emissions from Cattle Grazing, in Gg N_2O

1990	1995	1999	2000
0.003	0.002	0.002	0.002

Indirect Nitrous Oxide Emissions From Nitrogen-Containing Substances Used In Agriculture

This includes as follows:

- emissions from nitrogen compound atmospheric precipitation;
- emissions from leaching nitrogen compounds from soils.

Nitrous oxide emissions from nitrogen compound atmospheric precipitation and from leaching nitrogen compounds from soils are calculated based on the quantity of mineral fertilizers and manure used.

Table 4.8 Indirect Emissions of Nitrous Oxide from Fallout of Ammonia and Nitric Oxides and Leaching of Nitrogen Compounds from Soils, in Gg N_2O

	1990	1995	1999	2000
Fallout	1.076	0.295	0.504	0.525
Leaching	8.066	2.216	3.776	3.933
Total	**9.142**	**2.511**	**4.280**	**4.458**

Aggregate nitrous oxide emissions from arable soils are provided in Table 4.9.

Table 4.9 Aggregate Nitrous Oxide Emissions from Arable Soils, Gg N_2O

	1990	1995	1999	2000
Direct emissions	14.338	5.06	6.724	7.595
Organogenic soil use	7.181	6.691	6.691	6.691
Grazing	0,003	0,002	0,002	0,002
Indirect emissions	9.143	2.511	4.281	4.459
Total	**30.665**	**14.264**	**17.698**	**18.747**

The main source of methane emissions in Belarus is cattle breeding (89%), primarily enteric fermentation of the cattle (86%).

The main sources of nitrous oxide are direct emissions from peat soils (36%) and application of nitrogen mineral fertilizers (32%), as well as indirect nitrous oxide emissions (24%), also mainly from application of nitrogen mineral fertilizers (Fig. 4.1).

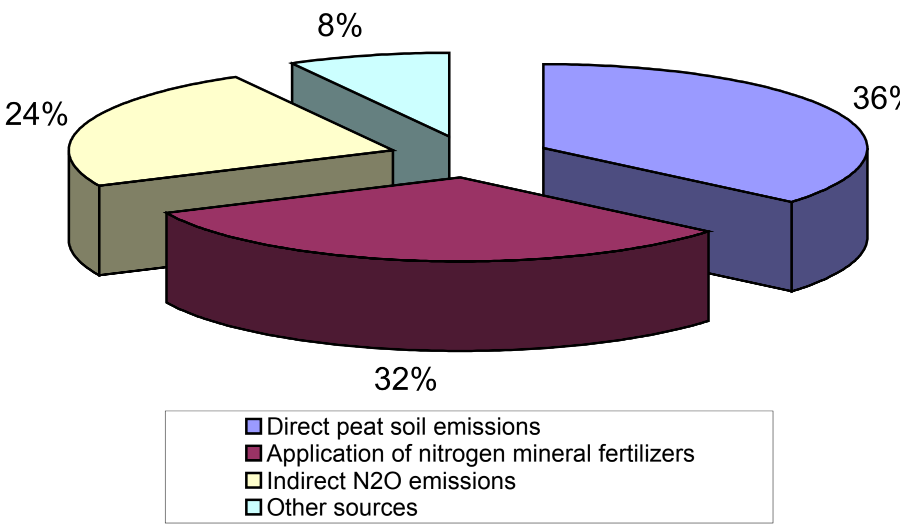


Fig. 4.1. Structure of Nitrous Oxide Emission Sources

In general, the downward trend of emissions of dominant GHG is typical. This is especially true with respect to methane: emissions reduced from 529.7 thousand tonnes in 1990 to 334.1 thousand tonnes in 2000 (by 37%). Nitrous oxide emissions reduced from 30.6 thousand tonnes in 1990 to 14.2 thousand tonnes in 1995 (by 53.6%); while they increased by 18.6 thousand tonnes (by 31%) by 2000 due to the increased nitrogen mineral fertilizer usage (see Fig. 4.2).

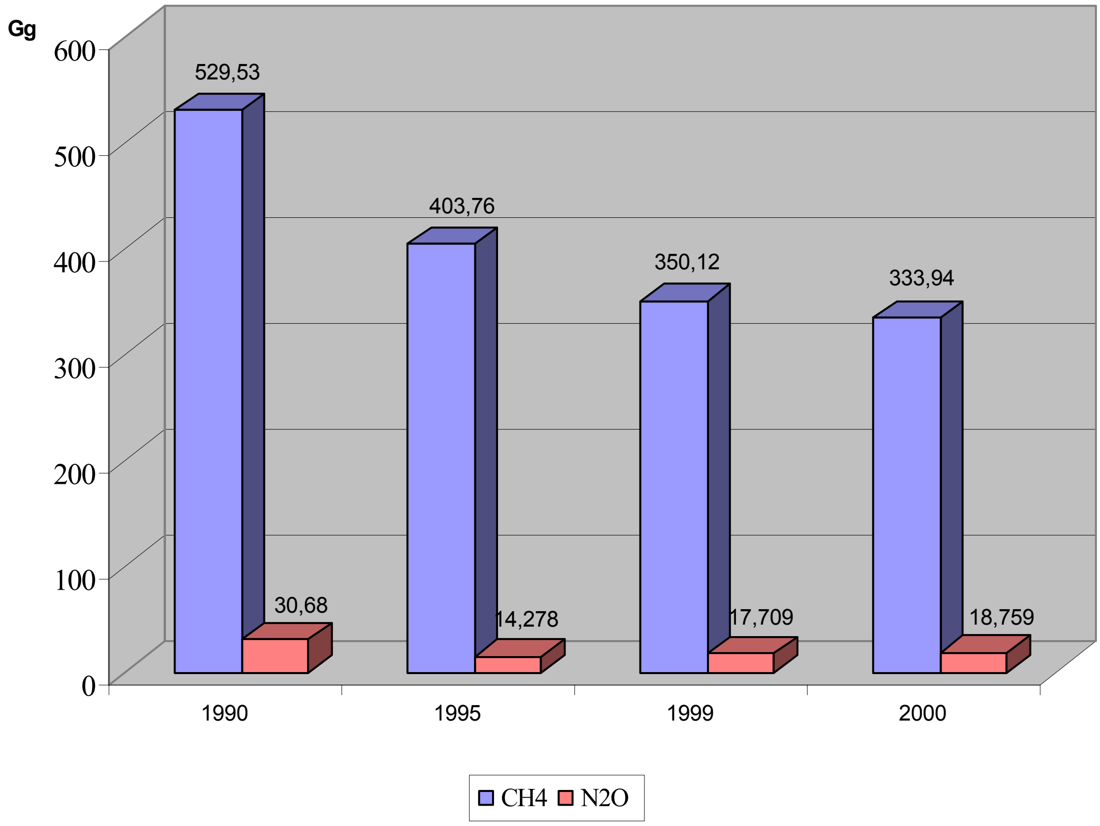


Fig. 4.2 Greenhouse Gas Emissions in Agriculture

The uncertainty of initial statistical data and uncertainty of emission factors combined form primarily the uncertainty of GHG emission estimates. In most cases, the second uncertainty significantly exceeds the first one. Since emission factors used are mainly from the IPCC Guidelines, their uncertainty is taken to be in accordance with this document and in most cases is within the limit of 20%. In the majority of cases, the statistical data uncertainty is within 3-10% range.

5. LAND-USE CHANGE AND FORESTRY

Globally, three most important factors of change in land use and forestry management may lead to carbon dioxide removals and emissions:

- changes in forests and other wood biomass reservoirs;
- conversion of forest and meadow lands;
- land retirement.

Therefore, greenhouse gas sources and sinks involve processes transforming biomass and soil. In certain situations, however, trace gaseous components of the atmosphere - CH_4, CO, N_2O and NO_X - are also emitted, thereby contributing to the greenhouse effect.

National and departmental statistical reports, handbooks, methodical guidelines, different archives, publications, etc., research findings obtained by the task force working on this problem (Biogeocenosis Diversity of Belarus: Information and Simulating System /Sachok G.I., Tatyanok D.V., Kolyada V.V., et al. – Minsk, 1996, 240 pp.), as well as reports and findings of studies in territorially and typologically distributed evaluation of productivity and parameters of the biogenic cycle of chemical elements in the Belarusian ecosystems provided data for making calculations.

The data composition in the module is rather extensive, diverse and multi-dimensional. Many aspects, however, are characterized by incomplete, heterogeneous and difficult-to-compare data. Only explicit estimates of indicators were obtained with respect to a number of particular aspects.

5.1. Calculation of Carbon Dioxide Removals and Emissions in Different Ecosystems

The subject of the study (estimation) is: a) land-use change and b) forestry. The most potent agent - CO_2 reservoir and sink – is forest biomass and forest products, specifically wood increment rate defining the biomass growth as a whole. It depends on the specimen composition, forest stand composition, density, quality of locality, underwood development and other factors.

Geographically, Belarusian forests fall into the category of middle-latitude forests. They have distinct latitudinal zonal distribution featuring three subzones from north to south: broad-leaved-spruce, oak-dark coniferous, spruce-hornbeam forests (hornbeam-oak-dark coniferous) and broad-leaved-pine (hornbeam) forests. As of 01.01.2000, the total area of the forest fund was 9,007 thousand hectares. Percentage of forest land (36.3%) of Belarus is close to optimal. At the beginning of the XX century, it was somewhat higher than the current one. That was, however, the period of a drastic decline up to the 40s-60s when the percentage dropped below 20%. Over the post-WWII period, the percentage of forest land has been continuously increasing.

The land use includes such large sectors as the agriculture (9,257.7 thousand ha) and forestry (8,436.8 thousand ha), with the total land area being 20,759.9 thousand ha. Bogs account for 964.3 thousand ha (as of 01.02.2001). The land fund structure is rather dynamic - the land area belonging to farms and individuals significantly decreased (by 1,152.9 thousand hectares) over the five-year period (1996-2000). Part of this land and that of land of other categories have been categorized as environmental territories. In addition, shrub and low forest have grown on a part of area of hey-meadows and pastures on the abandoned land and in river floodplains. The change in the area in other land-use spheres is also significant.

Therefore, in the *Land Use and Agriculture* sector, the following three types of land-use change are most critical from the point of view of CO_2 sinks and emissions:

- changes in forests and other wood biomass reservoirs;
- conversion of forest and meadow lands;
- land retirement (fully or partially).

These changes are related to the biomass and soils. They are estimated by 3 algorithms for each of four years.

The main sink of CO_2 is depositing it in the forest biomass.

To obtain accurate estimates, a rather detailed block-diagram of forest area distribution is used. There are three types of wood species (coniferous, hard deciduous, soft deciduous)* and six age groups (I class young stands, II class young stands, middle-aged stands, immature stands, mature and overmature stands) - totally 18 categories (Figs. 5.1, 5.2). The area (thousand ha), annual growth rate, or mean annual increment rate (in t of dry weight/ha), and the percentage of carbon in dry biomass were determined for them (D is taken to be 0.5 for all biomass categories).

The total carbon removals (E, thousand tonnes of C) is calculated by the formula:

$$\mathrm{E} = \sum_{1}^{18} A * B * D$$

The change in forest, being the wood biomass reservoir, implies logging and biomass conversion through burning or oxidation. There are two logging categories: final harvesting and thinning operations/sanitation felling. A portion of lumber is used for wood – 12% and 10% of the harvesting depending on the category, respectively. The conversion factor of the merchantable wood is taken to be 0.7 (m^3 - dry biomass) (0.88; 0.95; and 1.0 are recommended by the IPCC Guidelines). The calculation algorithm is H=F*G, where F – merchantable wood (thousand m^3 of round wood), G – conversion factor, H – total biomass hauled from forest (thousand tonnes of dry weight).

The removed biomass (E) during conversion of forest and meadow lands over 10-year period is determined by the formula

$$E=A*D \text{ at } D=B-C,$$

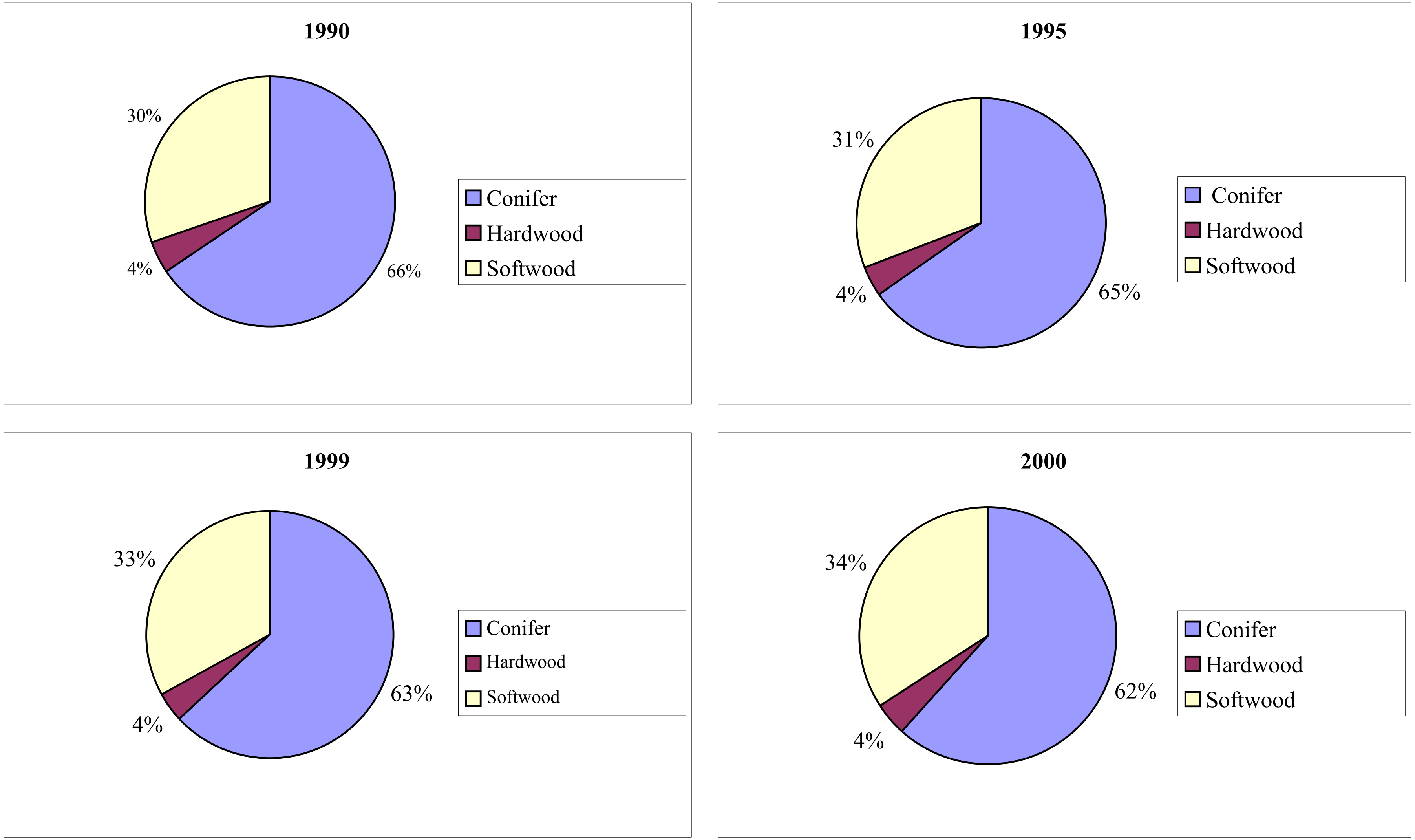


Fig. 5.1 . Change in Forest Species Composition

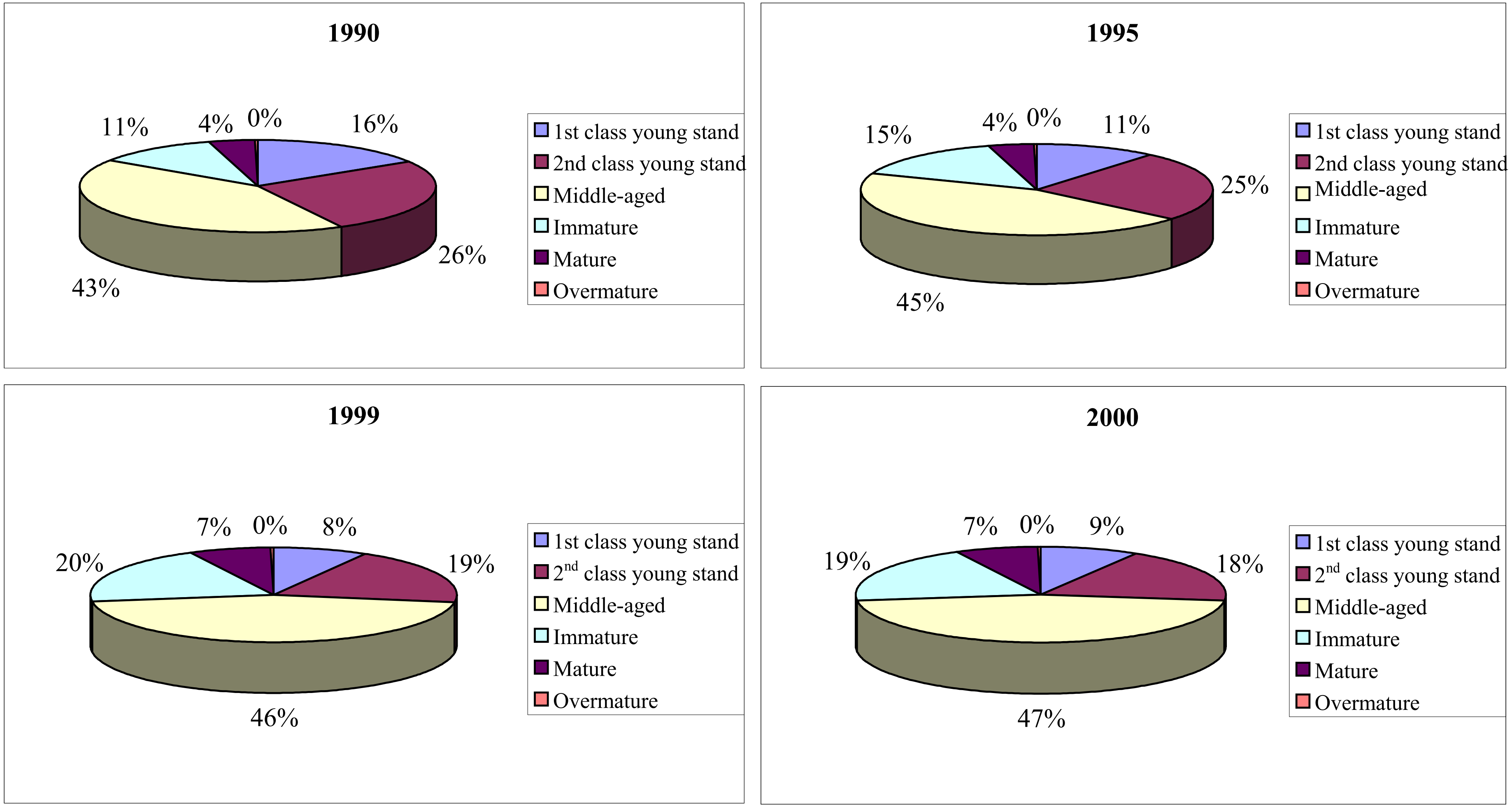


Fig. 5. 2. Forest Age Structure

where A – annually converted area, thousand ha; D – net change in biomass density, thousand tonnes of dry weight/ha; B – biomass before conversion; C – biomass after land conversion, tones of dry weight/ha.

The quantity of biomass burnt on the site, oxidizing on the site and burnt not on the site is calculated as fractions.

The conversion of forest and meadow lands over the 10-year period is characterized by an average converted area A (thousand hectares), biomass before the conversion (B) and after the conversion (C) (tonnes of dry weight/ha) for each type of land (forest, meadow). The net change in biomass density D=B-C, average annual biomass loss E=A*D, as well as the quantity of biomass left to decompose – G=F*i are estimated, where F – fraction of biomass left to decompose, i – quantity of released carbon (thousand tonnes of C); i = G*H, where H – fraction of carbon in biomass. Then, an immediate release during burning and delayed emissions resulting from decomposition are determined and total annual release of carbon and its CO_2 equivalent are calculated.

Burning forest biomass in the place of growing produces emissions of trace gas components – CH_4, CO_2, NO_2, NO_x. In this case, CH_4 and CO_2 emissions are estimated as fractions of a flux of carbon released during burning. Nitrogen is estimated by the ratio N/C in the dry biomass, NO_2 and NO_x – as fractions of the nitrogen estimate.

Land retirement may be accompanied by significant removals and emissions, or these effects may be absent. The estimation is based on the assumption that soils return to the natural condition. Two components are calculated: annual storage of carbon of the above-ground phytomass on land abandoned less than 20 year ago and the same on land abandoned for a period of more than 20 and less than 100 years. These indicators change year-wise. After 1990, the reforestation has been underway accompanied by CO_2 removals characterized by the upward trend year-wise.

The change in carbon content in mineral soils is estimated for two soil groups: intensively and unintensively cultivated soils.

As a result, the net change is derived – soil carbon removals over the 20-year period.

In estimating CO_2 emissions during liming, the data on types of materials are converted to $CaCO_3$. Emission values are given for reporting years.

5.2. Estimation of Carbon Dioxide Emissions from Reclaimed Peat Land in Belarus

Currently, the area of reclaimed marshland in Belarus is about 1.4 million hectares. Being in the reclaimed condition, they are not capable of accumulating, since an intensive aeration of a residual peat layer and destruction of a bog vegetation stopped peat accumulation processes, while mineralization processes lead to emissions of additional quantities of carbon dioxide releasing from an organic material (OM) of peat deposited in ancient times.

The lower the ground-water level (GWL) is, the larger is the zone covered by biochemical peat mineralization processes releasing carbon dioxide into the atmosphere. This results in formation of water-soluble compounds like fulvic acids and others carried away by water flows beyond the peat-field boundary. A part of an organogenic layer from reclaimed peat soils is eroded by wind as deflation processes emerge. A larger portion of the organic material produced by agricultural crops is removed from fields in the form of harvests, while the quantity of afterharvesting crop residue is not sufficient to replenish the mineralized and wind-eroded soil organic material. Due to the above reason, the annual OM balance on such land is negative. The upper reclaimed part of a peat-field reduces by 1-2 cm a year [4], on the average, thereby continuously transferring field layers from a geological to biogenic cycle. As a result, peat degrades to carbon dioxide, ammonia, water and other mineralization end products. This implies that during cultivation of mineralized peat soils and worked-out peat deposit areas carbon passes from geological to biogenic cycle releasing to the atmosphere an additional quantity of carbon dioxide which was removed from it by the bog vegetation in ancient times.

To determine average statistical percentage of carbon and nitrogen in the organic mass of different peat groups and types in Belarus, the reference literature has been analyzed over the last 50 years [5-15]. Results are provided in Table 5.1.

Table 5.1 shows that quantitative indicators of an average carbon/nitrogen content in fen and highbog peat in Belarus are close to those of fen and highbog peat in Russia provided in monograph of I.I. Lishtvan, N.T. Korol [44]. The Table data on the transitional type have not been analyzed because the sample was small and, hence, the data provided in the monograph were used [44].

Table 5.1 Average Statistical Carbon and Nitrogen Content by Peat Groups and Types, % against OM

Peat group	Quantity of samples	Average		Minimum average value		Maximum average value		Standard error	
		C	N	C	N	C	N	C	N
Fen type									
Grass and moss	6	4 58.3 -	- 3.1	58 -	- 2.6	58.6 -	- 3.9	0.14 -	- 0.19
Grass	7 45	58.6 -	- 3.1	54.3 -	- 1.9	61.9 -	- 4.6	1.17 -	- 0.08
Wood and moss	- 1	- -	- 2.3	- -	- 2.3	- -	- 2.3		
Wood and grass	- 7	- -	- 3.0	- -	- 2.3	- -	- 3.4		- 0.17
Wood	- 9	- -	- 3.1	- -	- 2.3	- -	- 3.7		- 0.16
Average by type	11 68	58.5 -	- 2.9	54.5 -	- 1.9	61.9 -	- 4.6	6.68 -	- 0.06

Table 5.1 (continued)

Peat group	Quantity of samples	Average		Minimum average value		Maximum average value		Standard error	
		C	N	C	N	C	N	C	N
Transitional type									
Moss	-	-	-	-	-	-	-		
	1	-	1.7	-	1.7	-	1.7		
Grass	3	49	-	40.2	-	62.1	-		-
	1	-	2.0	-	2.0	-	2.0		6.68
Wood and	-	-	-	-	-	-	-		
grass	1	-	1.9	-	1.9	-	1.9		
Wood	-	-	-	-	-	-	-		
	1	-	1.9	-	1.9	-	1.9		
Average by	3	49	-	40.2	-	62.1	-	0.72	-
type	4	-	1.9	-	1.7	-	2.0	-	0.06
Highbog type									
Moss	52	51.3	-	42.7	-	60.5	-	0.42	-
	39	-	0.9	-	0.4	-	1.6	-	0.04
Grass and	27	53.8	-	42.3	-	63.8	-	0.73	-
moss	10	-	1.2	-	0.9	-	1.7	-	0.08
Grass	11	60.2	-	56.3	-	63.5	-		
	6	-	1.2	-	0.9	-	1.5		
Wood and	-	-	-	-	-	-	-		
moss	1	-	1.21	-	1.21	-	1.21		
Wood and	1	60.4	-	60.4	-	60.4	-		
grass	1	-	1.1	-	1.1	-	1.1		
Wood	-	-	-	-	-	-	-		
	1	-	1.2	-	1.2	-	1.2		
Average by	91	56.4	-	42.3	-	63.8	-	0.45	-
type	58	-	1.1	-	0.4	-	1.7	-	0.04

Since 1913, the dynamics of OM has been observed in reclaimed peat soils in Belarus and so far over 125 experimental findings have been published. According to the generalized data [4,16-43], valid OM average statistical loss is as follows: 3.5-4.4 t/ha a year from cultivation of perennial grass; cereal crops - 6.0 t/ha, and intertilled crops - 9.8 t/ha. If the peat-field is reclaimed, but not used for crop cultivation, organic material losses increase up to 11.1 t/ha, because a small quantity of root and the above-ground crop residue passes into soil.

Annual loss of organic material, nitrogen and carbon and carbon dioxide emissions from reclaimed peat soils due to different techniques of cultivating reclaimed and also worked-out peat deposits are provided in Table 5.2.

Table 5.2

Loss of Organic Material, Nitrogen, Carbon and Carbon Dioxide Emissions from Reclaimed Peat Soils in Belarus Due to Different Cultivation Techniques, t/ha/year

Cultivated crops	Number of tests	Fluctuations	Organic material loss ($X \pm mt_{0.95}$)	Carbon loss	CO_2 emissions	Nitrogen loss	NO_3 feasible quantity
All crop types on the average throughout Belarus	125	1.7-15.9	6.7±0.6	3.9±0.3	14.3±1.3	0.2±0.02	0.7±0.06
Perennial grasses:							
Total results*	36	1.7-11.1	4.4±1.0	2.6±0.6	9.4±2.1	0.1±0.03	0.4±0.1
Various reclamation techniques **	34	1.7-8.8	3.7±0.8	2.1±0.5	7.9±1.7	0.1±0.02	0.4±0.08
Normal reclamation ***	31	1.7-6.8	3.5±0.6	2.0±0.3	7.5±1.3	0.1±0.02	0.4±0.06
Cereal crops	12	3.5-10.3	6.0±1.1	3.5±0.6	12.8±2.3	0.2±0.03	0.6±0.1
Intertilled crops	16	5.5-15.9	9.8±1.6	5.7±0.9	20.9±3.4	0.3±0.05	1.0±0.2
Arable rotations:	66	3.5-15.3	7.0±0.8	4.0±0.5	14.9±1.7	0.2±0.02	0.7±0.08
Intertilled rotations	87	3.5-15.9	7.7±0.8	4.5±0.5	16.4±1.7	0.2±0.02	0.8±0.08
Reclaimed virgin soil			10.0	5.8	21.3	0.3	1.0
(data from A.Z. Baranovsky [19, 20])			11.1	6.4	23.6	0.3	1.1

* Ground-water level from 0.5-2.5 m
** Ground-water level from 0.5-1.5 m
*** Ground-water level from 0.5-0.9 m

Therefore, reclaimed, but not arable peat deposits, primarily worked-out through peat extraction, and their edges, as well as peat soils used for cultivation of intertilled crops contribute to maximum losses of the organic material (10-11.1 t/ha/year), carbon (5.8-6.4 t/ha/year) and nitrogen (0.3 t/ha/year) (9.8±1.6; 5.7±0.9; 0.3±0.05, respectively). Reclaimed peat soils used for cultivating perennial grass contribute to minimum losses of the organic material (3.6±1.0), carbon (2.0±0.3) and nitrogen (0.1±0.02).

The structure of crop areas on reclaimed peat soils depends on the peat layer depth. Grain and grass rotations with 40-50% of cereal crops and 50-60% of perennial grass (40% and 60%, respectively, were used for making calculation) are recommended on soils with the peat layer depth over 1 m in the dried state. Cultivation of predominantly perennial grass combined with cereal crop cultivation within the period between regrassing is recommended on soils with the peat layer depth less than 1 m that corresponds to the rotation with 80% of perennial grass and 20% of cereal and other annual crops.

Under these conditions, an annual consumption of the OM from 1 ha of a rotation area with the peat layer depth less than 1 m will amount to:

$3.6 \times 0.8 + 7.0 \times 0.2 = 4.28 \approx 4.3$ t/ha;

while for soils with the peat layer depth more than 1 m:

$3.6 \times 0.6 + 7.0 \times 0.4 = 4.96 \approx 5.0$ t/ha.

To calculate CO_2 emissions from the reclaimed peat soils, the following factors were used:
K_{CO_2} – factor of conversion carbon to carbon dioxide;
Kc – factor of carbon content in organic material.

The total loss of the peat organic material from reclaimed peat soils is determined by the formula:

$$P_{орг.} = P \times S$$

where P – annual organic material loss, t/ha; S – area of reclaimed peat soils, ha.

Carbon dioxide emissions from reclaimed peat soils is determined by the formula:

$$Э_{CO2} = P_{орг.} \times K_c \times K_{CO2}$$

where K_c – factor of carbon content in organic material; K_{CO2} – factor of conversion of carbon to carbon dioxide (≈3.67).

The main conclusion made based on the data provided is as follows: over recent 10 years, the acreage of the reclaimed peat soils has not increased at all. Over the same period, however, failure of melioration systems and other factors resulted in rebogging of about 33 thousand hectares. This led to the reduction of carbon dioxide emissions from reclaimed peat soils by 286.1 thousand tonnes compared to 1990 over the last ten-year period. CO_2 emissions from the reclaimed peat soils are expected to gradually decrease over the years to come due to a complete degradation of the peat layer and subsequent rebogging of the degraded land. Currently, no accurate data are available on the area of completely degraded peat soils, however, in many places outcrops of sand that was earlier underlying peat have been discovered.

5.3. Estimation of Carbon Dioxide Emissions from Worked-out Peat Deposits and Peat Deposits under Mining

Carbon dioxide emissions from worked-out peat deposits or peat deposits being mined are considered in this submodule. By a worked-out peat deposit (site) is meant an area on which peat extraction has been terminated due to exhaustion of recoverable peat reserves or due to technological or economic inefficiency of further peat extraction related to the deposit bottom topography, high-ash peat layers, difficult-to-drain areas, etc.

Currently, the worked-out peat deposits and some sites are being turned over mainly to the agricultural or forest sectors.

To calculate CO_2 emissions from worked-out peat deposits, the following data are needed:
- area of worked-out peat deposits and peat deposits being mined, ha;
- organic material loss, t/ha/year;
- carbon loss, t/ha.

Special sources that could provide the complete data required for estimating carbon dioxide emissions from worked-out peat deposits are not available. The research data on the carbon content in the organic material are available in the literature, while carbon dioxide emissions data were obtained by generalizing earlier research findings. The required data on the area of worked-out peat deposits and ash content are provided in the Inventory Handbook *Peat Reserves of the Byelorussian SSR* (1979); *Arrangement of Peat Resources Management and Protection in the Republic of Belarus up to 2010*; Data of the Forestry Committee of the Council of Ministers of the Republic of Belarus.

The following coefficients are used for calculating CO_2 emissions from the worked-out peat deposits and peat deposits under mining:

K_{co_2} – factor of conversion carbon to carbon dioxide;
Kc – factor of carbon content in organic material.

Total peat organic material loss from the worked-out peat deposits and peat deposits under mining is determined by the formula:

$$P_{орг.} = P \times S$$

where P – annual organic material loss, t/ha; S – area of worked-out peat deposits and peat deposits under mining, ha.

Carbon dioxide emissions from worked-out peat deposits are determined by the formula:

$$Э_{CO2} = P_{орг.} \times K_c \times K_{CO2}$$

where K_c – factor of carbon content in organic material; K_{CO2} – factor of conversion of carbon to carbon dioxide (≈3.67).

5.4. Estimation of Carbon Dioxide Removals from Atmosphere and Methane Emissions by Natural Bogs

Removals of carbon dioxide by natural marsh ecosystems is considered in this submodule.

The mechanism of CO_2 removals or release operates as follows. Green plants synthesize organic substances from carbon dioxide and water using light energy and converting it into the chemical bond energy. Generally, the photosynthesis process may be expressed by the following equation:

$$CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6\ H_2O + 6O_2$$

During this process, water oxidizes to oxygen, while carbon dioxide is reduced by water hydrogen and converted to carbohydrates [45]. To synthesize one grammolecule of glucose, plants consume 674 kcal of cosmic energy. This is the way the green plants form high-energy organic compounds from carbon dioxide and release oxygen into the atmosphere instead of consumed carbon dioxide.

Cosmic energy converted to chemical bond energy by plants is used in biological processes, primarily, for plant respiration, while the remaining energy is stored on the Earth in the form of humus, peat, brown and black coal.

Generally, the equation of the carbonhydrate decomposition reaction has the following form:

$$C_6H_{12}O + 6O_2 \rightarrow 6\ CO_2 + 6H_2O + 674\ kcal$$

The reaction-released energy is none other than the solar energy earlier stored by plants. Decomposing one glucose grammolecule releases 674 kcal of energy used by microorganisms to support their vital processes. Carbon dioxide is released to the atmosphere, while oxygen is removed from it and used to oxidize carbon.

After dying off, plant organic material is mineralized by aerobic microorganisms using air oxygen. The end products of organic compound mineralization are carbon dioxide and water, and in case of decomposition of nitrogen and sulfur-containing organic compounds, the respective oxides also form.

In the summer season, carbon dioxide is released into the atmosphere through respiration of living organisms and OM mineralization day and night, while photosynthesis removes it from the atmosphere only in the daytime.

The difference between carbon absorbed and released during these two opposite processes is used for growing the organic material which after dying off of plants is transformed into peat converting to brown or black coal under favorable geological conditions. Bogs remove carbon dioxide from the atmosphere and, at least, partially do not release it back for millenniums. Contrary to this, forests and meadows fully release carbon dioxide back to the atmosphere after mineralization of organic material of died-off plants, i.e. over approximately from 5-500-year period. According to data [51] obtained by conducting balance experiments, from 5 to 15% of biomass produced by bog vegetation annually converts to peat in Belarusian bogs, while this value varies from 6 to 52% [52, 53] in different regions of Europe. This means that carbon removed from the atmosphere by bog vegetation through photosynthesis is not fully released into it. Remaining carbon is stored in the form of peat as a result of incomplete mineralization.

To estimate the carbon dioxide removals to Belarusian bogs, the bog area (S) by types of deposits and the quantity of carbon dioxide (Pco_2) annually removed from the atmosphere by one hectare of bog needs to be known. The bog area data were obtained from the Inventory Handbook *Peat Reserves of the Byelorussian SSR* (1979), *Arrangements of Efficient Management and Protection of Peat Resources of the Republic of Belarus up to 2010* and Data of the Ministry of Natural Resources and Environmental Protection.

To determine Pco_2, the annual peat increment needs to be known. For making calculations, the increment data relating only to the last subatlantic period, - which still continues (approximately last 2,500 years), - were used. These data were obtained by generalizing our own and references results derived from studying peat-field increment on different bogs in Belarus. To convert linear values of peat increment to weight values, peat volume weight (γ), moisture and ash content and carbon percentage in peat need to be known.

The formula given below is used to calculate carbon dioxide removals from the atmosphere to bogs being in the natural condition.

The annual carbon dioxide removals from the atmosphere to 1 hectare of a natural peat bog is calculated by the formula:

$$Pco_2 = 10000\times h\times\gamma\times K_W\times K_A\times K_C\times Kco_2$$

where 10000 – factor of conversion from m^2 to ha; h – annual peat layer increment rate, m; W – average peat moisture content, %; A - average peat ash content, %; γ - peat density in field, t/m^3; K_c – factor of carbon content in organic material; Kco_2 – factor of conversion of carbon to carbon dioxide (≈3.67).

The moisture coefficient is calculated by the formula:

$$K_W = (100-W) / 100$$

W – average moisture content by peat types, %;

The ash content coefficient is calculated by the formula:

$$K_A = (100-A) / 100$$

A - average ash content by peat types, %.

Table 5.3 presents values of the above coefficients for different peat types obtained through calculations from [44, 54].

Table 5.3 Values of K_W, K_A Coefficients and K_C Factor Depending on Peat Types

Peat Type	K_W	K_A	K_C
Fen	0.106	0.924	0.585
Transitional	0.095	0.953	0.586
Highbog	0.088	0.976	0.564

The annual carbon dioxide removals from the atmosphere to natural peat bogs is determined by the formula:

$$P\Sigma co_2 = Pco_2 \times S$$

S – bog area, ha.

In addition to CO_2, the atmosphere also contains trace quantities of methane (CH_4). It forms in bogs during incomplete or anaerobic (in the absence of air) decomposition of the organic material and oxidizes to carbon dioxide in the atmosphere. Methane is presumed to perform a useful function – it maintains stability of the ozone layer in the upper atmosphere blocking lethally dangerous solar ultraviolet radiation [46]. Methane production is one of the important functions of wetlands and shallow seas worldwide. No special research has been conducted to estimate methane emissions from bogs in Belarus. To estimate methane emissions, data published by foreign scientists were used [47-50]. A large limit of CH_4 emissions (0.05 – 16.61 g/m^2/season) indicates that this problem requires more in-depth research [50]. Peat bogs may produce unit methane emissions reaching 65% of the total emissions over the vegetation period. Therefore, to determine annual regional estimates, methane emissions in dynamics and over a lengthy period should be studied.

Thus, the annual carbon dioxide emissions from drained peat bogs is by one order of magnitude higher than the CO_2 removals to natural marsh ecosystems, and hence, restoration of all biosphere functions of bogs after termination of peat extraction by rehabilitating the peat land (rebogging), as applied to peat deposit mining, should be a compulsory principle of the biosphere-compatible nature management.

The resulting values of CO_2 removals and emissions are presented in Table 5.4 and Figs. 5.3, 5.4. It is noteworthy that the total emission indicator is characterized by an irregular variability and the total removals shows an upward trend.

Table 5.4 Dynamics of CO_2 Removals and Emissions, Gg

Year	Total Emissions	Total removals
1990	23,676.9	-36,397.4
1995	18,344.2	-36,501.8
1999	20247	-39,545.4
2000	20,583.6	-39,565

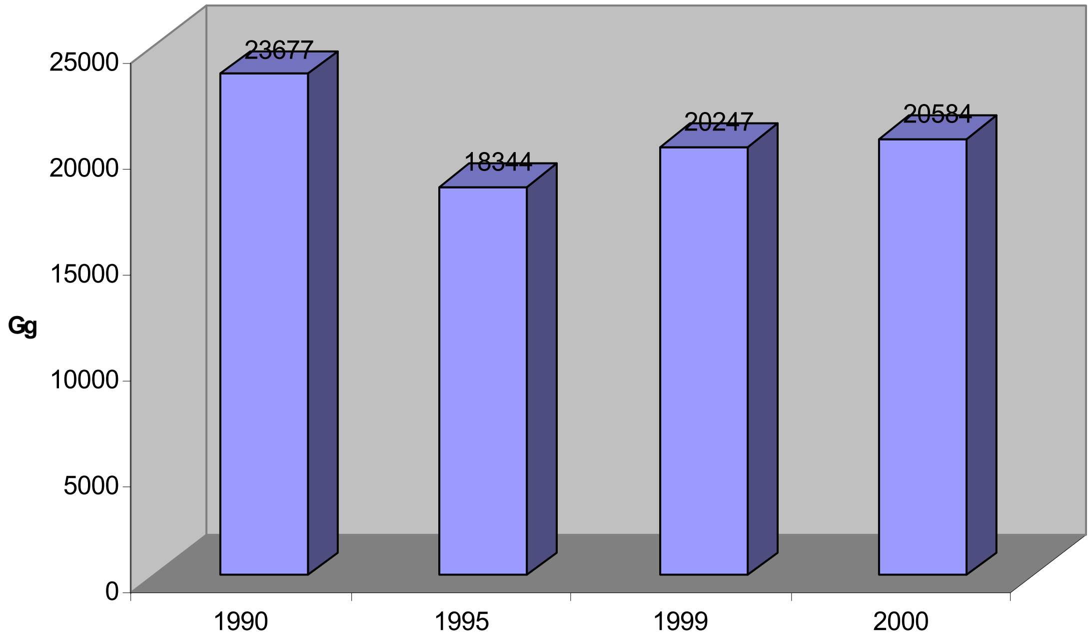
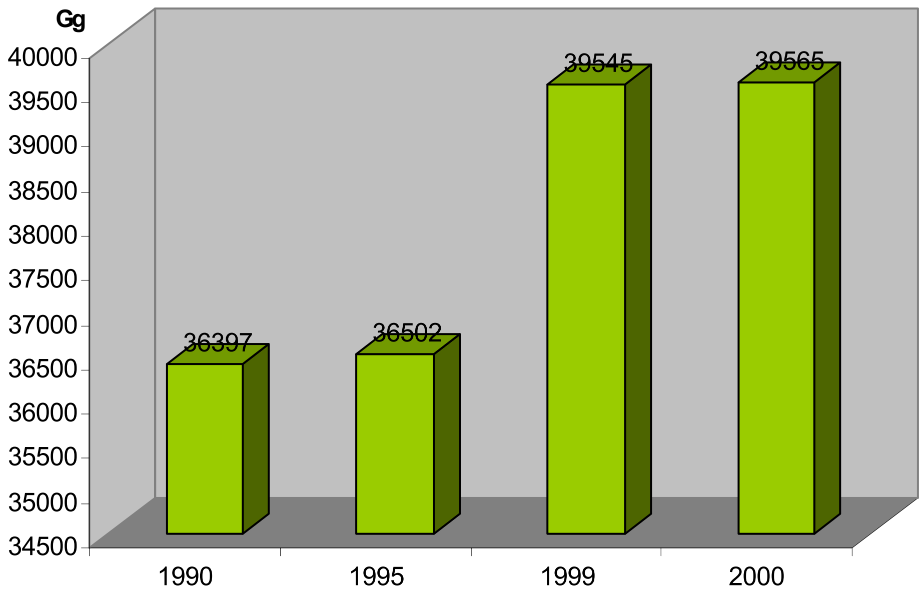


Fig. 5.3. Dynamics of Carbon Dioxide Emissions



ig. 5.4. Dynamics of Carbon Dioxide Removals

The m(… umptions taken with regard to the initial data used for obtaining estimates, and also assumptions taken with respect to the aggregation level of the initial data used as the input data in the calculation scheme, various factors meeting the regional specifics and researchers experience in this sphere have been specified. Actually, the methodology presented in the recommended document and guidelines has been implemented without reservation.

Consistency of year-wise results is high. It is supported by:

– using a uniform strategy of developing the database of the base year (1990) and remaining years (1995, 1999 and 2000);

– referring to uniform basic data sources, namely, data of statistical reports, inventories, handbooks, catalogues, etc.;

– using an integrated scheme and algorithms of data analysis, specifically model calculations of organic material's productivity and reserves based on its structural and fractional composition by applying the data and simulation system *Biogeocenosis Diversity of Belarus* and the integrated system of the EXCEL format worksheets of the IPCC Guidelines.

Data completeness is not sufficient due to some aspects and reasons. Lacking the representative data in the Forest Inventory in particular and in other sources in general, in order to estimate forest ecosystems, the 1988 data were used for 1990, 1993 data - for 1995 and the data for 1999 forest area structure was obtained by interpolating between 1993 and 2000. It is difficult to estimate the effect of the so-called "summer house construction" being conducted on the land of different categories – forest, shrub, including water-logged abandoned lands, arable land of collective/state farms, etc. CO_2 dynamics in this sector is ambiguous: CO_2 emissions prevailed at the development stage, while the removals by tree and shrub vegetation could play an important role at the stage of initial operation (actual data are not available).

In general, our study covers 90% of the Belarusian territory (without urban areas, rural settlements, water bodies, transport and some other units).

The data obtained provide a rather accurate estimates of removals and emissions in this module. The analysis of the data used allows the obtained estimate of removals and emissions to be regarded as sufficiently representative, with the uncertainty not exceeding 10% for CO_2 emissions and about 7% for CO_2 removals.

6. WASTE

Landfills, incineration of solid waste and waste water treatment are the main contributors to greenhouse gas emissions from waste.

Like worldwide, solid waste is disposed at dump sites in Belarus. Currently, waste is not incinerated, as the only municipal solid waste incineration plant in Belarus is no longer in operation since 1990. Waste water is treated at treatment facilities biologically using the aerobic method.

In this module, the following GHG emissions sources are considered:

Municipal waste disposal sites - CH_4
Waste water:
industrial – CH_4
domestic – CH_4, N_2O

Data sources:
- operators of municipal waste disposal sites and treatment facilities;
- utility enterprises, Vodokanals (water-supply companies), special transportation facilities, enterprises, etc. The data were requested either directly from the facilities management or through Municipal and District Inspectorates of Natural Resources and Environmental Protection;

- National Water Resources Inventory for 1996–2000;
- reports on Research Work of BRC ECOLOGY containing results of waste management research [16];
- data of the Ministry of Statistics and Analysis of the Republic of Belarus.

The initial data are provided in Tables 6.1-6.2.

6.1 Solid Waste Landfilling on Municipal Waste Disposal Sites

The data of research into municipal waste disposal sites have demonstrated that most of them do not meet regulatory environmental and sanitary waste management standards because of poor siting, engineering and operation.

In accordance with the IPCC Guidelines (1996) recommendations, the municipal waste disposal sites are subdivided into managed and unmanaged sites by the degree of methane formation, with the latter being further subdivided into deep (>5m) and shallow (<5m) sites.

On the basis of the definition of the municipal waste disposal site manageability, all municipal waste disposal sites in Belarus are categorized as unmanaged because of poor engineering design (mainly, due to lack of “purging”, that is, ventilation). Thus, the data collected are related to two methane emission sources: deep municipal waste disposal sites with the surface dump height > 5m and shallow municipal waste disposal sites - < 5m.

Not only municipal, but also industrial waste may be disposed at municipal waste dump sites, with the latter accounting for 50-70% of the total waste quantity in some cases.

The industrial waste comprises organic waste, namely, food processing waste, industrial wood residue, leather waste, etc.

Following the IPCC Guidelines recommendations, only solid municipal waste are subject to accounting. It comprises domestic waste; garden/park and similar waste; trade or other commercial activity waste.

The standard (used by default) method allows CH_4 emissions to be calculated based on the three following basic parameters:

A – quantity of municipal solid waste landfilled at municipal waste disposal sites of different categories;

B – fraction of organic carbon subject to decomposition and its actually decomposed quantity;

C – fraction of CH_4 in gas formed at municipal waste sites.

6.1.1. Estimation of Total Quantity of Landfills at Municipal Waste Disposal Sites

The initial data required for estimating methane emissions from municipal waste disposal sites in 1990 have been compiled from two sources: waste disposal sites inventories prepared by the Ministry of Housing and Utilities (MHU) in 1989 and by the Institute of Natural Resources Utilization and Ecology (INRUE) of the National Academy of Sciences of Belarus in 1992.

The MHU inventories contain the data on the area, operating time of municipal waste disposal sites and the quantity of waste accumulated. These documents lack the information regarding the annual quantity of waste going to the municipal waste disposal sites and the ratio of municipal and industrial waste in the landfills. These data are presented in the inventories of the waste disposal sites prepared by the INRUE in 1992.

Knowing the quantity of accumulated waste within a specific area by 1989, enabled to calculate the depth of waste with some conventionality and based on this criterion to subdivide municipal waste disposal sites into deep (depth > 5m) and shallow (depth < 5m). Possible accumulated quantities in 1989 and 1990 have been also accounted. As a result, it has been found that 39 deep and 115 shallow municipal waste disposal sites, respectively, operated in Belarus. In 1990, the annual waste landfilling at deep municipal waste disposal sites amounted to 1,250.8 Gg (Table 6.1), at shallow municipal waste disposal sites - 507.150 Gg (Table 6.2); the total quantity of landfilled waste amounted to 1,757.95 Gg.

The inventories prepared by the Belarusian Research Center "Ecology" (BRC ECOLOGY) in 1995 provided initial and rather complete data on the annual waste landfilling at the municipal waste disposal sites in 1995. 27 deep and 135 shallow municipal waste disposal sites at which 1250.72 Gg and 580.398 Gg of municipal waste was filled, respectively operated in 1995; the total quantity of landfilled waste amounted to 1831.118 Gg.

Closure of a number of large municipal waste disposal sites (in Brest, Kamenets), which reached their capacity, resulted in reduction in the number of deep municipal waste disposal sites in 1995 compared to 1990, while the total number of waste disposal sites increased. To service these cities, the municipal waste disposal sites placed in new areas were put into operation where, despite a significant annual accumulation rate, waste depth has not yet reached 5 m and, hence, these municipal waste disposal sites are categorized as shallow (less than 5 m).

Table 6.1 Municipal Waste Accumulation at Municipal Waste Disposal Sites with Surface Dump over 5 Meters

Waste quantity/year, Gg				
Oblast	**1990**	**1995**	**1999**	**2000**
Brest	189.195	143.970	218.175	194.950
Vitebsk	156.605	232.200	176.850	199.900
Gomel	160.460	157.610	208.775	186.181
Grodno	125.320	183.860	135.475	141.775
Minsk	467.535	388.840	854.592	906.995
Mogilev	151.710	144.240	242.850	214.025
Belarus, total	**1,250.825**	**1,250.720**	**1,836.717**	**1,843.826**

Table 6.2 Municipal Waste Accumulation at Municipal Waste Disposal Sites with Surface Dump less than 5 Meters

Waste quantity/year, Gg				
Oblast	**1990**	**1995**	**1999**	**2000**
Brest	87.884	185.035	120.967	173.783
Vitebsk	72.235	96.621	57.886	57.297
Gomel	102.885	56.550	84.665	78.730
Grodno	67.620	60.220	82.162	87.861
Minsk	123.166	109.992	134.154	139.924
Mogilev	53.360	71.980	72.170	71.786
Belarus, total	**507.150**	**580.398**	**552.004**	**609.381**

The data provided by the Belarusian Ministry of Statistics and Analysis supplemented by and adjusted based on records received through inquiries about the sites served as the initial data in annual landfilling of municipal waste at the both types of municipal waste disposal sites in 1999 and 2000. It should be noted the Ministry of Statistics and Analysis keeps records of waste generated both by households and organizations/industrial enterprises. The second group includes waste generated by public units (cultural/communal and trade), including businesses, as well as industrial waste. Lacking the data on the quantity of specific industrial waste landfilled at the municipal waste disposal sites, the composition of municipal waste is assumed to comprise domestic waste and 50% of commercial/industrial waste to calculate CH_4 emissions.

According to the inventories data, 25 deep and 112 shallow municipal waste disposal sites operated in 1999 compared to 25 deep and 154 shallow municipal waste disposal sites in 2000. From 1995 to 1999-2000, the upward trend in the quantity of waste disposed at landfills has been observed – the total quantity amounted to 2,453.207 Gg (Fig. 6.1) in 2000.

The increased waste quantity in landfills in 1999 and 2000 compared to 1990 and 1995 is explained by a tighter control over the removal of waste to municipal waste disposal sites in settlements and by registering earlier unaccounted municipal waste disposal sites – mainly small and located in district centers and urban settlements.

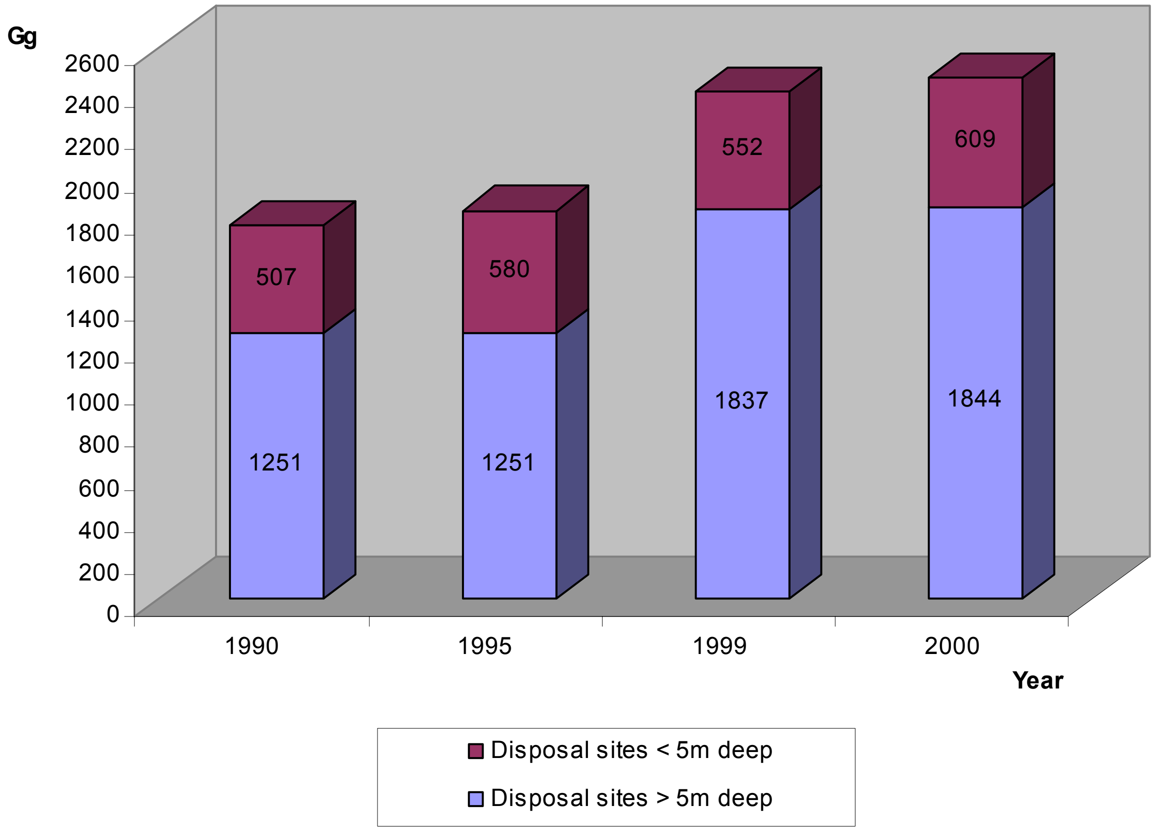


Fig. 6.1. Dynamics of Municipal Waste Accumulation

6.1.2. Calculation of Methane Emission Correction Factor

According to the IPCC Guidelines, the standard methane emission correction factor (MCF) for deep and shallow municipal waste disposal sites is 0.8 and 0.4, respectively.

The obtained data on the share of waste each type of municipal waste disposal site contains on a year-wise basis allow for calculation of the weighted average methane emission correction factor for each type of the municipal waste disposal sites and the methane emission correction factor for each year. The methane emission correction factor ranges from 0.67 to 0.71 depending on the year and the lowest was observed in 1995 due to a relatively high fraction of waste landfilled at shallow municipal waste disposal sites.

6.1.3. Estimation of Specific Methane Formation Rate

The specific methane formation rate depends on the fraction of degradable organic carbon (DOC) in municipal solid waste landfilled at municipal waste disposal sites. The IPCC Guidelines present standard values of degradable organic carbon for main waste types (percentage by weight):

Paper and textiles – 40;
Waste generated in gardens and parks (non-food) – 17;
Food waste – 15;
Wood and straw waste (excluding lignin carbon) – 30.

According to the MHU data and our research-based findings, of the waste listed above and landfilled at the municipal waste disposal sites, the following types were in the municipal solid waste composition in 1991 and 1995, respectively:

paper and cardboard	27%	and	15%;
textiles	5%	and	15% ;
garden/park waste	~3%	and	~3%;
food waste	26%	and	20%.

Based on these data, the percentage of the DOC (by weight) for Belarus is determined by formula 2 (IPCC Guidelines), year-wise:

1991 – (27 + 5) x 0.4 + 3 x 0.17 + 26 x 0.15 +2.5 x 0.3 = 17.96%
1995 – (15 + 10) x 0.4 + 3 x 0.17 + 20 x 0.15 +4 x 0.3 = 14.71%

As the waste composition inventories are not available, the DOC values for 1999-2000 are taken by default based on the data determined for 1995.

In order to determine the methane formation rate per unit waste (Gg CH_4/Gg MSW), the following values have been taken into account:

1 – methane emission correction factor (from 0.67 to 0.71), year-wise;
2 – fraction of degradable organic carbon in MSW (0.1796 and 0.1471);
3 – actually degradable fraction (standard value equaling 0.77);
4 – fraction of carbon released in the form of methane (standard value equaling 0.5);
5 – factor of conversion of methane carbon to methane proper (16/12).

6.1.4. Estimation of Total Net Annual Methane Emissions

Given the total quantity of municipal solid waste landfilled at municipal waste disposal sites and actual methane formation rate per unit waste, the annual gross methane formation may be calculated. Inasmuch as methane formed at municipal waste disposal sites is not utilized in Belarus and the methane oxidation correction factor is taken as 1, the net annual methane emissions equal gross methane emissions.

The year-wise net methane emissions from municipal waste disposal sites were as follows, Gg CH_4:

1990 – 111.83	1999 – 128.07
1995 – 92.64	2000 – 129.67

that is presented in the diagram (Fig. 6.2).

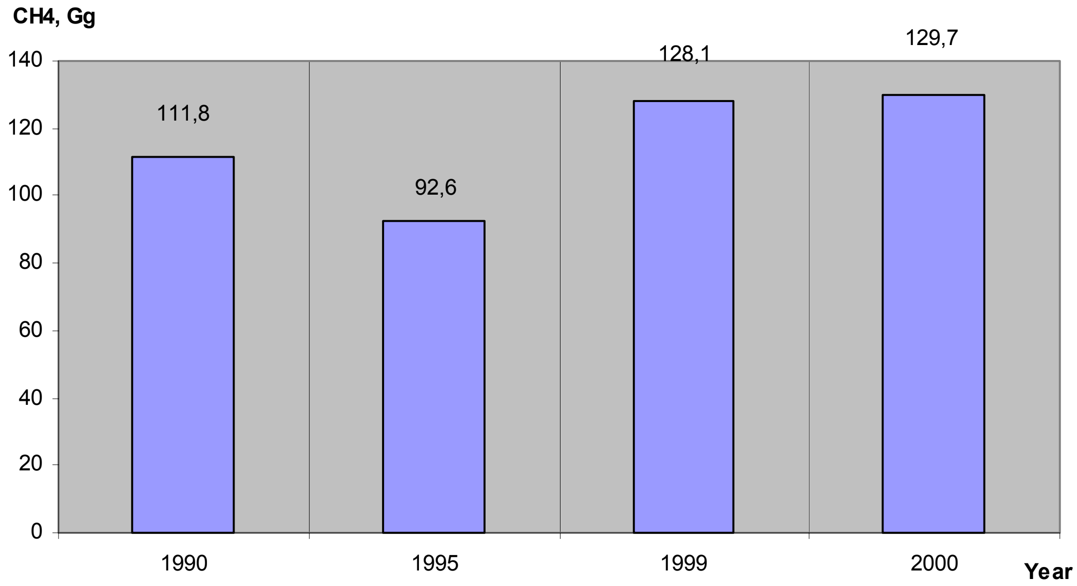


Fig. 6.2 Methane Emissions, Year-Wise

The reduction in methane emissions in 1995 compared to 1990 was primarily due to the reduced fraction of the degradable organic carbon in municipal solid waste. The methane emissions growth in 1999-2000 is explained by the increased quantity of landfilled waste mainly at deep municipal waste disposal sites characterized by a higher methane emission correction factor.

6.2 Methane Emissions from Waste Water Treatment

Treating waste water containing a large quantity of organic material, including domestic, commercial (non-industrial) and a portion of industrial waste water leads to significant methane emissions. Industrial waste water emissions are estimated at 26 to 40 Gg/year, while municipal waste water – approximately 2 Gg/year.

Due to this, the IPCC Guidelines recommend to consider separately commercial and industrial waste water emissions.

The anaerobic treatment process used to treat a portion of municipal waste water at the public waste water treatment facilities is responsible for waste water-induced methane emissions. A portion of industrial waste is also discharged into the public sewage system and vice versa, as a rule waste water treatment facilities of large-sized (urban-area forming) industrial enterprises receive municipal waste water for treatment. For industrial cities, – mainly Oblast centers and some industrially developed District centers, - the fraction of industrial waste water amounts to 25-30% of the total municipal waste water and in a number of towns (Mozyr, Polotsk – Novopolotsk, Osipovichy, etc.) reaches 50% and higher. Currently, industrial waste water is not in excess of 34.5% in Belarus as a whole, while it amounted to 40.5% in 1990 (Table 6.3).

The initial data for calculation of CH_4 emissions from industrial waste water have been collected, analyzed and summarized.

It has been noted above, however, that the main process used for treating both industrial and municipal waste water in Belarus is an aerobic biological treatment. Hence, organic material decomposes under aerobic conditions preventing methane from being formed. Anaerobic digesters available at a number of treatment sites are not in operation and accumulated sludge is not cleaned. The accumulated sludge from waste water is regularly removed and landfilled at municipal waste disposal sites jointly with solid waste.

Therefore, methane emissions from waste water treatment are negligibly small and actually are at the zero level. Methane emissions from waste water sludge have been accounted in calculations of methane emissions from solid waste at municipal waste disposal sites.

6.3 Nitrous Oxide Emissions Related to Human Waste Product

The IPCC Guidelines recommend the method for calculating nitrous oxide emissions from human vital activity. In this Section, the human vital activity implies the product of direct biological human activity excretion of which is directly related to nutrition and protein consumption.

Below are provided main parameters for calculating nitrous oxide emissions:

- protein consumption per capita (kg/person/year);
- population size;
- nitrogen fraction in protein (by default – 0.61kg N/kg protein);
- emission factor, EF_6 (the standard default value - 0.01 kg N_2O-N/kg);
- conversion ratio 44/28.

Protein consumption per capita and population size are provided according to the data of the Belarusian Ministry of Statistics and Analysis. Calculations have demonstrated that the highest nitrous oxide emissions (0.77 Gg) were observed in 1990. A drastic decline in protein consumption by the households in 1995 resulted in the N_2O reduction down to 0.63 Gg. In 1999-2000, the protein consumption per capita increased and reached 1990 level, but nitrous oxide emissions did not exceed 0.75 Gg due to the decreased population size.

The emission factor uncertainty in combination with initial data uncertainty, including statistical data, are primarily responsible for the uncertainty of estimates of GHG emissions. The IPCC Guidelines emission factors have been used and recalculated by using the weighted-average method to comply with our own data. The emission factor uncertainty may be estimated at 10%.

The data from the Ministry of Statistics and Analysis supplemented and adjusted by the data collected directly at the sites serve as the basic data in the *Waste* module. In the majority of cases, the statistical data uncertainty is within the range of 3-10%, on the average is 6%.

Table 6.3 Waste Water Treated, Year-Wise

Oblast	Waste water supplied to treatment facilities, thousand m^3								Effluent treated to standard quality, thousand m^3			
	From industrial enterprises				From municipal facilities and households							
	1990	1995	1999	2000	1990	1995	1999	2000	1990	1995	1999	2000
Brest	33,853	21,773	25,064	24,381.1	67,592	68,488	75,586.9	75,758.4	101445	90261	100650.9	100139.5
Vitebsk	50,798.9	42,392.4	40,153.4	37,913.1	64,676.9	71,562.9	73,861.5	75,217	115475.8	113955.3	114014.9	113130.1
Gomel	96,283.1	56,327.8	65,562.6	65,962.4	80,917.7	71,115.9	77,623.4	83,250.2	177200.8	127443.7	143186	149212.6
Grodno	42,878.5	36,475.3	35,402.8	33,162.9	79,376	76,340.9	75,436.3	78,110.5	122254.5	112816.2	110839.1	111273.4
Minsk	9,771	10,209	13,562.329	13,562.851	31,012	27,800	29,610.7	31,081.801	40783	38009	43173.029	44644.652
Mogilev	54,842	52,069.5	48,713.6	46,761	99,477	95,719	77,933	77,164.1	154319	147788.5	126646.6	123925.1
Total: thousand m^3 %	288,426.5 40.5	219,247 34.8	228,458.729 35.8	221,743.351 34.5	423,051.6 59.5	411,026.7 65.2	410,051.8 64.2	420,582.001 65.5	711478.1 100	630273.7 100	638510.529 100	642325.352 100

7. SUMMARY

The conducted studies have demonstrated that green house gas emissions from different national economy sectors are responsible for the global warming effect.

The major contributor is carbon dioxide total emissions of which amounted to 72,888.15 Gg in 2000, or 58% of the base 1990 level and 91% of the level of 1995, that is the year of maximum decline in GDP and emissions (Tables 7.1-7.5).

Table 7.1 Dynamics of CO_2 Emissions and Removals, Gg

Description	1990	1995	1999	2000
Emissions	126,148.44	79,799.08	76,838.05	72,888.15
Removals	-36,397.4	-36,501.84	-39,545.39	-39,565.02
Total	**89,751.04**	**43,297.24**	**37,292.66**	**33,323.13**

CO_2 emissions accounted for about 63% in 2000 of the total global warming effect. Dynamics of change in CO_2 removals over 1990-2000 is not so significant as that of emissions. In 2000, they amounted to 39,565.02 million tonnes, or 108.7% compared to 1990 and 1995.

CO_2 emissions are mainly provided by the *Energy* module – 51,026.74 Gg, or 70%, while the module *Land-Use Change and Forestry* is responsible for CO_2 removals – 39,565 million tonnes, or 100%.

Methane emissions amount to 12,839.19 Gg of CO_2 equivalent, or 24.27% of the total GWE. The energy provides 20%, agriculture – 34.6% and waste – 21% for 2000 level. Compared to 1990 and 1995, energy and agriculture show most significant changes.

N_2O emissions in 2000 amounted to 6,748.8 Gg of CO_2 equivalent, or 12.75% of the total GWE.

In general, the global warming effect in 2000, with removals being accounted, amounted to 52,911.13 Gg. Removals reduced CO_2 emissions by 54.3% and GWE by 35%. In 1990, removals reduced the GWE by 10% and in 1995 by 27.1%.

The rate of change in the GWE compared to that of the GDP over 1990-2000 is significantly higher, with the GWE continuously decreasing. GHG emissions in the *Energy* module (Figs. 7.1-7.3) are mainly responsible for decreasing.

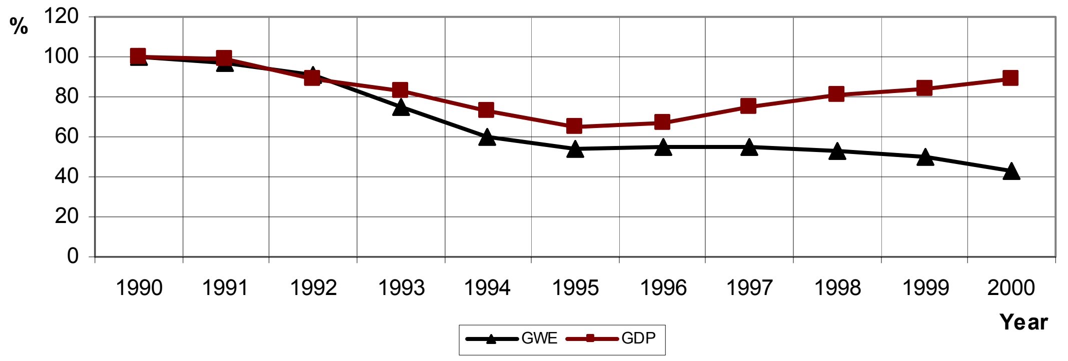


Fig. 7.1 GWE and GDP Dynamics

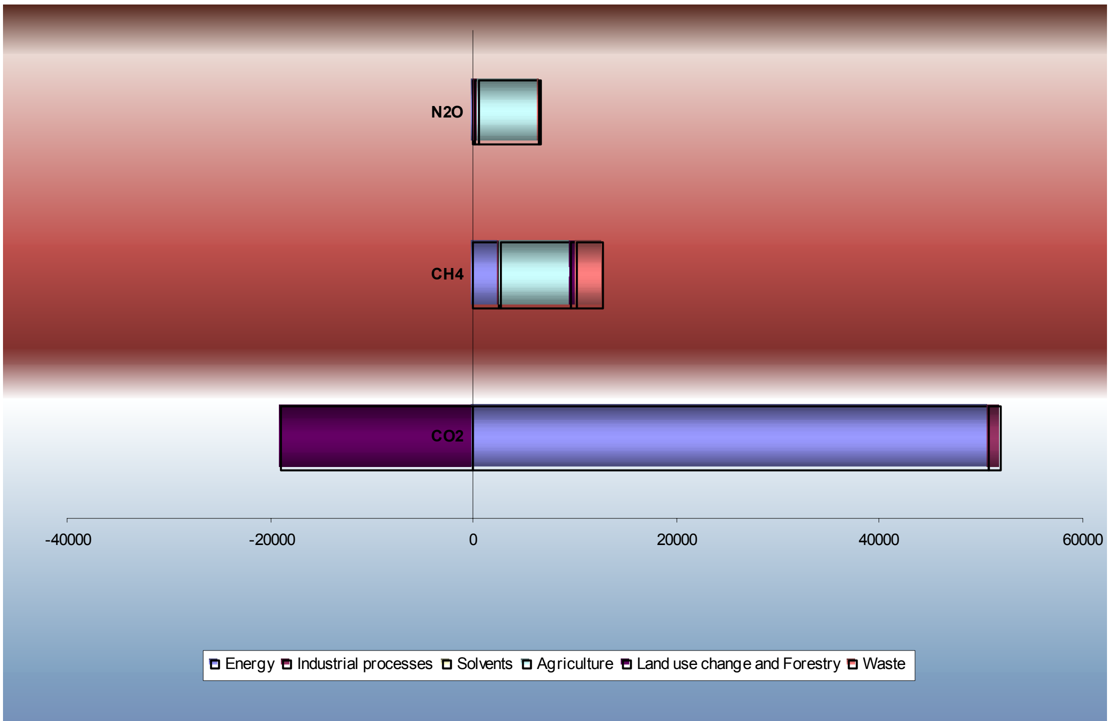


Figure 7.2 Contribution of Categories of Sources (Sinks) to Aggregate GWE in 1990

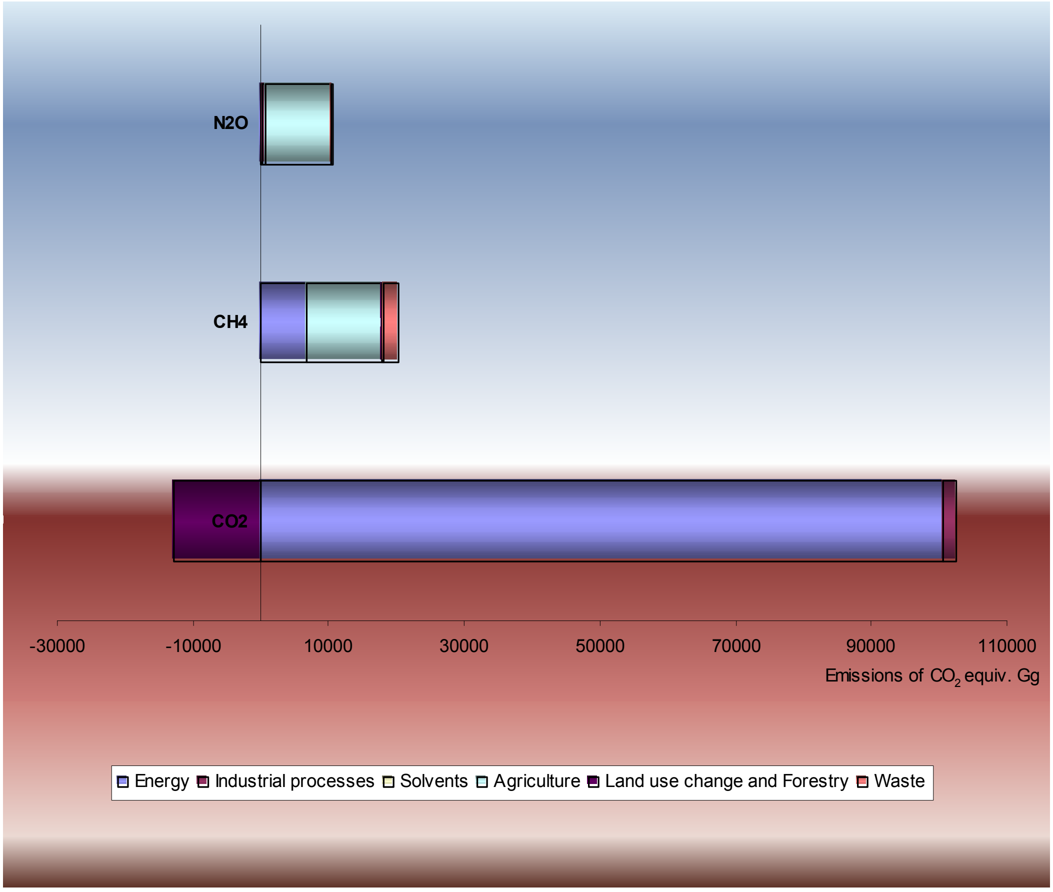


Figure 7.3 Contribution of Categories of Sources (Sinks) in Aggregate EGW in 2000

Dynamics of the change in GHG not being in the GWE composition is shown in Fig. 7.4.

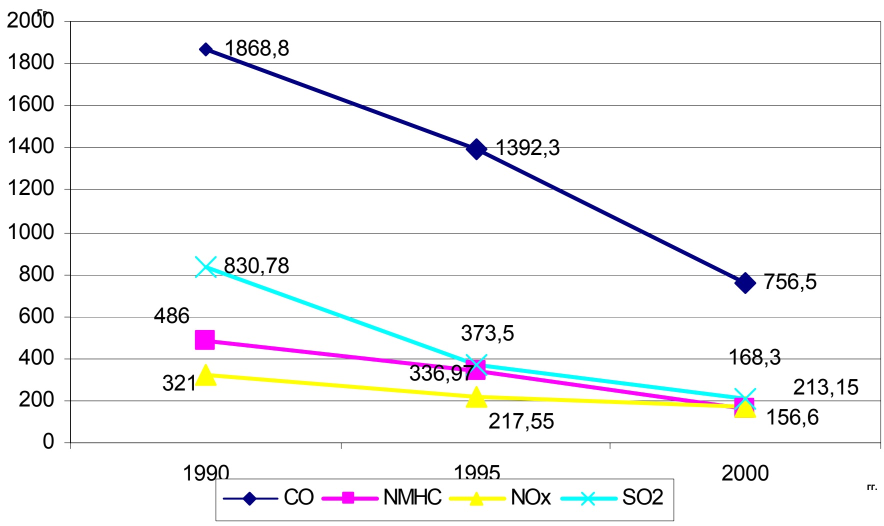


Fig. 7.4 Dynamics of CO, NMHC, NOx, SO_2 emissions

Carbon oxide emissions are defined by transport emissions in the *Energy* module.

CO emissions reduced to 756.5 thousand tonnes in 2000 and accounted for 40% of the base 1990 level, or 54% compared to the 1995 level. The decreased freight and passenger traffic is mainly responsible for the CO emissions reduction.

Emissions of non-methane organic compounds are mainly defined by emissions from transport in the *Energy* module and partially in the *Solvents* module. The reduced transport emissions primarily resulted in the reduction due to the above-mentioned reasons.

Nitrogen oxide emissions, defined predominantly by energy processes, also reduced.

Sulfur dioxide emissions are defined mainly by emissions in the *Energy* module and reduced by 55% from 1990-1995 and by 74% by 2000 compared to 1990 and amounted to 213.15 thousand tonnes.

Decreasing fuel consumption combined with decreasing fuel oil fraction and increasing gas fraction contributed to the reduced emissions.

The uncertainty of activity data and emission factor have been determined primarily through expert appraisal and changed from 1 to 35% in different items. The activity data in the *Solvents* module are characterized by the highest uncertainty and in the agricultural sector it amounted to 20%, while in the main module – *Energy* – the uncertainty of the activity data and emission factors is not so significant. This actually determined the total combined uncertainty of inventory data at a level of 3.056%.

Further research should be specially focused on collecting the activity data, since they define accuracy of subsequent calculations of greenhouse gas emissions. Some emissions and removals factors also need to be refined.

Table 7.2 Contribution of Source (Sink) Categories to Aggregate GWE in 1990

Categories of GHG sources and sinks	**Emissions, Gg**			**Emissions of CO_2 equivalent, Gg**				**Percentage of aggregate GWE, %**
	CO_2	**CH_4**	**N_2O**	**CO_2**	**CH_4**	**N_2O**	**Aggregate GWE**	
Energy	100,615.2	321.04	0.77	100,615.2	6,741.84	238.7	107,595.74	89.08
Industrial processes	1,856.35	1.15	1.12	1,856.35	24.15	347.2	2,227.7	1.85
Solvents								
Agriculture	0	529.53	30.68	0	11,120.13	9,510.8	20,630.93	17.33
Land-use change and forestry	-12,720.51*	6.09	0.04	-12,720.51	127.89	12.4	-12,580.22	- 10.41
Waste	0	111.83	0.77	0	2,348.43	238.7	2,587.13	2.15
TOTAL	**89,751.04**	**969.64**	**33.38**	**89,751.04**	**20,362.44**	**10,347.8**	**120,461.28**	**100**
	Percentage of aggregate GWE, %			74.51	16.90	8.59	100	

* emissions	23,676.89
removals	- 36,397.40
Total:	- 12,720.51

Table 7.3 Contribution of Source (Sink) Categories to Aggregate GWE in 1995

Categories of GHG sources and sinks	Emissions, Gg			Emissions of CO_2 equivalent, Gg				Percentage of aggregate GWE, %
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	Aggregate GWE	
Energy	60,552.2	288.05	0.43	60,552.2	6,049.05	133.3	66,734.55	102.05
Industrial processes	902.65	0.78	0.84	902.65	16.38	260.4	1,179.43	1.82
Solvents								
Agriculture	0	403.76	14.28	0	8,478.96	4,426.8	12,905.76	19.95
Land-use change and forestry	-18,157.62*	20.42	0.02	-18,157.62	428.82	6.2	- 17,722.6	- 27.10
Waste		92.64	0.63		1,945.44	195.3	2,140.74	3.28
TOTAL	**43,297.23**	**805.65**	**16.20**	**43,297.23**	**16,918.65**	**5,022.0**	**65,237.88**	**100**
	Percentage of aggregate GWE, %			66.37	25.93	7.7	100	

* emissions 18,344.22
Removals - 36,501.84
Total: - 18,157.62

Table 7.4 Contribution of Source (Sink) Categories to Aggregate GWE in 2000

Categories of GHG sources and sinks	Emissions, Gg			Emissions of CO_2 equivalent, Gg				Percentage of aggregate GWE, %
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	Aggregate GWE	
Energy	50,741.57	123.27	0.36	50,741.57	2,588.67	111.6	53,441.84	102.05
Industrial processes	1,277.78	1.61	1.01	1,277.78	33.81	313.1	1,624.64	3.10
Solvents								
Agriculture		333.94	18.76		7,012.74	5815.6	12,828.34	24.50
Land-use change and forestry	-18,981.38*	22.90	0.04	-18,981.38	480.9	12.4	-18,488.08	- 35.30
Waste		129.67	0.76		2,723.07	235.6	2,958.67	5.65
Total	**33,037.97**	**611.39**	**20.93**	**33,037.97**	**12,839.19**	**6,488.3**	**52,365.86**	**100**
	Percentage of aggregate GWE, %			63.09	24.52	12.39	100	

* emissions 20,583.64
removals - 39,565.02
Total: - 18,981.38

PART III. NATIONAL STRATEGY OF GREENHOUSE GAS EMISSION REDUCTION IN THE ECONOMY OF THE REPUBLIC OF BELARUS

I. ENVIRONMENTAL PROTECTION STRATEGY AND MEASURES FOR GREENHOUSE GAS EMISSION REDUCTION

1. POLICY AND MEASURES FOR GREENHOUSE GAS EMISSION REDUCTION

For conservation and rational use of natural resources and environmental protection in the Republic of Belarus, it is necessary to provide comprehensive measures for protection of atmosphere, protection and rational use of land, forest and water resources, rational agricultural practices, environmentally safe use of biotechnologies and toxic chemicals, and environmentally safe disposal of all types of waste.

The laws adopted in the country "*On Environmental Protection*" (No. 126-3 of 17 July 2002), "*On Protection of Atmospheric Air*" (No. 29-3 of 15 April 1997), "*On Waste*" (No. 444-3 of 26 October 2000) and others aim at giving priority to environmental interests and a balanced use of natural resources rather than to economy of production and economy of natural resources management.

At present, the National Strategy of Sustainable Socio-Economic Development of the Republic of Belarus for the period of up to 2020 (NSSD-2020) is being developed. In conformity with the Concept of the National Strategy of Sustainable Socio-Economic Development of the Republic of Belarus for the period of up to 2020, adopted by the Resolution of the Ministry of Economy of the Republic of Belarus (Protocol No. 29 of 1 November 2002), the essential principles of the environmental policy should be:

- supporting the integrity of ecosystems through effective management of natural resources;
- reducing the pressure on the environment by the economy (in the course of its growth);
- environmental protection as an integral part of the development process;
- social and environmental interaction for improving the quality of life; and
- further developing cooperation taking into account global environmental interdependence.

These principles should be used to develop in the NSSD-2020 a system of spheres and measures for implementation of the environmental policy. The most important task remains to mitigate the Chernobyl nuclear disaster consequences in terms of ensuring best possible safe conditions for life of the people and rehabilitation of natural facilities. It is necessary to ensure safe environmental conditions for people living in towns and regions with hazardous levels of pollution of atmospheric air, water sources, etc.

For implementation of the environmental policy, the Council of Ministers of the Republic of Belarus approved the National Action Plan on Rational Use of Natural Resources and

Environmental Protection of the Republic of Belarus for 2001-2005 (Resolution No. 12 of 21 June 2001).

The National Action Plan, based on the environmental legislation of the Republic of Belarus and international Treaties and Agreements, defines the range of actions aimed at solving tasks on rational use of natural resources and environmental protection. The main tasks of the National Plan on Protection of Atmospheric Air are:

- reducing the amount of pollutants emitted into the atmospheric air from stationary and mobile sources in large towns and industrial centres;
- improving the system of standards on atmospheric air quality with due account of international requirements and commitments taken by Belarus within international conventions and agreements;
- improving methods of evaluation of emissions and of the content of pollutants in atmospheric air, including greenhouse gases; and
- developing the system of air pollution monitoring in cities and industrial centres.

1.1. Main Lines Of (Strategy) Of Socio-Economic Development

The main means for and indicator of development of the national economy and solution of social problems is growth in gross domestic product (GDP), which should take into account the scopes of use of benefits and services, the available resources and effectiveness of their use, supplemented by compulsory ensuring of favourable environmental situation.

According to programmes and predictions of socio-economic development, solution of the above problems and meeting of the requirements would necessitate 2.7-3.0 time increase of the GDP over 2001-2020, whereas the average annual increment should be 5.0-5.6%. As regards the structure of economy, it is envisaged to gradually decrease the share of commodity output (from 45.6% in 2000 to 40-41% in 2020) and increase the share of services from 39.9 to 45-46%, respectively. As regards the GDP structure, it is planned to increase, by 2020, the share of accumulations up to 30-31% against 25.7% in 2000 and the share of investment from 19,8% to 24-26%.

It is envisaged that dynamics of the level of production effectiveness and competitiveness and reduced impact on environmental must be attained through decreased use of raw materials, energy and labour resources, more rational structure and improved technologies, practical use of scientific and technological progress and of prioritised environmentally safe and waste-free technologies. Implementation of such conditions and requirements would help reducing material intensity of commodities and services over the period of 2001-2020 by 18-19% and of energy intensity by 45-60%. This would make it possible to halve the emissions of greenhouse gases.

The main macroeconomic indicators of socio-economic development of the Republic of Belarus in the basis (1990, 1995, 2000, 2001 and 2002) and the prediction periods (2003, 2005, 2010 and 2020) are given in Table 1.1.

Briefly commenting the data in this Table and in other sources it is necessary to note the following most typical lines and trends in the total socio-economic and environmental development (condition) of the country from 1990 to 2002, which in fact predetermine its prediction.

In conformity with the demographic predictions, the number and the share of able-bodied age population will be increasing for 5-6 years more, reaching the highest level of 63% by 2008-2010. After that it is predicted to gradually decrease, however at least during the subsequent 15 years there will not be shortage of labour resources in Belarus. It is predicted that young people will make a high share of labour resources, which will make favourable preconditions to provide mobile and high-skill specialists for the national economy.

The main goals of the state demographic policy are decrease of mortality and increase of longevity of population, stabilisation of childbirth and optimisation of migration processes. This will be facilitated by implementation of social policy measures aimed at increasing the standard of living of population, developing the social sector and environmental protection, as well as designing and implementing the National Programme of Demographic Security of the Republic of Belarus.

The main tasks of the employment policy include formation of its rational structure in accordance with the demands of the reformed economy and increasing effectiveness of use of labour resources.

For its implementation, a balanced investment policy will be required, including creation of new jobs, more active inter-sectoral redistribution of employees to social spheres of the economy, and development of effective tax incentives for development of private businesses. It is necessary to develop effective mechanisms for a better protection of population against unemployment.

Table 1.1 Basic macroeconomic indicators [1)]

Indicator	Unit of measure	1990	1995	2000	2001	2002 [4)]	2003	2005	2010	2020
		reported					predicted			
Average annual population numbers, total	‘000’ people	10189.3	10193.8	10005.0	9970.7	9924.8	9880.8	9787.2	9549.1	9027.1
change index	% of 1990	100.0	100.0	98.2	97.9	97.4	96.9	96.1	93.7	88.6
Ratio of urban to rural population	%	66.4:33.6	68.0:32.0	70.0:30.0	70.4:29.6	70.9:29.1	71.4:28.6	72.3:27.7	74.8:25.2	78.8:21.2
Gross domestic product (production)	billion roubles	26310.7	17154.6	23278.8	24372.9	25518.4	27050-27177	31607-32380	41405-43065	64150-69700
change index	% of the previous year	–	65.2	135.7	104.7	104.7	106.0-106.5	135.0-138.3	131.0-133.0	242.6-263.6
change index	% of 1990	100.0	65.2	88.6	92.8	97.2	102.3-102.8	119.5-122.5	156.6-162.9	242.6-263.6
Sectoral structure of GDP (in current prices*):										
commodity production sector, total	%	68.9	49.2	45.6	42.8	41.3	43.0	42.3	41.7	41.0
including: industry	%	37.9	27.6	26.5	26.1	26.0	27.1	27.1	26.8	26.4
agriculture	%	22.7	15.1	11.6	9.7	9.0	9.4	8.7	8.4	8.0
construction	%	7.7	5.4	6.4	5.9	5.3	5.6	5.6	5.7	5.9
3										
Reduction (-) of GDP energy intensity	%	–	-14.1	-28.1	-4.0	-4.7	-4.5-(-5.5)	-8.4-(-11)	-16-(-20)	-10-(-15)
Growth of social labour productivity	%	–	76.3	134.9	104.6	105.4	107.3	142.8	136.0	133.0
Industrial products	billion roubles	22301.1	13692.9	22511.2	23839.4	24912.2	21520-21624	23980-24729	27817-29180	35520-38575
change index	% of the previous year		63.5	164.4	105.9	104.5	104-104.5	128-132	116-118	127.7-132.2
	% of 1990	100.0	63.5	100.7	106.6	111.4	111.5-112.1	124.3-128.2	144.2-151.2	184.1-200.0
Agricultural products (all types of entities)	billion roubles	7777.4	5724.2	6256.5	6369.1	6413.7	6831-6863	7650-7824	8874-9154	11330-12300
change index	% of the previous year		95.3	109.3	101.8	100.7	106.5-107.0	112-114	116-117	127.7-134.5
	% of 1990	100.0	73.6	71.4	72.7	73.2	78.6-78.9	88.0-90.0	102.1-105.3	130.3-141.6
Consumer goods output	billion roubles	5915.5	3543.0	6512.3	6955.1	7219.4	7652.6	9443.0	11995.0	17560.0
change index	% of the previous year (period)	107.6	59.9	183.9	106.8	103.8	106.0	145.0	127.0	146.4
	% of 1990	100.0	59.9	110.1	117.6	122.1	129.4	159.6	202.8	296.9

Indicator	Unit of measure	1990	1995	2000	2001	2002 [4]	2003	2005	2010	2020
		reported					predicted			

* – The GDP structures is calculated in comparative prices of 2002

[1] The indicators are given mainly in relative magnitudes: final years of 5-year periods – growth rates for 5 years; interim years – for one year. Cost indicators are given in comparative prices of 2002.

[2] Industry, forestry and agriculture, construction.

[3] Transport and communications, trade and public meals, procurement and sales, housing and communal sector and services for population, health sector, physical culture and social security, education, culture and arts, science and scientific services, finances, credits, insurance, management, and civil associations.

[4] Data for 2002 are tentative.

Basic Macroeconomic Parameters Of Socio-Economic Development

As stated earlier, the basic means for ensuring and the indicator of sustainable development of the national economy and for solution of social and environmental tasks is the "status" of GDP. The five-year period of 1996-2000 became a crucial stage in socio-economic development of Belarus in terms of overcoming deep crisis phenomena taking place after the disintegration of the USSR and not always adequate liberal economic reforms of 1991-1994. In particular, liberalisation of prices in 1992 resulted in a severe financial crisis and galloping inflation. In 1994, GDP made only 72.8% of the level of 1990, the industrial output was 69% and investments into basic capital was 56.5%, respectively.

Going back to Table 1.1, it should be stated, with regret, that in comparative prices GDP, even in 2002, did not reach the level of 1990, making only 97.2%. It is only in the predicted period that the task is set to exceed this level, reaching 102.3-102.8% in 2003 and 119.5-122.5% in 2005.

In the following years, it is predicted that GDP (production), with account of other factors, will be more optimistic: 156.6-162.9% by 2010 and 242.6-263.6% by 2020 as compared to the level of 1990.

There are some obvious positive shifts in the sectoral structure of GDP and in the basic period as well as for the future: from 1990 till 2002 the share of the commodity production sector actually decreased from 68.9% to 41.4%, i.e. by 27.5 percent points (it is predicted that this indicator will reduce to 41.0% by 2020). On the contrary, the share of services for the basic period increased from 28.5 to 45.0% (16.5 percent points), and it is predicted that by 2020 it will increase to 45.6%.

These structural shifts (the ratio of commodity output to services) indicate to the actual "turning" of the country's economy towards meeting interests of people and society, i.e. towards principles of socially oriented market economy.

While in 1995 energy intensity of the economy decreased by 14.1% as compared to 1990, then in the next 5-year period this decrease was 28.1%; in 2001 this decrease was 4.0% as compared to the previous year and in 2002 it was 4.7%; it is predicted that this future decrease will be as follows: by 4.5-5.5% in 2003, by 8.4 – 11.0 in 2005, by 16 – 20% over 2006 – 2010 and by 10-15% over 2011-2020. Labour productivity increased in 1995 by 76.2% against 1990; afterwards, both in the basic and in the predicted periods there was a stable trend towards its growth.

Volume indicators and change indices of industrial output, both as a whole for the basic and for the predicted periods, are given in Table 1.1. We will give a more detailed review of the current and future (predicted) sectoral structure of industry:

- in 1990, the sectoral structure was obviously dominated by machine building and metalworking sectors (34.2%); afterwards their share in the basic and the predicted periods decreased and stabilised at the level of 22-25%, i.e. on the average at 9-12 percent points;

- a trend towards decrease of the share, although to smaller extent, is typical also for the light industry (from 17.2% in 1990 to 7.1% in 2002 and, as predicted, to 8.4% by 2020);
- there is a clear trend towards increase of the share of food industry (from 14.9% in 1990 to 21.6% in 2002 and, as predicted, to 22.8% by 2020) and, to smaller degree, of the chemical and petrochemical industry (9.0-14.8-13.8%, respectively); of forestry, woodworking and wood pulp and paper industry (4.4-5.4-6.7%, respectively); and of ferrous metallurgy (0.9-3.3-3.2%);
- with slight variations from a period (year) to another period (year), there is more or less stable share occupied by the construction materials sector (3.7% in 1990; 3.9% in 2002; and 3.5% predicted for 2020);
- the share of basic producers of greenhouse gases is clearly increasing (though also with significant variations between period (years): the share of the energy sector increased from 2.6% in 1990 to 13.8% in 1995; in 2000-2002 it exceeded the level of 1990 by 5.8-6.8 percent points; it is predicted that this share will be rather high by 2020; a similar trend is typical of the fuel industry.

Stemming from the general long-term development strategy for the industry, oriented towards resource-saving and science-intensive type of reproduction, the following priority sectors and production spheres have been determined:

- information technologies;
- microelectronics and equipment of its manufacture;
- instruments making and precision machine building;
- new materials of various designation;
- home and health equipment;
- biological and fine chemical technologies;
- machines, equipment and products for agriculture;
- high-precision technologies and defence technologies.

The most important direction of the industrial policy in the future will be stimulation and state support of the most advanced sectors of specific enterprises and production facilities determining the “points of growth”, concentration of forces and resources for implementation of most effective measures ensuring immediate results in production of competitive, import-substituting and export-demanded products.

On the whole, it is envisaged that industry and its sectors will be developed in conformity with the Concept and the Programme of Development of the Industrial Complex of the Republic of Belarus for 1998-2015 (approved by Edict no. 246 of the President of the Republic of Belarus of 14 may 1998).

Table 1.2 shows volume indicators of development of industrial sectors (the condition and the target option).

In the future, the target option provides for faster rates of development of ferrous metallurgy (it is planned to increase its output to 650-700% in 2020 as compared to 1990), electricity generation (to

490-530%), chemical and petrochemical industry (282-307%), food industry (282-306%), and forestry, woodworking and wood pulp and paper industry (280-304%). Somewhat slow rates of development are envisaged for fuel industry (208-226%) and construction materials industry (194-211%); to much smaller degree – for machine building and metalworking industry (119-129%); and the light industry output in 2020 may be only at 90-98% of the level of 1990.

The main trends and lines of future development of industrial sectors in the Republic of Belarus are characterised as follows.

Energy economy (EE) of the Republic of Belarus includes systems for extraction, transportation, storage, generation and distribution of all types of energy resources: gas, oil and its refinery products, solid fuels and electrical and heat energy. They cover 25.6% of capital investments into industry, 20% of fixed production assets, and 13.8% of industrial output.

The core of EE of Belarus is *power engineering sector*, the production potential of which includes 23 large power plants with the total power of 7.6 million kW (7.8 million kW for the country as a whole), as well as district boiler plants with the output up to 10,000 Gcal/h, about 7,000 km of high-voltage network electricity transmission lines (ETL), and over 10,000 km of district heating networks.

It is envisaged that reconstruction of oil refineries (Mozyr OR and “Naftan” OR) will help improve the degree of oil refining to 85%, i.e. very close to world standards; this will help increasing export of products of better quality and broader range of generated petroleum products, and – what is most essential – reduce greenhouse gas emissions (primarily carbon oxides) not only at the stage of primary oil refining, but also at all stages of use of the final products.

Fuel industry is an important component of EE. In Belarus, it ids represented by enterprises mining and processing peat and oil, including huge oil refineries with the output capacity about 40 million tons of oil a year. However, due shortage of raw materials, the production capacities are used only by about 25%.

One of the priority lines of development of peat industry includes manufacture of peat-and-lignin briquettes through a fuller utilisation of lignin, i.e. production waste of the Rechitsa and Bobruysk hydrolysis enterprises. Reconstruction of briquette production facilities (shops) and reduced allocation of new lands for new dumpsites of the enterprises will make it quite possible to increase, by 2005, the output of peat briquettes by almost 30%.

It is envisaged that in the future the energy economy (EE) will be developed so as to solve the following tasks:

- maximum possible meeting of the needs of domestic users in fuel and energy resources, predominantly by using local resources;
- ensuring energy security of the country and increasing its energy independence on the basis of an optimised structure of the fuel and energy balance (higher share of secondary energy resources, local types of fuel, untraditional and reusable sources of energy, like

wind, solar and biological energy, small hydraulic energy facilities), a broader use of new effective technologies for generation of electricity, implementation of measures for energy saving in all sectors of the economy, including social sphere;

- development of progressive technologies for oil refining that increase the level of its extraction, use and quality of its refining;
- improvement of different forms of interaction (impact) of EE with the environment so as to reduce negative impacts on the nature.

It is envisaged to optimise the structure of generating sources in the electricity generation sector through the use of steam-gas and turbine technologies, increased generation of electricity as regards the heating cycle, conversion of boiler houses into small CHPP – all this will allow maximum meeting the increased demand for electricity and increase efficacy of heat supply in then populated centres of the country.

The *ferrous metallurgy* sector included 16 enterprises having independent balances, and is subdivided into sub-sectors: mining and dressing of non-ore raw materials, production of ferrous metals, production of pipes, reprocessing of ferrous metals, and production of metal ware for industrial use.

Production output of chemical and petrochemical industry was increased by 51.6% over 1996-2000. Products of this industry is invariably in high demand on the domestic and world markets; the latter market being dominated by potassium fertilisers export of which to foreign countries other than CIS countries was stably increasing over this period of time.

The priority lines include:

- development of new generations of chemical products, above all, modern chemical fibres and threads, plastics, elastomers, progressive types of mineral fertilisers and chemical ingredients of fodder mixtures, products of the main and small-weight chemistry, as well as consumer goods;
- taking into consideration modern global trends in the field of innovations and current problems facing by the chemical industry of the Republic of Belarus, it is envisaged to manufacture products based on advanced technologies, ensuring the use of environmentally clean materials, as well as aimed at improving consumer properties of commodities, improving their range, reducing costs of production; first of all, this concerns production of environmentally clean (safe) polymers, chemical fibres and threads, synthetic rubber, catalysts and other products;
- it is envisaged to update and put into operation new facilities for production of enamels, varnish, lacquers, paints, fibre glass, glass wall paper, fine cloth for printed-circuit boards, polyester thermoplastics; plasticisers, polymer materials, glues, low pressure polyethylene of various density, nitric fertilisers, cord fabric, caprolactam, and other products;

Table 1.2 Industrial Outputs, Target Option (Difference)

(Billion roubles in comparative prices of 2002)

Industrial sector	Unit of measure	1990	1995	2000	2001	2002	2003	2005	2010	2020
Electricity sector	billion roubles	501.6	1573.5	1573.7	1864.9	1800.2	1807.7-1816.4	1990.3-2052.5	2169.7-2276.0	2450.9-2661.7
	% of 1990	100.0	313.7	313.7	371.8	358.9	360.4-362.1	396.8-409.2	432.6-453.7	488.6-530.6
Fuel industry	billion roubles	887.6	490.3	1086.6	1349.1	1241.6	1226.6-1232.6	1366.9-1409.6	1502.2-1575.7	1847.0-2005.9
	% of 1990	100.0	55.2	122.4	152.0	139.9	138.3-138.9	154.0-158.8	169.2-177.5	208.1-226.0
Ferrous metallurgy	billion roubles	173.6	273.7	637.0	694.4	682.9	688.6-692.0	767.4-791.3	862.3-904.6	1136.6-1234.4
	% of 1990	100.0	157.7	366.9	400.0	393.4	396.7-398.5	442.1-455.8	496.7-521.1	654.7-711.1
Chemical and petrochemical	billion roubles	1736.3	1630.5	2660.2	2678.3	3062.5	3185.0-3200.4	3453.0-3561.0	3950.0-4143.6	4901.8-5323.3
	% of 1990	100.0	93.9	153.2	154.3	176.4	183.4-184.3	198.2-205.1	227.5-238.6	282.3-306.6
Machine building and metalworking	billion roubles	6598.4	2656.8	4477.5	4920.2	5069.7	5186.3-5211.4	5803.2-5984.3	6531.0-6857.3	7849.3-8525.1
	% of 1990	100.0	40.3	67.9	74.6	76.8	78.6-79.0	87.9-90.7	99.0-103.9	119.0-129.2
Forestry, woodworking and wood pulp and paper	billion roubles	848.9	604.3	1086.6	1111.0	1117.4	1140.6-1146.1	1294.9-1335.4	1613.4-1692.4	2379.8-2584.5
	% of 1990	100.0	71.2	128.0	130.7	131.6	134.4-135.0	152.5-157.3	190.1-199.4	280.3-304.5
Construction materials	billion roubles	713.9	581.5	768.1	813.4	807.0	817.8-821.7	887.3-915.0	1029.2-1079.7	1385.3-1504.4
	% of 1990	100.0	81.5	107.6	113.9	113.0	114.6-115.1	124.3-128.2	144.0-151.2	194.0-210.7
Light industry	billion	3318.5	912.2	1611.1	1468.1	1469.2	1527.9-	1678.6-	1975.0-	2987.7-

Industrial sector	Unit of measure	1990	1995	2000	2001	2002	2003	2005	2010	2020
	roubles						1535.2	1731.0	2071.8	3240.3
	% of 1990	100.0	27.5	48.5	44.2	44.3	40.0-46.3	50.6-52.2	59.5-62.7	89.9-97.6
Food industry	billion roubles	2874.7	1938.4	3615.7	3987.8	4469.6	4626.8-4649.2	5251.6-5415.7	6286.6-6594.7	8098.6-8795.1
	% of 1990	100.0	67.4	125.8	138.7	155.5	160.9-161.7	182.7-188.4	218.7-229.4	281.7-305.9
Other	billion roubles	1639.9	741.2	1217.7	952.3	972.5	1312.7-1319.0	1486.8-1533.2	1891.6-1984.2	2486.4-2700.3
	% of 1990	100.0	45.2	74.3	58.1	59.3	80.0-80.4	90.7-93.8	115.3-121.0	151.6-164.7
Total	billion roubles	19293.4	11402.4	18734.2	19839.5	20692.6	21520-21624	23980-24729	27817-29180	35520-38575
	% of 1990	100.0	59.1	97.3	102.8	107.3	111.5-112.1	124.3-128.2	144.2-151.2	184.1-200.0

- beginning from 2006 (after a radical update of enterprises), the main line of development of the sector should be systematic use of new technologies oriented towards resource saving and environmental orientation of production facilities and rational use of natural resources;
- it is envisaged to pay special attention to a comprehensive processing of raw materials using production waste. This will require a new range of equipment for cleaning gaseous, liquid and solid substances that would reduce man-made environmental impacts; improvement of the range of catalysts and reaction initiators of a new generation and technological processes of their basis, which would ensure increased output of polyolefin, organic synthesis products and other environmentally clean products.

In the *machine-building complex*, the growth of production was accompanied by progressive structural sectoral shifts through dominant development of science-intensive, high-tech, export-oriented and import-substituting sectors. This is supported by selective support provided by the state to enterprises and production facilities that were selected as “points of growth”, as well as active development of management at enterprises. Despite general crisis condition of the economy, principally new industrial and consumer products have been developed and put into production that are in demand on domestic and foreign markets. The share of certified products in 2000 reached 58%, which facilitated its competitiveness and improved their sales in domestic and foreign markets.

The main tasks of the *construction complex* include: maximum supply of highly effective construction products to meet the needs of the national economy; creation of new and modernisation of existing fixed production assets; ensuring further growth of export of construction materials, structures and services; and updating of the production potential.

To increase efficacy of the construction complex, it is envisaged to implement the following long-tern sectoral programmes:

- The Main Lines for development of material and technical base for the construction sector in the Republic of Belarus for 1998-2015;
- The Programme for reduction by 2003 of use of production resources in the construction and the construction materials industry by 25-30% on the average;
- The programme for creation of the national regulatory framework in the construction sector;
- The Programme of Actions of the Ministry of Construction and Architecture on implementation of the long-term investment policy till 2015;
- The Programme of updating and re-equipment of the active part of fixed assets of construction sand specialised organisations of the Ministry of Construction and Architecture till 2005;
- The State Scientific and Technical Programme *Developing and Implementing Novel Materials, Energy-Conservation Technologies and Resource-Saving Structural Systems of Dwelling Houses Reducing Resources and Energy Consumption in the Process of Housing Construction and Maintenance.*

Agribusiness has as its main task: to ensure fuller and reliable provision to population of food products and the processing industry aims at providing raw materials; to make more active export of agricultural produce and to use this for strengthening food security of the country.

To overcome negative conditions in the AB of the country, the Programme has been designed for improvement of the agro-industrial complex of the Republic of Belarus in 2001-2005; implementation of the main lines of the programme would allow forming micro and macroeconomic management systems ensuring sustainable development and gradual increase of agricultural output.

By the main parameters the priority lines of development of *transport* must be:

- reconstruction and modernisation of essential transport communication lines, facilities, and systems and bringing them in compliance with the world standards;
- updating and rehabilitation of the production potential and replacement of physically and morally outdated equipment and transport equipment;
- creation of required conditions for attraction of transit streams;
- improvement environmental control over operation of transport facilities, making such control stricter.

The comprehensive system of environmental measures must ensure, in the foreseeable future, limiting (reducing) adverse impacts by the use of transport vehicle on man and environment.

On the whole, it should be noted that the last two years have been crucial for the Republic of Belarus in terms of overcoming high rates of inflation, instability of the national currency rate; reducing cross-subsidies; and over-regulation prices. The current stage of development is characterised by a comparative stability in the monetary sphere, reduced redistribution processes through the pricing mechanism and, as a result, achievement of a high certainty of economic development, opportunities for objective analysis of the state of the real economic sector and for prediction of its development.

1.2. Main Lines Of The National Climatic Programme

Effective planning and management of the national economy requires analysis and account of a greater number of economic, social and natural indicators.

To this end, it is necessary to organise a large information basis and a system for its effective use for the interests of planning and management of various aspects of economic activities. The essential element of the information basis is climatic information.

Climate has always exerted a substantial impact on human community. History of civilisation knows a lot of examples when changing climatic conditions have had catastrophic affect on the fates of many countries and peoples. Despite an increased independence of man from natural phenomena, impacts of climate and weather changes on human activities remain to be substantial. Generally, dependence of the main economic sectors and of the national economies on climate has even become higher when expressed in absolute terms. During periods of unfavourable climatic conditions the global reserves of grains reduced from 20 to 5-10% while the cost of grains went up several times. While in 1960's the loss of the global community resultant from unfavourable climatic conditions were about several dozen billions of US dollars, today they make up about 100 billion dollars. The summer flood of 2002 in Europe inflicted damage to European countries amounting to about 20 billion US dollars.

In 1978, US Congress passed a Bill according to which climatic surveys were made through legislation a long-term national policy of the government and personally controlled by the President. In 1980's and, especially, in 1990's the overwhelming majority of countries adopted national climate programmes. The Republic of Belarus is one of a few countries that does not have their own climate programme.

Intensive modern warming of climate has brought attention of the world community and encouraged scientists, practitioners and politicians to consider climate as an essential natural resource redistribution of which among states has serious socio-economic and political consequences that define well-being of the states.

Effect of global warming may be substantial in many countries. Danger presented by large-scale draughts and floods and the elevation of the world ocean level raise acute issues related to food, potable water and heath of the people. Already today, many states of the world have been put on the brink of survival by continuous extreme climatic phenomena (draughts, floods).

Growing understanding of the fact that natural resources are limited and it is required to preserve them makes the climate change problem a priority problem. This is confirmed by fact that this problem is discussed by parliaments of different countries and during international assemblies.

This is related first of all to the circumstance that dependence of a number of economic sectors on the changing climatic conditions is not decreasing in its absolute terms, but, on the contrary, is growing together with the growth of production. Practically, all economic activities and daily life of the people and life of vegetation and wildlife are connected with climatic and weather conditions. They may be favourable, but may bring up significant complications for life, may cause destructions or damage or pose threats to health and even to life. By estimates of experts, maximum losses may be included into the following three groups of extreme climatic events: floods, draughts and tropical hurricanes.

In conditions of changing climate climatic resources may be redistributed and bring benefits to countries with improving climate or losses to countries with deteriorating climate.

The economy of our country, as of other countries, sustains a significant damage every year due to natural hydrometeorological phenomena. Examples include draughts of 1992, 1994, 1995, 1996, 1997, 1999, 2001 and 2002 as well as strong floods and water rise in the south of the country in 1974, 1979, 1993 and 1999. Incomplete account of climatic information results in high losses in agriculture, energy and construction sectors. It is absolutely necessary to take into account climatic aspects of natural phenomena (repeatability, distribution, intensity, duration, coverage, etc.) so as to design and justify measures for protection and for creation of agricultural and energy reserves.

Stronger impact exerted by a new powerful climate-forming factor like human activities, the present tendency towards climate change and its extreme nature have given a certain push for development of climatic research in many countries of the world, including Belarus. Human impact on climate is not limited anymore by change of climate in large towns of the country. Large-scale land reclamation operations have made a significant input into the climatic changes.

Development of independent economy requires a thorough study of climatic resources so as to optimise agricultural production, expand opportunities for account and use of climate in the energy and construction sectors and, in the long run, for development of the respective strategy of response by industry and agriculture to climate changes.

Covering of applied climatology by commercial activities may bring about preparation of climatic materials that are not sufficiently qualified. This may be the source for taking of erroneous decisions connected with a high damage and, probably, tragic consequences.

Historically, our country has not had scientific institutions making climatic research, while most of the FSU republics have hydrometeorological institutions or climatologic departments in the institutes of geography, and train personnel of higher and middle qualification. In the past, Belarus used scientific research results of the USSR institutions, although they not always took into consideration the specific features and needs of our republic. Given this fact, it is necessary to organise on the Republic of Belarus a system for training climatology specialists and meteorologists, which would make it possible, in the future, to organise respective research entities.

Ratification and approval of, and accession to the UN Framework Convention on Climate Change by 186 countries demonstrates that the global community has recognised the fact that climatic changes present a serious threat to socio-economic development of the world countries.

In conformity with the National Strategy of Sustainable Socio-Economic Development of the Republic of Belarus, the gross domestic product (GDP) should exceed, by 2010, the level of 1990 by 20-30%, which will require respective measures for reducing emissions of greenhouse gas and its precursors, higher sequestration of carbon dioxide by forest systems and natural wetlands as well as taking of measures for adaptation of the economy to changing climatic conditions. These issues can be solved within the National climatic programme, which was drafted in 1999, but now it requires some detailing and supplementations.

The Main Objectives And Tasks Of The National Climatic Programme

The main objectives of the programme include the following:

- To set an effective system for provision to state authorities, ministries and departments and to population of the country of reliable hydrometeorological information and predictions of possible climatic changes so as to prevent negative and take into account positive consequences of the climate changes for the country economy and population.
- To reduce damage caused by hazardous climate changes.
- To ensure the fulfilment of international commitments of the Republic of Belarus in conformity with the UN Framework Convention on Climate Change and the Kyoto Protocol for reducing anthropogenic climate changes through stabilisation (decrease) of greenhouse gas concentrations.

These objectives can be achieved through solution of the following tasks:

- developing a network of hydrometeorological observations, improving the system of collection, analysis, control, storage and dissemination of climatic information so as to ensure the most complete sand timely support of governmental, and other authorities and of individuals with climatic information;
- making inventory of greenhouse gas sources and sinks;
- implementing a national policy and taking respective measures to limit anthropogenic emissions and increasing removals of greenhouse gases;
- ensuring effective use of climatic resources by all sectors of the economy, health system, etc.;
- improved application of climatic information in the interests of different economic sectors;
- better understanding of the processes and factors having impact on climate;
- making more complete estimates of impacts exerted by natural and anthropogenic factors on regional and local climate;
- designing possible scenarios of climate change and extreme climatic phenomena (draughts, floods, severe and warm winters);
- developing recommendations for assessment of possible socio-economic sand environmental consequences of climate changes in Belarus for adaptation of the national economy to new climatic conditions. improved use and protection of natural resources depending on climatic conditions; and
- creating scientific, technological and regulatory basis for prevention of dangerous changes of climate and adaptation of development of the economy of the Republic of Belarus to climatic changes.

This must be a long-term programme including several stages. The first five-year stage (2004-2008) of the programme implementation will include making of scientific research aimed at solving priority tasks for setting up a system of management of climatic data, including also inventory of greenhouse gas sources and sinks, designing of scientific grounds for prediction of climatic changes and development of the national strategy for mitigation of impact on climate. The second stage of implementation of the National climatic programme (2009-2013) will emphasise the development of a system of comprehensive and interconnected technological, economic, organisational and technical actions to reduce anthropogenic impacts on climate and adaptation of the economy to changing climate. This stage will require high financial inputs, since it is connected with the development and introduction of new production technologies reducing greenhouse gas emissions, large-scale implementation of the energy-saving policy and transfer to new energy-saving sources, etc.

The National climatic programme must be integrated into the Global climatic programme so as to cooperate climatic research and carry on a common strategy for reduction of adverse impacts on climate change on the economy.

The Structure Of The National Climatic Programme

The National climatic programme includes the following four basic sub-programmes:

1. The sub-programme of climatic data, including issues of optimisation of the network of observations, setting of a system of observations and assessment of greenhouse gas and natural and anthropogenic aerosols sources and sinks; and setting a data management system.
2. The sub-programme for research into climate changes, including issues of anthropogenic impacts on climate, development of physical grounds for prediction of climate changes and of extreme climatic phenomena, etc.
3. The sub-programme of application of knowledge about climate in the national economy and adaptation of the economy to climate changes, including such major issues as:
   - Developing methods for assessment of climate impacts on different economic sectors;
   - Assessing economic effectiveness of the use of climatic information;
   - Preventing adverse consequences of climate changes for Belarusian economy through timely and comprehensive adaptation of different economic sectors to changing climate.

We also included into this sub-programme issues of socio-economic consequences of climate changes, although structurally they can make up an independent sub-programme.

4. The sub-programme of development of the National strategy and system of measures for reducing anthropogenic impacts on climate.

2. ENERGY SECTOR

The share of the energy sector, including all energy-related processes related to mining, storage, transportation and use (combustion) of organic fuel, in the structure of greenhouse gases having direct greenhouse effect include the following, distribution by categories of sources (without CO_2 removal):

carbon dioxide (CO_2) ~ 70%,
methane (CH_4) – 38.6%, and
nitrous oxide (N_2O) – 2.4%.

The structure of sources of emission from the energy sector of the basic anthropogenic greenhouse gas (CO_2), for 2002, was as follows: energy sector, including fuel processing and energy generation and transmission (64.3%), transport (~11%), industry (~7%), and communal sector (~10%).

In view of the determining role of CO_2 emission from energy-generation use (combustion) of fuel in the total national emission of greenhouse gases, the basic provisions of the strategy on reduction of greenhouse gas emissions will be also connected, primarily, with problems of restriction of CO_2 emission in the energy system of the country.

In the Belarusian economy, with deficit of its own energy resources, the energy economy (EE) is an essential component for operation and development of productive forces and for increasing the standard of living of population.

2.1. Prediction Of Development Of The Energy Sector

The main problem of development and operation of the fuel and energy complex in Belarus is its high degree of dependence on import.

The needs of the country in energy resources is covered by 15-18% by its own resources generated in Belarus (oil, casinghead gas, fuel peat, firewood, etc.) while the remaining share is covered by imported energy resources; in 2001, the share of import from Russia was 97.1%.

The ratio of local and import-substituting fuel and energy resources (FER) is permanently changing towards a higher share of local FER (primarily firewood and wood waste).

In conformity with the Concept of the National Strategy of Sustainable Socio-Economic Development of the Republic of Belarus till 2020, development of the fuel and energy complex will be aimed at stable covering of the country needs in FER taking into account their rational use.

The following lines should be priority lines:

- Ensuring energy security of the country and increasing its energy independence on the basis of an optimised structure of fuel and energy balance (higher share of secondary energy resources, local fuel, untraditional and renewable energy sources, like wind, solar and biological energy, small hydraulic energy facilities), a broad introduction of new efficient electricity generation technologies, further development of electrical energy system, and measures aimed at saving of energy in all sectors of the economy, including social sphere;

- Developing progressive oil refining technologies that increase the level of its use and quality of petroleum products;

Improving forms of interactions of the EE with the environment so as to mitigate adverse environmental impact; and

- Diversifying FER supplies by types of energy resources and suppliers.

The Concept of the National Strategy of Sustainable Socio-Economic Development of the Republic of Belarus till 2020 envisages a structural change of industry that should be aimed at further strengthening and development of promising sub-sectors and production facilities through introduction of new technologies and progressive resource- and energy-saving and environmentally clean technologies; slowing down of rates of development of traditional, basically metal- and energy-intensive sub-sectors and production facilities; and some reduction of the share of the machine building and metalworking sectors.

Implementation of actions for reducing greenhouse gas emission in Belarus is based on the provisions of the national strategy of most effective response to expected climatic changes so as to prevent their adverse consequences.

The main requirements to performance of actions in this field are as follows:

1. National actions of response to climatic changes must be coordinated with the total range of measures provided by the Concept of National Strategy of Sustainable Socio-Economic Development of the Republic of Belarus till 2020 so as to preclude unfavourable impacts of such actions on the life of society.

2. Priority actions in this field must ensure (with minimum costs) the fulfilment by Belarus of its commitments according to the UN Framework Convention on Climate Change.

Just like other economic sectors, the EE suffered from a crisis in 1990's. Gross use of fuel and energy resources had been stably slowing down before 1995, and then stabilised at the level of 35-37 million tons of equivalent fuel (coal equivalent).

The economy of Belarus is characterised by a high rate of energy intensity in GDP. In conformity with the global practice, effectiveness of use of FER is estimated by means of the GDP energy intensity indicator, which made in our country (by purchasing power parity) 0.503 kg of fuel equivalent/US$@ppp, as for 1 January 2000 (for comparison, this indicator in 1996 was 0.404 in USA, 0.420 in Finland, and 0.284 in Great Britain). Over the same period, use of energy per capita in the republic made 3430 kg of fuel equivalent/man (in 1996, this indicator was: 11284 in USA, 8016 in Finland, and 5416 in Great Britain).

Over 1990-1995, while GDP went down by 34.8%, energy intensity of GDP dropped by 14.1%, which was caused, mainly, by reduced use of FER resultant from production slump. Measures taken for reformation and liberalisation of the economy sand state support of the priority sectors and production facilities created conditions which allowed, for the first time since 1992, to stop the drop and, beginning with 1996, gross domestic products has been growing every year. With GDP growth by 28.3% in 1999, as compared to 1995, gross use of FER (without raw materials) in 1999 and 2000 practically was at the level of 1995. With growth of GDP by 37% (in 1995-2000), energy intensity of GDP reduced by 28%, which was connected with a growth of the economy and an active energy-saving policy.

Alongside a positive trend towards decrease of energy intensity of GDP (kg of fuel equivalent/$US), there is seen a negative trend towards increase of costs for energy resources required to produce one unit of GDP ($US/$US). In 1998, as compared to 1996, energy intensity of GDP reduced by 14.7%, while the costs of energy resources per GDP unit increased by 6.3% and, hence, efforts on saving of energy resources are not sufficient to compensate for higher costs of FER. This situation is caused not that much by growing prices for imported energy resources, but rather by a significant growth of costs related to their transportation ands conversion inside the country.

The total saving of FER in the country in comparable conditions, from 1996 to 200, was estimated by specialists at 6.8 million tons of fuel equivalent, including more than 4 million tons of fuel equivalent through energy-saving measures and more than 2 million tons of fuel equivalent through additional measures.

Over 1996-1998, the legal basis was formed in Belarus for effective use of fuel and energy resources: The law “On Energy Saving” was adopted in July 1998; the National programme on energy saving (Programme) for the period till 2005 was developed in 2000; the Council of Ministers passed a range of resolutions; construction norms and rules as well as standards of the Republic of Belarus were adjusted and put into effect; a range of methodological documents were prepared; long-term sectoral and regional energy-saving programmes were drafted; the prognosis programmes are detailed with due account of achieved outputs.

Conceptual tasks are to be solved by the use of state management the main mechanism of which is regulation of use of FER through creation and use of legislative and regulatory frames and economic incentives for rational use of FER.

Funding of the most important actions for saving of fuel and energy resources within the energy-saving programmes is made using innovation funds of the Ministry of Energy, sectoral innovation funds, state budget, the national fund “Energy Saving”, proper funds of enterprises, and preferential credits.

To create conditions for implementation of the energy-saving policy, economic mechanisms have been developed, including tariff, penalty and incentive mechanisms.

Use of the national potential for energy saving over 1996-2000 was made with due account of the priority lines indicated in the Programme, such as:

- modernisation and increasing of efficiency of boiler plants;
- introduction of steam and gad turbines and gas and turbine plants;
- optimisation pf heat supply schemes and conditions;
- conversion of steam boilers to water heating;
- replacement of electrical boiler plants by more economical heat sources;
- introduction of a system of energy account and regulation;
- use of secondary energy resources;
- decrease in energy transmission losses;
- use of frequency-regulated drives;
- installation of energy-saving lighting fixtures;
- introduction of new energy-saving technologies, equipment and materials;
- use of unconventional; and renewable energy sources; and
- practical use of an economic mechanism for stimulation of energy saving and other measures.

Organisational and economic mechanisms for stimulation of energy saving measures, developed and put into use during the above period of time, allowed, in many respects, preventing bad economic management and use of FER and stimulating use of fast-to-pay back technological and technical actions.

In the past period the implementation of the Main lines of the energy policy (since 1996) the financial position of the EE sectors has been constantly deteriorating due to systematic delayed payment of fees by many users of FER. As a result, the planned rates of update and modernisation of fixed assets have not been achieved, i.e. there is crisis of moral and physical ageing of equipment that continues to deepen.

There is a huge unused potential for energy saving in the communal, energy, industrial and agricultural sectors.

Taking into consideration the potential in 1996-2000 and options for development of the national economy in 2001-2005, the potential for energy saving in 200o5 can be estimated at 5575-7234 thousand tons of fuel equivalent (~50% in the communal and housing sector, ~13.5% in the energy sector).

By the indicators attained in 200-2002, the Council of Ministers of the Republic of Belarus defined, in its resolution No. 1820 of 27 December 2002, additional measures for economical and effective use of FER for 2003-2005 by national state governing authorities and other organisations subordinated to the Government of the Republic of Belarus:

- tasks were set for 2003-2005 on the annual reduction of energy intensity in GDP by at least 4.5%:

- annual decrease of FER use by the real economic sector was set at 7% minimum, and specific tasks were set to each ministry and department;

- scopes of substitution of fuel and energy resources purchased from other countries were defined through the use of local fuel (peat and biomass) and untraditional energy sources at least by 600,000 tons of fuel equivalent in 2005 against 2002, including by 200,000 tons of fuel equivalent in 2003.

The organisational and economic basis of the energy saving policy in the future should be development of the required legislative, regulatory and technical frames, including standards, construction norms and rules, sectoral technological designing norms and a range of other regulatory documents defining requirements in the field of energy saving.

The main technical priorities in the field of energy saving for the period till 2005 include:

- increasing efficacy of operation of generating sources through changing of the structure of generating facilities towards broader use of steam and gas technologies and gas and turbine technologies, increased generation of electricity by use of heat, conversion of boiler houses into mini CHPPs, optimised operation of the energy sources, and optimum distribution of load within the energy system;

- updating and increasing efficacy of boiler houses by transferring steam boilers to water-heating mode, and heating networks; use of draught air from the upper part of the boiler houses buildings; using of economisers and other heat exchangers for use of secondary energy resources (SER); equipping boilers with automatic devices for controlling combustion and regulation processes or of production control (monitoring) of the boiler fuel use modes through portable meters of heat loss and regulating heat energy use conditions, installing heat accumulators; etc.

- practical use of boiler equipment using fuel waste of production, agricultural and forestry and woodworking sectors;

- reducing loss and technological use of energy resources during transportation of heat and electrical energy, natural gas, oil and petroleum products through reduced auxiliary use of serviced units, technical update and optimised load of electrical lines and transformer substations, heating networks and heating points, compressor plants on gas pipelines, pumping stations in the heating networks, oil and product pipelines using regulated electrical drives;

- organisation of mini CHPP based on steam-generator plants (SGP) and gas-turbine plants (GTP) in compressor stations of gas pipelines;

- creation of technical conditions (uniting heating networks, construction of junctions, heat accumulators, etc.) for maximum transfer of loads from boiler houses of any departments to CHPPs, with the cost of heat energy for the owners of boiler houses at the level of its production cost for CHPP;

- adjustment and automatic regulation of hydraulic and heat modes of operations of heating networks (recalculation and use of plates, replacement of network pumps, regulation, etc.);

- replacement of heating electrical boiler houses by fuel-fired boiler houses (mostly using local fuel, waste fuel), as well as switching over of all electrical drying plants and heating stoves (where this is expedient) to fuel-fired plants;

- introduction of automatic systems for regulation of energy use in the heating systems, lighting systems, hot and cold water supply systems and ventilation systems of dwelling, public and production rooms and in all types of technological plants;

- designing and putting into use of new energy-saving technologies for heating, thermal treatment and drying of products, new construction and insulation materials with improved heat and physical characteristics and, in particular, of special additives for production of concrete-reinforced products; energy and technological facilities for production of cement, glass, bricks, oil refinery, for chemical and food enterprises, etc;

- further development of the system of account of all types of energy resources, including account of their use for heating dwelling rooms as well as use of multi-tariff energy meters;

- maximum use of secondary heating resources (hot water, condensate, flue gases, ventilation emissions, wastewater) in technological processes, heating systems and hot water systems of industrial centres and in towns and other populated centres;

- designing and practical use of effective biogas plants for generation of combustible gases and fertilisers from animal farming, plant farming waste and from specially grown biomass;

- designing and practical use of technologies designed for use of municipal waste for heating;

- practical use of heat pumping installations at industrial enterprises in centralised and individual heating systems;

- practical use of economically expedient of wind, solar and other untraditional energy sources;

- technical update of motor vehicles and tractors, including transfer to diesel fuel, liquefied and compressed natural gas; designing and practical use of economical engines, improved systems of diagnostics and regulation and of optimum operational modes;

- designing and practical use of technologies for generation of fuel for diesel installations from methanol and technical rapeseed oil;

- designing, organisation of production and practical use of energy-saving equipment, devices and materials;

- decentralisation of the system of energy supply to users, including heat, fuel, compressed air with small loads and rapidly changing operational modes;

- maximum decrease of energy costs in housing and communal sector by introducing regulated system of heating, ventilation, hot water supply, lighting and reuse of heat from ventilation discharge, wastewater, use of energy-efficient construction materials, structures and solar heaters.

The strategic goal in the field of energy saving till the year 2015 must be decrease of energy intensity of GDP as compared to 1999 by 40-45% and, as a consequence, decrease of the country dependence on import of FER, which can be attained through following measures:

- restructuring of economic sectors and industries, increasing efficiency of energy resources by using new energy-saving technologies, equipment, devices and materials and utilisation of secondary energy resources;

- increase of the share of local fuel sand production waste and of untraditional and renewable energy sources in the fuel balance of the country;

- introduction of boiler equipment operating on combustible production waste, agricultural and forestry waste, woodworking waste and municipal waste.

In conformity with the Main Lines of Energy Policy of the Republic of Belarus for 2001-2005 and till 2015, the main goal of the Energy Policy of the Republic of Belarus is searching for ways and reforming of mechanisms of optimum development and operation of EE sectors, as well as technical implementation of reliable and effective energy supply to all economic sectors and to population that would ensure manufacture of competitive products and attainment of standards and quality of life of the people equal to other developed European states and preservation of safe environment.

The above goal should be attained through following measures:

- identification of impacts by the level of development of production forces and social conditions of life of the people on the use of energy resources;
- determination of the optimum ratio between import and proper generation of energy resources, including maximum use of untraditional and renewable sources of energy;
- selection of reliable and economically beneficial suppliers of FER from other countries;
- preservation of the integrated technological management in the EE;
- rational structure of energy capacities and system of energy transportation;
- reliable and economical provision of energy to users with maximum effective use of energy resources through introduction of energy-saving organisational and technical measures;
- use of the geopolitical position of the country for transit of all types of energy resources as well as for export of electricity generated in the country;
- meeting the needs of regions and towns and cities in energy resources through expansion of their share of property in the fixed assets of energy generating facilities, including setting of their own municipal facilities, which should also include more rights for management and income generation, but requiring at the same time preservation of the integrated technological management of the entire EE;
- taking into account of main specific features of energy supply in the regions contaminated with radionuclides;
- implementing a technological policy oriented towards a radical increase of production efficiency, distribution and use of FER and environmental security of the EE facilities;
- giving priority for deep refining of oil at OR and a comprehensive use of hydrocarbon materials;
- replacement of light oil products in internal combustion engines.

Goals of the energy policy shall be attached through following measures:

- use of the pricing and tax policy that would ensure elimination of disproportions in prices (tariffs) for energy resources and other commodities or services and a gradual transition to prices and tariffs meeting the world prices as the upper limit and the self-financing price as the lower limit;
- creation of a competitive environment in all sectors of the EE by organisation of fully-fledged economic market entities and market infrastructure;

- provision of regulatory frames and development of a system of regulatory acts that regulate relations of energy market subjects between themselves as well as with state government bodies and public;
- improvement of incentives for a broad economically expedient involvement in the fuel balance of fuel resources, renewable energy sources and municipal and production waste;
- implementation of an active investment policy.

Main programmatic documents for development of the EE: The Main Lines of Energy Policy of the Republic of Belarus for 2001-2005 and till 2015, approved by Resolution No. 567 of the Council of Ministers of the Republic of Belarus on 27 October 2000; the National Programme of Energy Saving for 2001-2005, approved by Resolution No. 56 of the Council of Ministers of the Republic of Belarus on 16 January 2001; the Sectoral Programme on Rational Use of Natural Resources and Environmental Protection for 2003-2005 of the “Belenergo” Concern.

MAIN LINES OF ENERGY POLICY OF THE REPUBLIC OF BELARUS FOR 2001-2005 AND TILL 2015

Environmental Aspects Of Development Of The EE:

Over the recent time, impact of the EE on the environment has been decreasing due to total reduction of used boiler and oven fuels, higher use of natural gas and decreased use of black oil, and introduction of environmentally clean technologies and equipment.

Permanent reduction of nitrogen, carbon and sulphur oxide emissions allows Belarus to fulfil its commitment of the Convention on Transboundary Transfer, although the economic result for the country is rather modest, since more than 70% of oxide fallout is caused by transfer from Western countries. The input of all sources of the Republic of Belarus in the total amount of fallout makes 10.4%, and only 2.5% from the EE enterprises. As a result, the effect of reduced emissions from the EE facilities is not visible in practice; however, this does not decrease responsibility of the EE facilities as regards reduction of harmful emission to the environment.

The environmental part of the Energy Policy includes the following:

1. Reduction of harmful emissions from energy facilities by taking relatively inexpensive actions, like use of multi-channel burner devices, organisation of multi-step combustion of fuel with re-circulation of flue gases, substitution of black oil by natural gas, and creation of a system of continuous control and regulation of emissions at facilities.
2. Distribution of investments for introduction of environmentally progressive actions must be made on the basis of comprehensive environmental and economic calculations and ranking of priorities by minimising costs per unit of emission reduction.
3. Formulation of the tariff and pricing policies encouraging all economic entities to develop and use environmentally clean technologies and equipment.
4. Further introduction at OR of deep oil refining technologies that would make it possible to produce black oil with any sulphur content.

5. Improvement of the atmosphere monitoring system and the operative control system, including economic and administrative impacts and covering all emission sources.
6. Improvement of the legislative frame in accordance with economic opportunities of the country and the world standards.

NATIONAL PROGRAMME OF ENERGY SAVING UP TO 2005

1. Main Provisions Of The National Programme Of Energy Saving Till 2005

The supreme priority of the energy policy of the Republic of Belarus, along with the sustainable provision of energy resources for the country, is creation of conditions for functioning and development of the economy and maximum efficient use of fuel and energy resources.

The objective of the National Programme of Energy Saving till 2005 is defining of priorities in the activities of the control bodies at different levels and of economic entities in issues of rational use of FER, development of projects and actions for different sectors including estimation of required investments, their effectiveness and terms of implementation.

The main conceptual tasks of the National Programme are:

1. To reach by 2015 the energy intensity of GDP at the level of industrial countries.
2. To ensure by 2005 the planned increase of GDP without increasing the consumption of FER.

2. General Lines And Priorities Of The Energy-Saving Policy

The strategic activities in the field of energy saving for the period till 2005 must be reduction of energy intensity of GDP and, as a consequence, reduction of the country dependence on imported FER, which can be achieved through the following measures:

- restructuring of economic and industrial sectors;
- increasing efficacy of use of energy resources through introduction of new energy-saving technologies, equipment, devoices and materials and utilisation of secondary energy resources;
- increase in the national fuel balance of the share of less expensive fuels as well as of local fuels and production waste and untraditional and renewable energy sources.

From the point of reduction of greenhouse gases, the National Programme can be regarded as equivocal: on one hand, reduction of energy use objectively causes reduced emission of greenhouse gases, but on the other hand, increase of the share of local fuels with higher emission factors will have an impact on the actual emission of greenhouse gases.

Therefore, this section includes a more detailed consideration of measures aimed at reducing the use of fuel and, as a result, decreased emission of greenhouse gases.

Organisational and economic lines:

- development of new and improvement of the existing economic mechanisms stimulating higher energy efficiency in manufacture of products and provision of services;
- making the state expertise of emergency efficiency of project options and of regular energy surveys of economic entities;
- review of the tariff policy for heat and electrical energy and fuel.

Technical and technological lines:

1. Increasing efficiency of generating sources by changing the structure of generating facilities towards broader use of steam and gas as well as gas turbine technologies.
2. Updating and increasing efficacy of boiler houses by switching over steam boilers to water-heating operational modes.
3. Updating heat insulation in all elements and equipment of boiler houses sand heating networks.
4. Designing and putting into operation new energy-saving technologies for heating, thermal treatment and drying of products, and new construction and insulation materials with improved heat and physical characteristics.
5. Maximum use of secondary heat energy resources in technological processes, heating systems and hot water supply of industrial centres and populated localities.
6. Equipping boilers with automatic system for control of combustion processes and regulation, automatic regulation of hydraulic and heating modes of the heating networks, use of energy resources in the systems of heating, lighting, hot and cold water supply and ventilation of dwelling, public and production rooms.
7. Further development of the systems of account of all energy resources.
8. Economically expedient use of untraditional sources of energy.

Implementation of the above actions will allow attaining predicted macroeconomic indicators presented in Table 2.1, where the first scenario of development of the country's economy is based on the data of the draft Concept of the Socio-Economic Development of the Republic of Belarus for 2001-2005, which predicts the growth of GDP by 23.1% as compared to 2000 (absolute values of GDP per purchasing power parity are calculated on the basis of data of the European comparison programme), while the second scenario is based on the prognosis of the Committee on Energy Efficiency of the Council of Ministers of the Republic of Belarus.

Table 2.1. Dynamic of basic actual macroeconomic and energy indicators of the Republic of Belarus

Development scenarios	GDP in 2000, million US$@ppp	GDP in 2005, million US$@ppp	Average annual growth of GDP, %	Saving of FER in 2005 compared to 2000		Average annual saving of FER, %	Energy intensity of GDP in 2005, kg of fuel equiv/ US$@ppp
				'000' t of fuel equiv.	%		
Scenario 1	67 400	82 948	4.24	7234	23	4.6	0.379

Scenario 2	67 400	79 351	3.32	5575	17.7	3.54	0.396

3. Investment And Tariff Policies

The main source of funding of energy-saving projects is and, probably, will remain in the near future one's own resources of enterprises and borrowed resources.

For implementation of large investment projects, the most appropriate source of funding is foreign banks. However, this is possible on condition that the suggested funding scheme will be envisaged in international programmes.

Beside the above funding sources, the system of financial support of the state energy-saving policy must be formed by the following funding forms and sources:

- stock capital;
- leasing funding;
- "Energy Saving" funds from the budgetary sector.

The country still has a practice when electricity is sold to users at the price rates regulated by the Ministry of Economy.

The existing tariff system for heat and electrical energy, using cross subsidies, has a negative impact on the economic sectors.

The essence of main principles of the tariff polo icy, from the point of energy saving, can be formulated as follows:

1. Tariffs for all types of energy resources must ensure balance of socio-economic interests of producers and society, keeping in mind, first of all, minimisation of cross subsidies for groups of users receiving preferences and taking of adequate measures for protection of low-income population groups.
2. The level of tariffs for electricity and heating energy as well as prices for fuel must create economic conditions ensuring development of energy-saving technologies in production processes of FER producers and users.
3. Timely and justified adjustment of tariffs.

For further development of the Main Lines and the National Programme of Energy Saving, Sectoral Programmes have been adopted as well as Resolution of the council of Ministers of the Republic of Belarus No. 1820 of 27 December 2002 called "On Additional Measures for Economical and Effective Use of Fuel and Energy Resources".

This, in particular, the Programme on Energy Saving of the Ministry of Housing and Communal Economy for 2003-2005 stipulated a 20% reduction of the use of FER by implementation of the following actions: reduction of loss of heat energy in the heating networks through optimisation of the heating lines length, laying of pre-insulated pipes, improving heat insulation, reducing use of fuel by using individual heating points, plate heaters and other equipment, reconstruction of boiler houses by transition to gas, reduced use of electricity for pumping and cleaning of wastewater by means of new technologies, optimisation of operation of pumping and air-blowing equipment, decreased supply of heat with hot water by using a set of automatic regulation devices in the hot water supply and heating systems, reduced use of fuel by installation of high-efficacy plate heaters, frequency regulating electrical drives, etc.

As a result, use of FER in the housing and communal sector will be reduced, by 2005, from 2414.4 to 1831.6 thousand tons of fuel equivalent.

SECTORAL PROGRAMME OF NATURAL RESOURCES MANAGEMENT AND ENVIRONMENTAL PROTECTION FOR 2003-2005 OF THE "BELENERGO" CONCERN

Development of this Programme was dictated by the need to determine main lines of environmental protection activities in the energy sector, aimed at rational use of natural resources and improvement of the environment in the near future (2003-2005).

This Programme includes a range of measures required to solve immediate tasks in the energy sector aimed at reducing environmental impact by applying most effective methods and techniques in conditions of shortage of financial resources.

Objectives of the Programme:

1. Identification of the main lines of environmental protection activities in the energy sector for 2003-2005.
2. Further reduction of harmful environmental impacts by energy facilities.

Tasks of the Programme:

1. Ensuring a comprehensive approach to rational use and saving of fuel and energy resources, as well as water resources.
2. Further reduction of harmful substances release by improving technological processes.
3. Improving the local environmental protection monitoring system.
4. Drafting proposals for different facilities for reducing environmental load taking into account shortage of financial resources.

The Sectoral Programme specifies two important aspects:

1. If the current proportions of the fuel balance are preserved, construction of sulphur-removing plants hardly probable and inexpedient, since this would require huge investments (commensurable with the cost of the plants) that will not be working due to a large share of idle time (70-90% during the year).
2. Construction of nitrogen-removing plants during the period considered is also hardly probable due to large costs and, hence, a high cost of emission reduction. Efficacy of this method

(cost per unit of reduced emission) is 1-2 orders of magnitude lower than the cost of technological measures.

The main solutions aimed at reducing nitrogen oxide emissions are still technological (fuel combustion) measures aimed at decreasing nitrogen oxide emissions. Equally important is the proposal to introduce production control of the combustion mode of the boilers using portable or stationary devices, which allows decreasing the use of fuel, nitrogen oxide emissions and the climate-forming carbon dioxide.

Measures connected with the use of gas analysers were described in the previous sectoral programme and the available experience confirms high environmental and economic efficiency of such measures.

One of the relevant jobs included into the programme is “Research for Identification of Fuel Saving Reserves for Energy Boilers through CO Control”. The purpose of this research is to determine environmental reserves that can be rather easily (practically, without additional capital investments) identified and selected by transition to operation modes with critical excess of air and the content of CO in flue gases up to 10-20 ppm.

Further modernisation and technical update of energy facilities using modern energy plants, application of combined schemes for generation of heat and electrical energy and use of advanced fuel combustion technologies allows both energy-saving and environmental effects.

TRANSPORT

Since, according to the IPCC methodology, combustion of fuel by transport facilities is included into the module “Energy”, the policy and measures for reducing greenhouse gases in the transport sector of the Republic of Belarus are considered in this Section.

By the data of inventory of greenhouse gases emissions, the main source of emission in the transport sector is motor vehicles; its share is about 75% of CO_2 emission and, therefore, the main emphasis is placed on motor vehicles.

Specific features characterising the motor transport sector of the Republic of Belarus:

- reduced scope of cargo transportation;
- there is a trend towards a significant reduction of the number of common-use transport vehicles. At the same time, the number of motor vehicles owned by individuals and nongovernmental organisations is growing;
- the degree of wear of the fixed productive assets, transport vehicles and installations remains high;
- the existing system of state statistics gives distorted ideas about the use of oil motor and gas motor fuel and, hence, about environmental pollution with spent gases from passenger transport, since it takes into account only the impact of passenger buses as well as of organisations’ cars and

taxis that are not owned by individuals and neglects individual cars and passenger buses owned by individuals. There are no statistical data on environmental impact by transit transport facilities.

It is necessary to note that in conditions of expected growth of the economy and if the existing trends in the development of the transport sector remain, the country will face a range of difficulties and problems related to increased road traffic, number and structure of transport facilities lagging far behind the demands, the length of transport lines sand their low quality, and a low initial technical level of transport facilities and of their operational conditions.

This will entail a sharp deterioration of such transport operation indicators as safety of traffic and environmental impact.

To ensure environmental safety of operation, repair and maintenance of motor vehicles, it is required to review the existing regulatory and methodological frame with due account of structural changes in the sector and in the regulatory and legislative acts concerning environmental protection issues.

Development of the motor transport system in the Republic of Belarus over the period of 2005-2015 is based on the main lines for improvement of the motor transport system reflected in the “Concept of Development of the Transport Sector of the Republic of Belarus”, “The State Programme of Development of Transport Sector of the Republic of Belarus” and “The Concept of Socio-Economic Development of the System of the Ministry of Transport of the Republic of Belarus till 2015”.

The main programmatic documents on environmental protection in the motor transport sector include the Environmental Programme for 2002-2005 and the Concept of Mitigation of Negative Environmental Impact of Transport (draft document).

The objective of Environmental Programme for 2003-2005 is a comprehensive solution of problems connected with improvement of environmental indicators in the transport sector: increased environmental safety of transport, reduced emission of pollutants to the environment, creation of conditions for mitigation of adverse impact of transport facilities on the environment in conditions of shortage of financial resources, and maintenance of favourable environmental conditions.

The experience gained in the fight against adverse impact of motor vehicles on the environment has defined the range of measures included into the programme:

1. Regulatory and legislative support:

- developing the Concept for solution of environmental problems in the transport sector till 2010;
- developing a system of environmental audit in the organisations of the sector;
- developing a sectoral environmental monitoring system.

2. Organisational support:

- developing principles for comprehensive management of environmental activities in the organisations of the sector;
- ensuring permanent control over pollutant emissions to atmosphere from transport facilities;
- reducing the rate of idle runs and increasing the use of carrying capacity of the rolling stock;
- reducing the use of motor fuel by improving the structure of motor vehicle fleet.

3. Technical support and modernisation of equipment:

- setting up posts for controlling toxicity and smoke content in exhaust gases; equipping enterprises with diagnostic and gas analysing equipment;
- re-equipping motor vehicles of some enterprises using gas cylinders with compressed natural gas or liquefied hydrocarbon gas;
- supplementing the fleet with motor vehicles meeting norms of EURO-2 and EURO-3;
- equipping motor vehicles with neutralisers of exhaust gas.

4. Scientific support:

- developing a comprehensive system for collection and analysis of statistical reports on environmental protection;
- developing a database of scientific and technical documents devoted to environmental problems if motor vehicle.

5. Training and advanced training of personnel:

- training and advanced training of environmental protection specialists;
- organising workshops devoted to environmental protection problems.

6. Information support:

- exchange of information on environmental protection between transport ministries of CIS countries;
- provision to enterprises of current regulatory and other documents on environmental protection.

3. INDUSTRIAL PROCESSES

The main industrial sectors that are sources of greenhouse gases are metallurgy, chemical and petrochemical industry, and construction materials industry. Production facilities of these industrial sectors generate and emit practically all greenhouse gases, however the input of different sectors to the total emission strongly varies (Table 3.1).

Table 3.1. Input of industrial sectors and individual production facilities into greenhouse gases emission in 2002, %

	The share of sectors and production facilities in the total greenhouse gas emissions, %						
	CO_2	**SO_2**	**CO**	**NO_x**	**NO_2**	**CH_4**	**NMH**
Total, including:	100	100	100	100	100	100	100
Metallurgy, including:			**62.4**	**78.6**		**90.1**	
- production of steel			28.3	38.5		90.1	
- ferrous metal rolling			27.9	35.9			
- cast iron casting			3.5				
Chemical and petrochemical industry, **including:**		**94.9**	**37.6**	**21.4**	**100**	**9.9**	**97.2**
- production of caprolactam			31.0	4.3			
- production of sculpture acid		94.6					
- production of nitric acid				13.7	100		
- production of ammonia		0.3	5.2				82.9
- other chemicals			1.4	3.4		9.9	14.3
Production of construction materials, **including:**	**100**	**5.1**					**2.8**
- production of cement	64	5.1					
- production of lime	36						
- production of asphalt							2.2

Also, the greenhouse gas emissions are different between production facilities of the same sector. The most significant sources of greenhouse gases emission in industrial sectors are production of cement (CO_2, SO_2) and lime (CO_2); production of electrical steel (CO, NO_x, CH_4) and ferrous metal rolling (CO, NO_x); production of cast iron (CO); production of caprolactam (CO, NO_3), production of ammonia (SO_2, CO, NMH), nitric acid (NO_x, NO_2) and sulphuric acid (SO_2).

Over the period of 1990-2000, the total volume of greenhouse gases emission in industry went down 1.4 times, which was related to economy recession in Belarus and the resultant decrease of production output.

3.1 Prediction Of Development Of Industrial Sectors

The Concept of the National Strategy of Sustainable Socio-Economic Development of the Republic of Belarus for the period of up to 2020 and the Concept and the Programme of Development of Industrial Sector of the Republic of Belarus for 1998-2015 stipulate a serious restructuring of industrial sectors.

This restructuring must be aimed at development of advanced sub-sectors and production facilities through introduction of new machinery and equipment and progressive energy- and resource-saving environmentally clean technologies.

There is a plan for a slowdown in the development of traditional, basically metal- and energy-intensive sub-sectors and production facilities as well as accelerated development of science-intensive and export-oriented production facilities. The highest rates of development are planned for such sectors as food, forest, woodworking and wood pulp and paper industries.

The construction materials industry should be developed mostly towards creation and organisation of production facilities for manufacture of new effective materials, structures and products. As regards planned scopes of construction for the future, the existing production facilities do not meet the demand only for some types of traditional construction materials, including lime. Therefore, it is planned to put into operation additional production facilities for manufacture of lime, up to 200,000 tons a year. [Comprehensive Prediction of Scientific and Technical Progress of the Republic of Belarus for 2001-2020, Volume 2, Minsk, 2000]

When analysing prospects for development of the metallurgical industry, it can be noted that the RUE “Belarusian Metallurgical Plant” (BMP), which is the leading steel manufacture, plans to put into operation modern high-productivity equipment of production of steel, which will increase the output capacity from 1500 thousand tons of block castings to 1700 thousand tons a year. Parallel to reconstruction of steel furnaces, it is envisaged to install additional gas-removal equipment, which will reduce pollutants emission to atmosphere.

Production of rolled ferrous metal will not be significantly expanded in the analysed future.

Total production output of metallurgical facilities is such that it exceeds almost 2 times the demands of the national industry. The actual volume of cast iron casting today makes about 35% of production capacities. In the future, it is planned to slightly increase the output of cast iron. However, this process will be accompanied by technical update of foundries and use of new technologies (for example, output of high-strength cast iron), ensuring better environmental safety of production.

Priority lines of development in the chemical and petrochemical industries will include creation and manufacture of new generations of chemical products, basic and small chemical products and consumer goods.

The facility for production of caprolactam that exist at one enterprise of the country should be reconstructed by 2010. Its capacity will not be increased, being at the level of 110-120,000 tons a year. However its reconstruction will help increase competitiveness of its products in the world market, also through improved environmental characteristics. Thus, CO emission from the caprolactam production will be cut by 104 tons a year.

The main of development of ammonia production facilities will be reconstruction ensuring reduced energy use and increase of productivity by 50,000 tons a year.

The facility for production of nitric acid, which was put into operation in 1963, is morally outdated; the equipment is worn out; this brings about serious environmental problems. To solve this problem, it is necessary to build a modern unit for production of nitric acid in the next 10 years.

As regards production of sulphuric acid required for production of phosphorous fertilisers, it is planned to increase its output 1.5 times by 2005. To this end, reconstruction of the existing facility has been started, which also includes installation of new types of filters (“Monsanto”) in the absorption section of the sulphuric acid shop. This will allow reducing discharge of sulphuric acid by 70.6 tons a year.

Environmental orientation of industrial production facilities is also assisted through implementation of the Programmes of Rational Use of Natural Resources and Environmental Protection, which are developed not only for the whole country (now in force is the National Action Plan on Rational Use of Natural Resources and Environmental Protection of the Republic of Belarus for 2001-2005), but also for different administrative territorial units (the Action Plan on Rational Use of Natural Resources and Environmental Protection of Gomel Oblast for 2001-2005, the Action Plan on Rational Use of Natural Resources and Environmental Protection of Vitebsk Oblast for 2001-2005, etc.) and for different sectors of the economy. Such sectoral programmes have been developed for 2002-2005 (the Sectoral Programme of Environmental Protection for 2002-2005 of the Ministry of Industry of the Republic of Belarus, the Sectoral Programme of Environmental Protection for 2002-2005 for organisations of the “Belneftekhim” Concern, etc.).

In the recent years, one of the essential lines of work for ensuring environmentally safe economic activities in the country has been environmental certification, which is a component of the national environmental programme. The Belarus has a Subsystem of Environmental Certification in the framework of the National Certification System. Ten international standards ISO 14000 adopted by the country have been used as the basis for development of a package of guidelines and methodological documents for the Subsystem of Environmental Certification.

Some enterprises of the country have already adopted ISO 14001-2000, including the RUE “BMP”. This work is continued nowadays. The Ministry of Natural Resources and Environmental Protection of the Republic of Belarus and the Committee on Standardisation, Metrology and Certification of the Council of Ministers of the Republic of Belarus have developed the Schedule for introduction and certification of the environmental protection systems in conformity with the requirements of international ISO 14000 standards for 2003-2005. It is planned to introduce international ISO 14001-2000 standard at about 90 enterprises, including sectors that are main sources of greenhouse gases emission. Creation at enterprises of environmental management system (EMS) will in many respects facilitate mitigation of adverse environmental impacts as well as economic effects.

4. AGRICULTURE

Agriculture is an important source of emission of methane and the main source of emission of nitrous oxide. The dominant part of methane (>99%) is caused by emission from farming animals; nitrous oxide is emitted to atmosphere mainly as a result of use of nitric fertilisers and peat soils. Input of other sources from this sector (incineration of agricultural waste in the fields, vegetation remnants, etc.) is insignificant. In view of this, when emissions are predicted, the main emphasis was placed on said categories and the prognosis of changes in the agro-industrial complex.

4.1. Agriculture Development Forecast

For a quantitative prediction of greenhouse gases emissions in the agricultural sector by the IPCC methodology, prognosis values of indicators are needed that will allow direct assessment of future emissions. At the same time, the guiding documents defining the strategy of development of the agro-industrial complex (the Programme for Increase of Efficacy of the Agribusiness for 2000-2005; the Programme of Socio-Economic Development of the Republic of Belarus for 2001-2005, etc.) contain predictions for development of the agro-industrial complex output represented by magnitudes of merchandise products which are very difficult to use for direct estimation of future emissions. In view of this fact, basic prognosis indicators of development of the agro-industrial complex, in conformity with the said documents, were transformed (recalculated) into magnitudes included into calculation modules.
For animal farming, the basic magnitudes are prognosis indicators for the livestock. Two scenarios have been analysed for development of animal farming. The first (basic) scenario provided that livestock would stabilise at the contemporary level; the above documents stipulate a growth of its productivity without increase of the livestock numbers.

The second possible development scenario used for estimation of the range of changes in emissions was based on the indicators stated in the Prognosis of Socio-Economic Development of the Agro-Industrial Complex of the Republic of Belarus till 2015, envisaging some growth of the livestock numbers. Figures 4.1 and 4.2 show prognosis magnitudes of livestock and poultry used in the two development scenarios.

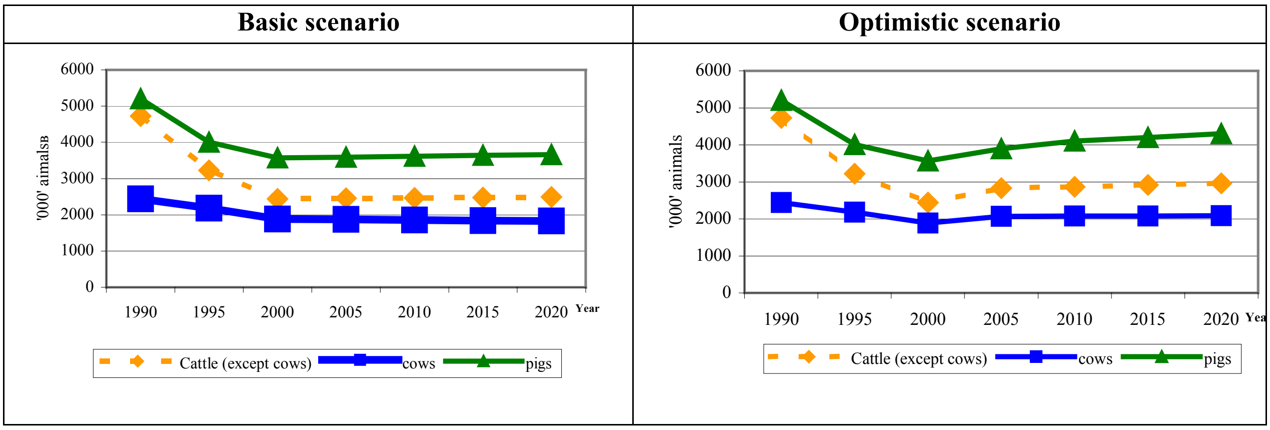


Fig. 4.1. Prognosis of the dynamic of livestock for two scenarios of animal farming development

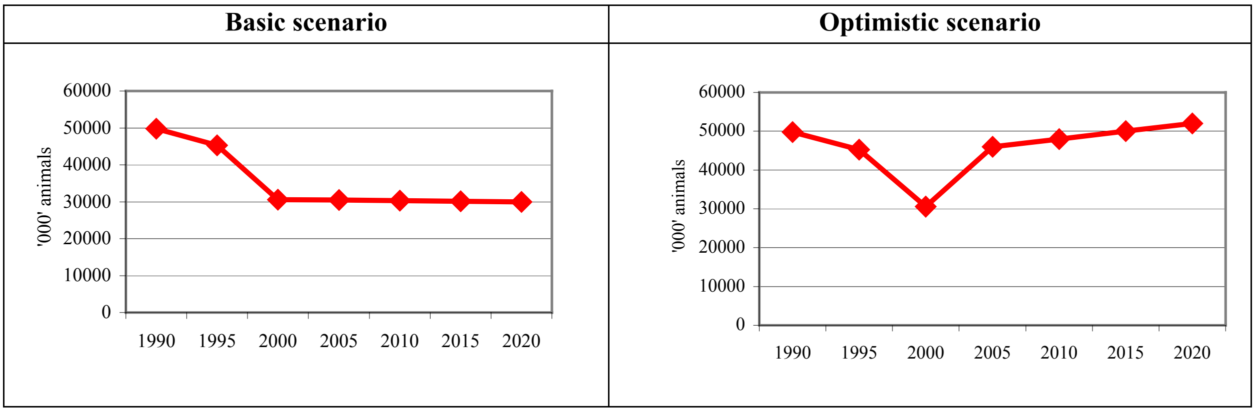


Fig. 4.2. Prognosis of the dynamic of poultry for two scenarios of animal farming development

Plant growing is a source of some emission of greenhouse gases, mainly due to utilisation of vegetation remnants. The available predictions of plant growing envisage a growth of gross output of grains, potato, sugar beet, flax and other crops. However, taking into consideration that growth of crops is planned through increase of the yield, it could be expected that the amount of vegetation remnants will increase to a lesser degree, therefore, we took prediction values of emissions till 2020 for this category of sources at the level of 2000.

Prediction of the use of nitric mineral fertilisers

The annual demand for nitric mineral fertilisers, by the data provided by the Belarusian Research Institute of Soil Studies and Agrochemistry, was determined at 600,000 tons; it is expected that this level of use of nitric fertilisers can be reached by 2005. Therefore, for the period till 2020 a stable level of use of nitric fertilisers has been adopted, at the indicated level.

Prediction of the use of peat soil and wetlands

According to the prediction made by the NASB INRUE the end of 1990's, areas of peal soil used in agriculture will be gradually reduced due to degradation of peat areas covered by land-reclamation activities. It is not planned to use of new peat areas for agricultural purposes, therefore it was assumed that, given today's rates of degradation, the areas of peat and wetland used in agriculture might constitute in 2020 about 780,000 ha.

5. CHANGE IN LAND USE AND FORESTRY

In the Republic of Belarus, the land stock is characterised by a substantial dynamic. Table 5.1 shows its parameters for the commencement of the period.

Table 5.1. Structure Of Belarusian Land, Beginning Of The Century, In Thousand Ha

Types of land	As for 01.01 2001	As for 01.01.2002	As for 01.01.2003
Total area of agricultural land	9257.7	9204.7	9156.3
including arable land	6133.2	5761.1	5616.2
forests and other wood-covered	8436.8	8571.1	8677.8
wetlands	964.3	934.0	931.4
water covered	475.2	475.6	477.1
roads, passages, cutting, pipelines	358.1	358.4	360.3
streets, squares and other common use systems	154.7	153.0	152.1
buildings and yards	328.7	329.8	329.4
disturbed	24.1	19.6	13.2
other	760.3	713.8	662.2

Over the last 20 years, the area of agricultural land has decreased by 717,700 has (7.4%), while the area of arable land by 640,100 ha (10.3%).

In the last 5 years, the decrease of land use has made: agricultural land by 306,700 ha and arable land by 586,000 ha. Nevertheless, it is predicted that this drop will be followed by a small increase of agricultural land area (in thousand ha): 9,250 by 2005; 9,500 by 2010; 9,500 by 2015-2020.

The total area of the forest fund made, as for 1 January 2003, about 3.3 million ha, including wooded areas of 7.9 million ha; 85.6% of wooded area is managed by the Forestry Committee.

The forests included into the State Forestry Fund are characterised by the following parameters: the total area of land makes 9310.5 thousand ha; the total reserve of standing trees is 1370 million m^3. The total change of the reserve makes over 27 million m^3/year; the average change of reserves per hectare of wooded land is 3.6 m^3/year; the reserve per hectare of wooded land is 173 m^3; the same for mature and overmature woods it is 231 m^3. The high-capacity forests (Ia – II) include 83.3% of the area. Perish of woods without fire of different causes made: 8,435 ha (2000), and 10,974 ha (2001). In 2001, fire covered about 359 ha (1,111 fire incidents; 22 ha perished).

5.1. Prediction Of Development Of Land Use And Forestry

According to the Strategic Plan of Development of Forestry in Belarus, b7 2005 it is expected to transit to continuous husbandry in all forest management entities of the Committee of Forestry and introduce an information system for management of forestry; by 2010 it is planned to increase the total volume of forest use to 18 million m^3.

Prediction of the items of CO_2 balance in the sector “Land-use change and forestry” was made according to methodology that was used earlier for assessing the dynamic of CO_2 for the period of 1990-2000.

In this sector, emission of CO_2 and small gas components results from three groups of processes and phenomena:

- changes in forests and in other wood biomass reservoirs;
- conversions of forests and meadows;
- termination of the use of land.

We took into consideration the most important processes generating emissions and removals.

Detailed estimates of emissions of these gases were made earlier for the period of 1990-2000. Here, we continued calculations using the same methods on the data observed in 2001, and also using materials of predicted economic activities for 2005, 2010, 2015 and 2020. In so doing, it is predicted that the wooded area over the entire prediction period would grow. Initial data about composition of species, age structures, reserves and increase of standing trees are given in Table 5.2

As can be seen from Table 5.2, forests are grouped into three groups (coniferous, hard-leaved and soft-leaved) by their typological properties. Each group is divided into 6 age classes; for each class the average age, the average reserve of standing trees, the average productivity and the average decrease have been determined. For five key years (the initial year is known while the 4 subsequent years are predicted years) a detailed structure of wooded areas is given. Change in the wooded areas corresponds to statistical (2001) and predicted indicators representing percentage of forestland in the country from 37.6% to 39%. Reserves, increase (specific productivity) and decrease are given by the age classes in conformity with the data for the entire pilot period.

The specific productivity by different age classes is taken as invariable for different years. It is assumed that felling of trees, with the varying wooded area, does not change the composition of tree species and the age structure, therefore the predicted annual increase of wooded area is distributed pro rata for all formation classes and age classes. However, another option seems quite justified when due to high intensity of tree felling the share of young trees and immature woods will increase. These data were used to calculate reserves of the surface phytomass of vegetation (Table 5.3), as well as CO_2 quantities equivalent to them. According to data (Table 5.3 used, we can trace a typological and age structure of standing wood reserves and their variability from year to year in respect to the predicted increase of wooded areas in the country. By calculations, the initial value of standing wood reserves will grow over 30 years by 34.5 million tons, which is equivalent to about 69 million m^3 of phytomass and changes in CO_2 reserves by about 63 million tons.

The initial data (Table 5.2) were used to calculate the decrease of standing woods and equivalent CO_2 values. Their values, given in Table 5.4, characterise the magnitude of “adjourned” emission of CO_2, connected with the annual formation of mortmass and its accumulation that is not fully accounted in this methodology for calculation of emissions. Depending on climatic conditions, the period of decomposition of mortmass fractions may be as high as 10 years or even more.

According to this methodology the following specific processes are taken into consideration that cause CO2 emission: conversion of wooded areas, including felling of main felling and improvement (environmental) felling, wood fires, taking of land from use, change in the content of carbon in mineral land, liming of agricultural soils, etc. Many of the above processes include transformation of mortmass, i.e. decrease accompanied by CO_2 emission.

Disturbed wetlands enhancing carbon dioxide emissions to atmosphere include peat fields that are used or have been used, drained border strips of such peat fields as well as drained peat soils.

These areas, unlike natural wetlands with undisturbed water conditions, emit carbon dioxide to atmosphere as the final product of peat mineralisation on the drained (dried) layer and absorb oxygen from atmosphere that is used for oxidation of organic matters. Total emission of carbon dioxide from disturbed wetlands in Belarus makes 13.3 million tons a year.

The accumulated scientific knowledge and practical experience make it possible to develop and implement a range of organisational and management as well as engineering actions reducing carbon dioxide emissions to atmosphere from disturbed wetlands. These actions include:

1. Adoption of the decision by the Government to transfer to local authorities powers for determination of the lines of future use of exhausted peat fields after they have been depleted by peat briquettes enterprises.
2. Environmental rehabilitation of disturbed wetlands through adequate rehabilitation measures and renewal of peat formation processes.

Table 5.2. Species Composition, Age Structure, Areas, Specific Reserves, Productivity And Decrease Of Forestry Ecosystems In Belarus

Group of species	Age group	Wooded, thousand ha					Average age, years	Average reserve, m^3/ha	Average productivity, m^3/ha a year	Average decrease, m^3/has/year
		2001	2005	2010	2015 г	2020				
Coniferous	Young trees, 1st class	377.5	382.6	387.7	392.8	397.9	20	33	1.0	0.6
	Young trees, 2nd class	1018.1	1031.9	1045.6	1059.4	1073.1	40	127	3.9	3.3
	Middle aged	2162.8	2192.0	2221.3	2250.5	2279.7	60	221	7.0	5.3
	Immature	974.6	987.8	1000.9	1014.1	1027.3	80	243	5.7	4.9
	mature	259.4	262.9	266.4	269.9	273.4	100	227	3.2	3.9
	Overmature	9.8	9.9	10.1	10.2	10.3	120	295	2.9	4.3
Hard-leaved	Young trees, 1st class	30.9	31.3	31.7	32.2	32.6	20	31	1.0	0.2
	Young trees, 2nd class	56.6	57.4	58.1	58.9	59.7	40	101	3.2	1.4
	Middle aged	141.7	143.6	145.5	147.4	149.4	60	191	5.2	3.2
	Immature	39.1	39.6	40.2	40.7	41.2	80	222	4.7	3.8
	Mature	36.3	36.8	37.3	37.8	38.3	100	215	3.5	3.2
	Overmature	3.4	3.4	3.5	3.5	3.6	120	285	1.4	3.4
Soft-leaved	Young trees, 1st class	267.0	270.6	274.2	277.8	281.4	10	18	0.6	0.2
	Young trees, 2nd class	350.4	355.1	359.9	364.6	369.3	20	54	1.9	0.8
	Middle aged	1269.3	1286.5	1303.6	1320.8	1337.9	30	151	4.7	2.7
	Immature	500.8	507.6	514.3	521.1	527.9	40	211	5.4	4.3
	Mature	256.5	260.0	263.4	266.9	270.4	50	220	4.7	3.6
	Overmature	17.4	17.6	17.9	18.1	18.3	60	231	3.8	3.2
	Total	7771.6	7876.6	7981.6	8086.7	8191.7				

Table 5.3. Reserves Of Earth-Surface Phytomass (A) And The Equivalent CO_2 Quantity (B) In Forests Ecosystems Of Belarus, Million Tons

Group of species	Age group	a					b				
		2001	2005	2010	2015	2020	2001	2005	2010		2020
Coniferous	Young trees, 1st class	11.3	11.5	11.6	11.8	11.9	20.8	21.1	21.3	21.6	21.9
	Young trees, 2nd class	45.8	46.4	47.1	47.7	48.3	84.1	85.2	86.3	87.5	88.6
	Middle aged	162.2	164.4	166.6	168.8	171.0	297.7	301.7	305.7	309.7	313.7
	Immature	102.3	103.7	105.1	106.5	107.9	187.8	190.3	192.8	195.4	197.9
	Mature	35.0	35.5	36.0	36.4	36.9	64.3	65.1	66.0	66.9	67.7
	Overmature	1.6	1.6	1.7	1.7	1.7	3.0	3.0	3.1	3.1	3.1
Hard-leaved	Young trees, 1st class	1.2	1.3	1.3	1.3	1.3	2.3	2.3	2.3	2.4	2.4
	Young trees, 2nd class	6.8	6.9	7.0	7.1	7.2	12.5	12.6	12.8	13.0	13.1
	Middle aged	28.3	28.7	29.1	29.5	29.9	52.0	52.7	53.4	54.1	54.8
	Immature	10.2	10.3	10.5	10.6	10.7	18.7	18.9	19.2	19.4	19.7
	Mature	10.9	11.0	11.2	11.3	11.5	20.0	20.3	20.5	20.8	21.1
	Overmature	1.2	1.2	1.2	1.2	1.2	2.1	2.1	2.2	2.2	2.2
Soft-leaved	Young trees, 1st class	6.7	6.8	6.9	6.9	7.0	12.2	12.4	12.6	12.7	12.9
	Young trees, 2nd class	17.5	17.8	18.0	18.2	18.5	32.1	32.6	33.0	33.5	33.9
	Middle aged	107.9	109.4	110.8	112.3	113.7	198.0	200.7	203.3	206.0	208.7
	Immature	50.1	50.8	51.4	52.1	52.8	91.9	93.1	94.4	95.6	96.9
	Mature	35.9	36.4	36.9	37.4	37.9	65.9	66.8	67.7	68.6	69.5
	Overmature	3.0	3.0	3.0	3.1	3.1	5.4	5.5	5.6	5.6	5.7
	Total	637.9	646.5	655.2	663.8	672.4	1170.6	1186.4	1202.3	1218.1	1233.9

Table 5.4. Reserves Of Earth-Surface Phytomass (A) And The Equivalent CO_2 Quantity (B) In Forests Ecosystems Of Belarus, Million T

Group of species	Age group	Phytomass					CO_2				
		2001	2005 г	2010	2015	2020	2001	2005 г.	2010 г.	2015 г.	2020 г.
Coniferous	Young trees, 1st class	0.21	0.21	0.21	0.22	0.22	0.38	0.39	0.39	0.40	0.40
	Young trees, 2nd class	0.84	0.85	0.86	0.88	0.89	1.54	1.56	1.58	1.61	1.63
	Middle aged	2.98	3.02	3.06	3.10	3.14	5.46	5.54	5.61	5.68	5.76
	immature	1.88	1.90	1.93	1.95	1.98	3.45	3.48	3.54	3.59	3.63
	Mature	0.64	0.65	0.66	0.67	0.68	1.18	1.19	1.21	1.23	1.24
	Overmature	0.03	0.03	0.03	0.03	0.03	0.05	0.06	0.06	0.06	0.06
Hard-leaved	Young trees, 1st class	0.03	2.30	0.02	0.02	0.02	0.04	4.22	0.04	0.04	0.04
	Young trees, 2nd class	0.12	0.13	0.13	0.13	0.13	0.23	0.24	0.25	0.24	0.24
	Middle aged	0.52	0.53	0.53	0.54	0.55	0.95	0.97	0.98	0.99	1.01
	Immature	0.19	0.19	0.19	0.19	0.20	0.34	0.35	0.35	0.36	0.36
	Mature	0.20	0.20	0.21	0.21	0.21	0.37	0.37	0.38	0.38	0.39
	Overmature	0.02	0.02	0.02	0.02	0.02	0.04	0.04	0.04	0.04	0.04
Soft-leaved	Young trees, 1st class	0.12	0.12	0.13	0.13	0.13	0.23	0.22	0.23	0.23	0.24
	Young trees, 2nd class	0.32	0.33	0.33	0.33	0.34	0.59	0.61	0.61	0.61	0.62
	Middle aged	1.98	2.01	2.03	2.06	2.09	3.63	3.69	3.73	3.78	3.83
	Immature	0.91	0.93	0.94	0.96	0.97	1.69	1.71	1.73	1.76	1.78
	Mature	0.66	0.68	0.68	0.69	0.70	1.21	1.25	1.24	1.26	1.28
	Overmature	0.05	0.55	0.06	0.06	0.06	0.10	1.01	0.10	0.10	0.11
	Total	11.70	11.86	12.02	12.18	12.34	21.48	26.9	22.06	22.35	22.64

3. Bringing the sowing area structures on drained peat soils in compliance with the projects of land reclamation and scientific recommendations.

4. Transition to environmentally and economically justified methods of use of degraded peat soils.

5. Prevention of fires on peat land.

Justification of expediency of each of the above actions is given below.

Action 1. Transfer to local authorities powers for determination of the lines of future use of exhausted peat fields after they have been depleted by peat briquettes enterprises. The necessity of this action includes the following.

According to the existing procedure, local authorities have the right to determine lines of use of only those exhausted peat fields that have been exploited by local enterprises of “Selkhozkhimia”, “Selkhoztekhnika”, collective farms, etc. However, local authorities do not have the right to change the lines of use of exhausted peat fields that are owned by peat briquette enterprises, because when a project for construction of each briquette enterprise was approved the Government of the BSSR also approved the lines of use of exhausted peat fields. As a rule, at that time (30-50 years ago) practically all exhausted peat fields were transferred, without any scientific justification, for agricultural use and only very few of them were designed for construction of water reservoirs, and the most inconvenient were assigned for afforestation.

However, science has proved and long practice has confirmed that a major part of Belarusian exhausted peat fields are not fit for use as agricultural land for numerous reasons (genesis, geomorphology, hydrology, agrochemical properties of the residual peat layer, the nature of underlying rocks, etc.). For example, about 50% of peat fields in Belarus have been formed by turning shallow ancient lakes into bogs, therefore peat reserves lie over a layer of sapropel. Restoration of the residual peat layer over sapropel does not allow regulating water conditions for agricultural crops, because after removal of a multi-metre peat layer water catchment areas of ancient lakes are restored and in rainy seasons such land is flooded, which prevent preparation of soils, sowing, caring for crops and their harvesting. Typical examples include exhausted areas of the Braslav (900 ha) and Zhitkovichi (1600 ha) briquette enterprises which were transferred to agricultural enterprises after expensive restoration operations and then were written off and abandoned because they did not bring yields of agricultural crops for a number of years running.

Another cause is difficulties met while organising favourable water conditions of agricultural crops on exhausted peat fields located on the slopes of watersheds. As a rule, more elevated areas of such land remain over-drained while lower areas become over-humidified; therefore in both cases efficacy of agricultural use of such land remains low.

Often, exhausted peat fields of upper and transient types have been transferred for agricultural use, though their residual layers of peat have acid reaction and, therefore, agricultural plants perished. Liming of such land is unprofitable from economic point of view, because it requires the use of large doses of liming materials. Despite expensive restorative operations, such land was withdrawn from agricultural practices because of its inefficiency. Left abandoned and drained, such land intensely pollute atmosphere with carbon dioxide through mineralisation of peat.

There are also other reasons why exhausted peat fields cannot be used as agricultural land. However, even in those cases when satisfactorily productive agricultural land has been organised on exhausted peat fields, the duration and efficacy of its use has been limited in time due to rapid destruction of a thin (usually about 0.5 m) peat layer through processes of mineralisation and erosion. When the underlying rocks outcrop to the earth surface, it creates an unfavourable micro relief of the terrain, conditions for growing of agricultural crops become worse and productivity of such land sharply decreases.

The most correct way is to use exhausted peat fields for environmental protection, after groundwater rises to the surface of the residual peat layer and bog- and peat-forming processes are resumed. However, without a solution by the Government local authorities will not be in a position to change the lines of use of exhausted land, formerly used by briquette enterprises, and switch over from agricultural to environmental protection practices. Agricultural enterprises and forestry management authorities refuse to take over such land even after its restoration according to the relevant projects. For this reasons, many briquette enterprises sustain significant losses for fire protection of depleted and unused peat fields.

The director of every briquette enterprise is compelled to seek, in every case, a specific solution by the Government allowing a change in the line of use of exhausted areas. To get such governmental solution takes a lot of time because it requires coordination of multiple applications with many authorities; therefore, it is not infrequent that directors of briquette enterprises have to discontinue their soliciting about changing the lines of use of such areas. Being abandoned and drained, each hectare of exhausted peat fields annually emits to atmosphere up to 20-23 tons of carbon dioxide.

Thus, there is a contradiction between the outdated and scientifically unjustified way of use of peat fields exhausted by briquette enterprises and scientific data and practices of us of such areas.

This contradiction can and must be solved by transfer of powers from the Government to local authorities to define lines of use of exhausted peat field.

Action 2. Environmental rehabilitation of disturbed wetlands through rebogging. To this end, it is necessary to raise the level of groundwater in disturbed wetlands to the peat layer surface. Two scenarios are possible for raising groundwater levels: the first is active renewed watering and construction of engineering structures, most often deadlock dams or spillways on the water-spilling channels; the second is slow self-rehabilitation of disturbed wetlands with gradual vegetation growth and soil filling of drainage channels without building engineering structures. This scenario is the cheapest, however, it is efficient only on peat fields located within river flood beds, while on drained peat fields giving other geomorphologic structure the process of self-rehabilitation of disturbed peat fields may go on for dozens of years. For example, in the north-eastern part of the Yelnya peat field a drainage network was built in 1930's, but extraction of peat was not started. By today, the drainage network channels have been grown with vegetation, but they still continue to exert draining impact on the peat layer, which creates favourable conditions for mineralisation of the upper peat layer and causes fires.

Thus, when specific projects of rehabilitation of disturbed wetlands are designed, it is necessary to develop individual engineering measures with due account of geomorphology, the nature of underlying rocks, properties of peat deposits, etc.

As a rule, measures on restoration of disturbed wetlands are several times cheaper than their remediation for agricultural, forestry or water use.
Priority facilities for restoration may include exhausted peat fields of the peat briquette enterprises "Starobinsky", "Zitkovichsky", "Osveysky" and others.

Actions 3. Bringing the sowing area structures on drained peat soils in compliance with the projects of land reclamation and scientific recommendations. There are three factors that define the speed of decrease of the peat layer on drained peat soils: compaction, mineralisation of organic matters and erosion. The speed of such processes depends on the intensity of drainage, mechanical cultivation of land, amount of fertilisers used, input into soil of vegetation remnants after harvesting, duration of use for the crop, as well as botanic composition, degree of decomposition and peat ash.

In conditions of black crops the annual deficit of balance of organic matter in peat soils, in tons per hectare, is: 9.8 ± 1.6 for tilled crops; 6.0 ± 1.1 for grains; and 3.6 ± 0.7 for perennial grass. Experiments have proved that when perennial grass is grown without over-grassing for more than 5 years, the rates of mineralisation slow down and the deficit of organic substances does not exceed 2 tons per hectare a year. Such slowing of mineralisation rates is explained by the fact that soil with meadow grass is not tilled for a number of years and is compacted while the formed turf of perennial grass mitigates impacts of external environmental factors on the peat layer, above all, aeration of the drained layer. When sown on peat soils, perennial grass gives a maximum yield of useful products with minimum use of organic matter in the soil.

Therefore, the Main lines of land-reclamation construction and use of such land in the country recommended the following:

- wetlands with the depth of peat up to 1 metre, in a drained condition, should be used only for perennial grass or cultivated hayfields and pastureland where crops should be cultivated in the period of over-grassing. More frequent location of crops on such soil may be allowed only as exception in the farms where more than half of the arable land is located on such soil, with compulsory performance of actions that ensure restoration of a positive balance of the organic matter;
- wetlands with the depth of peat more than 1 metre, in a drained condition, should be used for meadows as well as grains and grass crops rotation in which sowing areas under perennial grass is at least 50%.

As can be seen, the Main lines did not envisage cultivation of tilled crops and limited areas of land under grains on peat land. Unfortunately, these recommendations have been neglected almost everywhere; many farms cultivate, instead of perennial grass, not only grains but also tilled crops like potatoes, corn, beetroot, cabbage and other crops, which inevitably causes accelerated degradation of the peat layer.

The result of incorrect use of drained peat soil includes not only its degradation, but also a high emission of carbon dioxide to atmosphere: when tilled crops are used it makes 17-25 t/has/year, grains – 10-15, and perennial grass – about 7 t/ha.

It is quite possible to reduce carbon dioxide emissions to atmosphere from drained peat soils, if perennial; grass is cultivated instead of tilled crops, as recommended in the projects for land reclamation on such soil and in scientific recommendations. However, it will be possible only if land users have benefits after transition from tilled crops to perennial grass. At present, due to misbalance of prices, it is more economically beneficial to grow potato, cabbage, corn, beetroot and other tilled crops on peat soils, than make hay or grass meals. In developed countries, for example in Germany, Austria, etc., farmers get additional money from the state when they do not cultivate other crops, except perennial grass, on peat soil. Our country does not have such a system. The state policy of the use of peat soil must be changed so that land users find it more beneficial to cultivate meadow crop. This can be achieved through adjustment of the pricing and taxation policies.

Another important measure may be preservation of the peat layer by introducing mixed-layer crops. The essence of this is that soil with the thickness of the peat layer 0.5-1 m is tilled by means of special ploughs to the depth of 1.4 m. As a result, the alternating layers of peat and underlying rock with the width of 35-40 cm are turned to a tilted position at about 40 degrees. The subsequent surface tillage forms an arable layer with at least 10% of organic matters and the peat layer is turned under the arable layer. Research conducted for 15 years have shown that the balance of organic matters in such soil is close to zero, which testifies to preservation of the peat layer; respectively, the balance of carbon dioxide is also close to zero.

Such actions were performed in the country on about 30,000 ha of land and shown a high agronomic and economic efficacy of such actions, since it radically improves agrophysical, agrochemical and biological properties of soil. The pay back period of such actions is not more than two years. However, despite effectiveness, further work in this direction has been stopped due to wear of two pilot ploughs. It was planned to start manufacture of such ploughs in Mozyr, but these plans have not been turned to life.

Action 4. Transition to environmentally and economically justified methods of use of degraded peat soils. Use of peat soil in conditions of black crops led to its degradation. By official data of the State Committee on Land Resources, Geodetics and Cartography, there are 190,000 ha of degraded peat soils in the country, including 18,200 ha where underlying sand outcrop to the surface. At present, there are no any unequivocal recommendations on the use of such sand.

In principle, three scenarios are possible: the first is to develop and test in 2-3 farms a special land use system for such soil, cultivating mostly legumes, like lupine, soya, etc. The second scenario is to organise rehabilitation of such areas, though it would not always be expedient because of possible flooding of the adjacent land. The third scenario is to organise afforestation of such areas, which will allow cleaning atmosphere from excessive dioxide and improving the environment. However, there are no any completed scientifically justified recommendations for any the above scenarios, since no pilot research has been performed or, if performed, then in a limited scope that is not sufficient.

Action 5. Prevention of fires on peat land. All exhausted peat fields are fire hazardous, especially those that have operating drainage systems, drained peat soils and peat field under exploitation. Natural wetlands with disturbed hydrological conditions, when they are affected by the surrounding land-reclamation systems, also become one of most fire-hazardous areas; they are affected by severe fire almost every year, and such fires usually cover the adjacent woods.

Annually, the number of peat fires in the country makes from 2.5 to 8 thousand. According to our preliminary estimates, annual massive release of carbon dioxide as a result of fire on peat land can be compared to carbon dioxide emission from drained peat soil.

Occurrence of fire on peat land is caused by different meteorological, topographic, man-made and other factors.

Often, the cause of fire-hazardous situations on drained peat areas include: use of land-reclamation system not in their rated operation modes due to absence of funds for repair or maintenance of engineering structures; therefore many land-reclamation channels are used only for drainage, which results in excessive drainage and drying of land. Other causes include faulty or absent fire-prevention actions, systems or installations (water reservoirs or channels) or absence of reliable water supply systems for combating fires.

Fire-hazardous situations occur more frequently on wetland where drainage forest-reclamation work has been performed, caused by lowering of the groundwater levels below admissible. At present, at the absolute majority of forest-reclamation facilities there is no system for regulation of the groundwater levels, and land-reclamation channels operate only for drainage.

Fire-hazardous situations occur on exhausted peat land because of continued drainage impact by drainage systems, which have not been blocked when this land was transferred to forestry management authorities.

On natural bogs, fire-hazardous situations occur because of impact from surrounding drainage systems, since many natural wetlands are located within meliorated areas.

Fire is greatly facilitated by insufficient environmental education of population, lack of special awareness raising actions among local communities explaining them harmful impacts of fires and causes of fire.

In view of the stated above, it is necessary to develop a range of organisational and management actions for prevention of fire on peat land. Besides, it is necessary to design methods for estimation of massive release of carbon dioxide from peat land fires.

The rates of felling of woods were determined with due account of scenarios proposed in the Strategic Plan of development of forestry in Belarus for woods as a whole and using data extrapolated from the source “Forest Use in Belarus: History and Contemporary State” for forests managed by the State Committee of Forestry, as an interim scenario which is closer to the second. Calculations showed that the first scenario of wood felling if exhaustive, reducing sink of carbon dioxide by a third. The second scenario was calculated for a part of wooded areas. Thus, in accordance with the plan, it is planned to substantially increase intensity of forestry use, up to 18 million m^3 in 2015, while in 2000 it was only 10.8 million m^3. Emissions of this type are extended in time because they depend on specific economic use of timber.

Emission of carbon dioxide during fire depends on many conditions. It is very difficult to predict, since it depends very much on weather during the warm season. Especially hazardous periods are early spring and summer dry seasons. Due to this, we use the average multi-annual estimates for such indicators. It is known that the average annual area covered by fires in one year differed not only year-by-year, but also decade-by-decade; it made in 1961-1970 about 3594 ha; in 1971-1980 about 1678 ha; 1981-1990 about 1652 ha; in 1991-200 about 4477 ha. This made it possible to determine the average fire area at 1.1 ha and the total area covered by fires over one year at 285 ha on the average (260 fires per year). This series of 40 years can be considered sufficiently representative. However, the share of wood burned during fire is not defined. In this connection, we used the magnitude received for 2001; though this is an underestimation. However, it can be rather representative since the human-induced factor plays here an important role.

Application of lime is a significant factor of carbon dioxide emissions to atmosphere. The level of soil liming was significantly decreased by the end of 1990’s, now remaining at the same level. It is expected that it will increase to some extend to maintain the current conditions and pre-emptive response (Tables 5.5 and 5.6). In terms of optimisation of soil nutrients, it is recommended to use a scenario with the use of $CaCO_3$ for the respective prediction years at 2500, 2300, 2000 and 2000 thousand tons. However, a substantial increase of CO_2 emission is noted.

Table 5.5 Main Emission Factors

Factors, unit of measurement	2001	2005	2010	2015	2020
Final harvesting of liquid timber, million m^3	4.39	4.45	5.15	6.00	6.00
Interim harvesting and other felling, million m^3	7.12	7.48	6.80	7.00	7.00
Liming scopes, thousand tons $CaCO_3$	1607	1700	1750	1775	1800

Table 5.6. CO_2 Emissions, Gg

Factors	2001	2005	2010	2015	2020
Tree felling	6181	5467	5467	5467	5467
Liming	780	821	843	854	865
Total:	**6961**	**6288**	**6310**	**6321**	**6332**

When forest biomass is incinerated, there is emission of small gas components at the place of vegetation growth: CH_4, CO, NO_2, NO_x. Emissions of CH_4 and CO are estimated as the share of carbon flow released during combustion. Nitrogen is estimated by the ratio N/C in the dry biomass, NO_2 and NO_x are estimated as shares from the estimated nitrogen. The calculation results are shown in Table 5.7.

Table 5.7 Emission Of Small Gas Components, Gg

Year	**CH_4**	**N_2O**	**NO_2**	**CO**
2001	4.14	0.03	1	36
2005	3.26	0.02	1	28
2010	3.16	0.02	1	28
2015	3.16	0.02	1	28
2020	3.16	0.02	1	28

6. WASTE

The main sources of greenhouse gas emission connected with waste are:

- disposal and incineration of solid waste (CH_4 and CO_2);
- wastewater treatment (CH_4);
- human activity waste (N_2O).

In Belarus, the most substantial input into greenhouse gas emission is made by burial waste at fields and, to a lesser extent, waste resultant from human activities.

At present, waste is not incinerated in the country.

Wastewater treatment is made using biological methods in sludge basins the depth of which, as a rule, does not exceed 1-2 m. Consequently, decomposition of organics takes place in aerobic conditions excluding generation of methane. Digestion tanks available at some wastewater treatment plants do not work, and accumulated sludge is not treated. Wastewater sludge is taken out regularly and transported to dumpsites together with solid waste. Methane emissions from wastewater sludge are taken into account when methane emission from solid waste at dumpsites is calculated.

6.1. Prediction Of Improvement Of The Waste Treatment Systems

To predict greenhouse gas emission from buried municipal solid waste (CSW) in the fields, it is necessary to take into consideration two main aspects:

- the tendency in change of gas emission over the previous years with a view of possible extrapolation of such tendency for the coming 10-20 years;
- prospects for development of industrial sectors connected with the waste management sector, stemming from the existing legislative acts (resolutions, future plans, concepts of sustainable development, etc.).

Inventory of methane emission. Nature of changes in methane emission over the previous period of 1990-2002 is presented in the chart by years (Fig. 6.1). It should be noted that these selected time period covers the period when there was a sharp slack in the national economy (1993-1995). In 1993-1995, the share of food waste in total waste decreased, which resulted, primarily, in the decrease of the share of degradable organic matter in waste.

It was assumed by default that from 1995 to 2002 the share of organic matter remained unchanged and, therefore, methane emission can be explained by increased volumes of buried waste (mainly in deep fields characterized by a relatively high factor of methane adjustment) and, to a smaller extent, by taking account of previously unaccounted fields, which mostly included waste fields in district centres and urbanised localities. These processes were facilitated by a range of factors, two of which are, probably, the main factors, i.e. stricter control over transportation of waste to waste fields and inventory of volumes of waste disposal facilities in the country made by the Belarusian Research Centre "Ecology" in 1995 on assignment of the Ministry of Natural Resources and Environmental Protection of the Republic of Belarus. Stricter control over waste carried to waste fields was established following Resolution on the Cabinet of Ministers of the Republic of Belarus No. 176 of 31 March 1995 "On Standards of Payment for Disposal of Production and Consumption Waste", as well as putting into force of the regulatory document "Procedure of Issue of Permits for Disposal of Waste in the Environment", approved by the Ministry of Natural Resources and Environmental Protection of the Republic of Belarus on 10 April 1995, No. 40.

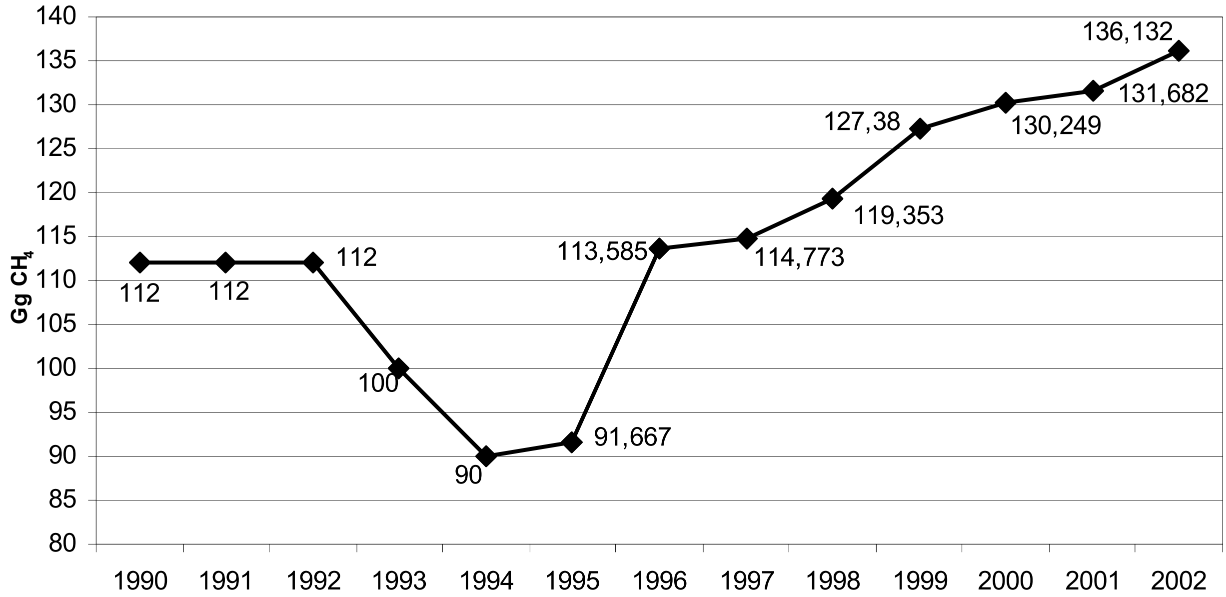


Fig. 6.1. Methane emission over 1995-2002

Thus, the year 1995 became a sign year for the country as regards account and control over disposal of municipal solid waste in waste fields. In the years that followed, no cardinal changes were seen in this field that could substantially affect the volumes of disposed waste or its morphological composition.

It was in 1996 when a sharp increase of methane emission occurred, i.e. when norms of payment for disposal of waste were put into effect and the number of fields was calculated and, hence, the volumes of placed (buried) waste were also accounted in full. Beginning from 1996 till 2002, there was seen a permanent and invariable increase of methane emission due to increased waste volumes. Therefore, the period of 1996-2002 was taken for determination of a stable trend in the change of methane emission.

The magnitude of annual increase in methane emission from 1996 to 2002 varied from 1.148 to 8.021 Gg, making on the average 3.74 Gg of CH_4.

Policy and measures for reduction of methane emission. Today, burial of waste in waste fields is the most widely used method of decontamination of waste in all countries, since waste fields provide a cheap and easy method of disposal of municipal waste, although, due to establishment of more rigid requirements to waste burial, costs of disposal of waste in waste fields are increasing. In addition to that, more active public opinion makes it more difficult to find suitable fields for organization of waste fields because waste dumpsites present potential sources of environmental pollution. Basic impact of waste fields on the environment is connected with generation of biogas and filtrate; such environmental hazard persists for a long period. For the Republic of Belarus, capital costs for construction of waste fields, compared to other methods of waste decontamination, remain priority costs when selecting methods for waste disposal.

At the same time, search and application of resource-saving technologies represent an important line for the economic development of the country today. One of the most essential ways for increasing efficacy of resource saving is a comprehensive use of waste in different sectors of the national economy, including reuse/recycling of municipal waste. Reuse/recycling of many types of waste is provided through organisation of its collection and sorting as well as treatment technologies used.

Separate collection and sorting of municipal waste (from living houses, public organisations, etc.) requires a special organisation: either at the source (near houses) or centralised collection at special enterprises. Separate collection and sorting helps change qualitative and quantitative compositions of MSW, reduce its amounts, improve and accelerate the process of composting of its organic components, decrease the amounts of harmful substances that get into ground with filtrate, etc.

The National Programme of Municipal Waste Management developed by the Ministry of Housing and Utilities and approved by the Government defined, for the period of till 2007, a systemic approach to solution of the municipal waste problem, from the stage of introduction of separate collection of waste to its complete industrial treatment and maximum utilisation of valuable secondary resources. In conformity with the above Programme, Oblast and Minsk City programmes for management of municipal waste have been drafted for the period of 1999-2005.

This Programme defined 17 towns and cities (Brest, Baranovichi, Vitebsk, Orsha, Polotsk, Novopolotsk, Gomel, Mozyr, Kalinkovichi, Zhlobin, Rogachev, Lida, Borisov, Zhodino, Minsk, Mogilev and Bobruysk) where it is planned to introduce, step-by-step, the system of separate waste collection. At the same time, efforts are made to find opportunities to make plastic containers. Separate collection of waste has been started in the towns of Brest Oblast (Brest, Baranovichi, Pinsk, Pruzhany, Kamenets, Stolin), Gomel Oblast (Rechitsa, Mozyr), Grodno Oblast (Grodno, Lida), Minsk Oblast (Nesvizh), and in the City of Minsk. By the end of 2002, about 125,000 people were covered by the system of separate collection municipal waste; 20,000 were involved only in 2002; however this is only 1.7% of the total urban population.

Given the fact that a significant share in municipal waste includes paper, textile, broken glass and polymer materials, the country has organised a network of stations for collection of secondary raw materials from population, including 948 stations in the consumer cooperation system and 58 in the housing and communal sector, which will be expanded according to Resolution No. 269 of the Council of Ministers of the Republic of Belarus of 2 February 2003 “On Improvement of the System of Collection and Use of Some Types of Secondary Raw Materials”. This is done to ensure return of valuable secondary resources to the economy and decrease load on waste fields. Development of the network of collection stations also aims at gradual introduction of separate collection of waste by population. The UE “Ecores” organised in Minsk 34 stations for collection of secondary raw materials. Organisations of the housing and communal sector of Mogilev Oblast have also organised 19 stations for collection of secondary raw materials. Five similar stations have been opened in Mozyr, Gomel Oblast.

In conformity with the Programme, master schemes of sanitary cleanup of 10 large cities have been developed, including Minsk, Brest, Vitebsk, Gomel, Baranovichi as well as Lida, Mozyr, Kalinkovichi, Polotsk and Novopolotsk districts. Now similar schemes are developed for cities of Grodno, Mogilev, Zhlobin, Rogachev, where it is planned to organise separate collection and sorting of garbage.

In 2000-2002, a pilot sorting station was built in the town of Nesvizh and a sorting and transfer station in the city of Brest; construction of sorting and transfer stations has been started in Pinsk, Kletsk and Stolbtsy; reconstruction of garbage processing plant has been put into operation in Minsk, including a shop for compaction of waste. Construction of a sorting and biomechanical plant has been started in Borisov, however, due to lack of financial resources, this work has been fulfilled for 9% and then suspended. Project and cost estimate documents have been developed and approved for a range of sanitary treatment facilities.

Available resources did not allow commencing, in full, implementation of costly actions, including planned construction of garbage processing plants (GPP) and broad use of separate collection of municipal waste by people.

In view of this fact, the majority of actions have not been implemented till now, although some of them were envisaged in the National Programme of Rational Use of Natural Resources and Environmental Protection for 1996-2000.

The Concept of National Strategy of Sustainable Socio-Economic Development of the Republic of Belarus for the period of up to 2020 (hereinafter the Concept), developed by the National Commission on Sustainable Development of the Republic of Belarus, emphasised the need to develop a programme of separate collection of waste during that period with due account of the existing situation as one of the priority measures in the field of municipal waste management.

Resolution of the Council of Ministers of the Republic of Belarus No. 283 of 27 February 2003 “On Approval of the National Programme for the Year of Order and Territory Planning” envisaged the following measures:

(par. 2.24) to develop and approve, according to the established procedure, regulations on separate collection of municipal waste (March 2003); develop, with due account of local conditions, and approve regional regulations on separate collection of municipal waste (May 2003);

(par. 2.25) for the purpose of maximum utilisation of secondary raw materials, to ensure covering at least 10% of population by the system of separate collection of municipal waste, first of all in towns defined by the National Programme of Management of Municipal Waste (2003).

In execution of Resolution No. 283 of the Council of Ministers of the Republic of Belarus, the draft "Regulations on Organisation of Separate Collection, Storage and Transport of Municipal Waste" have been designed; this document is now at the stage of coordination and approval. Chapter 3 of the Regulations "Procedure and conditions for separate collection of municipal waste in communal areas" in particular states:

- municipal waste generated in populated localities as well as discovered unattended waste shall be collected (separately collected) and used as secondary raw materials as much as possible;
- organisation of separate collection of municipal waste is to be the part of the state system of management of activities on collection and use of waste as secondary waste;
- for the purpose of maximum possible use as secondary raw materials of waste paper, textile, glass, polymers and synthetic materials, metal and organic components making part of municipal waste, they should be collected mostly separately;
- it is prohibited to transport by the organisation that performs planned regular sanitary cleanup and to place in the fields of municipal waste generated during activities of legal entities, containing reusable secondary raw materials;
- organic components of municipal waste suitable for composting (organic kitchen waste, organic waste of animal farming, etc) must be composted, as much as possible, in plots of land allotted or transferred for construction and/or maintenance of the living house or for private farming and/or gardening;
- organisations that manage municipal waste shall be obliged to inform population, organisations and institutions about the procedure of collection and removal of waste, and conditions of collection for the purpose of its maximised use as secondary raw materials;
- owners of municipal waste must collect municipal waste separately by its types and place it into special containers according to a contract made with the servicing organisation, preventing entry of harmful substances into waste.

Thus, the Concept, as well as other shorter-term programmes related to management of waste envisage, mostly, introduction of separate collection and sorting of municipal waste so as to extract secondary raw materials. Separate collection and sorting of municipal waste is one of the key aspects of the resource saving policy and, at the same time, should result in reduction of amounts of buried waste and decreased content of organic waste as potential sources of methane emission.

In developed European countries, the share of municipal waste generated per person varies from 0.85 kg/day/man (Ireland) to 1.29-1.7 kg/day/man (France, Finland), making on the average 1.2 kg/day/man. In the Republic of Belarus, this indicator permanently increases from 0.58 kg/day/man in 1996 to 0.69 kg/day/man in 2002; increase of the amounts of waste in Belarus has been registered despite decrease of its population.

II. PROSPECTIVE ESTIMATION OF GREENHOUSE GAS EMISSIONS AND ESTIMATION OF EFFICIENCY OF MEASURES FOR REDUCTION IN EMISSIONS

1. ENERGY

1.1. Prospective Estimation Of Greenhouse Gas Emissions And Estimation Of Efficacy Of Measures For The Energy Sector

A scenario of greenhouse gas emission was developed for optimistic development of the economy (maximum rates of increase of GDP, industrial output and other economic growth indicators). Besides, this scenario provides for a doubling of the electricity use by population and bringing this indicator to the level of developed countries.

Gross consumption of FER will be growing in future at the average rate of 2-2.5% a year (Fig. 1.1). By 2020, the gross use value will reach 50 million tons of equivalent fuel, which will make about 80% of the level of 1990. Energy intensity of GDP will decrease by 3-4% a year on the average.

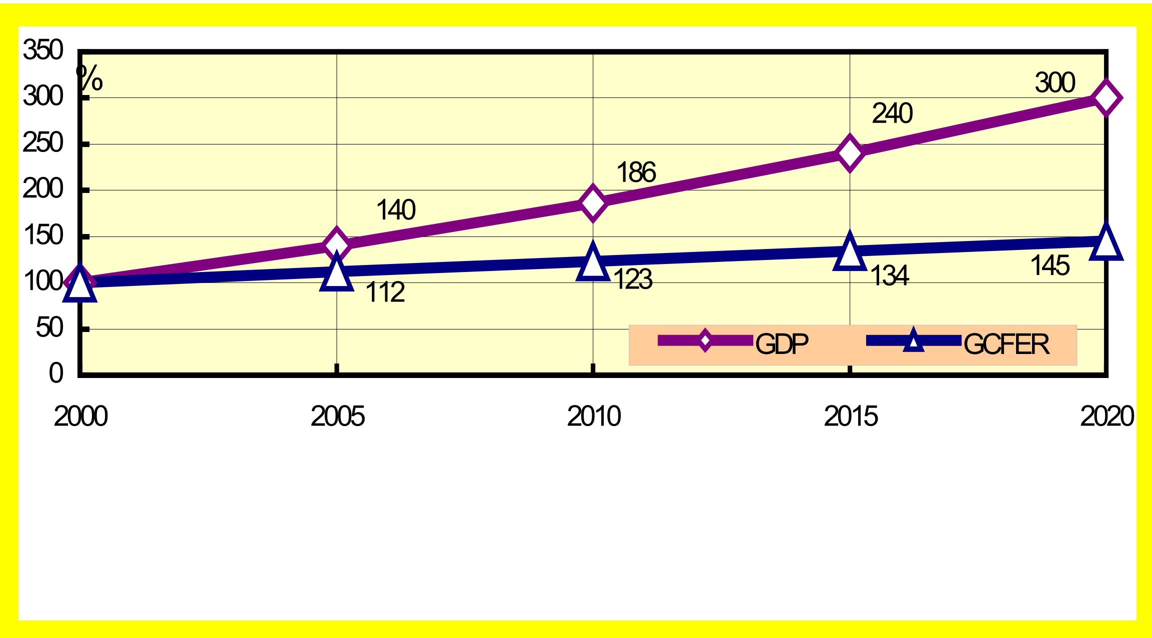


Fig. 1.1. Indices of GDP growth and gross consumption of FER (GCFER) for the period of 2000-2020

For reasons of energy security and with due account of future changes of prices for energy resources (in accordance with the predictions made by the Institute of Economics of the Russian Academy of Sciences, prices for natural gas will reach the level of oil prices and will exceed coal prices), it is envisaged that the share of black oil used for generation of heat and electrical energy in the fuel balance will increase. At present, the Main Lines of the Energy Policy of the Republic of

Belarus for 2001-2005 and for the period till 2015 are detailed; these Lines were approved by Resolution No. 567 of the Council of Ministers of the Republic of Belarus of 27 October 2000. As stipulated in this document, hydraulic power plant using coal will be built: the first unit may be put into operation by the end of the 1st budgetary period before 2012, while by the end of the 2nd budgetary period, by 2017, two more units may be commissioned. Taking this into account, the fuel balance is predicted as follows (see Table 1.1).

Table 1.1. Predicted Fuel Balance, Thousand Tons Of Equivalent Fuel

Fuel	2000	2005	2010	2020
Natural gas, total	19751	21415	21758	21470
Casing head gas (production)	334	290	240	145
Black oil	2828	2310	2760	4270
Coal	403	270	930	2200
Coke	83	80	90	110
Communal oven fuel (COF)	159	80	40	20
Liquefied gas	394	227	203	190
Dry gas from oil refining	447	640	715	860
Fuel peat	100	130	200	350
Peat briquettes	741	670	810	1240
Fire woods	984	1230	1360	1630
Production waste (wood)	138	220	700	1950
Combustible SER	220	180	220	280
Motor vehicle gasoline	1471	1659	2021	2728
Diesel fuel	2538	3014	3682	4935
Kerosene	88	130	180	300
Other fuels	87	160	130	100
TOTAL for all types of fuel (without feedstock)	**30765**	**32706**	**36040**	**42778**

Given account of the above, the prospective estimates of CO_2 emission will be as follows, based on the planned use of fuel (Table 1.2).

Table 1.2. Carbon dioxide emission for the module "Energy sector:" taking into account changed structure of fuel use

Year	1990	1995	1999	2000	2005*	2010*	2020*
Emissions of CO_2, Gg	100 615	60 552	55 185	50 741	56 610	62 618	74 787

* Prospective estimates

There exists another approach to prospective estimation of greenhouse gas emission based on the data on gross domestic product and its energy intensity.

$$E_{CO2} = GDP * EE * K_{CO2}, \quad (1.1)$$

where: E_{CO2} is greenhouse gas emission, Gg
GDP is gross domestic products, roubles ($)

EE is energy intensity of gross domestic product, kg of fuel equivalent /rouble ($) of GDP
K_{CO2} is the greenhouse gas emission factor, Gg of CO_2/ kg of fuel equivalent.

GDP (gross domestic product). Beginning from 1996 the slump in production was overcome and a positive dynamic of macroeconomic processes was achieved; annual increase of GDP and industrial output and consumer goods. It should be noted that taken in comparatives prices of 2002 the gross domestic product even in 2002 did not reach the level of 1990, making 97.2%. And only in the predicted period the task is set to exceed this figure: 102.3-102.8% in 2002 and 119.5-122.5 in 2005.

In the future, the gross domestic product (production output), including other factors, is predicted at a more optimistic level: 156.6-162.9% by 2010 and 242.6-263.6% by 2020 as compared to the level of 1990.

EE (energy intensity of gross domestic product). Decrease of energy intensity of GDP was reached in 2000 by 28.1%, in 2001 by 4.0% and in 2002 by 4.7%. According to predictions, future decrease of energy intensity of GDP will be: in 2003 by 4.5-5.5%; by 2005 by 8.4-11.0%; over 2006-2010 by 16-20% and over 2011-2020 by 10-15%.

K_{CO2} (the greenhouse gas emission factor). The greenhouse gas emission factor is an aggregated emission factor, depending on the fuel structure. Beginning from 1990, it was permanently decreasing and made 0.0598 Gg of CO_2/TJ in 2000. This is due, primarily, to increased share of natural gas with lower emission factors, and in conformity with the planned structure of fuel use, it is predicted to be slightly decreased.

Greenhouse gas emission is presented in Table 1.3, based on macroeconomic indicators.

Table 1.3. Greenhouse gas emission, based on macroeconomic indicators

Greenhouse gas emission, Gg	2000	2003	2005	2010	2020
Pessimistic scenario*	50742	58854	70122	93261	150942
Optimistic scenario**	50742	50051	52000	54496	71821

* Pessimistic scenario.

It implies absence of energy-saving measures aimed at reducing fuel use and elimination of its loss, from production to consumption. It is also assumed that energy intensity of gross domestic product (GDP) remain invariable during the prediction period. Thus, growth of GDP is accompanied by a growth of energy use and by a respective growth of greenhouse gas emission.

** Optimistic scenario.

It implies implementation of the entire range of planned energy-saving measures. This will have a natural impact on the use of fuel and, hence, on GDP energy intensity, i.e. stipulating its constant reduction. As a result, by 2020, with the GDP increase 2.5 times as compared to 1990, greenhouse gas emission will not reach the level of the basis year of 1990.

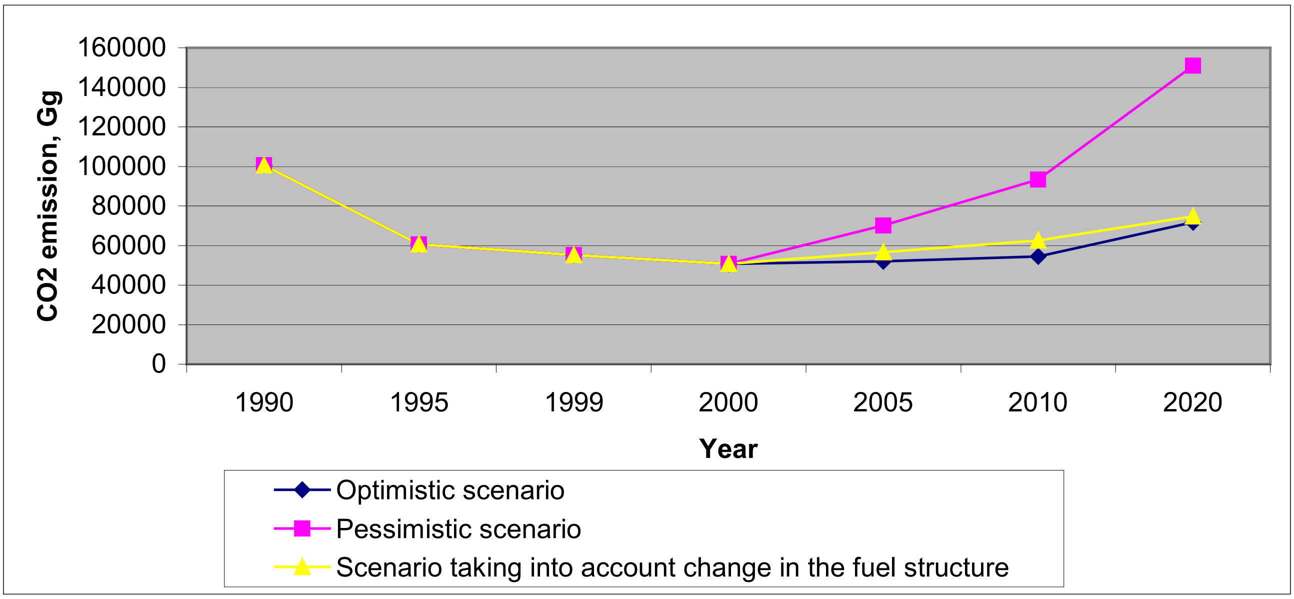


Fig. 1.2. Greenhouse gas emission

1.2. Prediction Of Methane Emission

The main source of methane emission in the module "Energy sector" is volatile emissions from oil and gas systems (their share is 85.9%). Volatile methane emissions have been determined using the methodology of IPCC, based on predicted data on oil and gas, taken from Main Lines of the Energy Policy of the Republic of Belarus for 2001-2005 and till 2015, approved by Resolution No. 567 of the Council of Ministers of the Republic of Belarus on 27 October 2000 (Table 1.4).

Table 1.4. Volatile Methane Emissions From Oil And Gas Systems, Gg

Year	Oil			Gas				Total
	Production	Refining	Storage	Production	Transportation	Other leaks		
						From energy and industry sectors	From other sectors	
2005	0.17	0.50	0.09	2.23	76.06	50.75	2.81	132.61
2010	0.14	0.53	0.10	2.03	83.32	55.61	3.07	144.80
2015	0.12	0.59	0.11	1.75	86.78	57.92	3.20	150.47
2020								154

Table 1.5 shows prospective estimates of methane emission from combustion of fuel and from oil and gas systems.

Table 1.5. Methane Emission For The Module "Energy", Gg

Emission source	Year			
	2005	**2010**	**2015**	**2020**
1. Fuel combustion	18.0	19.0	20.0	21
2. Volatile emissions	132.6	144.8	150.5	154
Total	150.6	163.8	170.5	175

1.3. Prediction Of Nitrous Oxide Emission

Nitrous oxide emission in the module "Energy sector" makes less than 1%; its serious prospective assessment is inexpedient and absolute values are estimated within 0.036-0.50 Gg.

Table 1.6 shows prospective estimates of greenhouse gas emission for the module "Energy".

Table 1.6. Estimates of greenhouse gas emission for the module "Energy sector"*

Year	**CO_2, Gg**	**CH_4, Gg**	**N_2O, Gg**	**CO_2, equiv. CO_2.**	**CH_4, equiv. CO_2**	**N_2O, equiv. CO_2**	**GWE, equiv. CO_2**
2005	70 122 56 610 52 000	151	0.42	70 122 56 610 52 000	3 171	130	73 423 59 911 55 301
2010	93 261 62 618 54 496	164	0.46	93 261 62 618 54 496	3 444	143	96 848 66 205 58 083
2020	150 942 74 787 71 821	175	0.49	150 942 74 787 71 821	3 675	152	154 769 78 614 75 648

* carbon dioxide emissions for the pessimistic scenario
carbon dioxide emissions taking into account the changed structure of fuel consumption
carbon dioxide emissions for optimistic scenario

As can be seen, emission of gases with direct greenhouse effect per module "Energy" will be increasing, which is due to predicted growth of GDP and fuel use.

During the period till 2010, the period of restoration and accelerated growth of the national economy, the conditions for accession to the Kyoto Protocol of UNFCCC can be considered as quite adequate for Belarus as regards levels of man-induced emissions. The Republic of Belarus should make significant efforts, especially as regards finding required investments to the energy sector, so that during the period defined by the Protocol (2008-2012) not to exceed levels of carbon dioxide emissions equivalent to greenhouse gas emissions in the country in 1990.

2. INDUSTRY

2.1. Prospective Estimation Of Greenhouse Gas Emission And Estimation Of Efficacy Of Measures In Industry

Input of industry into emission of greenhouse gases is small, i.e. 3.1% as for the level of 2000; however it went up 1.7 times during 1990-2000.

Therefore, prediction of greenhouse gas emission in industry is not expedient.

Greenhouse gas emissions in industry are defined, mainly, by production output. However, in view of implementation of the industrial environmental policy and measures the rates of grow of greenhouse gas emission will be lower than the rates of grow of production output. Predicted indicators of development of sub-sectors that are main greenhouse gas sources are approximately the same in the above-mentioned documents; therefore, prediction of greenhouse gas emission is made using the same scenario.

2.2. Prediction Of Greenhouse Gas Emission

Greenhouse gas emission is made by two sources: production of cement and production of lime. In cement production, greenhouse gas is generated at the stage of production of clinker, which is an interim process product.

Calculations show that by 2020 there may be a 15% maximum growth of greenhouse gas emission against 2000.

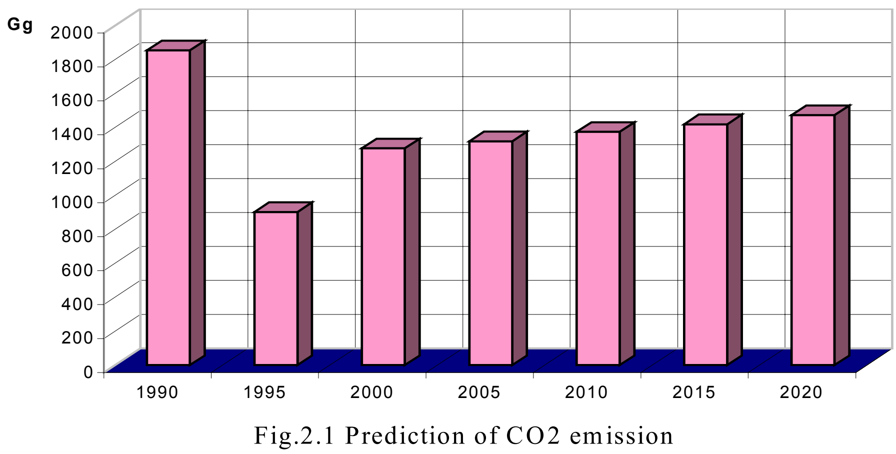


Fig. 2.1. Prediction of CO_2 emission

2.3. Prediction Of Sulphur Dioxide Emission

The main sources of SO_2 emission are production of cement, ammonia and sulphuric acid. Since 94-96% of SO_2 emission is due to production of sulphuric acid, then this source will be determining the total emission trend (Fig. 2.2).

According to data received, by 2020 the level of CO_2 emission will make about 64% of the emission level of 1995. In view of the planned increase of output of sulphuric acid, the predicted growth of emission will make 45% compared to 2000.

2.4. Prediction Of Carbon Oxide Emission

The main sources of carbon oxide emission include production of caprolactam, ethylene and propylene, ammonia and some metals.

According to the obtained data, emissions of CO in 2020 may be 7.8 Gg, i.e. as compared to 2000 and taking into account environmental aspects of production, emissions of this compound may make less than 3% (Fig. 2.3).

2.5. Prediction Of Nitrous Oxide Emission

The main sources of nitrous oxide emission are metallurgy ands some chemical industries.

Since the main source of NO_2 emission is production of nitric acid, then the predicted magnitude of emission by 2020 will not practically change. Some reduction of emissions may take place due to planned reconstruction of outdated equipment (Fig. 2.4, 2.5).

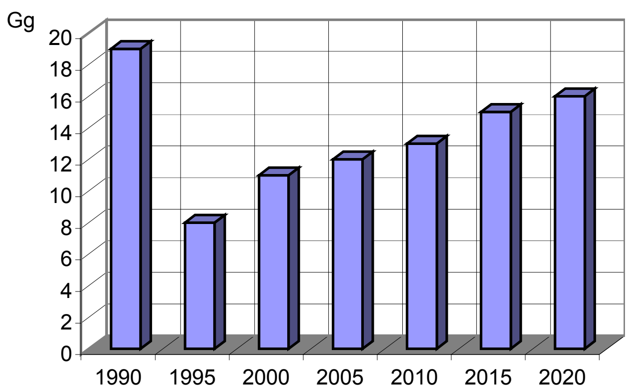


Fig. Fig. 2.2 Predicted emission of SO_2

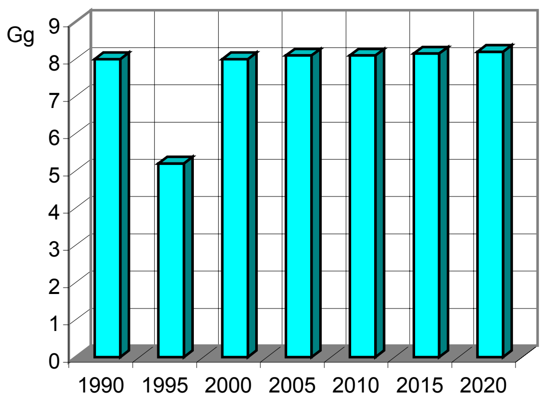


Fig. 2.3 Predicted emission of CO

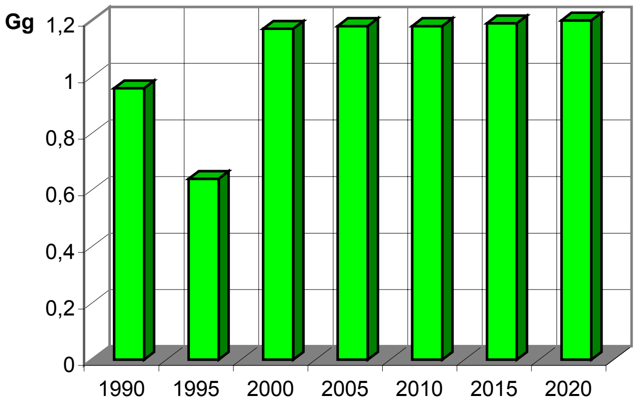


Fig. 2.4 Predicted emission of NO_x

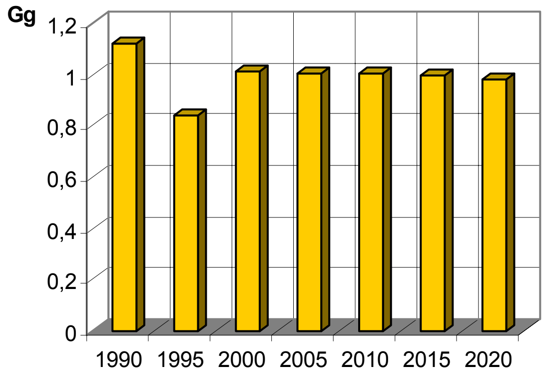


Fig. 2.5 Predicted emission of NO_2

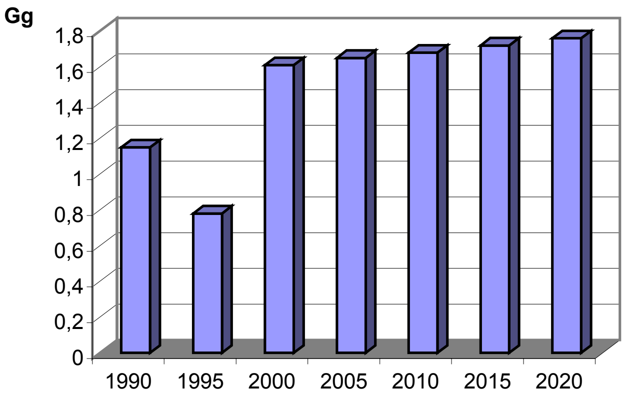


Fig. 2.6 Predicted emission of CH_4

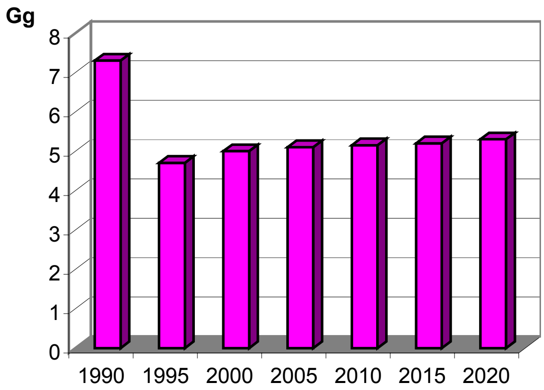


Fig. 2.7 Predicted emission of NMH

2.6. Prediction Of Methane Emission

Calculations show that in future there may be some insignificant growth of methane emission in view of the planned increase for steel output. Compared to 2000, growth of methane emission in 2020 will be about 9% (Fig. 2.6).

2.7. Prediction Of Non-Methane Hydrocarbon Emission

The main sources of non-methane hydrocarbons (NMH) emission are production of ammonia, whose input into the total volume of NMH emissions is over 82%.

Calculations show that for the period of 2000-2020 there may an increase in the total GWE from industrial processes by 11.7%, which is determined, mainly, by rates of growth of industrial output. However, taking into consideration the planned measures for ensuring environmentally safe economic activities in the country, the growth of greenhouse gas emission will be much lower than the production output (Fig. 2.7).

Table 2.1. Prediction Of The Input Of Industrial Processes Into The Total GWE

Year	Emissions, Gg			Emissions equivalent CO_2, Gg			
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	Total GWE
2005	1320	1.65	1.0	1320	34.7	310	1664.7
2010	1370	1.68	1.0	1370	35.3	310	1715.3
2015	1420	1.72	0.99	1420	36.1	307	1763.1
2020	1474	1.76	0.98	1474	37.0	304	1815.0

3. AGRICULTURE

3.1. Prospective Estimation Of Greenhouse Gas Emission And Estimation Of Efficacy Of Measures In Agriculture

Predictions of greenhouse gas emission from agriculture were built on available prediction estimates of development of animal farming, voles of mineral fertilisers used and areas of agricultural land with organogenic soil. Since for development of animal farming there are two possible scenarios, we examined two methane emission scenarios. For nitrous oxide, the main sources of which are nitric mineral fertilisers and organogenic soil, we calculated only one scenario of emissions, since it can be expected that the use of nitric fertilisers will reach their required demands by 2005 and then will stabilise; as regards rates of degradation of meliorated organogenic soil we also have one scenario.

3.2. Prediction Of Methane Emission

Calculations show that in future, with different scenarios of development of animal farming, there will be no increase of methane emission (Table 3.1, Fig. 3.1).

Table 3.1. Prediction Of Methane Emission In Agriculture, Thousand T (Gg)

Development scenario	1990	1995	2000	2005	2010	2015	2020
Basic	530	404	334	337	337	336	336
Optimistic	530	404	334	380	385	388	393

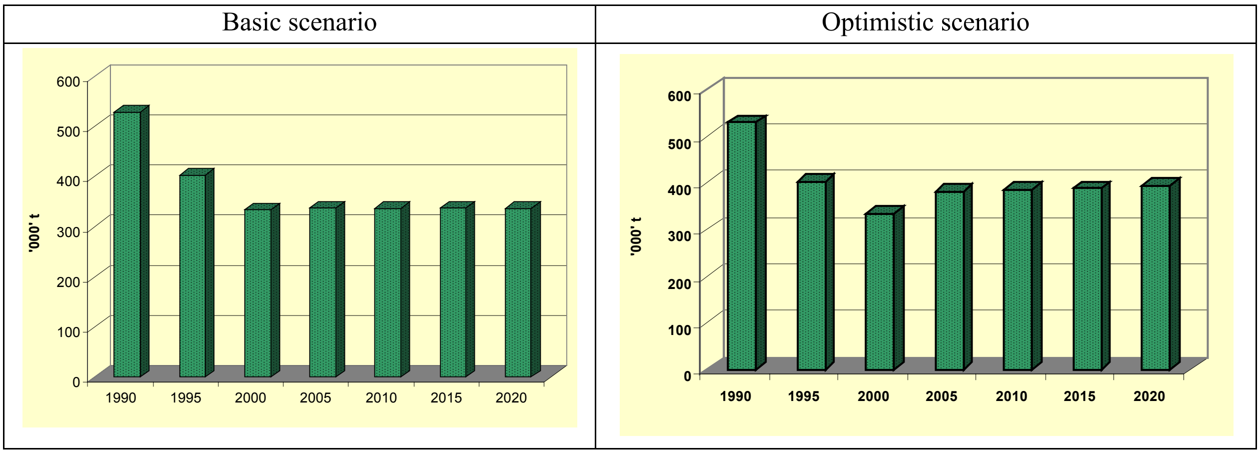


Fig. 3.1. Prediction of methane emission in agriculture for two animal farming development scenarios

By 2020, its level will not reach the level of 1995 (not speaking about the level of 1990) and will be 337,000 tons for the basic scenario of development and 393,000 for optimistic scenario. As compared to 1990, methane emission in 2020 will make: 64% for the basic scenario and 74% for the optimistic scenario.

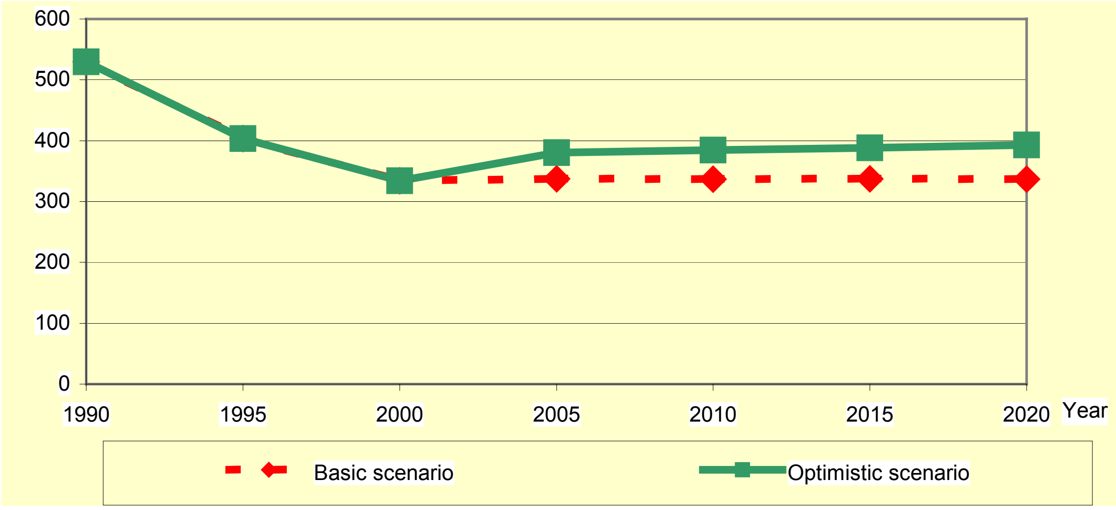


Fig. 3.2. Comparative trends of methane emission for two scenarios of animal farming development

3.3 Prediction Of Nitrous Oxide Emission

According to the data received, nitrous oxide emission in 2020 may be 26,500 tons or 86% of the 1990 level (Table 32.) As compared to 2000, there may be an increase of nitrous oxide emission by about 1.4 times (Fig. 3.2).

Table 3.2. Prediction Of Gross Nitrous Oxide Emission, Gg

1990	1995	2000	2005	2010	2015	2020
30.7	14.3	18.8	27.1	26.9	26.7	26.5

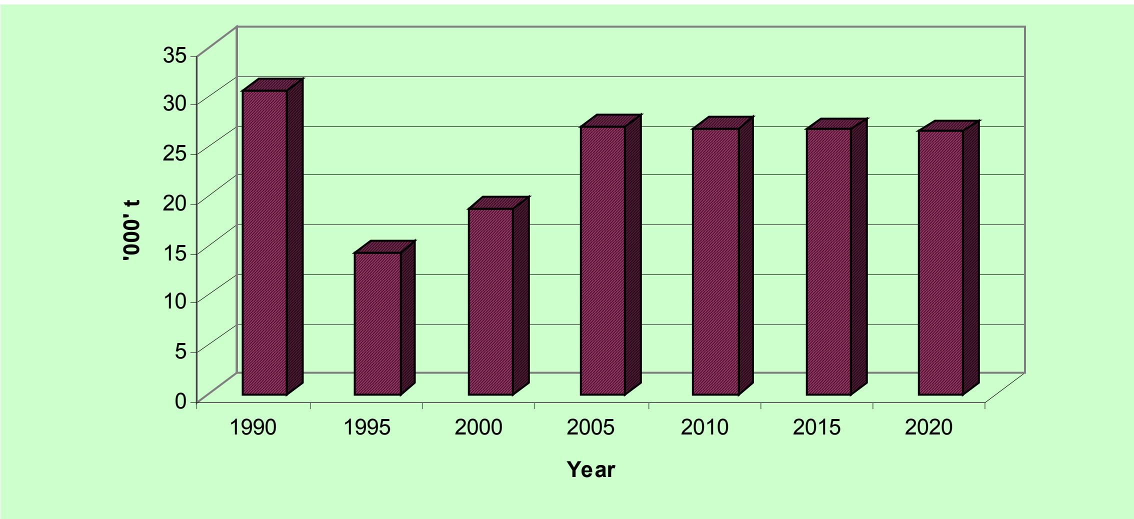


Fig. 3.3. Prediction of gross nitrous oxide emission in agriculture

Since main sources of nitrous oxide emission are the use of nitric fertilizers and peat soil, then it is precisely the ratio of these sources will determine the general trend of emissions (Figs. 3.3, 3.4). As regards the use of peat land in agriculture, we can with enough assurance state that its area will be reduced, thereby reducing emissions. At the same time, the use of nitric fertilisers has a trend towards increase; the volume of their use, by different estimates, may reach the required level in the near year. Calculations show that by 2005, as compared to 2000, there may be increase of direct and indirect emissions of nitrous oxide (due to predominant use of nitric fertilisers) by about two times with the subsequent stabilisation of emission levels.

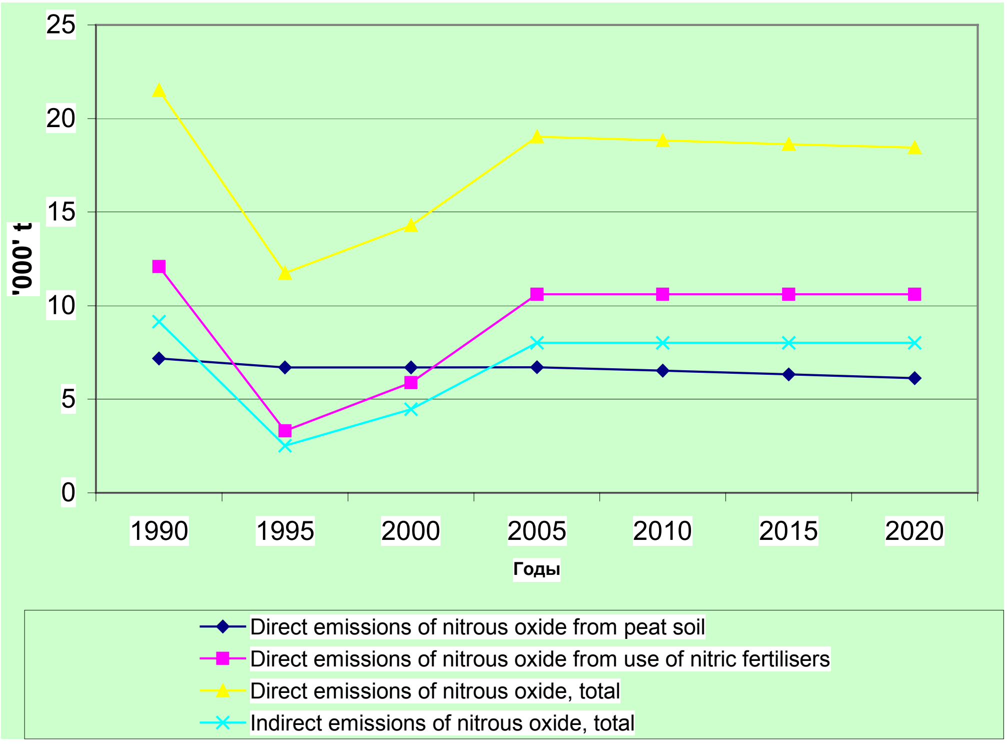


Fig. 3.4. Prediction of nitrous oxide emission in agriculture

4. LAND-USE CHANGE AND FORESTRY

4.1. Prediction Of Emissions And Removals Of Greenhouse Gases In Forestry

The main sink of CO_2 in our country is its deposition in forest biomass. For its estimation, we used data on the topological structure of forest vegetation and their territorial distribution, shown in the tables. Estimates of CO_2 sinks were calculation by the magnitude of specific increase of forest (production) and forest areas for every differentiated species and age categories. Results of the calculations are show in Table 4.1. This table includes values for the annual production (increase) of above the surface phytomass and the equivalent quantity of CO_2 (Gg).

The estimates were made for 2001, 2005, 2010, 2015 and 2020. As can be seen from Table 4.1, the main role in the removal of CO_2 is played by middle-age coniferous and small-leaved forests as well as young forests of the second group and immature trees of these forest formations.

It should be noted that there was a substantial jump in the forest areas between 2000 and 2001. It was connected not only with new afforestation, but also with inclusion of significant areas contaminated with radionuclides. Also, in 2015, the predicted scope of forest use will be 18 million m^3, while in 200 it was 10.8 million m^3.

It is necessary to note that new forest planted in 2001 included 33,226 ha, among them 662 ha on areas burned by fires in the previous years. Natural restoration of forest activities were organised on 7209 ha.

In 1988-2001, afforestation was performed on about 60,776 has of land contaminated with radionuclides, including 42,326 ha of forest fund; 18,450 ha were taken out from other use.

In 2001, fir trees dried out in 8,109.8 ha, with the wood stock of 1.9 million m^3, which was twice as high as in 1999.

From Table 4.1 it can be seen that removal of CO_2 emission for the prediction period is noticeably higher that it was observed in 1990's, making from 47.28 to 49.84 million tons.

The volume and the structure of product output in many respects depend on the technologies used during the prediction period. The share of new technologies in forestry in the total production out would be from 11% in 200, to 16% in 2005, 215 in 2010 and 30% in 2020.

Removal of CO_2 is also facilitated by withdrawal from use of tilled land and pastureland. Here, processes can be observed staring from the current to t-20 and further from t-20 to t-100 years. Estimates of the second component are very unreliable, as well as the respective statistical materials. Therefore, we used only the first (basic) component. The area of afforestation over the precious 20 years period would be 593.6 ha for 2001, 750.2 ha for 2005, 838.6 ha for 2010, 953.0 ha for 2015 and 542.0 ha for 2020. Respective sinks of CO_2 are shown in Table 4.2.

.

Table 4.1. Annual Production Of Phytomass Above The Earth Surface (A) And The Equivalent Amount Of CO_2 (B) In Forests Ecosystems Of Belarus, Million Tons

Formation groups	Age classes	a					b				
		2001	2005 г	2010	2015	2020	2001	2005	2010	2015	2020
Coniferous	Young trees, 1st class	1.13	1.15	1.16	1.18	1.19	2.08	2.11	2.13	2.16	2.19
	Young trees, 2nd class	3.67	3.71	3.76	3.81	3.86	6.73	6.82	6.91	7.00	7.09
	Middle aged	7.57	7.67	7.77	7.88	7.98	13.89	14.08	14.27	14.45	14.64
	Immature	3.02	3.06	3.10	3.14	3.18	5.54	5.62	5.69	5.77	5.84
	Mature	0.73	0.74	0.75	0.76	0.77	1.33	1.35	1.37	1.39	1.40
	Overmature	0.02	0.02	0.03	0.03	0.03	0.04	0.05	0.05	0.05	0.05
Hard-leaved	Young trees, 1st class	0.11	0.12	0.12	0.12	0.12	0.21	0.21	0.22	0.22	0.22
	Young trees, 2nd class	0.23	0.23	0.23	0.24	0.24	0.42	0.42	0.43	0.43	0.44
	Middle aged	0.47	0.47	0.48	0.49	0.49	0.86	0.87	0.88	0.89	0.90
	Immature	0.10	0.10	0.10	0.11	0.11	0.19	0.19	0.19	0.19	0.20
	Mature	0.09	0.09	0.09	0.09	0.09	0.16	0.16	0.16	0.17	0.17
	Overmature	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Soft-leaved	Young trees, 1st class	0.93	0.95	0.96	0.97	0.98	1.71	1.74	1.76	1.78	1.81
	Young trees, 2nd class	1.51	1.53	1.55	1.57	1.59	2.76	2.80	2.84	2.88	2.91
	Middle aged	4.19	4.25	4.30	4.36	4.42	7.69	7.79	7.89	8.00	8.10
	Immature	1.40	1.42	1.44	1.46	1.48	2.57	2.61	2.64	2.68	2.71
	Mature	0.56	0.57	0.58	0.59	0.59	1.04	1.05	1.06	1.08	1.09
	Overmature	0.03	0.03	0.03	0.03	0.03	0.05	0.05	0.05	0.05	0.05
Total		25.77	26.12	26.46	26.81	27.16	47.28	47.92	48.56	49.20	49.84

Table 4.2. Factors And Sinks Of CO_2 In Forests Ecosystems Of Belarus

Factors, sinks, units of measurement	2001	2005	2010	2015	2020
Taking land out of use, '000' ha	593.6	750.3	838.6	953.0	542.0
Sink of CO_2, Gg	3260	4130	4610	5240	2980
Increment of standing wood, million t	25.77	26.12	26.46	26.81	27.16
Sink of CO_2, Gg	31890	32470	33190	32530	33210
Total sink of CO_2, Gg	35150	36590	37810	37770	36190

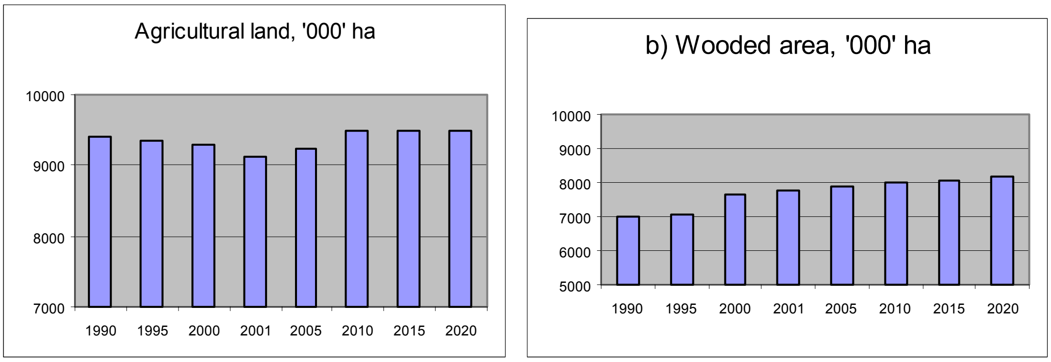


Fig. 4.1. Dynamic of agricultural (a) and wooded (b) land

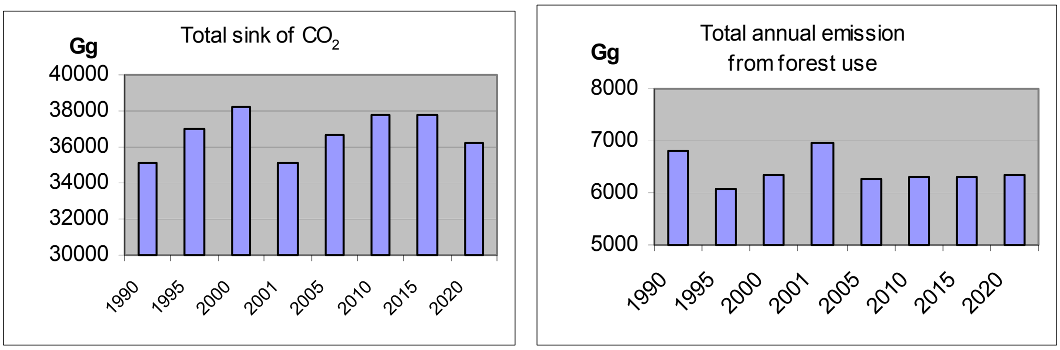


Fig. 4.2. Emissions and removals in the Land-use change and forestry

To facilitate interpretation of the dynamic and prediction of sinks and emissions, we used materials of the previous research on the topic for 1990-2000. On the whole, we can see and predict decrease of arable land and increase of wooded area, which in the long run increases removal of CO_2. Levels of soil liming and forest use rates proposed for the prediction period are practically stabilising the resultant sink on the background of increased wooded areas (Figs. 4.1, 4.2). Implementation of scenarios of economic activities with a higher level of tree felling and a higher level of liming (2000-2500 thousand tons) substantially decreases CO_2 sink by Belarusian ecosystems (by 20-30% or more)

The following two groups of natural and economic processes can be pointed as measures that can facilitate manifestations of greenhouse effect in the country as a whole:

a) reducing emission of CO_2 to atmosphere from forest ecosystem and definite changes in land use;

b) increasing productivity (increase) and thereby increasing biomass reserves in forest ecosystems as well as some changes in land use.

Thus, massive felling actually brings the forest ecosystem to a condition characterised by minimum productivity and high reserves of waste. Here, two directions may be effective: 1) restoration of forests through preservation of young trees during felling and planting new woods, mass-scale or selective; and 2) maximum possible economic use of residual waste. This ensures conventional transformation of areas after cutting into young woods of the 1st age on some areas.

Since maximum productivity it typical for 2nd age young stands, middle-age and immature stands, then it is possible to noticeably increase CO_2 emission sink, with the same wood area, by increasing the share of these three most productive age categories (II-IV) in the total wooded area. Overmature forests should be preserved provided there are historic, environmental or other reasons for this. The scenario suggested in the Strategic Plan of Development of Forestry of Belarus recommends a strategy of forest use with an increased level of felling. In this case, already in ten years there is evidence of substantial rejuvenation of the forest stocks, which facilitates CO_2 removal. In this scenario, the balance “emissions – removals” is shifted towards sinks at the expense of retention of carbon in products and items of timber processing and biomass as a whole.

Termination of agricultural use of low-productivity land, especially seen in the last decade, can be accompanied by CO_2 emission from soils. The most expedient from environmental point of view is afforestation of such areas. The same is true about remediation of disturbed land unsuitable for agriculture. Afforestation of such land increases CO_2 sink, making it higher than emission. Wooded areas become a reservoir for carbon dioxide removal.

Liming of soil, which is a technological link required in land cultivation practices in the country, is a powerful source of CO_2 emission. At present, the need for liming of soil has become much smaller, since over the last decades a generally high oxidation of soil has been attained that should be maintained. Nevertheless, the above-mentioned optimum scenario of liming (2000 t or more a year) substantially increases CO_2 emission from soil. We have considered the liming scenario with a stable balance of removal and emission at a lower level.

By 2020, an optimum afforestation value will be achieved, i.e. 39.6%. In this connection, taking of land from use should be practically terminated, and this will reduce CO_2 removal.

4.2. Prediction Of Emission And Removal Of Greenhouse Gases In Wetland Ecosystems

For predictions it was assumed that the area of wetlands in their natural condition would not change due to termination of land reclamation and stabilisation of peat areas under exploitation.

By 2020, complete destruction of peat layer will take place on 12% of degraded peat soil where the peat layer is less than 0.3 m. Other 57,000 ha of ineffectively used peat soil will be taken out of agricultural use. For these reasons, the total area of drained peat soil will be increased by 80,000 ha.

The area of peat soil with the depth of peat layer over 1 m will decrease by 12% because this soils area will be included into the category of soil with the peat layer less than 1 m. For the sake of calculation, it was conventionally assumed that dynamic of drained peat areas will occur in equal shares over 2000-2020.

The area of rehabilitated wetlands will increase by 80,000 ha, including 57,000 ha through rehabilitation of ineffectively used peat soil and 23,000 ha of exhausted peat fields.

For sink calculation it was assumed that 1 ha of lower wetlands absorbs 0.71 t of carbon dioxide a year and 1 ha of upper wetlands absorbs 1.36 t.

Carbon dioxide emission by drained peat soil with the depth of the peat layer less than 1 metre makes 8.56 t/ha, while when the peat layer depth is over 1 metre this emission is 9.62 t/ha.

Carbon dioxide emission from 1 ha of exhausted peat fields makes 22.5 t a year and from 1 ha of peat fields under exploitation it is 11.3 t a year.

The area of used peat fields will be stabilised at the level of 2000.

Methane emission from 1 ha of lower and rehabilitated wetlands makes 0.005 t a year, and that of upper moirés makes 0.04 t.

As a result, the following conclusions can be made:

1. By 2020, carbon dioxide emission from reclaimed peat soil will decrease by 718,700 tons a year as compared to 2000.
2. Carbon dioxide emission from exhausted peat fields will be decreased by 574,000 tons a year.
3. Carbon dioxide removal in natural wetlands will remain at the level of 2000 and will make 1,365,600 tons a year.
4. Carbon dioxide removal in rehabilitated wetlands will be increasing constantly due to increased area of rehabilitated wetlands on inefficient drained peat soil and exhausted peat fields and will increase by 56,800 tons a year.
5. The total effect on emission reduction and increase of removal will make about 1,350,000 tons of carbon dioxide a year.
6. Methane emission will increase by 350 tons a year through increase of the area of rehabilitated wetlands.

5. WASTE

5.1. Prediction Of Methane Emission

As predicted in the Concept, population numbers in the country will continue to decrease by about 50,000/year and will make in 2010 about 9,500,000 and in 2020 about 9,000,000 people. Keeping this in mind as well as retained rates of growth of municipal waste per capita, it is found out by extrapolation that by 2020 Belarus would not reach the average European level of municipal waste generation per capita: in 2010 this indicator will be increased up to 0.81 and in 2020 it will be 0.96 kg/man/year (Fig. 5.1). The total amount of municipal solid waste in Belarus would be:

In 2010: 0.81·365·9500000 =2,808,675 tons;

In 2020: 0.96·365·9000000 =3,153,600 tons.

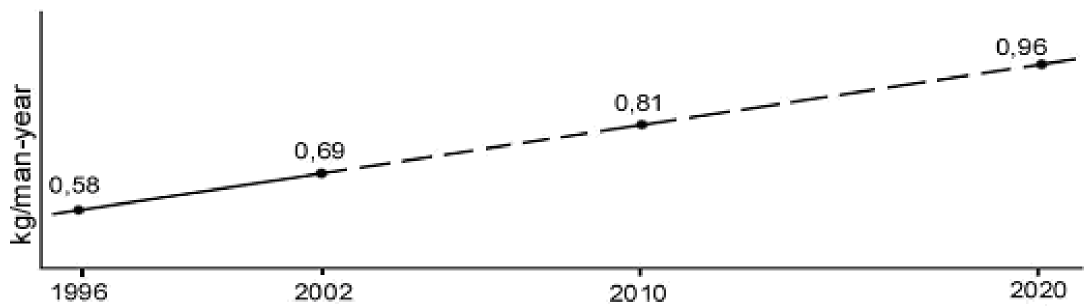


Fig. 5.1. Prediction of the increase of municipal solid waste by 2020

Separate collection of waste will help reduce the amount of organic waste such as food, wood, paper, textile waste in the waste buried in the waste fields. These organic wastes make up to 40-60% of the total waste. It should be noted that, firstly, some types of secondary raw materials (wood and paper waste) were collected in the past, and secondly, that some amount of this raw material cannot be extracted during separate collection and sorting because it is contaminated. Thus, it can be suggested that the amount of organic waste in the total waste after separate collection and sorting procedure will not decrease by 40-60% (on the average), but rather by 20%.

As stated before, by the end of 2003 separate collection practices should cover 10% of population in 17 large cities. Keeping in mind this planned coverage rate, it can be assumed that annual coverage of population by separate collection practices would be 3-5%. With such rates, separate collection and sorting of waste in the country will cover, by 2010, up to 35% of population, i.e. 50% of urban population, and by 2020, the entire urban population may be covered.

Separate collection of waste and extraction of organic-containing waste as well as reduction of the total amount of waste will help decrease the share of degradable organic waste (DOW). In 2000, due to absence of inventory of waste morphological composition, the DOW value was taken, by default, according to data of 1995, making 14.71%. If the separate collection process develops according to the optimistic scenario, when up to 30% of organic waste will be extracted out of 70%

of generated municipal waste, the amount of DOW in the remaining waste will be decreased, thus making:

in unsorted part – 14.71% and
in sorted part – 14.71 x 2/5 = 5.88%

According to the basic scenario, without separate collection, methane emission, based on the predicted amount of buried waste, will be: 148.46 Gg of CH_4 in 2010 and 166.69 Hg of CH_4 in 2020 (table 5.1).

According to the optimistic scenario (with separate collection and sorting of municipal waste), the predicted methane emission in 2020 will be 96.65 Gg of CH_4 (Table 5.1). Predicted methane emission for 2010 was determined by interpolation and will make about 177 Gg of CH_4 (Fig. 5.2).

Implementation of the planned actions on separate collection and sorting of municipal waste will allow reducing methane emission from municipal solid waste in the Republic of Belarus by 20% by 2010 and by 42% by 2020.

Table 5.1. Prediction Of Methane Emission For 2010 And 2020

Year	Total amount of municipal solid waste (MSW), buried in landfills, ton	Share of waste collected jointly/ separately	Methane flew correction factor (MCF)	Share in MSW of degradable organic carbon (DOC)	Share of DOC, which actually degrades	Share of methane released as methane	Convers ion ratio	Annual methane emission (Gg of CH_4)
Predicted methane emission acc. to the basic scenario								
2010	2808675	1/0	0.7	0.1471	0.77	0.5	16/12	**148.46**
2020	3153600	1/0	0.7	0.1471	0.77	0.5	16/12	**166.69**
Predicted methane emission acc. to the optimistic scenario								
2020	3153600	0.3/0.7	0.7	0.1471	0.77	0.5	16/12	50.01
	3153600		0.7	0.0588	0.77	0.5	16/12	46.64
							Total:	**96.65**

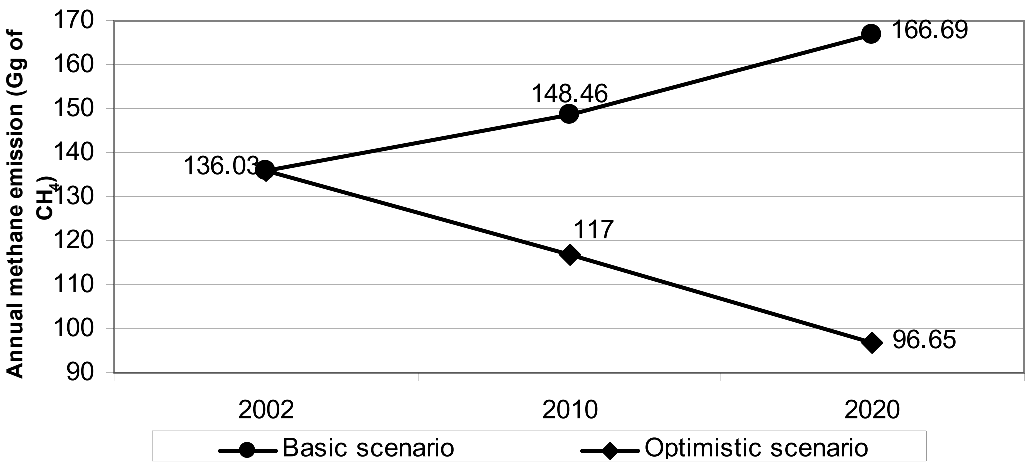


Fig. 5.2. Predicted methane emission for 2010-2020.

5.2. Prediction Of Nitrous Oxide Emission

When nitrous oxide emission is calculated connected with human activities, the management of IPCC suggests methodology based on protein consumption. Taking into account consumption of protein per capita in the country, we calculated N_2O emission using this methodology for the period of 1990-2002 (Table 5.2).

Table 5.2. Nitrous oxide emission from human activities

Year	Consumption of protein per capita (kg of protein/(man-year))	Population (persons)	Total annual emission of N_2O (Gg of N_2O/year)
1990	28.3	10188900	0.725
1995	24.4	10210400	0.626
1999	29.8	10045200	0.753
2000	29.9	10019500	0.753
2001	30.5	9990400	0.766
2002	30.7	9898600	0.768
2010	32.4	9500000	0.774
2020	35.0	9000000	0.792

As can be seen from Table 5.2, change in emission over the recent years has been insignificant. Special measures aimed at increasing consumption of protein in the country are not stipulated by plans for the future, although it can be assumed, that, given increased well-being of the people, consumption of protein per capita will be increasing. Nevertheless, we can hardly expect a significant increase in N_2O emission, since this process will be taking place on the background of decreased population numbers. Predicted nitrogen emission, most probably, will not exceed 0.77-0.79 Gg of N_2O (Fig. 5.3). Ultimately, the main role in future greenhouse gas emission from waste and human activities will be played by methane (Table 5.3).

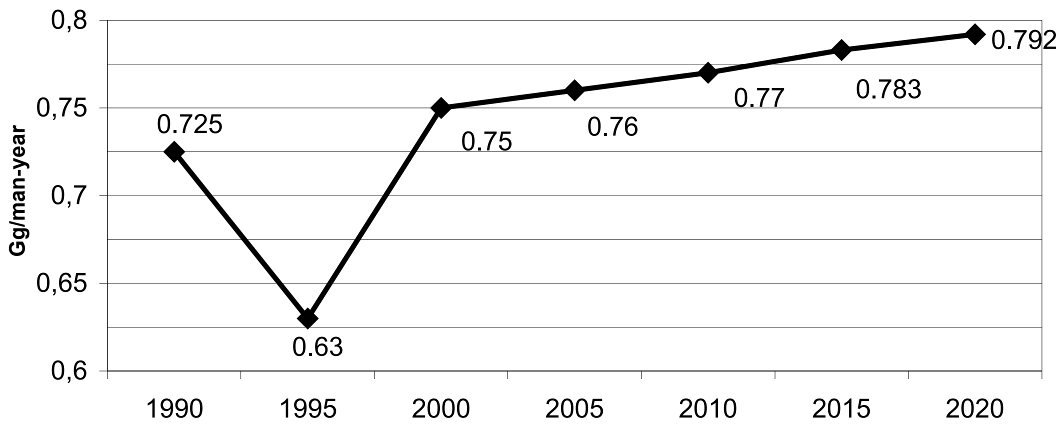


Fig. 5.3. Nitrous oxide (N_2O) emission from human activities

Table 5.3. Predicted Greenhouse Gas Emission From Waste Disposal Facilities And Human Activities

Year	**CO_2, Gg**	**CH_4, Gg**	**N_2O, Gg**	**CO_2, equiv. CO_2.**	**CH_4, equiv. CO_2**	**N_2O, equiv. CO_2**	**GWE, equiv. CO_2**
2005	0	130	0.76	0	2730	235.6	2965.6
2010	0	117.0	0.770	0	2457	238.7	2695.7
2015	0	98.0	0.783	0	2058	242.73	2300.73
2020	0	96.65	0.792	0	2029.65	245.52	2275.17

III. RESUME

The policy and measures for reducing GHG emissions and GHG emissions and removals forecast are reviewed in the work.

The increase in the GHG emissions is due to the increased output in all industrial sectors, while science-intensive productions are being intensified. Given this fact and prioritization of resources and energy saving processes, the GHG emissions growth will be less than the GDP growth.

The following targets are to be addressed in the future by developing the energy economy (EC):

- meeting to the maximum requirements of domestic consumers in fuel and energy resources, predominantly by utilizing local resources;

- providing energy security of the country and enhancing its energy independence by optimizing the energy budget structure (increasing the share of secondary energy resources, local types of fuel, unconventional and renewable energy sources, namely, wind/solar/bio power engineering and midget hydropower plants), extensively introducing novel effective electric power generation technologies and implementing energy conservation measures in all sectors of economy, including the social sphere, and improving forms of interaction (impact) between EC and environment to mitigate adverse effect on the nature.

The structure of electricity-generating sources in the power engineering sector is to be optimized by introducing combined-cycle and turbine technologies, increasing electric power generation through heating cycle, converting boiler plants to mini-heating and power plants (HPP), thereby allowing the ever-growing demand for electric power to be met to the maximum and efficiency of supplying heat to Belarusian settlements to be increased.

The strategic objective in the energy conservation sphere is to reduce the GDP energy intensity and, hence, to decrease dependence of Belarus on the fuel and energy resources import and the above objective may be reached through as follows:

- restructuring economy and industry sectors;

- increasing efficiency of energy by implementing novel energy-saving processes, equipment, instrumentation and materials, utilizing secondary energy resources;

- increasing local types of fuel, industrial waste, unconventional and renewable energy sources in the fuel balance of Belarus.

Institutional and economic spheres of the energy conservation policy are as follows:

- developing new and improving existing economic mechanisms stimulating higher energy efficiency of manufacturing products and providing services;
- conducting public examination of energy efficiency of projects and regular energy surveys of economy entities;
- revising heat, electric power and fuel tariffs.

Engineering and technological spheres of the energy conservation policy are as follows:

1. Increasing overall performance of generating sources by changing the structure of generating capacities through more extensive use of combined-cycle and gas-turbine technologies.
2. Modernizing and increasing overall performance of boiler plants by converting steam boilers to hot-water boilers.
3. Modernizing thermal insulation on all components and equipment of boiler plants and district heating networks.
4. Developing and implementing novel energy-saving processes for heating, thermal treatment and drying products, innovative construction and insulation materials with improved thermal and physical characteristics.
5. Utilizing to the maximum thermal secondary energy resources in processes, heating and hot water supply systems of industrial centers and settlements.
6. Equipping boiler plants with computerized firing control systems, automatically controlling hydraulic and thermal regimes of the district heating networks, energy consumption in heating, lighting, hot/cold water supply and ventilation systems of dwelling, public and production premises.
7. Further developing the system of accounting of all types of energy.
8. Introducing unconventional energy sources, provided that they are economically feasible.

The priority spheres in the chemical and petrochemical industries include as follows:

– developing new generations of chemical products, primarily state-of-the-art chemical fibers and yarn, plastics, elastomers, advanced mineral fertilizers and chemical ingredients of feed mixtures, products of large-scale and small-scale chemical sector and also consumer goods;

– systematically implementing novel technologies to promote resources saving, production ecologization and rational nature management starting from 2006 (following the basic modernization of enterprises) as the sector’s priority sphere;

– focusing on comprehensive raw materials processing and waste utilization. This would require development of basically new range of facilities for treating gaseous, liquid and solid materials capable of reducing anthropogenic impact on the environment; increasing the range of catalysts and initiators of new-generation reactions and processes based on them to increase the production of olefine polymers, organic synthesis products and other ecologically clean products.

The State Scientific and Engineering Program of *Developing and Implementing Novel Materials, Energy-Conservation Technologies and Resource-Saving Structural Systems of Dwelling Houses Reducing Resources and Energy Consumption in the Process of Housing Construction and Maintenance* is to be implemented in the construction sector.

The priority spheres of the transportation sector development in terms of main parameters are to be as follows:

– restructuring and modernizing most critical communications, facilities and systems to bring them into compliance with world standards;

– renovating and restoring the production potential, replacing depreciated and obsolete equipment and transportation facilities;

– creating enabling environment for attracting transit flows;

– improving and tightening the ecological control over operation of transportation facilities.

An integrated system of environmental measures is designed to limit (decrease) the adverse effect of transportation facilities operation on the community and environment in the near future.

Accumulated scientific knowledge and experience allow for developing and implementing a range of institutional/economic and engineering measures reducing carbon dioxide emissions from disturbed bogs. These measures include as follows:

– ecologically restoring disturbed bogs by rebogging to resume peat-formation processes;

– bringing the structure of crop areas on reclaimed peat soils in compliance with melioration projects and scientifically substantiated recommendations;

– changing over to ecologically and economically substantiated methods of using degraded peat soils;

– preventing fires on peat lands.

In accordance with the developed GHG emissions forecast, the trend toward the increased GWE would be observed by 2020. In general, according to the optimistic scenario, the GWE would amount to 76,512.72 Gg in 2020 that is actually 1.5 times higher than the aggregate GWE in 2000 and by 36.5% lower compared to the 1990 base. However, the global warming effect would be growing significantly slower than the GDP. It would increase mainly through GHG emissions in the *Energy* sector. The contribution of the industry and *Waste* sector to the GWE would be minor – 2.3% and 2.9%, respectively, agriculture – 19.96%. The *Land-Use Change and Forestry* sector would remove about 24.17% of greenhouse gases due to sinks.

CO_2 emissions totaling 91,981.1 Gg by 2020 would mainly contribute to the GWE. CO_2 emissions would totally increase by 30% compared to 2000 and decrease by 25% compared to the 1990 base.

Table 1 Dynamics of CO_2 Emissions and Sinks, Gg

Description	2000	2005	2010	2015	2020
Emissions	72,888.15	85,125.7	89,254.9	92,445.7	94,160.1
Sinks	-39,565.02	-37,984.0	-39,218.2	-39,192.4	-37,626.16
Total	33,323.13	47,141.7	50,036.7	53,253.3	56,533.5

In 2020, the CO_2 emissions would exceed 71% of the total global warming effect. According to the forecast, sinks would reduce nearly by 5% in 2020 compared to 2000, while they would increase by 3% compared by 1990.

Among different national economy sectors, the energy sector would provide main CO_2 emissions in 2020 – 71,821 Gg, or 78.1%, while the *Land-Use Change and Forestry* sector would provide CO_2 sinks - 37,626 Gg or 100%.

In 2020, methane emissions of the CO_2 equivalent would amount to 13,235 Gg, or nearly 17% of the total GWE according to the optimistic scenario. The agriculture-induced emissions would provide the bulk of methane (>53%). In this case, the energy would account for 28%, waste - 15%. Compared to 2000, the contribution of energy to the methane emissions would increase by 40%, and decrease by 15% compared to 1990.

According to forecast data, N_2O emissions would amount to 8,922 Gg of the CO_2 equivalent in 2002, or 11% of the total GWE.

The predictable increase in GHG emissions in the energy sector is conditioned by the predicted GDP growth and by higher fuel consumption, respectively. GHG emissions, however, will be substantially lower than that of the 1990 level.

Compared to 1990 and 2000, the predicted GWE in 2020 would be 63.5% and 146%, respectively. The increase in comparison with 2000 will be due to a substantial growth in the GDP (Fig. 1). Compared to 2000, emissions in all sectors would increase, while sinks in the *Land-Use Change and Forestry* sector would remain actually at the 2000 level.

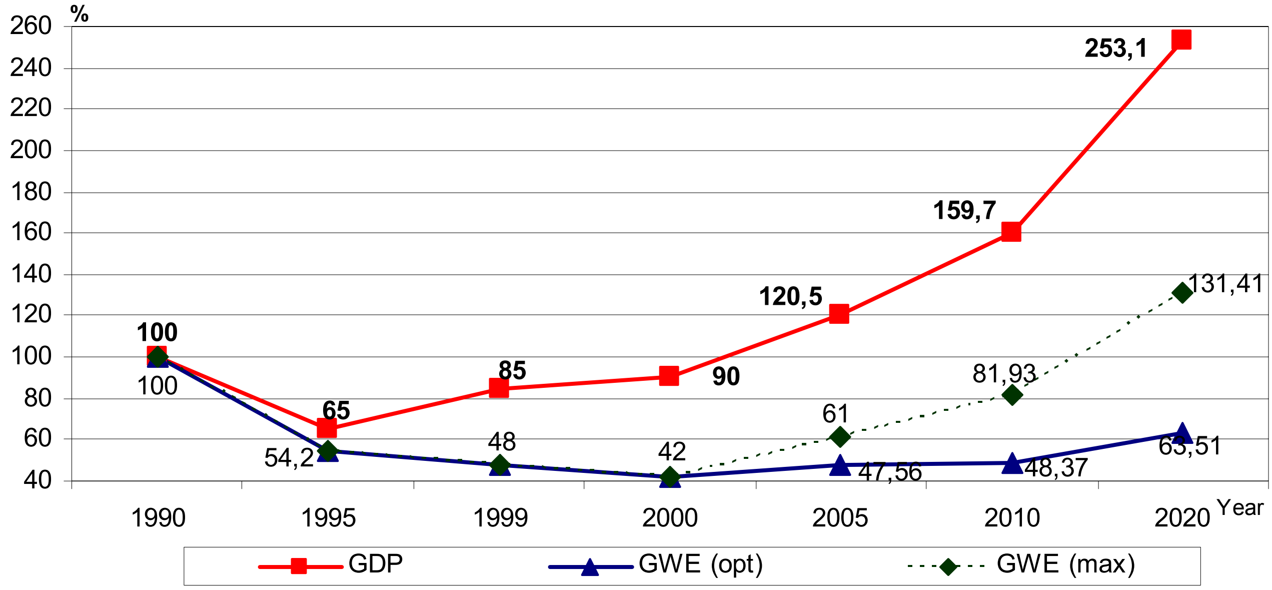


Fig. 1. GDP and GWE dynamics

Table 2 Contribution of Source (Sink) Categories to Aggregate GWE in 2005

Categories of GHG sources and sinks	Emissions, Gg			Emissions of CO_2 equivalent, Gg				Aggregate GWE percentage, %
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	Aggregate GWE	
Energy	52,000	151	0.42	52,000	3,171	130	55,301	96.52
Industrial processes	1,320	1.65	1.0	1,320	34.7	310	1,664.7	2.90
Solvents								
Agriculture	0	337	27.1	0	7,077	8,401	15,478	27.01
Land-use change and forestry	– 18,555.3*	20.67	0.02	– 18,555.3	434.07	6.2	– 18,115.03	-31.62
Waste	0	130	0.76	0	2,730	235.6	2,965.6	5.19
TOTAL	34,764.7	640.32	29.3	34,764.7	13,446.77	9,082.8	57,294.27	100
	Aggregate GWE percentage			60.68	23.47	15.85	100	

* emissions 19,428.7
removals – 37,984
Total: – 18,555.3

Table 3 Contribution of Source (Sink) Categories to Aggregate GWE in 2010

Categories of GHG sources and sinks	Emissions, Gg			Emissions of CO_2 equivalent, Gg				Aggregate GWE percentage, %
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	Aggregate GWE	
Energy	54,496	164	0.46	54,496	3,444	143	58,083	99.68
Industrial processes	1,370	1.68	1.0	1,370	35.3	310	1,715.3	2.94
Solvents								
Agriculture	0	337	26.9	0	7,077	8,339	15,416	26.46
Land-use change and forestry	– 20,082.3*	20.71	0.02	– 20,082.3	434.91	6.2	– 19,641.19	-33.71
Waste	0	117.0	0.770	0	2,457	238.7	2,695.7	4.63
TOTAL	35,783.7	640.39	29.15	35,783.7	13,448.21	9,036.9	58,268.81	100
	Aggregate GWE percentage			61.41	23.08	15.51	100	

* emissions 19,135.9
removals – 39,218.2
Total: – 20,082.3

Table 4 Contribution of Source (Sink) Categories to Aggregate GWE in 2020

Categories of GHG sources and sinks	Emissions, Gg			Emissions of CO_2 equivalent, Gg				Aggregate GWE percentage, %
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	Aggregate GWE	
Energy	71,821	175	0.49	71,821	3,675	152	75,648	98.87
Industrial processes	1,474	1.76	0.98	1,474	37.0	304	1,815.0	2.37
Solvents								
Agriculture	0	336	26.5	0	7,056	8,215	15,271	19.96
Land-use change and forestry	– 18,940.5*	20.85	0.02	– 18,940.5	437.85	6.2	– 18,496.45	– 24.17
Waste	0	96.65	0.791	0	2,029.65	245.52	2,275.17	2.97
TOTAL	54,354.5	630.26	28.78	54,354.5	13,235.5	8,922.72	76,512.72	100
	Aggregate GWE percentage			71.04	17.3	11.66	100	

* emissions 18,686.1
removals – 37,626.6
Total: – 18,940.5

Pessimistic Scenarios of Development
(with the lowest influence of environmental measures)

Table 5 Contribution of Source (Sink) Categories to Aggregate GWE in 2010

Categories of GHG sources and sinks	Emissions, Gg			Emissions of CO_2 equivalent, Gg				Aggregate GWE percentage, %
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	Aggregate GWE	
Energy	93,261	164	0.46	93,261	3,444	143	96,848	98.12
Industrial processes	1,370	1.68	1.0	1,370	35.3	310	1,715.3	1.74
Solvents								
Agriculture	0	385	26.9	0	8,085	8,339	16,424	16.64
Land-use change and forestry	-20,082.3*	20.71	0.02	-20,082.3	434.91	6.2	-19,641.19	– 19.90
Waste	0	148.46	0.770	0	3,117.66	238.7	3,356.36	3.40
TOTAL	74,548.7	719.85	29.15	74,548.7	15,116.87	9,036.9	98,702.47	100
	Aggregate GWE percentage			75.53	15.31	9.16	100	

* – emissions 19,135.9
removals –39,218.12
Total: –20,282.3

Table 6 Contribution of Source (Sink) Categories to Aggregate GWE in 2020

Categories of GHG sources and sinks	Emissions, Gg			Emissions of CO_2 equivalent, Gg				Aggregate GWE percentage, %
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	Aggregate GWE	
Energy	15,0942	175	0.49	15,0942	3,675	152	154,769	97.76
Industrial processes	1,474	1.76	0.98	1,474	37.0	304	1,815.0	1.15
Solvents								
Agriculture	0	393	26.5	0	8,253	8,215	16,468	10.40
Land-use change and forestry	-18,940.5*	20.85	0.02	-18,940.5	437.85	6.2	-18,496.45	-11.68
Waste	0	166.69	0.792	0	3,500.49	245.52	3,746.01	2.37
TOTAL	133,475.5	757.3	28.78	133,475.5	15,903.34	8,922.72	158,301.56	100
	Aggregate GWE percentage			84.32	10.04	5.64	100	

* – emissions 18,686.1
removals –37,626.6
Total: –18,940.5

PART IV. ASSESSMENT OF VULNERABILITY, CLIMATE- CHANGE IMPACT AND ADAPTATION MEASURES

1. AGRICULTURE OF BELARUS

1.1. Prospects of Agribusiness Development in the Republic of Belarus

Prospects of the Belarusian agribusiness sector (AB) development for the near 10-year period have been reviewed in a number of forecasting documents [1-3].

According to [1], the AB development trends in the forecasting period would be as follows:

1. Dynamic growth in AB output of products as a whole and per capita.

2. Stabilization of production at the following levels by 2015: grain – 9–10.5 mln tonnes, potato – 11–12 mln tonnes, vegetables – 1.3–1.6 mln tonnes, milk – 7.5–8.5 thou tonnes, meat (deadweight) – 1.0–1.2 mln tonnes, fiber flax – 110–120 thou tonnes.

3. Reaching rational population nourishment standards balanced in terms of most important food components (the daily energy content of the diet is to be increased up to 3,500 Kcal, i.e. by 12% against the existing level).

4. Relative decrease in the share of AB products import by increasing export, thereby reaching the export-import ratio of 2:1.

5. Growth in the AB gross output by 30% compared to the 1990 level and that of agricultural produces – by 40–65%.

Two options of the AB sectors development have been substantiated based on trends and predicted conditions. Option 1 (inertial) is the forecast of the output of agricultural produces being adequate to the condition of the domestic food market, provided that the current tendency of the population effective demand is maintained. Option 2 (targeted) provides for the growth in output till the food products to the population are supplied according to medical standards, while the AB export orientation is being accounted.

The most critical AB target for the short-term period (up to 2005) is to ensure the food security of Belarus. The output of major types of agricultural produces in 2005 is to be as follows: grain – 7.3 – 7.5 mln tonnes, potato – 9–10 mln tonnes, sugar beet – 1.7–2.0 mln tonnes, vegetables – 1.4–1.5 mln tonnes, flax fiber – 85–90 thou tonnes, rape seed – 155–175 thou tonnes, fruits – 500–650 thou tonnes, milk – 5,900–6,000 thou tonnes, meat (live weight) – 1,180–1,200 thou tonnes, eggs – 3.7–3.8 bln pcs. [3].

The sector prioritizes, first of all, the development of animal husbandry, flax, grain, sugar beet and vegetable oil subsectors. Growth priorities are as follows: producing flax, food wheat, rape, tritikale for compound feed, programs *Sugar, Vegetable Oil* and *Baby Food*; maintaining large-scale highly effective production in the form of collective farms, state farms, interfarms and processing/servicing enterprises; governmental market regulation; further developing established specialization; reforming land relations, supporting the development of the market and its infrastructure; and supporting irrigation projects, recultivation of lands and encouraging private farms development [2].

The IPCC last (third) Report [4] provides evidence that the global greenhouse effect would entail unprecedentedly rapid climate changes in the XXI century which will substantially effect all subsectors of the economy. Undoubtedly, among the sectors, the agricultural sector is most climate-sensitive. It is noted in the Report that concepts of agrarian sector sustainable development are formulated without due regard to the rapidly changing global climate. The opinion of stability of the current landscape and climate state prevails among the practician economists, while findings of the studies provide evidence that the countries and economic structures, which would be capable of adequate adaptive restructuring to meet expected environmental changes, would benefit under conditions of rapidly changing climate [4].

Existing assessments of climate change-related effects in the agriculture are based on future climate scenarios, developed primarily through global climatic models (GCM), as well as on their agroclimatic interpretations using methods of statistical and simulation modeling.

In setting the observed changes in the GHG and sulfate aerosols content for the XX century, the best GCM efficiently reproduce positive secular trends of surface air temperature [5]. They include the models developed in the Climate Research Center (Hadley, Great Britain). This fact and also results of examinations conducted to choose the best GCM for Belarusian conditions [6] allowed the Hadley Climatic Research Center's GCM (*HADCM2* and *HADCM3* versions) to be chosen as the main research models. The first forecasting assessments of agroclimatic conditions in Belarus are based on implementing the *GFDL* (USA) and *CCC* (Canada) models. Specific results of calculations based on these scenarios are also provided in this Report [7-10].

Expected agroclimatic indicators based on the HADCM3 scenario for Belarus using the simulation CLIMATE – SOIL – YIELD system have been calculated by O.D. Sirotenko, E.V. Abashina and V.N. Pavlova in the Russian Agricultural Meteorology Research Institute (Obninsk). That system was used for similar calculations to prepare the RF National Communications on Climate Change.

1.2. Change in Agroclimatic Conditions

Forecasting studies of agroclimatic indicators have been recently conducted by the Institute of Natural Resources Utilization and Ecology of the National Academy of Sciences of Belarus (INRUE NASB). They are based on regionalization of the *HADCM2* model-produced climatic scenario and on regression dependencies of different agroclimatic indices on monthly mean air temperature over the base observation period [11, 12].

Assessments for the 2010-2039 period show the increase in the total temperature above 0.5 and 10 °C approximately by the same value – 200–220 °C. The increment in the total temperature above 15 °C is substantially higher and more strongly expressed in the northerly located Minsk (387 °C) than in southerly located Vasilevichy (294 °C).

Of specific interest is the forecast assessment of wetting conditions for which the Selyaninov hydrothermal factor (HTF) was selected to characterize it. The values of index of HTF<0.7 characterize extremely dry conditions. Knowing calculated estimates of the shift of dates of transition through 10 °C and changes in respective total temperature and also model estimates of predicted monthly mean precipitation, it is easy to assess HTF changes corresponding to them. Preliminary calculations show that as both total temperature and precipitation increase in Belarus, the overall decrease in HTF values by 0.2–0.3 units may be expected that will allow Belarus to remain in the zone of sufficient wetting [11, 12].

First forecast assessments of the change in agroclimatic indicators in Belarus for the (USA) *GFDL* scenario of 2 x CO_2 have been obtained in terms of the FSU economic regions [13]. Agroclimatic changes implied the increase in the vegetation period by 54 days, in total active temperature by 1088 °C, moisture deficiency by 0.8 and decrease in HTF by 0.04.

The recent studies of O.D. Sirotenko et al. allowed for obtaining estimates of agroclimatic indicators for current and expected climate of Belarus for different periods of the XXI century, if the *HADCM3* model is realized. Table 1.1 contains forecast estimates for major agroclimatic indicators Oblast-wise for the 2020–2029 period. They are characterized by the vegetation period duration (N), heat availability (January temperature – T_1 and July temperature – T_7), total temperature for a period with a temperature above 5 ° and 10 °C (ΣT>5 °C and ΣT>10 °C), mean temperature for the given period (TS), moisture availability (total precipitation – R), HTF, evaporation and evaporating capacity over the warm period of the year (evapotranspiration (EVT) and potential evapotranspiration (PEVT).

As Table 1 shows, the growth in thermal resources is primarily expected in Belarus. The July air temperature will increase by 1.0–1.3 ºC by 2020-2029. Winter temperatures are expected to increase more significantly. January mean temperature will increase by 2.5–2.9º C compared to the current level. Increase in air temperature will be accompanied by the increased duration of the frost-free period and plant vegetation (period with a temperature above 5 ºC). Table 1.1 contains predicted vegetation period changes (N).

Table 1.1 Change in Agroclimatic Indices in Case *HADCM3* Scenarios are Realized

Oblast	TS	ΣT> 5 °C	ΣT> 10 °C	N	R, mm	PEVT, mm	EVT, mm	HTF	T_7	T_1
Absolute indices of modern climate										
Vitebsk	13.1	2,432	2,081	187	417	569	521	1.73	17.6	-7.4
Grodno	13.2	2,610	2,217	198	430	677	595	1.64	17.7	-5.5

Minsk	13.2	2,528	2,175	192	418	627	555	1.66	17.9	-6.7
Mogilev	13.6	2,545	2,214	188	405	608	511	1.62	18.2	-7.5
Brest	13.7	2,755	2,394	202	434	659	612	1.55	18.3	-5.4
Gomel	13.9	2,738	2,371	198	420	718	610	1.54	18.5	-6.6
Absolute deviations of indices, 2020–2029										
Vitebsk	1.1	398	462	14	14	62	34	-0.31	1.0	2.9
Grodno	1.3	371	492	10	27	53	35	-0.28	1.3	2.5
Minsk	1.2	387	451	12	23	62	40	-0.26	1.2	3.0
Mogilev	1.1	447	484	17	3	46	27	-0.39	1.2	2.9
Brest	1.1	364	456	11	36	101	98	-0.24	1.3	2.5
Gomel	1.0	421	522	16	6	7	-3	-0.39	1.2	2.9

The expected increase in these indices by 5–8 days over a decade is favorable for the agriculture. As is known, a comparatively short vegetation period in Belarus leads to lower quality of field works and lower efficiency of agricultural machinery use. Longer vegetation period increases productivity of hay-fields and pastures, thereby leading to higher efficiency of animal husbandry due to increase in forage resources and decrease in indoor maintenance of cattle.

Given the thermal conditions or total temperature above 10º C, the area of Belarus is divided into four zones located latitudinally – from cool (with total temperature less than 2,000 ºC) to the warmest (with total temperature exceeding 2,400 ºC). Table 1.1 shows that total temperature is expected to increase by 450–500 ºC in 2-3 decades to exceed the current difference in 400 ºC between northern and southern regions of Belarus.

Therefore, after 2–3 decades, provided that the climate-warming scenario in question is realized, heat availability of agricultural crops in the cool zone in the north-east would exceed the heat availability level of the current warmest zone in the country. As regards southern regions, their agroclimatic heat availability analogs should be looked for 450-500 km southward 20-30 years later, that is, in the current Ukrainian forest-steppe.

The data on the expected increase in temperature (above 10 ºC), provided in Table 1.2, may be used for forecasting possible changes in the species composition of agricultural crops, if warming continues.

Table 1.2 Temperature Availability for Ripening or Reaching Economically Valuable Phases of Plant Development

Total temperature above 10 ºC over the period	Crop
400	Vegetable crops in protected ground
400	Garden radish, lettuce, spinach, salad onion
800	Garden turnip, turnip, cabbage (er), potato (er) using special farming techniques
1,000	Barley (er), winter rye (er), in warmer areas
1,200	Barley (er), peas (er), flax for fiber
1,400	Oat (er), barley (mr)
1,600	Barley (lr), spring wheat (er), winter wheat, corn (mr) in tassling phase, sugar beet for

	feed
1,800	Spring wheat (lr), sunflower for grain (er), sugar beet for sugar processing
2,200	Corn for grain (er), bean (er), millet (lr)
2,400	corn (mr) in milk-wax stage of ripeness (er), soya bean (er), grape (er)
2,500	Apricot (er), bean (lr), sunflower (lr) for grain, rice (er)
2,800	Corn for grain (mr), corn (lr) in milk-wax stage of ripeness, sorghum (er)
3,000	Corn for grain (mr), grape (mr)

er- early ripening
mr- mid ripening
lr – late ripening

Let us consider possibilities of this approach using Brest Oblast as an example. Currently, the total temperature above 10 ºC in this Oblast are 2,394 ºC. According to Table 1.2 data, total temperature of about 2,400 ºC allows wax ripeness of mid ripening corn varieties to be reached in 90% of cases, if timely sown. The total temperature (above 10 ºC) in Brest Oblast would amount to 2,850 ºC 20-30 years later that would allow for seeding without limitation mid ripening varieties of corn for seed, bringing late ripening varieties of that crop to milk-wax stage of ripeness, and also seeding early ripening varieties of sorghum and late ripening varieties of sunflower.

Increase in heat availability supplemented by sufficiently efficient area wetting in general may be used to introduce more heat-loving varieties (hybrids) and species of agricultural crops which, as a rule, are also characterized by higher productivity. Specific calculations need to be made to identify possibilities of expanding areas for such valuable crops as sunflower, sugar beet, soya bean, if warming continues.

According to Table 1.1 data, a universal increase in potential (PEVT) and, to a lesser degree, actual evaporation (EVT) is expected. The increased gap between these two indicators provides evidence of a possible increase in dryness degree (aridity) in Belarus during global warming. The expected universal decrease in Selyaninov HTF is also an explicit evidence.

1.3. Change in Agroclimatic Potential

In assessing agroclimatic resources of Belarus an its regions, A.N. Vitchenko (1996) considered four randomly set climatic scenarios reflecting (in relation to the climatic normal), on the one hand, increase in total precipitation against the background of cooling and, on the other hand, their decrease against the background of warming (Table 1.3) [14].

Table 1.3 Possible Scenarios of Climate Change in Belarus

Indicator	Scenario			
	I	II	III	IV
Air temperature, °C	-1.0	-0.5	+0.5	+1.0
Precipitation, %	+20	+10	-10	-20

Given the analysis of assessment of the climate change in Belarus, the scenario of air temperature increase by 1 °C and precipitation decrease (already observed in the central and southern part of

Belarus) is dangerous. For this variant of numerical experiment, the yield may decrease for cereal crops by 4–16%, potato by 8–20% and fiber flax by 16–26%. The exception is northern areas (Poozerie province landscapes) where cropping of winter cereal crops may lead to a slight increase in yield by 1-2% defined mainly by the improved thermal regime of the vegetation period (Table 1.4).

If air temperature is likely to increase, conditions for cultivating winter cereal crops in landscapes of Poozerie and Central Upland province will improve. In Sub-Polessie and eastern provinces they would remain close to long-term average conditions, and in Polessie province they would deteriorate and lead to lower productivity of these crops.

The increase in air temperature would lead to a higher discrepancy between stress of thermal regime of the vegetation period of barley and potato and, to a larger extent, of fiber flax and requirements of development of the given crops and would reduce their productivity in all Belarusian regions.

Increasing precipitation with decreasing air temperature leads to lower productivity of all crops (up to 10–15%, scenario I, Table 1.5) [14].

Table 1.4 Predicted Change in Yield of Major Agricultural Crops, %

Crop	Landscape province					Belarus
	Poozerie	Central Upland	Sub-Polessie	Eastern	Polessie	
Wither rye	101.3	94.0	91.2	92.9	85.6	93.2
Winter wheat	100.1	93.7	90.8	92.6	85.9	92.8
Spring barley	95.1	93.2	90.1	91.0	87.3	91.5
Potato	90.0	86.0	83.2	94.0	81.3	93.8
Fiber flax	82.5	78.7	73.1	74.7	66.9	75.5

Table 1.5 Change in Yield for Different Climatic Scenarios, %

Scenario	Oblast					
	Vitebsk	Mogilev	Minsk	Grodno	Brest	Gomel
Winter rye						
I	84	85	84	83	85	86
II	90	90	90	90	91	91
III	103	101	101	102	101	101
IV	110	105	106	108	106	104
Winter wheat						
I	86	87	86	86	88	88
II	93	94	92	92	92	94
III	106	102	103	105	103	103
IV	113	106	108	111	108	106
Spring barley						
I	84	88	88	87	87	88
II	94	96	96	96	95	97
III	109	105	106	107	102	104
IV	116	110	111	112	107	109
Potato						
I	90	90	91	92	91	88
II	97	96	97	98	97	94
III	114	109	109	111	109	105
IV	122	114	114	118	114	109

On the contrary, warming and reduced precipitation lead to some improvement of agroclimatic conditions of grain and potato cultivation, thereby increasing their yield by 5% -10% and 9% - 22%, respectively. However, a slight decrease in precipitation may lead to higher frequency of dry spells that would condition yield reduction.

Forecast assessment of the change in the bioclimatic potential (BCP), or according to other terminology, primary biological productivity implying the total productivity of dry above-ground biomass of the grass agroecosystem for a period of a year with a temperature above 5 °C based on implementing (USA) *GFDL* model for the scenario of $2xCO_2$ for Belarus have been made by O.D. Sirotenko (1991) in terms of economic regions of the former Soviet Union [10]. In this case, the BCP growth has been predicted by 7% with the current soil background and by 15% with an optimum mineral nutrition or sufficient level of moisture availability and by 16% for combination of two latter regimes. Agroclimatic changes imply the increase in the vegetation period by 54 days, total active temperature by 1,088 °C, moisture deficiency by 0.8, and decrease in HTF by 0.04. The increase in winter temperatures by 6.8 °C and summer temperatures by 3.1 °C is expected according to the $2\times CO_2$ scenario for the European territory of the FSU.

Current assessments of Belarusian arable land BCP under global warming according to *HADCM3* scenario are provided in Table 1.6. The undermentioned trend which may be of critical importance for the agricultural sector development emerges. According to the Table 1.6 data, arable land productivity with a highly intensified farming, i.e. Application of fertilizers and ameliorants in large quantities, would grow under climate warming. On the contrary, land productivity would decrease under climate warming, if fertilizers and ameliorants are applied at a low level. BCP values would substantially fall at low-level farming intensification (nearly by 11%). The data in Table 1.6 may be interpreted as follows: in case of climate warming under the scenario in question, fertilizer efficiency will grow in the Republic of Belarus.

Table 1.6 Change in Bioclimatic Potential of Arable Land and Climate-Dependent Yield of Cereal Crops for *HADCM* Scenario

Oblast	Current mineral nutrition level				Sufficient mineral nutrition and moisture availability level			
	BCP		CDY		BCP		CDY	
	Climate	2020–2029	Climate	2020–2029	Climate	2020–2029	Climate	2020–2029
	cwt/ha	Relative deviation, %			Cwt/ha	Relative deviation, %		
Vitebsk	63.1	-1	20.1	-4	141.9	4	46.9	-11
Grodno	77.1	-7	26.1	-3	149.4	3	47.8	-8
Minsk	78.1	-1	26.5	-2	148.7	3	48.5	-7
Mogilev	59.1	-6	20.6	-6	147.5	4	45.9	-12
Brest	88.7	3	25.3	-7	156.8	5	48.7	-9
Gomel	72.9	-11	20.7	-6	156.7	4	47.5	-14

Table 1.6 also contains the data characterizing possible changes in climate-dependent yield (CDY) of cereal crops with climate warming. Calculations based on dynamic models of the cereal crop

productivity validate, first of all, available data on high efficiency of farming chemicalization in Belarus – the yield may be increased from 20 – 26 to 46 – 49 cwt/ha, i.e. nearly 2-fold by optimizing conditions of mineral nutrition. However, both with low and high level of the farming technique, the yield would decrease with climate warming under the *HADCM3* scenario. The cause of the yield drop is the reduced vegetation period (accelerated ripening) due to higher thermal background. The above factor-related drop in yield of spring cereal crops may be prevented to some extent by selecting earlier sowing dates and/or by changing over to more late ripening varieties capable of more efficiently using increased heat resources.

O.D. Sirotenko et al. believes that using single climate-change scenario (even if it was calculated based on the GCM that proved itself to be efficient) is far from being sufficient to make informed conclusions. The need of continuing calculations using the simulation CLIMATE-SOIL-YIELD system for other scenarios is underlined that would significantly increase the estimates accuracy. (USA) *GFDL* scenario-based calculation results are provided in Table 1.7.

The data in the left side of Table 1.7 are comparable with the data for CDY in Table 1.6 by the CO_2 and soil fertility level. Differences between scenarios may be recognized as significant in the near decades. According to *GFDL* scenario, the increase in climate-dependent cereal crop yield (by 20%) in the early global warming period is expected. However, given that the expected yield growth is extremely low (only 1-3%) in the Baltic States and Ukraine, the result for Belarus may be related to some random causes. This conclusion is convincing due to one more fact that increase in the yield would be followed by decrease in the future, and estimates of the reducing yield for Belarus and Baltic State become nearly similar (see left side of Table 1.7).

Table 1.7 Expected Change in Yield (in % of Base Level) of Cereal Crops under *GFDL* Scenario Accounting for and without Accounting for Increase in CO_2 Content in Atmosphere

Country, region	Without accounting for CO_2			Accounting for CO_2		
	Forecasting period, years					
	30-40	60-70	90-100	30-40	60-70	90-100
Russia	-1	-5	-23	11	14	-1
Baltic States	3	-5	-4	16	14	21
Belarus	20	-3	-8	33	15	16
Ukraine	1	-13	-27	10	0	-11
Moldova	-4	-26	-41	3	-14	-28
Kazakhstan	-16	-22	-44	-6	-6	-25

The role of the observed CO_2 increase in atmosphere is of importance. It has been recognized that without accounting for a direct effect of the increased atmospheric CO_2 concentration on plants, it is not possible to make real assessments of the impact of greenhouse effect-induced expected change in the agricultural efficiency. The Table 1.7 data confirm the significance of accounting that factor. The positive effect of CO_2 enrichment completely (or even excessively) compensates possible drop in the yield induced by climate warming in Belarus under *GFDL* scenario (see Table 1.7). It may be presumed that the conclusion will be also similar for *HADCM3* scenario.

1.4. Belarusian Farming Adaptation to Climate Change

The above mentioned changes in main agroclimatic characteristics necessitate development of respective orderly actions of farming adaptation. These actions should be based on appropriate research supported by the Government in various forms (direct funding, grants, loans, etc). The farming strategy accounting for new agroclimatic conditions needs to be formulated. Research should encompass all farming subsectors from determining optimum terms of land treatment to culling and selecting optimum varieties meeting new conditions.

The following circumstance need to be taken into account:

- Major losses in the agricultural sector are related to the effect of hazardous weather events, such as dry spells, frosts, showers, hail, etc. Grounds are available to presume that increasing mean annual air temperature would increases frequency of extreme levels of heat and moisture that would adversely effect the development of agricultural crops. The reduction in yield of major agricultural crops due to unfavorable weather conditions may reach 50-60% and even higher in specific years. The yield drop (specifically of spring cereal crops) is caused, primarily, by dry spells.

- Increasing risk degree in the agricultural sector due to climate aridization would reduce the spring-summer period of sufficient moisture availability and deteriorate vegetation conditions.

- Irrigation farming technology is used at extremely low scale in the country.

- Prevalence of light (sandy and sandy-loam) soils in the south of the country under conditions of warming and climate aridization may require extremely costly interventions to adapt the agricultural sector and challenge its profitability in specific areas and regions.

Development of strategies of adaptation to climatic changes is based on a number of agreed objectives and assessment principles. The most common objectives are support to sustainable development and reduction in vulnerability. They are specified in each of the problems. Determining most critical climatic impacts implies distinguishing positive and negative effects related to them to subsequently choose adaptation actions. To identify units of impact under climate changeability-related risk, vulnerability is assessed. It is determined as a level at which the unit of impact discontinues or unfavorably changes. Vulnerable systems, activity, and regions are considered as objects of planned adaptation.

Identifying the adaptation strategy includes making a detailed list of possible adequate responses directed at negative and positive climatic effects. Six types of adaptation strategies are identified: prevented losses, assumed losses, spreading (distributive) losses, change of use or activity, and restoration of the initial state.

Four groups of strategies are distinguished, namely, long-term, tactical, unforeseen circumstances and analytical strategies.

The adaptation activity includes such procedures as study on limitations, determination of quantitative actions and formulation of alternative strategies, weighting of problems and assessment of increments, and recommended measures.

The system of adaptation to climatic events and changes, as well as to natural and technogenic emergencies and catastrophes has formed in the country and satisfactorily functions. Under the moderate continental (transitional) type of climate, adaptation to climatic changes proceeds in the forms of autonomous adjustment at the levels of intrinsic day-to-day and tactical response of agriculture to the weather change and extremely dangerous phenomena. This sphere is regulated to a large extent by normative documents.

In conclusion, major spheres of the Belarusian agricultural sector adaptation need to be specified:

- further farming intensification, namely, use of higher doses of fertilizers and other chemicalization agents supported by deep soil reclamation, given the fact that climate warming enhances efficiency of measures aimed at increasing soil fertility;

- introduction of more late ripening varieties (hybrids) more efficiently using increasing thermal resources of an area;

- expansion of postharvest (postcut) crops to utilize additional heat resources;

- expansion of areas of new (or currently cultivated on limited areas) highly effective crops (millet, corn, sunflower, soya bean, sugar beet, etc.) corresponding to agrometeorological conditions formed in the recent decade;

- selection of species and variety composition for new to be planted horticultural plantations with due regard to climate change trends (reduction in probability of tree frost injury, longer vegetation period, etc.).

According to estimates of BelRI [15], the Republic of Belarus may meet its requirements in food, fodder and industrial grain, provided that cereal and leguminous crops are sown on an area of 3-3.1 million ha in all categories of farms, including 2.6-2.7 million ha in state-owned farms, and 48-50/50-52 cwt are harvested respectively per ha of arable land. The areas of specific crops are economically substantiated for the farms: winter rye – 730-750 thousand ha, winter wheat – 250-280 thousand ha, spring wheat – 100-120 thousand ha, barley for various processing purposes – 700 thousand ha, oat – not more than 300 thousand ha, tritikale (mainly winter) – 100-110 thousand ha, buckwheat – 45-50 thousand ha, leguminous – 350-400 thousand ha. The grain shortage problem of Belarus may be solved by cultivating early ripening varieties of corn with the yielding capacity of 40-50 cwt/ha of grain. The needs of Belarus amount to 300-400 thousand tonnes of fodder grain and 75-100 thousand tonnes of seed. To reach these objectives, the corn areas for seed production need to be increased up to 100 thousand ha.

To meet the needs of the Belarusian textile industry for flax raw materials and for export, sown areas of the fiber flax need to be increased up to 110-120 thousand ha with fiber flax yielding capacity of 10-12 cwt/ha. Obtaining stable yields of sugar beet in the range of 300-350 cwt/ha, with sown areas limited to 50 thousand ha, would allow sugar refineries to be loaded with the increment in their capacity by 10-15%. The needs for oil raw materials require rape sown areas be expanded up to 100 thousand ha with the yielding capacity of 15-20 cwt/ha of seeds. Given the rising market demand in potato from cities and industrial centers of Russia and other CIS countries, it is economically justifiable to increase its sown areas up to 120-130 thousand ha, with an average yielding capacity of 200-220 cwt/ha.

It is suggested to allocate 2,100-2,200 thousand ha of the arable land for fodder crops (except fodder-grain crops), including 100 thousand ha – for root crops, 250 thousand ha – for silage corn and green fodder, 550 thousand ha – for annual grasses and ensilage crops (without corn), 1,200-1,300 thousand ha – for perennial grasses.

2. FORESTRY AND FOREST ECOSYSTEMS

2.1. Climate Impact Assessment

Problem Definition. Assessment Objectives. The objectives of the Section are as follows:

- assessing effects of the climate change on the forest cover in Belarus (its composition, productivity, carbon removals from atmosphere, resource potential, forest socially significant and protective functions), and also on the forestry management over the period up to 2050;

- identifying actions aimed at adapting the sector (forestry) and related sectors of the national economy to the climate change.

Research Field. The fields of research are as follows:

- areas of the State Forest Fund of the Republic of Belarus covering 9,247.5 thousand hectares as of 01.01.2001, or 44.5% of the total country's area;

- forestry as a sector of the national economy and a component of its forest products industry.

Time Framework. 1980; 1990-2000 – base period;

2000; 2030-2050 – the period under review; the assessment interval - depending on an interval of the long-term sectoral planning and/or a step of model assessments.

Requirements to Data. The forest fund composition, structure and dynamics should be assessed based on the State Forest Resources Inventory's data, while long-term assessment should capitalize on the sectoral (forestry) strategic planning data and also the model-based assessment of the climate dynamics in the area, with adaptation actions being accounted.

Method Selection, Application of Models. Models (biophysical and mathematical, integrated system models) are applied to forecast climate change parameters being essential for forest ecosystems and forestry. Results of empirical and statistical modeling of carbon content dependencies are used to assess carbon content, phytomass volume, photosynthesis-related removals of carbon from atmosphere, or otherwise its emissions to atmosphere caused by forest fires and mortmass organic matter decomposition. Unique productivity models are not used, since the respective complex of methods is sufficiently developed [1]. To assess the change in the daily variation in temperature underneath the forest canopy, the hydrodynamic model of meteorological elements has been used [2].

Impact Forecast. The forecast is made based on the accepted formal forecasts [3], [4], State Forest Fund Inventory's data and also silvicultural and prognostic, climatogenic and chorologic and phenological estimates and data [5, 7], and our own findings.

Selection of Scenario, Current Situation Assessment. Lands of the State Forest Fund (SFF) of the Republic of Belarus covered an area of 9,247.5 thousand hectares as of 01.01.2001, or 44.5% of the country's area. Of this, 7,591.8 thousand hectares (82.1%) are under the authority of the enterprises of the Forestry Committee (FC) of the Belarusian Council of Ministers. The remaining area of the forest fund is under the authority of different ministries and departments: Ministry of Defense (MOD) (3.7%), Ministry of Agriculture and Food (MAF) (3.8%), Ministry for Emergency (ME) (2.3%), Ministry of Education (MOE) (0.3%), and National Academy of Sciences of Belarus (NASB) (0.4%). The Administration of Affairs of the President (AAP) of the Republic of Belarus is in charge of national parks, Berezinsky Biosphere Reserve and experimental forest game hunting (area totaling 647.1 thousand hectares, or 7.0%). Local authorities manage 0.3% of the forest fund area - predominantly forest parks (Table 2.1). The FC total area of the forest fund amounted to 7,990.8 thousand ha as of 01.01.2002. Transferring lands from the MAF and MOD resulted in that increase.

A forest-free area includes forest fund areas not designated or unsuitable for silviculture (hayfields, water bodies, swamps, forest roads, clearances, sands, etc.). Forest land includes land designated for silviculture, namely, stocked forest and unstocked forest areas such as felled areas, burns, free-growing stands, perished stands, open stands and glades. These unstocked forest land is of critical importance in terms of reforestation and carbon storage, since it is a potential reservoir for storing removed atmospheric carbon. Swamps accounting for a significant share (497.6 thousand ha, or 5.4%) of the SFF land also play an extremely important role in terms of biospheric functions.

The total stem-wood resources in Belarusian forests are estimated at 1.34 billion m^3, including the stock of mature and overmature stands amounting to 137.15 million m^3 (or 10.2% of the total forest stock), of which coniferous species stands (common pine and European spruce) account for 63.17 million m^3, or 46.1% of the mature forest stock (Table 2.2, 2.3). The respective estimates of carbon stock in phytomass of SFF lands are given in Table 2.4.

Trend Forecast in the Absence of Climatic Changes. The current change in the forest stock is made up of the photosynthesis-related increment rate less the drain resulting from all types of cutting and tree death either natural (natural mortality) or due to anthropogenic and natural disasters such as fires, wind-induced windfalls and windbreaks (squalls, tornadoes, hurricanes), mass pest propagation and forest diseases, forest flooding and inundation, etc.

According to estimates of V.F. Baginsky and L.D. Esimchik [5], on the average, the basic (annual) increment rate of the stem wood is 6.3 m^3 per 1 ha of forested land, while mean drain is 1.8 m^3 /ha/year, i.e. mean basic change in the stock is 4.5 m^3 per hectare. As a result, the annual wood increment in Belarusian forests amounts to 35.3 million m^3. Given the average annual forest harvesting volume, which has been estimated at 10.2 million m^3 over recent years, the total basic change in forest stock is 25.1 million m^3.

The trend forecast of the timber resources and carbon stock, respectively, in the Belarusian forest fund is based on the following main principles:

- forest age-structure optimization: reaching approximately equal area ratio in each age class - somewhat over 20%, with the share of mature and overmature stands being about 15%;
- accumulation of wood in the forest fund due to incomplete use of growth (Table 2.5);
- change in the ratio of species in the forest fund composition by increasing the share of most economically valuable forest-forming species: pine, spruce, oak;
- increase in the area of stocked forest land through reforestation of unstocked forest land transferred from other users;
- reforestation of open stands, burns, cutover patches, glades, etc;
- annual loss of a fraction of the forest to fires and other natural and anthropogenic disasters.

Table 2.1 Structure of Lands of State Forest Fund of the Republic of Belarus (as of 01.01.2001)

Categories of forest fund lands	Total	Forest fund owners, including:							
		FC	MOD	MAF	AAP	ME	Local authorities	MOE	NASB
Total area of forest fund lands, thou ha	9,247.5	7,591.8	342.8	347.2	647.1	216.2	35.3	27.1	40.0
Forest lands, thousand ha:	8,275.7	6,880.5	224.1	337.4	542.2	196.1	33.2	25.3	36.9
- stocked forest land, thou ha	7,851.1	6,572.8	214.8	333.9	526.8	110.4	32.3	24.5	35.6
including mature and overmature stands, thou ha	623.0	506.5	22.4	14.8	69.8	2.9	0.4	1.4	4.8
- unstocked forest land, thousand ha;	424.6	307.7	9.3	3.5	15.4	85.7	0.9	0.8	1.3
Forest-free land, million ha;	971.8	711.3	118.7	9.8	104.9	20.1	2.1	1.8	3.1
Stem wood resources, million m^3	1,339.85	1,134.37	29.99	42.88	98.40	13.32	8.25	4.69	7.95
including in mature and overmature forest, million m^3	137.15	110.09	4.34	2.33	18.58	0.08	0.12	0.33	1.28

Table 2.2 Wood and Carbon Stock in Phytomass of Stands of Prevailing Tree Species in Belarus and Their Distribution by Age Classes as of 01.01.2001

Prevailing species	Subtotal, mln m^3	Average stock, m^3/ha	Stock (mln m^3) by age classes								Carbon stored in stands, million tonnes					
			Young stands		Middle-aged	immature	Mature and overmature		Average change in stock	Average age, year	Young stands		Middle-aged	immature	Mature and overmature	Subtotal
			I class	II class			total	Including overmature			I class	II class				
Pine	738.16	187.3	7.84	109.31	383.11	185.09	52.9	2.76	14.03	54	2.7283	30.3882	108.8032	56.6375	15.4997	214.0570
Spruce	167.89	213.1	4.21	17.79	87.49	48.17	10.23	0.1	3.06	52	1.7472	5.9419	26.5970	16.1370	3.2327	53.6556
Oak	43.23	164.9	0.83	4.55	21.14	7.84	8.87	0.84	0.67	66	0.4291	1.6744	7.9275	3.1438	3.4504	16.6253
Hornbeam	2.27	183.1		0.01	1.79	0.23	0.24	0.1	0.02	51	0.0000	0.0037	0.6713	0.0922	0.0934	0.8605
Ash	5.12	179.6	0.12	0.68	3.67	0.46	0.19		0.07	53	0.0620	0.2502	1.3763	0.1845	0.0739	1.9469
Maple	0.5	357.1	0.02	0.39	0.05		0.04		0.01	34	0.0103	0.1435	0.0188	0.0000	0.0156	0.1882
Elm	0.01	100.0			0.01					49	0.0000	0.0000	0.0038	0.0000	0.0000	0.0038
Birch	232.83	142.6	3.07	10.08	134.06	61.37	24.01	0.38	5.77	38	1.5872	3.7094	50.2725	24.6094	9.3399	89.5184
Aspen	27.39	164.5	0.43	2.03	4.16	7.08	13.69	2.01	0.68	33	0.1690	0.5481	1.1232	1.9753	3.3951	7.2107
Spreckled alder	21.18	118.7	0.19	2.15	8.61	8.12	2.11	0.02	0.66	28	0.0982	0.7912	3.2288	3.2561	0.8208	8.1951
Black alder	97.7	151.1	0.86	4.37	41.49	27.32	23.51	1.57	2.42	38	0.4446	1.6082	15.5588	10.9553	9.1454	37.7122
Lime	0.27	192.9			0.23	0.01	0.03	0.02		50	0.0000	0.0000	0.0863	0.0040	0.0117	0.1019
Poplar	0.41	227.8	0.01	0.01	0.06	0.22	0.11			35	0.0039	0.0027	0.0162	0.0614	0.0273	0.1115
Willow	0.43	43.4	0.12	0.13	0.14	0.04			0.03	18	0.0472	0.0351	0.0378	0.0112	0.0000	0.1312
Other	0.02	40.0		0.01	0.01					23	0.0000	0.0037	0.0038	0.0000	0.0000	0.0074
Shrub	2.11	11.8	0.23	0.24	0.43	0.1	1.11	0.05	0.74	4	0.0904	0.0648	0.1161	0.0279	0.2753	0.5745
Total	1,339.52	2,477.9	17.93	151.75	686.45	346.05	137.04	7.85	28.16		7.4174	45.1651	215.8410	117.0956	45.3812	430.9002

Table 2.3 Areas Covered by Stands and Carbon Stocks in Underwood Phytomass by Prevailing Forest Formations in Belarus as of 01.01.2001

Prevailing species	Area, thou ha					Underwood carbon, mln tonnes					
	Young stands		Middle-aged	immature	Mature and overmature	Young stands		Middle-aged	immature	Mature and overmature	Subtotal
	I class	II class				I class	II class				
Pine	262.0	859.4	1,793.7	794.5	230.3	0.2358	0.5586	1.3457	2.1524	0.9931	5.2856
Spruce	109.6	142.7	335.2	164.8	35.7	0.0658	0.0928	0.1766	0.4190	0.3626	1.1168
Oak	27.2	49.5	112.0	36.0	37.5	0.0082	0.0173	0.0307	0.0392	0.0126	0.1080
Hornbeam		0.3	9.9	1.3	0.9	0.0000	0.0001	0.0001	0.0035	0.0005	0.0042
Ash	3.2	5.9	17.6	1.2	0.6	0.0010	0.0021	0.0036	0.0062	0.0004	0.0133
Maple	0.9	0.2	0.3			0.0003	0.0001	0.0004	0.0001	0.0000	0.0009
Elm		0.1				0.0000	0.0001	0.0000	0.0000	0.0000	0.0001
Birch	183.8	193.6	861.8	281.9	108.4	0.1379	0.1452	0.2642	0.6894	0.2396	1.4763
Aspen	20.1	28.9	31.2	33.0	53.3	0.0251	0.0332	0.0490	0.0296	0.0330	0.1699
Spreckled alder	7.3	35.7	74.1	49.8	11.5	0.0091	0.0411	0.0430	0.0704	0.0498	0.2134
Black alder	51.6	86.7	282.3	128.3	96.4	0.0645	0.0997	0.1383	0.2682	0.1283	0.6990
Lime	0.1	0.2	0.9		0.2	0.0000	0.0001	0.0001	0.0003	0.0000	0.0005
Poplar		0.2	0.7	0.8	0.1	0.0000	0.0002	0.0002	0.0007	0.0008	0.0019
Willow	2.4	4.6	2.6	0.3		0.0030	0.0053	0.0070	0.0025	0.0003	0.0181
Others		0.3	0.2			0.0000	0.0003	0.0003	0.0002	0.0000	0.0008
Shrub	41.5	36.8	43.6	6.1	47.8	0.0519	0.0423	0.0783	0.0414	0.0061	0.2200
Total	709.7	1,445.1	3,566.1	1,498.0	622.7	0.6026	1.0384	2.1375	3.7231	1.8271	9.3288

Table 2.4 Total Carbon Stock in Phytomass of Forest Fund Land as of 01.01.2001

Forest fund land category	Carbon stock, mln tonnes		
	Total	In stands	In grass, dwarf shrub
Stocked forest land, Including:	440.2288	430.9002	9.3286
I class young stands	8.0200	7.4175	0.6025
II class young stands	46.2035	45.1651	1.0384
Middle-aged	217.9786	215.8410	2.1376
Immature	120.8187	117.0956	3.7231
Mature and overmature	47.2082	45.3811	1.8271
Unstocked forest and forest-free areas*			
Free-growing stands	0.3808		
Nurseries, plantations	0.0066		
Perished wood	0.0419		
Felled areas	0.0798		
Glades	1.7582		
Roads, clearances	0.05454		
Sands	0.0014		
Total	442.5520		

* calculation has not been made for pastures, hayfields, arable land, swamps, water bodies, farmsteads and other lands.

Table 2.5 Forecast Indicators of Wood Increment in Belarusian Forests and Atmospheric Carbon Removals to the Stand Stock up to 2070

Forecast indicator	Annual averages 10-year period-wise							
	2000	2010	2020	2030	2040	2050	2060	2070 and beyond
Basic change in stock, m^3 per 1 ha	4.50	4.66	4.82	4.97	5.13	5.29	5.45	5.60
Stocked area, mln ha	7.85	8.05	8.15	8.17	8.20	8.22	8.24	8.25
Basic change in stock in Belarus, mln m^3	35.30	37.49	39.24	40.63	42.07	43.46	44.87	46.22
Forest harvesting volume, mln m^3	10.25	17.40	20.86	23.23	24.55	24.82	24.94	25.08
Increase in forest stock, mln m^3/year	25.05	20.09	18.39	17.39	17.51	18.65	19.92	21.14
Carbon removals to stand growth, mln tonnes	8.062	6.466	5.918	5.597	5.635	6.002	6.411	6.804
Including I class young stands	0.136	0.109	0.100	0.095	0.095	0.101	0.108	0.115
II class young stands	0.842	0.676	0.618	0.585	0.589	0.627	0.670	0.711
Middle-aged	4.044	3.243	2.969	2.807	2.827	3.011	3.216	3.413
Immature	2.194	1.760	1.611	1.523	1.534	1.634	1.745	1.852
Mature and overmature	0.845	0.678	0.620	0.587	0.591	0.629	0.672	0.713

Socio-Economic Forecast in the Absence of Climatic Changes

The optimistic forest management forecast (Table 2.6), made in 1997 and provided herein, is yet far from meeting actual estimates. In 2000-2001, the forest harvesting totaled slightly over 10.2 million m^3 of timber, on the average. This was due primarily to the economic situation in the country: insolvency of a significant fraction of wood consumers, refusal to use parvifoliate species of wood (birch, aspen, alder, etc.) by many consumers primarily on hard-to-reach overmoistened land, and also unfavorable condition in the European forest products market following mass windfalls in forests of Germany, France and Austria. This is, however, positive from the ecological point of view.

Since 2000, the transfer of forests managed by collective/state farms and other users to the FC enterprises to be included into the forest fund is combined with the transfer of low-productive forest-free land, the part of which is subject to reforestation. The decision regarding the transfer of 134.6 thousand ha has already been taken and according to the forecast estimate the area of this land category is to reach 300 thousand ha by 2010 (3.8% of the current area of the stocked forest land), that would provide a significant potential for increasing percentage of forest land in a number of regions of Belarus. This would also provide an additional potential for removing atmospheric carbon to land ecosystems.

These considerations are accounted above (see Table 2.5).

Climate Forecast. The climate change in Belarus for the first half of the current century is assessed using the findings obtained from the general atmospheric circulation model *HadCM2* (Great Britain) [8]. The following factors define significant climatic variations for the forestry in the first half of the 21st century:

- increase in mean temperatures by 0.6-1.9°C, on the average, of all months of the year from 2010 to 2039 and by 1.0-2.9 °C beyond this period (Table 2.7);

- most radical rise in temperatures in winter months deteriorating plant hibernation conditions and increasing probability of thaws triggering vegetation;

- change in heat availability for forest stands during the vegetation period, namely such critical climatic indices as total period durations with mean daily temperature above temperature limits of 5 and 10 °C and total temperature of the respective periods (Table 2.8).

- increased probability of occurrence of extremely arid phenomena primarily in the summer months, since against the background of elevated temperatures precipitation remains actually unchanged during that period;

- reduction in soil freezing depth and period in the winter season to such an extent that this freezing may be not pronounced at all in specific years;

- precipitation increases insignificantly or is due to winter months when its role as a moisture source for the current year vegetation is minor (Table 2.9).

Table 2.6 Forecast of Annual Volumes of Principal and Intermediate Harvesting in Belarus (All Forest Users) (Scenarios 1 and 2 – According to: [3]).

Scenario	Harvesting, 10-year period-wise:							
	2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070 and beyond**
Principal forest harvesting [a], area, thou ha Total stock to be harvested, mln m^3/year								
1	37.4 8.1	57.9 12.3	67.2 14.4	72.4 15.4	73.8 15.8	73.8 15.8	74.1 15.9	74.6 16.0
2	37.4 8.3	57.9 13.1	67.2 15.8	72.4 17.6	73.8 18.6	73.8 18.8	74.1 18.9	74.6 19.0
3[c]	29.9 6.6	46.3 10.5	53.8 12.6	57.9 14.1	59.0 14.9	59.0 15.0	59.3 15.1	59.7 15.2
Intermediate forest harvesting (thinnings, sanitary cuttings) and other cuttings [b], total stock to be harvested, mln m^3/year								
1	6.32	8.65	9.36	10.01	10.27	10.27	10.34	10.4
2	6.32	8.65	10.27	11.44	12.09	12.22	12.28	12.35
Total forecast of forest harvesting volume, including all forest users, mln m^3/year								
1	14.42	20.95	23.76	25.41	26.07	26.07	26.24	26.40
2	14.62	21.75	26.07	29.04	30.69	31.02	31.18	31.35
3 [c]	10.25	17.4	20.86	23.23	24.55	24.82	24.94	25.08

Note:

[a] In the first scenario, the cutting age is taken at the level of the middle of the second half of the 5th (for second forest group) and 6th (for first forest group) age classes, with conventionally constant stock of mature stands; the second scenario suggests a gradual increment of stock per 1 ha of mature stands annually at a rate of 0.35%.

[b] The Strategic Plan of Forestry Development in Belarus [3] defines the intermediate forest harvesting up to 2020, and for the following period it will account for 65% of the principal forest harvesting that corresponds to the planned ratio of these two types of forest harvesting.

[c] The adjusted forest management forecast makes allowance for sluggishness of market-oriented transformations combined with the high saturation of the forest market with inexpensive Russian lumber and more complicated access to it due to forest certification procedures. In order to take into account these negative factors (in terms of economic effects), reducing coefficient of 0.80 has been used to calculate the third scenario.

Table 2.7 Mean Air Temperature Behavior Over Forecast Period

Month	Mean air temperature, °C			Difference between forecast and base period of 1961 – 1990, °C	
	1961 – 90	Forecast 2010 – 2039	Forecast 2040 – 2069	2010 – 2039	2040 – 2069
1	2	3	4	5	6
January	-6.84	-5.15	-3.97	1.69	2.87
February	-5.63	-4.32	-3.06	1.31	2.57
March	-1.077	-0.49	0.32	0.59	1.40
April	6.303	6.88	7.77	0.58	1.47
May	13.02	13.87	14.43	0.85	1.41
June	16.167	17.27	18.03	1.10	1.87
July	17.24	18.19	19.15	0.95	1.91
August	16.373	17.05	18.39	0.67	2.01
September	11.77	12.71	13.52	0.94	1.75
October	6.383	7.27	8.34	0.89	1.96
November	0.83	1.41	1.85	0.58	1.02
December	-3.493	-1.63	-1.36	1.86	2.13
Year, total	5.9	6.9	7.8	1.0	1.9

Table 2.8 Change in Specific Indices of Heat Availability for 2010-2039 Period Relative to 1960-1990 Base Period

Climatic index	Temperature limit, °C	
	5	10
Shift of date of spring steady transition through temperature limit, days	-3	- 4
Duration of period above temperature limit, days	+7	+6
Total temperature above temperature limit, ° C	+201.4	+184.7

Table 2.9 Precipitation Behavior Over Forecast Period

Month	Total precipitation, mm/month				
	1961 – 1990	Forecast		Difference between forecast and 1961 – 1990 period	
		2010–2039	2040–2069	2010–2039	2040–2069
January	37.1	38.7	43.5	1.6	6.4
February	30.1	32.6	33.3	2.6	3.2
March	35.7	37.4	36.1	1.7	0.4
April	41.8	38.6	41.7	-3.2	-0.1
May	54.4	55.1	55.4	0.8	1.0
June	79.5	84.0	81.2	4.5	1.6
July	81.9	85.2	86.3	3.3	4.5
August	70.2	72.9	72.4	2.7	2.3
September	56.5	57.6	57.3	1.1	0.8
October	47.0	49.4	47.8	2.4	0.8
November	49.8	50.9	51.5	1.1	1.7
December	46.9	47.8	50.2	0.9	3.3
Year, total	630.9	650.3	656.9	19.4	26.0

Quality Description. Economically significant climate change effects are as follows:

Change in basic growth of forest stands due to elevated active temperatures and increased vegetation season duration. Increased consumption of energy and stored nutrients for respiration during the vegetation season as a result of increased mean night-time temperatures.

Change in ripening time of ligneous plants' fruits and seeds due to earlier vegetation.

10-15-day shift of the silvicultural season commencement.

Increase in fire season duration, areas of forests potentially prone to fire hazard, general increase in fire hazard in forests and on peat bogs.

Change in forest stand formation due to shift in geographical ranges of major forest-forming species: spruce, hornbeam, spreckled alder.

Increase in probability of mass propagation of forest insects both primary (gypsy moth, nun moth, sawfly, screetch owl, pine tussock moth, leaf-rolling moth, etc.) and secondary (primarily, bark beetle and alike).

Transfer of land, which became unsuitable for agricultural use due to the increased zone of arid phenomena occurrence, to the forest fund.

Decrease/increase in efficiency of hydro-forest reclamation systems and emergence of negative side effects related to their operation.

Increase in probability of occurrence of late spring frosts and their higher harmfulness due to earlier vegetation.

Active overgrowing of swamps in connection with the total groundwater recession and increased rate of evaporation from surface of swamps and their catchment areas.

Increase in transpiration of forest phytocenosis.

Change in edaphic conditions for forest stand growing due to total groundwater recession.

Impairment of assimilation conditions due to reduced atmosphere transparency.

Impoverishment of the genetic material of the forest boreal flora and fauna.

Deterioration of water availability conditions due to total groundwater recession over a large area resulting from the combined effect of anthropogenic and climate-determined factors.

Expansion of species of the forest-steppe and steppe floristic complexes into forest ecosystems.

General acceleration of the cycle of matter in forest ecosystems, specifically accelerated rate of decomposition of forest tree waste and litter.

Enrichment of the biodiversity at the cost of species of thermo and xerophilous European-Asia Minor and Euro-Siberian and Aral-Caspian biotic complexes.

Plant productivity growth due to the reduced level of limiting CO_2 as a result of its increased concentration in atmosphere.

Deterioration of conditions of forest vegetation hibernation due to snow cover absence or its shorter availability period.

Reduced accessibility of the harvesting machinery to marshy felling areas in the winter season as a result of elevated temperatures, shorter snow cover availability and forest road freezing period.

Change Indicators. Economically significant climate-change effects are as follows:

Change in the basic stand increment rate within the range up to 10% due to the increased vegetation period by 15-20% (from 180-205 days to 195-230 in a year).

Change in ligneous plant fruit/seed ripening period and also that of forest berries due to earlier vegetation, possibly within 10-15 days and even more in specific years compared to average annual periods. This phenomenon has already emerged in specific years of the last decade.

In general, the shift of the silvicultural season commencement by 10-15 days should be considered as a favorable change, since it would allow forest planting (sowing) period to be prolonged to some extent and started with still remaining winter soil water storage. On the other hand, it is undesirable and even dangerous to delay planting operation completion even under new weather and climatic conditions, since the soil and litter surface rapidly dries out in May due to low amount of precipitation. The forced early forest planting occurred already in the 90s.

The increased fire period and area of forests potentially prone to fire hazard. The total increase in fire hazard in forests and on peat bogs has already occurred in specific years (1992, 1999, 2002) of the last decade (Tables 2.10, 2.11).

Table 2.10 Number of Fires and Area of Forests Burnt by Forest Fires in 1961-2000 and 1998-2001

Recorded fires, year-wise				Burnt area, year-wise, ha				Average area of 1 fire, year-wise, ha			
1961 – 1970	**1971 – 1980**	**198 1– 1990**	**1991 – 2000**	**1961 – 1970**	**1971 – 1980**	**1981 – 1990**	**1991 – 2000**	**1961 – 1970**	**1971 – 1980**	**1981 – 1990**	**1991– 2000**
26,805	27,285	23,538	28,453	35,937	16,784	16,516	44,770	1.34	0.62	0.70	1.07
1998	**1999**	**2000**	**2001**	**1998**	**1999**	**2000**	**2001**	**1998**	**1999**	**2000**	**2001**
876	3,959	2,569	1,111	567.7	6,260.8	1,931.0	442.8	0.65	0.63	1.34	0.40

Source: Forestry Committee of the RB Council of Ministers

The change in the stand formation related to the shift of range of major forest-forming species will be of a long-term character and would predominantly result in the reduced phytocoenotic resistance of forest-forming species sensitive to the climate change, to interspecies competition and also to insect and disease effect. In Belarus, the stands comprising spreckled alder, hornbeam and spruce fall into this land category. In particular, the number of days (over 120) with a relative air humidity over 80%, the total temperature above 10°C and May mean temperature define the current southern boundary of the spruce continuous distribution [6]. The shift of the respective isolines of these indices northward would also result in shifting by 150-180 kilometers the zone of spruce tolerance to climatic conditions. Supplanting the spreckled alder from southern boundaries of its range would be defined by an excessive heat inflow which presently confines it within current boundaries. The hornbeam northward distribution will be likely inadequate to the shift of direct-acting factors (temperature, precipitation), and will be related to a complex system of effects, since the present boundary of its distribution is determined by snow cover depth in southern Belarus, insufficient heat availability in its western region, and extreme winter temperatures in its central region [7]. Due to this reason, its northward distribution is likely to be not so significant and will be limited to tens of kilometers.

Table 2.11Dynamics of Forest Loss in 1991-2001 in Forest Fund being under Authority of Forestry Committee of the Republic of Belarus

Loss cause	Forest lost, year-wise, ha										
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Forest lost, total, ha	449	13,031	4,794	3,633	5,384	16,618	16,306	9751	6536	8027	10534
including: insect damage	-	-	30	380	47	59	206	28	32	26	42
wild animals damage	163	38	189	84	22	64	104	29	34	-	11
forest diseases	91	116	208	295	230	165	465	544	650	366	422
other anthropogenic factors	23		6	16	1		6			3	2
climatic hazard	47	98	340	686	2,481	10,692	14,075	7,805	4,083	5,917	9,097
including: windfalls and windbreaks							6,252	3,687			
inundation and flooding	-	292	1,387	134	136	540	316	514	221	582	564
fires	125	12,487	2,632	2,035	2,466	5,098	1,134	826	1,511	1,132	398

Source: Forestry Committee of the RB Council of Ministers

Note: Spruce forest drying up in 1994-2001 is included in the *Climatic hazard* line

Table 2.12Dynamics of Forest Pest and Disease Centers in Forests being under Authority of Forestry Committee in 1994-2001

Forest pests and diseases	Total area of centers as of beginning of reporting year, ha							
	1994	1995	1996	1997	1998	1999	2000	2001
Total:	204,751	210,207	171,726	182,594	230,986	227,205	164,016	200,171
Needles-eating insects	4,4267	68,505	4,693	1,723	63,630	62,555	265	13,027
including: pine moth	7,000	20,000	3,400	814	780	-	-	-
Nun moth	14,048	154,427	40	-	-	-	-	-
Pine screetch owl	-	-	-	-	-	-	-	11,650
Common pine sawfly	22,723	22,319	347	3	61,891	61,891	-	206
European pine sawfly	259	214	-	-	-	13	13	1,169
Stellar leaf-rolling sawfly	237	237	137	137	190	190	-	-
Spruce leaf-rolling sawfly	-	308	769	769	769	461	250	-
Leaf-eating insects	2,972	2,987	2,713	2,713	2,811	2,815	4,748	4,748
including: gypsy moth	26	26	-	-	-	-	-	-
Green oak and other leaf-rolling moths	57	57	5	5	5	5	5	5
Winter geometer	2,827	2,845	2,668	2,668	2,721	2,720	4,057	15,097
Oak sawfly	40	40	40	40	40	40	40	40
Brown-tail moth	-	-	-	-	-	-	68	455
Other forest pests:	2,679	3,058	9,426	3,979	1,367	1,841	1,357	3,335
including: borers	967	1,529	8,953	3,966	1,255	1,690	1,131	2,751
Chafers	75	75	0	9	67	105	127	202
Pine snout beetle	-	-	-	-	-	-	32	62
Pine bark bug	1,482	1,298	470	-	-	-	-	121
Pine-shoot moths	155	155	3	-	46	46	-	199
Forest diseases:	154,832	145,656	154,894	174,179	163,178	159,994	157,646	168,191
including: pine fungus	143,744	136,813	145,547	165,675	152,057	152,057	145,212	154,027

Source: Forestry Committee of the RB Council of Ministers

Higher probability of mass propagation of forest insects both primary leaf and needles-eating (gypsy moth, nun moth, sawfly, screetch owl, pine tussock moth, leaf-rolling moth, etc.) and secondary (primarily, bark beetle and alike). The tendency toward the increase in areas of the forest pest mass propagation centers and the number of insect species significantly damaging the forest stands has already emerged in the last decade of the 20th century (Table 2.12). Epidemics of pine moth (1993-1998), nun moth (1993-1995), pine screetch owl (2001-2002), common pine sawfly (1993-1996 and 1998-1999), European pine sawfly (1994-1995 and 2001) occurred. In 2001, an abrupt rise in activity of the winter geometer in its multiple centers was recorded in Belarusian oak forests

Transferring the land, which became unsuitable for agricultural use due to the increased zone of arid phenomena occurrence to the forest fund will require higher planting stock production, higher forest planting/sowing capacities, development of technologies meeting the specifics of this category of silvicultural areas, integrated actions aimed at reducing the young growth pests (primarily, chafers) population size. The Forestry Committee has already commenced this work (technology development, in particular) within the framework of the National Scientific and Technical Program *Forests of Belarus.* This has been also taken into account in developing the Program *Reforestation and Forestation in Forests of the Republic of Belarus for a Period up to 2015* [4].

Decrease/increase in efficiency of hydro-forest reclamation systems and occurrence of negative side effects related to their operation needs to be promptly assessed and appropriate recommendations should be made, since a) a rebogging process already encompasses a significant area of these territories; b) actively and passively reclaimed peat land both forested and unforested is one of the land categories in the forests fund most highly prone to fires; c) in a number of cases inefficient peat land reclamation (high and low-land bogs) has resulted not in higher productivity of stands, but in their degradation and loss of important components of the biological diversity.

Inasmuch as transpiration is significantly dependent on relative air and soil humidity, air temperature and also illumination, its increased intensity may be expected specifically over 2040-2069 period due to rise in mean monthly air temperature by 1.5–2º C during vegetation compared to the base period (1961-1989). Some increase in precipitation amount and wind speed may also contribute to this. These processes would be more pronounced on undermoistened soils, in which moisture storage and inflow need to be controlled by thinning operations [9, 10].

The change in forest soil water condition, with air temperature and forest phytocenosis transpiration being important factors of it in addition to precipitation [10].

Higher probability of occurrence of late spring frosts and their higher harmfulness may significantly affect the basic increment of oak (early frondescence form), spruce, lime and some other deciduous species and may also lead to the nipping of fruit, flowers and germs of ligneous plants and forest berries in specific years. This recurrent phenomenon was observed in Belarus in the last decade and led to actually complete failure of blueberry, cowberry and bog bilberry and, hence, to the reduced forest yield and feed stock for grouse-family birds and other berries-consuming birds and animals.

Intensive swamp overgrowing caused by total groundwater recession and higher evaporation rate proceeds naturally and may be assessed positively in terms of increasing forest resources. Although this phenomenon has not been analyzed quantitatively, the available experience in assessing swamp overgrowing for a number of to-be-designed wildlife reserves provides evidence of overgrowth of all categories of open bogs with pine, white birch, willow, black alder and spruce. As a rule, overgrowth makes up 15-30% (depending on the category of a bog and drainage level). Environmentally, however, this process should be considered rather as negative, since it leads to the loss of valuable wetlands extremely needed as the habitat for a significant number of species and forms of plants and animals not capable of living under other conditions.

Change in edaphic conditions for forest stand growing due to total groundwater recession substantially effects the condition of stands in the areas with an unstable groundwater recharge and that of the old-aged stands on lowland bogs. In particular, large-scale drainage led to black alder/ash forests degradation in Belarusian Polessie aggravated by insufficient precipitation for a number of years in 90s of the last century. On the other hand, this may result in the increased productivity of white birch stands in the forests growing on mesotrophic bogs and, hence, may contribute to introducing them into the composition of more economically valuable pine, spruce, oak and ash. This phenomenon, however, has not been yet impartially assessed, though field studies provide evidence of its emergence.

Impairment of assimilation conditions due to reduced atmosphere transparency falls to the category of insufficiently explored phenomenon and still is likely to be insignificant.

Impoverishment of the genetic material of the forest boreal flora and fauna against the background of enrichment of the biodiversity at the cost of species of thermo and xerophilous European-Asia Minor and Euro-Siberian and Aral-Caspian biotic complexes, as well as expansion of species of the forest-steppe and steppe floristic complexes to forest ecosystems are ecologically negative processes, but up to date clearly significant silvicultural effects are not observed or forecast in terms of direct economic losses or benefits. Ecological and genetic losses are inevitable and, thus, there is a need both to explore this process and develop appropriate integrated actions to reduce them.

General acceleration of the cycle of matter in forest ecosystems, specifically accelerated rate of decomposition of forest tree waste and litter is of no significant economic effect. Higher mineralization rate of the tree waste and litter may theoretically contribute to some increase in the stand productivity, but it is in the category of phenomena the promotion of or counteraction to which is meaningless.

Change in conditions of forest vegetation hibernation due to snow cover absence or its shorter availability period is in general most likely a negative phenomenon abruptly increasing variability of the heat regime of the forest litter and surface soil layers which serve as a habitat for different living organisms. Alternating thaws and frosts in winter months may extremely adversely effect dormant seeds, small animals, insects, etc. This phenomenon, however, may be assessed positively in relation to pests wintering in the litter, since this decreases their potential harmfulness.

Reduced depth and soil freezing period in the winter season will be and is currently a serious impediment to forestry operations and harvesting in bogged areas and also on mineral "isles" surrounded by such lands. The most critical component of the problem is that it is impossible to log considerable timber stock in mature black-alder and white-birch forests and in some types of pine forests, which were harvested predominantly in the winter season in the past when bearing resistance of peat soils sufficiently increased to allow for operation of heavy harvesting machinery. On the contrary, this phenomenon may be considered as positive from the ecological point of view (biodiversity conservancy), since this allows a biotic complex of old-aged paludal forests to be preserved on large areas.

The studies conducted using the Automated Regional Ecological Forecast System (AREFS) for regions similar to Belarusian conditions in terms of their natural and climatic characteristics have demonstrated in general a favorable effect of global warming on the forestry. The standing timber stock is expected to grow by more than 10% by 2050 [11].

The research conducted using the Belarusian data provide evidence of a complex character of an interactive effect of precipitation and increased air temperature on variability indices of the spruce radial increment. The tendency toward reduction in the above indices at elevated air temperature has been observed in the mixed (subtaiga) forest zone and in Polessie, while variability of indices throughout Belarus has been increasing as a whole. The last fact may be interpreted as the effect of deteriorated climatic conditions at the end of the XX century, while increased precipitation leads to higher indices of spruce radial increment in the subtaiga forest zone and to lower indices in Polessie. For the Carpathian variety of European spruce in its extrazonal insular stands in Polessie in proximity to melioration systems, the combined increase in air temperature and precipitation positively effects the stem productivity [12].

In addition to direct climatic factors (temperature, humidity, etc.) effecting phytocenosis productivity, there exists a number of factors which are climate-dependent or implicitly related to climate through complex feedback. This may include a higher activity of pests, higher aridity, etc. and also change in concentration of greenhouse gases, aerosols and ozone. Some of these factors may significantly reduce the probable plant productivity growth.

Phytocenosis productivity growth related to the increased CO_2 concentration in atmosphere may be assessed only by using specific mathematical models of dynamics of carbon dioxide in atmosphere and response of vegetation to the change in its concentration. The preliminary assessment of change in CO_2 concentration in atmosphere is rather contradictory. The Report prepared by Solomon and Limans, who were in charge of the US Biosphere Project (1989), stated that predicted rapid climate change in the XXI century may lead to a significant reduction in the forest area in the moderate climate zone. The two-fold increase in carbon dioxide concentration in atmosphere would result in destruction of 40% of boreal (northern) forests.

CO_2 effect on productivity should be positive in case its concentration changes not so rapidly [13]. According to the Italian scientists' data, the growth rate of pine trees increases by 25%, provided that the atmospheric carbon dioxide concentration remains at the 2050 forecast level. Table 2.13 provides absolute estimates of the carbon removals to the forest increment.

The increased aerosol and ozone concentrations are among the factors adversely effecting the productivity. These gases, in addition to reducing the quantity of incoming radiation, affect plant physiological processes during the vegetation period. According to the model-derived estimates of Russian scientists, the hardwood-biomass increment rate in the first half of the 90s of the last century in some Western and Central European countries reduced by 15% due to the anthropogenic increase in the ground ozone concentration alone. For Belarus, this reduction is estimated at 7-9%. Eastward, these figures reduced to as low as 6-7% in the Russia's regions bordering Belarus [14].

Table 2.13 Calculation of Carbon Removals to Forest Growth Subject to Increase in Atmospheric Carbon Dioxide Concentration by 1%/year

Predicted indicator	Annual averages, 10-year period-wise							
	2000	2010	2020	2030	2040	2050	2060	2070 and beyond
Carbon removals to stand growth accounting for response to increased CO_2 concentration in atmosphere, million tonnes	10.150	8.142	7.453	7.049	7.098	7.559	8.073	8.568
Including I class young stands	0.171	0.137	0.126	0.120	0.120	0.127	0.136	0.145
II class young stands	1.060	0.851	0.778	0.737	0.742	0.790	0.844	0.895
Middle-aged	5.092	4.084	3.739	3.535	3.560	3.792	4.050	4.298
Immature	2.763	2.216	2.029	1.918	1.932	2.058	2.197	2.332
Mature and overmature	1.064	0.854	0.781	0.739	0.744	0.792	0.846	0.898

The role of sulfur dioxide (SO_2) in the anthropogenic reduction in the hardwood biomass increment rate in Belarus is minor compared to that of ozone. The reduction in the increment rate throughout Belarus is estimated at 1 % over the same period.

Changing temperature/humidity condition will effect the daily variation in temperature underneath the forest canopy. Model estimates of variations in minimum (night-time), maximum (day-time) temperatures and ranges of the diurnal variation in temperature for 2010-2039 compared to the base period are give in Table 2.14.

Table 2.14 Monthly Average Change in Variables of Daily Variation in Air Temperature Underneath Forest Canopy (1m) in 2010-2039 Period Compared to 1961-1990 Base Period

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Month		January	February	March	April	May	June	July	August	Septembe r	October	November	December
Variation, ºC	Night-time temperature	1.9	1.9	1.0	1.0	1.1	1.1	1.1	1.1	1.0	0.2	0.1	1.0
	Day-time temperature	1.9	1.9	1.4	0.8	0.9	0.8	0.9	0.9	1.1	0.9	0.5	0.9
	Range	0.0	0.0	0.4	-0.2	-0.2	-0.3	-0.2	-0.2	0.1	0.7	0.4	-0.1

The decrease in the range of the diurnal variation in temperature during the warm season of the year and its increase during the cold season is observed against the background of the overall increase in night-time and day-time temperatures. The reason is a more significant rise in night-time and day-time temperatures during the warm and cold season of the year, respectively.

Geographic Analysis. Actually, all climate change-induced adverse effects would manifest themselves most in southern Belarus – Brest and Gomel Polessie – to a lesser extent in the subzone of hornbeam-spruce forests and to a minor extent in the Vitebsk Oblast and northern parts of Minsk, Mogilev and Grodno Oblasts. The analysis of the forest pathological situation in 2000-2002, however, has demonstrated that these areas may be also affected by extreme weather and climatic phenomena (dry spells, hurricanes, etc.) capable of triggering forest pest plagues, primarily propagation of the most dangerous spruce forest pest – a bark beetle.

2.2. Assessment of Adaptation Strategies and Measures

Identification of Objectives. Adapting forestry as a sector and its enterprises to new climatic environment and living conditions of the sector's major production object – forest stands – and in a broader sense – state forest fund land.

Identification of Adaptation Options. Adaptation of the sector to new weather and climatic environmental conditions should be aimed at both overcoming negative effects of these changes and obtaining the maximum benefit from them. The adaptation measures package should encompass the following major spheres.

Planning and Regulatory:

- developing the sectoral strategy and target programs of adaptation to new climatic environment;
- radically updating and making amendments in the sectoral regulatory and legal framework and reference data in connection with the ongoing climate change.

Institutional and Economic:

- implementing integrated measures defined by the sectoral strategy and adaptation program at the level of the Forestry Committee, regional production forestry associations and sectoral enterprises (forest enterprises, institutions).

Financial and Economic:

- developing the target program of economic adaptation of the sector to new climatic environment with justification of expenditures needed to eliminate and/or prevent climate change-related adverse effects to be covered from the republican budget and other sources.

Educational and Research:

- making amendments and addenda in the curricula of higher and secondary institutions of education training professionals for the sector;

- organizing target follow-up courses in the FC sectoral Training Center;

- developing respective instructional and methodical guidelines to be used in forest enterprises for advanced training of the sectoral personnel, etc.;

- arranging and implementing a package of research work to assess the climate change-related effects on the forest vegetation and forestry and devise measures to adapt the sector to such change.

3. HYDROLOGICAL CYCLE, WATER RESOURCES AND WATER MANAGEMENT

The most important problem for Belarus is unevenness of distribution and quality of water resources. Irregular availability of water resources for the population and in regions, different level of intensity of the agricultural and industrial production and requirements in water directly related to it, as well as existing specifics of approaches to the right of property in the national water legislation of the states bordering Belarus, all this attributes extraordinary significance to the problem of joint use of water of international water bodies. Water resources are characterized by a high sensitivity to the climate change, therefore, to develop adaptation measures under the changing climate, a unified information exchange system is needed to assess the water regime both of the whole region and specific states.

The Republic of Belarus ha*s* a large number of aquatic ecosystems including rivers (20.8 thousand), lakes (10.8 thousand), water storage reservoirs (153) and ponds (1.5 thousand). The total river length is 90.6 thousand kilometers. They are within the catchment areas of the Black and Baltic Seas. The main rivers are Berezina, Neman, Sozh, Pripyat, West Dvina and Dnieper. Of 146 km^3 of the annual precipitation, almost 110 km^3 evaporate into the atmosphere and only 36.0 km^3 (25%) transform into the local river runoff. 22.2 km^3 of transit water annually flow from neighboring areas. Total resources of the local river runoff are 56.2 km^3/year. The largest lakes are Naroch (80 km^2), Osveiskoe (52.8 km^2), Chervonoe (43.6 km^2). The total storage capacity of water reservoirs is 3.1 km^3, active storage capacity – nearly 1.2 km^3.

The most valuable in terms of power generation are the rivers of West Dvina and Neman. 21 small hydroelectric power plants (HEPP) with the total installed capacity of about 10 MW, including 14 HEPP with the total capacity of 7.8 MW, operate in Belarus. It is planned to commission 29 HEPP with the total installed capacity of nearly 7 MW by 2010.

A number of man-made water systems are available in Belarus. The Berezinskaya system 169 km in length connecting the West Dvina with Dnieper is located in the northern part of the country. In the south, in Polessie, two water-dividing connecting canals are available, namely, Dnieper-Bug and Oginsky canals. The former is a part of the Dnieper-Bug waterway nearly 735 km in length.

Surface water is used by the inland water transport providing mineral/construction/forest freight and passenger services along the rivers of Pripyat, Dnieper, Berezina, Sozh and Dnieper-Bug canal. Prior to 1986, iron ore was transported from Ukraine to the port of Brest. Freight traffic from Ukraine terminated after the Chernobyl nuclear disaster.
Relatively regular observations of hydrological parameters of rivers were started at the end of XIX century, while first isolated data on the chemical composition of surface water were obtained in the 30s of the XX century.

Currently, 125 hydrological stations operate on rivers and canals and 14 stations – on lakes and water storage reservoirs. Observations of hydrochemical condition of water bodies are conducted at

106 sites at 165 stations in basins of all large rivers. The hydrobiological control is conducted on 68 water bodies at 128 stations. Regular observations of the natural ground water level started from 1949 [2]. Observations of the natural and disturbed ground water regimes are conducted on 1,656 wells developed down to all water-bearing horizons (Fig. 3.1).

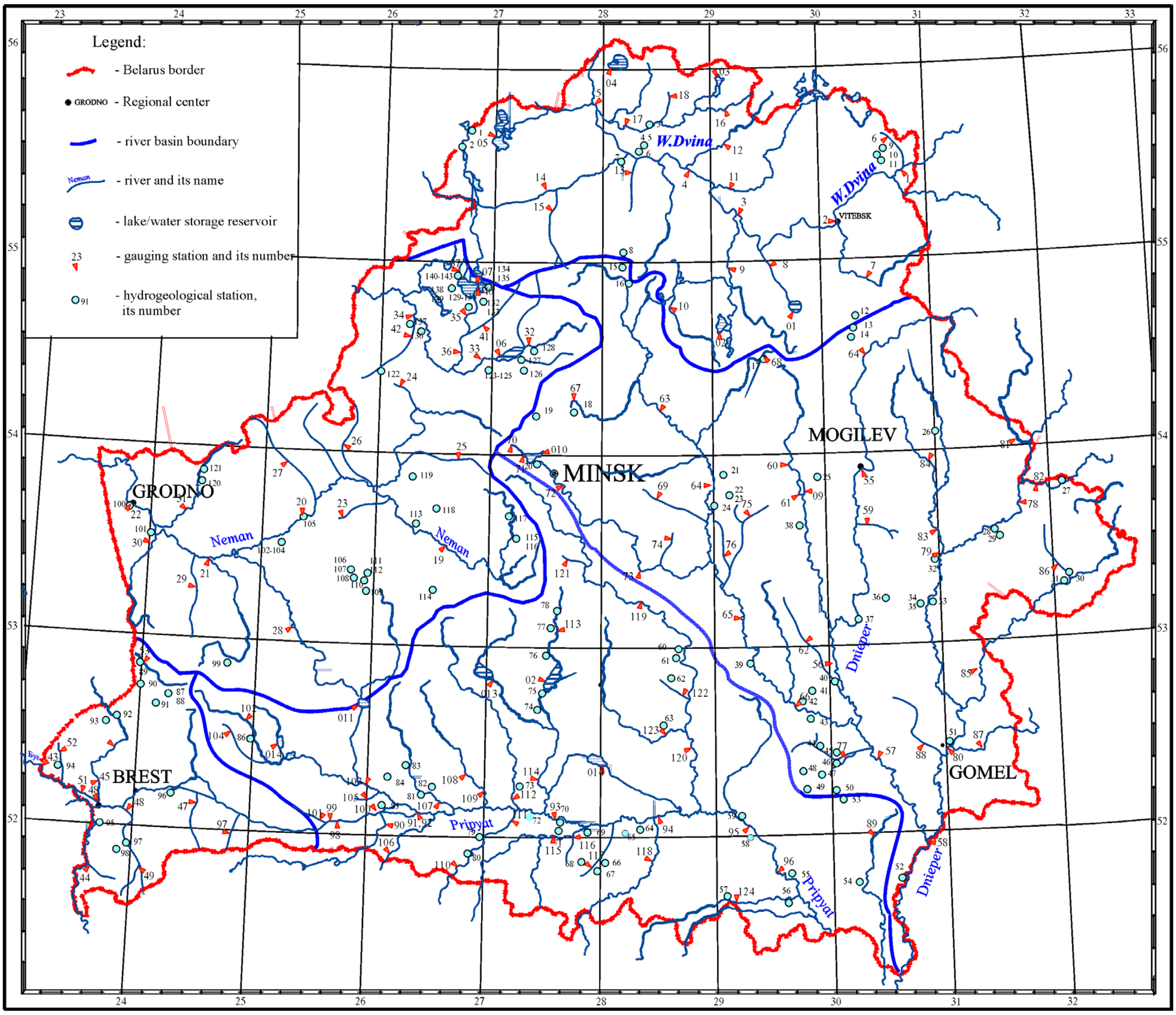


Fig.3.1. Diagram of hydrological and hydrogeological stations

To date, the Hydrometeorological Service has accumulated rather sizeable actual data on hydrological characteristics of rivers, lakes and water storage reservoirs. [3-5]. The hydrological data volume reduced as a number of gauging stations were abolished and, hence, observations of the river and lake water regimes were terminated.

Hydrological data used in this Section are taken from the official hydrology documents published by the USSR and BSSR Hydrometeorological Service [1, 3-6].

The Belarusian territory is divided into 6 zones in terms of specifics of the runoff regime, character of its relation with determining factors and runoff (Fig. 3.2). Table 3.1. contains main characteristics of hydrological zones and subzones in Belarus calculated for rivers with a catchment area of 1,000 km^2 for the normal year [12, 13].

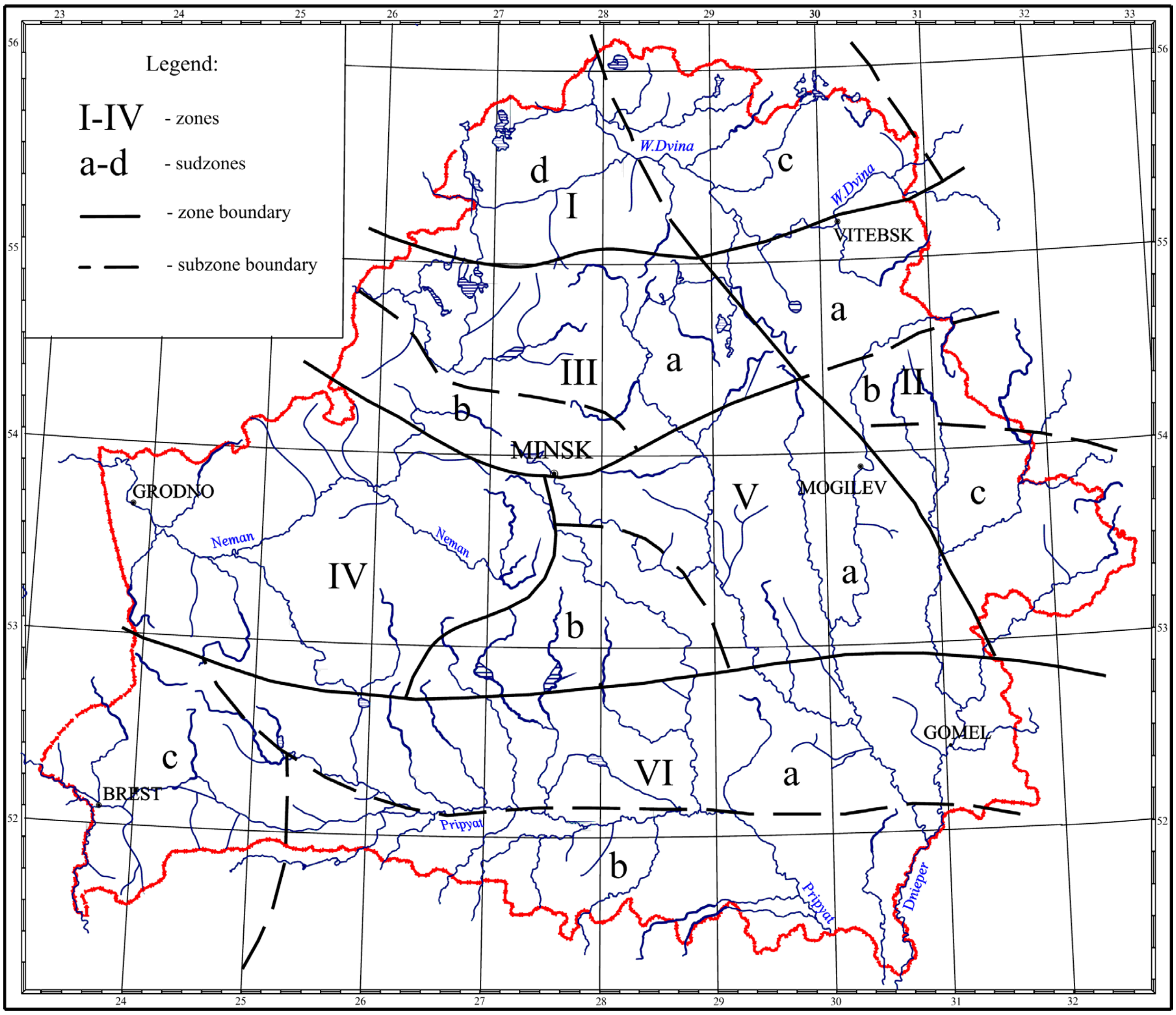


Fig. 3.2. Diagram of hydrological zones and subzones in Belarus

Table 3.2 Main Characteristics of Hydrological Zones

Zones and subzones	Average long-term annual runoff module l/(s·km^2)	Seasonal runoff, in % of annual		
		spring (III – V)	summer-fall (VI – XI)	winter (XIII- II)
Western-Dvinsky				
subzone **a**	7.0	61	29	10
subzone **b**	6.8	66	23	11
Upper-Dneprovsky				
subzone **a**	607	70	23	7
subzone **b**	604	68	23	9
subzone **c**	5.5	68	22	10
Vileisky				
subzone **a**	7.2	48	36	16
subzone **b**	7.5	40	40	20
Nemansky	6.0	45	35	20
Central-Berezinsky				
subzone **a**	5.6	52	32	16
subzone **b**	4.9	60	25	15
Pripyatsky				
subzone **a**	4.1	69	19	12
subzone **b**	3.5	59	26	15
subzone **c**	3.6	49	28	23

Analysis of Climatic Change Effect on River Runoff and Water Level in Lakes. Changing latitudinally geographical zones changes climatic factors and, hence, an average annual runoff in the area. The total reduction in the annual runoff is observed from north to south (Fig. 3.3).

The most important phase of the Belarusian rivers' water regime is a spring flood. The height of the spring flood above the normal (low-water) level on large rivers reaches 8.6-12.8 m. The flood height is approximately 2 times lower on medium and small rivers. The flood continues 30-120 days. The shortest flood occurs on the rivers of the Neman watershed area (30-50 days) and the longest – on the Pripyat watershed area (90-120 days). Spring flood recession duration is from 30 to 60 days.

Floods causing sizeable damage in the Belarusian river basins occurred 10-12 times over the last 50-70 years. The most significant of them were the floods in 1956, 1958, 1974, 1979, 1993 and 1999. The maximum flood on the Pripyat river was recorded in 1845, when the maximum level exceeded the datum plane of the modern gauging station by 675 cm in Mozyr, and the water discharge was estimated at 11,000 m^3/s. The last high flood occurred in 1999, when depth of flooding Polessie rivers' floodplains (Goryn and Ubort) reached 1.0–3.3 m. The flood substantially damaged the national economy.

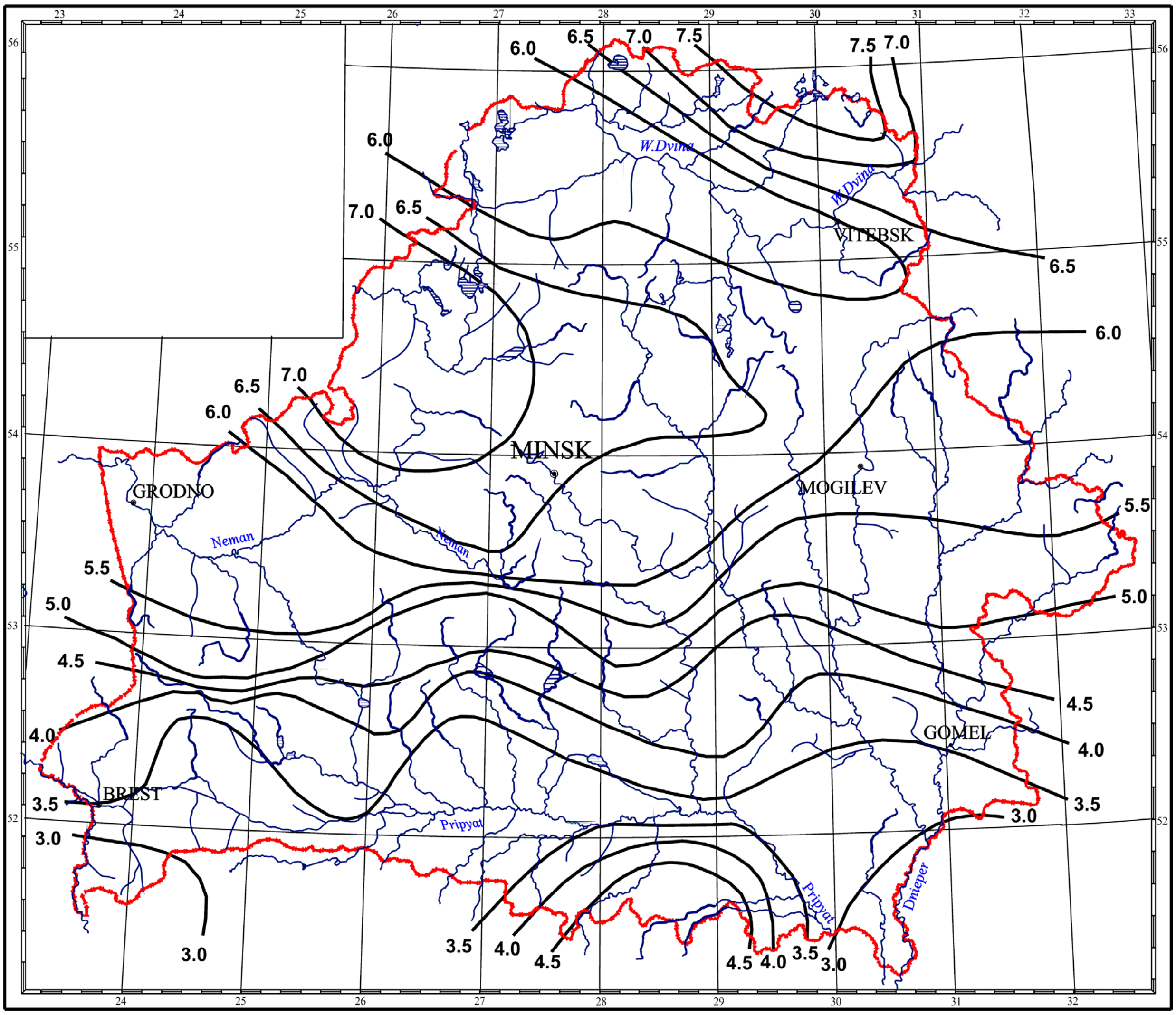


Fig. 3.3. Map of Mean Long-Term Belarusian River Runoff, l/(s km^2)

The spring flood on the rivers is followed by the summer-fall low-water periods when water levels reach minimum values. Its duration on the rivers of the West Dvina watershed area is 120-140 days, that of Pripyat – 135-165 days and on the remaining rivers – 190-205 days. In dry years (1939, 1951, 1952), drying of rivers and canals with the watershed area over 1,000 km^2 was observed.

Rivers freeze up for 80-140 days from the second decade of November. During severe winters, some small rivers may freeze down to the bottom for a period up to 4.5 months. In mild winters, freeze-up is not observed on rivers.

Currently, not only natural fluctuations of meteorological variables, but also anthropogenic factors define the hydrological regime of water bodies in Belarus [7-22]. It should be noted that the influence of the latter is increasing each year despite some economic recession and if underestimated, they may lead to significant errors in determining projected characteristics.

The projected change in water resources requires that actions to counter unfavorable effects of the climate change be taken well in advance [2, 17 – 25].

In water management terms, the most significant factor is accounting possible transformation of the dry-year hydrograph specifically if the overall volume of the predicted reduction in the annual runoff would fall within the summer/fall runoff low period. In this case, the water sector would encounter the following negative effects:

1) decrease in actual design supply of economy units using surface water;
2) drop in minimum water levels in rivers, thereby effecting the operation of water intakes not provided with a dam, domestic water transport and recreation;
3) ground water recession, specifically in riverain zones;
4) lower river water quality related to a lower degree of dilution of effluents and other pollution sources;
5) transformation of the rivers' hydrobiological regime caused by the change in the river level and speed regimes, increase in air temperature leading to deterioration of the oxygen regime and reduction in self-cleaning intensity.

The following should be pointed out when dealing with the climate change effects in more detail.

Forecast of Climate Change Effect on River and Lake Ecosystems. Increasing "thermal load" on rivers and water reservoirs may accelerate eutrophication processes. Shifting in the species composition (groups) of phytoplankton toward species (groups) with higher temperature optimum (for example, cyanobacteria) poses a substantial risk for drinking water quality.

Warming would affect fish resources. Uniform increase in water temperature in shallow water reservoirs would lead to weight loss of fish inhabiting cold water and cause plague of multiple bions.

A disruption of fish biocycle, peter-out of stenobiont fish from the fish fauna, change in species diversity and fish number and biomass are to be expected.

The experts believe that currently systematized hydrobiological data are not available, therefore it is not possible to statistically credibly record changes in structural parameters of aquatic organism communities in response to the effect of specific environmental factors and to identify in particular climatic change impact. There is a need to commence long-term "high-frequency" hydrobiological parameters observations of most characteristic water bodies within the framework of research monitoring.

Decreasing water levels in rivers and lakes is likely to increase ^{137}Cs and ^{90}Sr radionuclide concentrations in surface water of the Dnieper and Pripyat basins located in Gomel and Mogilev Oblasts.

Forecast of climate change effect on ground water level has demonstrated that if the annual temperature increases in Belarus by about 0.2 °C in the beginning of the XXI century, this may result in the ground water recession by 0.02 m relative to the normal. If the temperature increases by 1.5 °C by 2025, this would lead to GWL recession by approximately 0.03-0.04 m relative to the normal. Spring GWL amplitudes would decrease like it occurred in the late 80s-early 90s during the five-year warming, and the low-water levels would become even lower.

Risk of Inundation of Areas by Floods. The analysis of data on 1845 and 1931 floods shows that more catastrophic floods and high water may form in Belarus in the future. Such a situation is possible with a higher anthropogenic load on the watershed area leading to substantial change in conditions of runoff formation in hydrological terms.

Risk for Hydropower Engineering. All operating HEPP in the Belarusian power engineering system are categorized as small-sized units for which firm capacity is defined by the December runoff of design probability not lower than 95% in the year with low water. The firm capacity of Polotsk HEPP being currently designed and categorized as medium-sized is accepted based on the condition of 80-85% of the assured water supply.

Control structures of small-sized HEPP comprise small reservoirs for day storage which are climatically affected to a great extent. The increase in mean monthly temperatures of the surface water layer would lead to additional evaporation and respective power generation loss. Winter warming, however, in the last decades improves the ice conditions on water reservoirs and rivers.

Risk for Water Transport. The river flow is subject to substantial variation both within a year and year-wise under the effect of climatic factors. 46-62% of the annual runoff flows through rivers in spring on the average. Approximately an average of 4-6% of the annual runoff fall within each of 9 months of the summer and fall-winter periods.

In the years with low water in summer and winter months, the local flow may reduce down to 2-3% of the annual one, thereby affecting the water level and operation of the water transport involved in freight and passenger traffic by the rivers of Pripyat, Dnieper, Berezina, Sozh and Dnieper-Bug canal.

3.1. Adaptation Measures in Water Management

Increase in frequency and duration of dry spells would lead to the decline in level of rivers, lakes, and water storage reservoirs and, hence, would deteriorate the quality of the water. This would necessitate upgrading treatment of waste water discharged into these sources and relocation of polluters beyond the boundaries of water protection areas.

Reduced water levels and consumption during the low-water period would adversely effect the operation of the Belarusian inland water transport, HEPP and also radiation condition of surface water in Gomel and Mogilev Oblasts of Belarus. Aquatic flora and fauna are expected to change.

Due to the above, adaptation of the water sector and aquatic systems should be aimed at mitigating climate warming-related adverse effects and contribute to sustainable development of the Republic of Belarus.

Proposals on Most Critical Adaptation Measures

Major efforts in the water resources sphere are proposed to be focused on the following adaptation measures:

- development of flood control actions primarily for the Polessie region, with specifics of the river runoff formation in Ukraine being accounted for;

- development of a reliable hydrometeorological monitoring, extensive use of the radar and satellite data for assessing characteristics of the snow cover and planning water management, agricultural and forest protection measures;

- scheduled forest reclamation activity in the river basins as an efficient measure to control erosion water streams;

- substantiation of efficiency and feasibility of construction of underground water storage reservoirs in some regions of the country to regulate the water regime with the requirements of water users, i.e. to address the water supply problem, namely, increasing guaranteed water content of a source.

Implementing water supply actions is time-consuming, therefore large water management facilities need to be planned 25 years in advance and commissioned 10-15 years ahead of the water demand.

The long-term planning of the economic activity should take into account vulnerability of surface water and specific limitations of adaptation measures without reference being made to specific dates on the change onset. The adaptation of the economic activity should first of all include water conservation, extensive use of water-conservation processes, and more extensive use of agricultural land irrigation.

The priority list of possible projects proposed for development includes as follows:

- Comprehensive assessment of vulnerability of the Dnieper, Neman, West Dvina, West Bug and Pripyat rivers' water resources subject to climatic changes and economic development of these regions.

- Development of the unified information exchange system with neighboring states to assess water resources in terms of basin features.

- Development of the National system of acquisition, analysis and generalization of data on impact of hazardous climate change on aquatic ecosystems and water sector.

- Development of the process for regular publication of the Regional Climate Monitoring Bulletin to contain the Section relating to the water sector and aquatic ecosystems.

- Development of a system of preventive measures to adapt climate-dependent Belarusian economy sectors – agriculture, water economy and forestry – to the climate change.

The agricultural sector directly related to a specific degree of area wetting and water availability ranks next as the vulnerable economy sector which would be exposed to climate warming in the future.

Climate warming may significantly impair soil wetting conditions, increase evaporation, decrease moisture supply to fields and also prolong the vegetation period. All these factors would necessitate development of unsystematic mobile irrigation. This would entail the reduction in average annual water regulation effect of the irrigation reclamation on the reclaimed lands. Water resources in sources used for forced water supply to fields may also reduce. Hence, to supply water to irrigation and drainage/wetting systems, actions need to be taken to regulate surface and ground water runoff, supply water from outside and reuse of drainage water.

3.2. Climate Change Effect on Hydrological Regime

To assess changes of climate-effected water resources, two methods have been applied: statistical and water-balance, while biomanipulation models are used for studying aquatic ecosystems of the Narochansky lakes, and statistical methods are used to study ground water. The random component in the change in series of water discharge was analyzed by using tests of the number of rotary points and change in difference signs. Kendall and Spearman ***rho*** were also used.

The analysis of precipitation over the last century shows that a greater amount of precipitation was recorded at the beginning of the century, since G.Ya. Vangengeim western atmospheric circulation form dominated at that time. During the winter season, the Belarusian river runoff increased [2, 20, 22].

Warming in the 20s-30s of the last century was accompanied by the reduced precipitation specifically in the eastern part of the republic that led to the runoff reduction at that time and, hence, to negative differences in the Dnieper and West Dvina rivers' runoff during 1929-1945 and 1890-1902 [17].

The discharge of rivers for periods with high-wind speeds appeared to be somewhat lower than for periods with low-wind speeds. This is related to the reduced evaporation during periods of low-wind speeds. Comparing the difference in river runoff for epochs with high and low-wind speeds allowed the contribution of this factor to be assessed – it amounted to about 10% on the average.

Dynamics of extreme discharges over 100-year observation period in different months have been studied for the West Dvina and Pripyat rivers. Most frequently occurred abnormal years are as follows: with maximum discharge – 1931, 1932, 1933, 1958 and 1962, with minimum discharge – 1921, 1939, 1954, 1969, 1976 and 1984. The runoff formation is subject to wide-range fluctuations for rivers with small watershed areas compared to the rivers with large watershed areas.

Analysis of climatic change effect on ground water in basins of the largest rivers has revealed that intra-annual variation in the GWL has a specific climate-related regularity. The spring GWL peak is observed, as a rule, in April when levels rise from 0.4 to 2.3 m. In the summer season, the GWL is defined by temperature and precipitation of the previous one-two months. In this case, an inverse relationship with temperature of previous months was revealed – increasing temperature decreases GWL.

The analysis has demonstrated that there exists an annual cycle, as well as cycles lasting 3-4 and 6-7 years. The cycles of 2-3, 4-6 and 10-12 years are characterized by a higher occurrence. It is not possible to identify cycles of a longer duration because of short series of observations.

Increasing air temperature during the "warm" period (1988-1992) reduced the spring amplitude of the ground water level throughout Belarus. The "cold" period (1964-1968) was characterized by significant spring GWL amplitudes.

Climate Impact on River Ecosystems. Asynchrony in variation of major runoff types (annual, maximum and minimum) is characteristic of large Belarusian rivers. Comparative assessment of the change in average annual runoff and quantiles of different probability, as well as maximum and minimum runoff from 1961 to 2000 has demonstrated that differences in annual runoff over the selected averaging periods are within the calculation accuracy both for average and assured values. The runoff of large rivers has not actually changed. The increased Pripyat runoff observed in 1965-1985 may be explained by climatic changes (fluctuations of dryness of years).

Changes in maximum runoff are beyond the calculation accuracy and its reduction is characteristic of all rivers. The changes are most significant on the Berezina, Neman and Dnieper rivers and less substantial changes are observed on the West Dvina and Pripyat rivers.

The minimum runoff on rivers changed differently, for instance, the minimum Pripyat runoff substantially increased, while the increase was less on the Dnieper river (Orsha) and the runoff had not changed on the remaining rivers.

All past and current changes in hydrochemical background are within the bicarbonate-calcium water type.

*Climate Impact on Lake Ecosystems and Water Storage Reservoirs***.** The analysis of spectral density of time series of lake levels has revealed availability of a long-period component of 20-30 years for majority of Belarusian lakes.

A single-humped curve of the annual variation of lake levels with the peak in April-May is characteristic of Belarusian natural lake reservoirs in dry years (1951, 1959, 1964). Humid years (1987, 1990, 1998) are characterized by the double-hump curve with the first peak in March-April and the second one in fall-early winter.

Warming, observed over the last thirteen years (1989-2001), effected the temperature and ice regime of rivers, lakes and water storage reservoirs.

The surface layer water temperature in water reservoirs significantly increased since 1989. The most significant deviations from normal are observed in the spring period. In summer months the deviation from the mean long-term data decreases, while it increases in fall months.

The maximum water temperature over the entire observation period has been recorded on most lakes and water storage reservoirs in 2001 and amounted to 28.8 ^{0}C for the Naroch, 29.4 ^{0}C for Neshcherdo and 26.4 ^{0}C for Vygonoshchanskoe lakes.

Studies of the Naroch lakes' ecosystems allow the following conclusions to be made:

- it is easier to reveal the climate-change indication in lakes with a higher lake area-basin area ratio and by minimum mean annual lake levels;

- a mild water heating does not cause significant changes in the system dynamics, and only minor changes in the biomass quantity and shift in dates of biomass peaks are observed. The effect of heating on weeds is more pronounced in spring and early summer seasons, and the replacement of carnivores by filter-feeding organisms is observed in the zooplankton community.

The transition of water temperature through 4 ^{0}C, 10 ^{0}C a week earlier than usual over the 1989-2001 period and 4-8 days later than usual in the fall was observed on the Belarusian water reservoirs. The same tendency has been revealed for water temperature transition through 0.2 ^{0}C. The climate change resulted in the increased ice-free period duration. Rising temperature in the surface layer contributes to early active weed growth period and increases its duration (spring phytoplankton development).

Impact of Drainage Reclamation on River Hydrological Regime, Ground Water Levels and Climate. Up to date, nearly 1 million 400 thousand ha have been reclaimed in Polessie region.

The drainage reclamation simultaneously resulted in ground water recession, substantial reduction in evaporation losses from ground water surface, reduced radiation balance and transpiration moisture flow. Reclaimed bog soils heat more rapidly than unreclaimed ones, but they are characterized by lower thermal conductivity. Reclaimed and not covered with vegetation bog soils are heated up to 50-60 ^{0}C and higher, that is, by 11-20 ^{0}C higher compared to mineral soils. Reclaimed peat lands are characterized by significant diurnal ranges of soil surface temperature exceeding those of mineral soils by 7-8 ^{0}C. The grass cover smoothes this difference. During the vegetation period, the topsoil of the reclaimed peat land is colder than that of mineral soils. Over the vegetation period, the total air temperatures above 10 ^{0}C on reclaimed peat lands at a depth of 10 cm is lower by 400-500 ^{0}C than on mineral soils, and the frost-free period is shorter by 30-60 days. Bog soils drained by using tile drainage appear to be warmer than soils drained by open-channel drainage network [9-11, 20].

Irrigating reclaimed bog soils increases the radiation balance and reduces their maximum surface temperature by 6-10 ^{0}C.

The drainage reclamation that changed the water-air soil regime significantly effected the regime of many small and medium rivers. After the drainage reclamation, the hydrographic network density increased 2.5-4.9 times, thereby creating more favorable runoff conditions for floodwater discharge.

After the drainage reclamation, of 50 surveyed watershed areas the annual runoff increased on 26. Drainage most significantly effected small watersheds up to 2,000-3,000 km^2 in area in the first years (due to the reduced total evaporation and drawdown of ground water storage). In the first years, the annual runoff increased by 20-30% and base runoff by 50-70% and even more. No significant changes were observed on the other watershed areas.

In forecasting the climate change effect on surface water resources, the following variants have been considered:

Variant 1 – increase in mean annual air temperature by 2 °C compared to the current level with the precipitation remaining constant;

Variant 2 – reduction in annual precipitation by 10% with air temperature remaining unchanged;

Variant 3 – reduction in annual precipitation by 10%, while mean annual air temperature rises by 2 °C;

Variant 4 – reduction in the degree of peat formation (through drainage) and percentage of forestry area (through felling) in the watershed area and increase in the river network density (building irrigation and drainage canals) and percentage of tilled area (intensive cultivation of new agricultural land) by 5, 10, 20 and 30% of the current ones, with climatic conditions remaining unchanged.

It has been found through calculations that the third variant under which the runoff reduces by 45.2% is the most unfavorable forecast of the change in the Belarusian Polessie rivers' runoff. Superimposing 10% anthropogenic impact on this variant may lead to 50% reduction in the mean annual runoff.

The predicted climate warming would cause further negative response of both aquatic systems as a whole and its individual components and the river floodplains would be particularly effected as most sensitive landscapes.

4. SOCIAL AND ECONOMIC SYSTEMS

The climate in all the times was and will be in the future one of the main factors defining life on the Earth in all its manifestations.

In the recent years, the effects of the climate change have been extensively studied to assess them. These assessments are based on climatic forecasts having a high uncertainty with respect to specific regions.

Among the major effects, the change in natural ecosystems may be noted. According to specific estimates, specific ecosystems will fail to adapt to new climatic conditions that would lead to their extinction [1].

The climate change entails the higher frequency of extreme climatic phenomena (floods, droughts, severe and mild winters).

Global warming-related agroclimatic effects that would pose a serious food problem in the future are considered most critical in terms of social and ecological aspect.

The experts believe that the global warming effecting the agricultural sector and which is defined by unfavorable weather conditions even in countries with relatively stable climate may result in ecological damage that would represent a larger share of total losses to be sustained by all economy sectors.

If climate changes drastically, the Russian experts predict inevitable and radical restructuring of all farming systems, since agroclimatic zones are expected to shift northward and north-westward for significant distances, the vegetation period is expected to become longer by 1-2 months, thereby allowing cultivation of heat-loving crops in the north [2].

At the same time, the experts presume that agricultural crop productivity would reduce due to higher aridity. This effect, however, may be set off, to some extent, by the north and north-western regions of the European part of the country.

The change in productivity for the European region of Russia is estimated at 3-4% (with improvement of soil fertility being accounted) [2].

An integrated assessment of the geoecological situation in the urbanized areas has revealed a minimum geoecological stability of urban areas in the majority of regions of the country, in its middle, in particular. It has been found that specific microclimate significantly differing from that in the neighboring areas forms in the urban areas [3]. Due to this, global climate change would effect predominantly natural and ecological potential of the urban communities' geosystems and, to a lesser extent, it would effect the state of their natural and anthropogenic systems. It should be noted that the effect of geological factors in the urbanized areas is continuously increasing.

A number of conclusions of Russian experts may be related to Belarus.

It should be noted that currently the Belarusian agricultural sector is in deep recession. The major reason is decline in performance of existing collective and state farms aggravated by a limited use of innovative farming techniques. The technological backwardness and insufficient machinery fleet, unjustifiably high inputs (energy resources costs in Belarusian farming are 3-4 times that of the USA), and persistent price disparity under conditions of the forming market more and more necessitate radical reforming of the agricultural sector. Avalanching demographic problems (reducing population size, population aging, including a higher share of the population beyond the able-bodied age) contribute to degradation of the underdeveloped rural social infrastructure.

The current farming is not meeting the minimum level of the country's food security in terms of a number of important parameters. The designed Program of Improving the Agribusiness Sector in the Republic of Belarus for 2001-2005 being currently under implementation sets as its objective to form a new farming management system at the macro and microeconomic levels to ensure a sustainable socio-economic development in the sector by increasing its performance. With these objectives in mind, improving the farming management system and economic relations in the agribusiness sector, refurbishing the agricultural production technically and technologically, increasing rural housing construction and improving efficiency of the research are aimed at increasing the sector's performance (Table 4.1).

Table 4.1 Predicted Agricultural Output, '000 Tonnes

Product	Minimum level of food security	2000	2005 (forecast)
Grain	5,500 – 6,000	4,856	7,400
Rape	130 – 150	90	165
Sugar beet	1,300 – 1,500	1,474	1,850
Potato	6,000 – 6,500	8,718	9,500
Vegetables	800 – 1,000	1,379	1,450
Meat (live weight)	900 –1,000	845	1,250
Milk	4,200 – 4,500	4,504	5,950

Changing climate may entail specific adjustments of the predicted agricultural output.

Possible effects related to the change in agroclimatic variables influencing the agricultural production have been reviewed in Section 1. They may be summarized as follows. There exists a clear-cut dependence between the variation in integral hydrometeorological indices and variation in the country's economic indicators [4]. This interrelation is much more pronounced in grain production. Over the last decade, the change in the annual grain yield in Belarus is about 2.5 million tonnes. Given that the climatic component of the change in the grain yield is about 30-40% and a minimum price of one tonne of grain is USD 80, minimum economic losses would be estimated at

USD 80-100 million as a result of the reduced grain harvest in Belarus. Expert estimates show that weather and climatic conditions lead to the increase in the gross farm product by 15-20% as minimum, meat and milk – by 10-15%, and inputs for production of the cattle and swine - by 5-15%. Emerging severe aridity phenomena increase expenses related to unscheduled tillage, seed resowing over large areas, use of machinery above standards, additional fuel consumption, unforeseen remuneration of labor, etc. Costs for production of cereal crops during severe arid phenomena increase by 15-20% compared to the favorable years. This leads to a significant reduction in farming productivity by actually the same figure.

The problems of energy resources, specifically renewable energy, are closely related to climate change. Available estimates of thicker cloud cover and lower atmosphere transparency provide evidence that solar radiation influx reduces especially in large urban communities (direct solar radiation by 20%, and total radiation by several percents in the last several decades).

4.1. Climate Change Effect on Duration of Heating Season and Fuel Saving

Saving fuel and energy for heating needs is one of the most important socio-economic effects related to climate warming.

According to calculations based on the climate change forecast, the heating season would reduce by 1 month over a larger area of Euroasia and approximately by 2 weeks in the middle of Russia [6].

According to other data, the heating season would reduce by 60-30 days in the north and 10-15 days in the central and southern regions of the Former Soviet Union (FSU) by the beginning of the XXI century. The predicted climate warming by the mid-XXI century will contribute to further significant reduction in the heating season by 2-4 months in the north and by 1-1.5 months in the other FSU regions.

Lower severity of climatic conditions currently determining the cost of maintaining the economic activity would be most positive factor of climate warming for Belarus. Fuel and energy saving resulting from shorter and less severe cold season and, hence, lower energy costs for heating buildings may be one of the most substantial socio-economic effects of the expected anthropogenic climate warming for our region.

High costs are related to the need to maintain a comfortable air temperature in dwellings and production premises during a year. Such warming effects may be qualitatively assessed only by calculating the change in heating period duration, as well as heat deficit and total temperature exceeding the preset level of physiological comfort.

The Republic of Belarus has an extensively developed district-heating system network operating based on developed standards and norms. According to these standards, the heating season begins if mean diurnal air temperature reduces down to 8 ^{0}C, and the heating system should maintain a temperature of about 18 ^{0}C in the premises [7].

The ECHAM–1A model-based forecast suggests the change in air temperature in high altitudes be within the range from 0.5 to 2.5-3.0 ^{0}C by the mid of the current century [6].

In analyzing the aspects of the climate change effect on the power engineering, the change in heating season characteristics needs to be considered (Table 4.2).

Thus, the heating season reduced by 6-9 days mainly due to its earlier termination. A mean temperature of the heating season increased by 1-1.5 ^{0}C (predominantly in the north). All this resulted in the decrease in the degree-day total by 9-11%. This should appropriately effect the heating fuel consumption.

The change in climatic characteristics being observed will require adjustment of parameters of the construction climatology and *Construction Norms of Belarus*.

Mean monthly and mean annual temperatures in Belarus over the period from 1964-2000 were analyzed and the predicted mean monthly temperature for Belarus was determined based on the analysis and findings [8-11].

The analysis of the change in temperature has shown that it increases insignificantly in summer months compared to winter months that agrees well with studies in other countries. It should be noted that air temperature increases more significantly in the first half of the year, and in November-December even a minor decrease in temperature is observed.

The temperature change was calculated based on the above predictions of climate change from 0.5 ^{0}C to 3 ^{0}C over an interval of 0.5 ^{0}C.

Table 4.2 Change in Heating Season Characteristics

Oblast	Period, date		Duration, days		Mean temperature, ^{0}C		Total, degree-day		
	before 1990	**1989 –2001**	**before 1990**	**1989 –2001**	**before 1990**	**1989 – 2001**	**before 1990**	**1989 – 2001**	**difference, %**
Vitebsk	3.X – 26.IV	4.X – 21. IV	206	200	–1.9	–0.4	3,895	3,474	11
Minsk	6.X – 24. IV	6.10 – 19. IV	201	196	–1.4	–0.1	3,705	3,356	9
Grodno	8.10 – 23. IV	8.10 – 17. IV	198	192	–0.9	0.45	3,535	3,182	10
Mogilev	4.X – 24. IV	5.X – 18. IV	202	195	–1.9	-0.8	3,833	3,468	9.5
Brest	11.X – 20. IV	12.X – 13. IV	192	184	–0.55	0.5	3,370	3,033	10
Gomel	9.X – 20. IV	10.X – 13. IV	195	186	–1.3	-0.2	3,553	3,202	10

Figures 4.1 and 4.2 and Table 4.3 show actual change in the mean monthly temperature during different periods – from the coldest to the warmest. The period of 1991-2000, that is, the end of the

XX century is taken as a base period for making forecast calculations of the change in heating period duration and fuel saving.

Given the accepted assumptions, mean monthly temperature distribution curves were plotted versus mean annual temperature (Figure 4.3).
The base duration of the heating period amounted to 6.5 months. If mean annual air temperature rises from 0.5 ^{0}C to 3 ^{0}C, the heating period will reduce respectively by 6 and 36 days (up to 3 ^{0}C) (Fig. 4.3 and Table 4.4.).

Our calculations of the change in the heating period agree well with the data [6]. In this case, the major temperature rise is predicted in the first half of the year.

In addition to the effect of air temperature rise on the heating period, the effect of building heat loss in a cold period will be also observed.

Air temperature, wind speed and solar radiation are accounted as major weather factors influencing the building thermal regime in the methods for estimating the heating costs.

Temperature inside the premises serves as an important parameter for heat-supply calculations. Calculation of losses, with all factors being accounted for, is rather complex. However, it is pointed out in [2] that rather good results may be obtained by using only one variable – ambient air temperature – and in the initial approximation heat deficit may be determined by summing up differences between room air temperature (18 ^{0}C) and mean ambient air temperature in the cold period (with air temperature below 8 ^{0}C).

Below are provided calculations of heat losses of buildings with consideration made for the above assumptions.

The reduction in heat loss and, hence, saving fuel for heating premises with the temperature increase by 0.5 ^{0}C would be 3.5%, and with the temperature increase by 3 ^{0}C – 15.3%.

Therefore, the total fuel saving with temperature rise by 0.5 ^{0}C would be 6.6%, and by 3 ^{0}C – 33.8% (Fig. 4.4).

The obtained results rather well agree with the results obtained for countries of the Western Europe and European part of Russia [6].

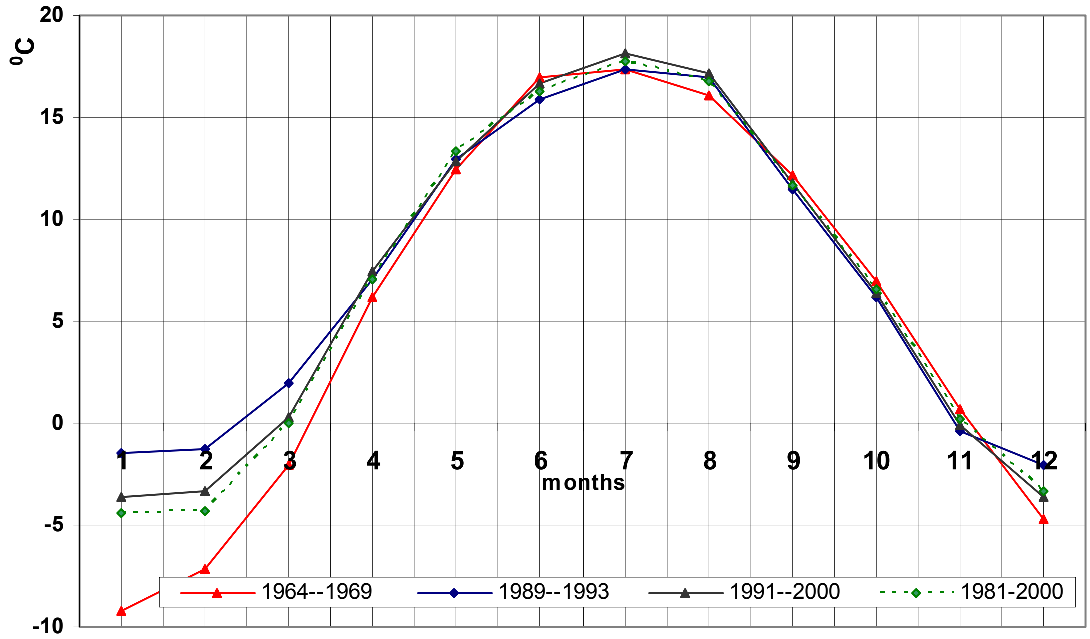


Fig. 4.1. Change in mean monthly temperature

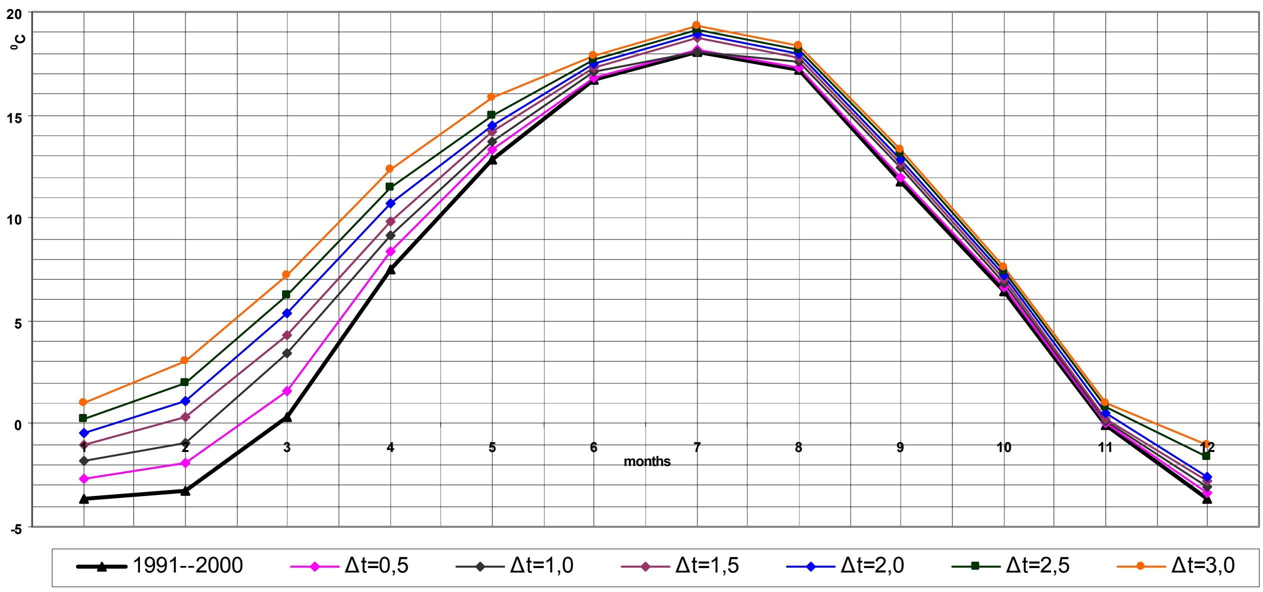


Fig. 4.2. Projected change in mean monthly temperature

Table 4.3 Reduction in Heating Period and Fuel Saving

Indicator	Change in temperature, ^{0}C					
	0.5	1.0	1.5	2	2.5	3
Change in heating period, day	6	11	16.2	22.4	28.6	36
Fuel saving due to shorter heating period, %	3.1	5.6	8.3	11.9	14.7	18.5
Fuel saving due to change in ambient air temperature in heating period, %	3.5	6.5	8.2	9.5	13.2	15.3
Total fuel saving, %	6.6	12.1	16.5	21.4	27.9	33.8

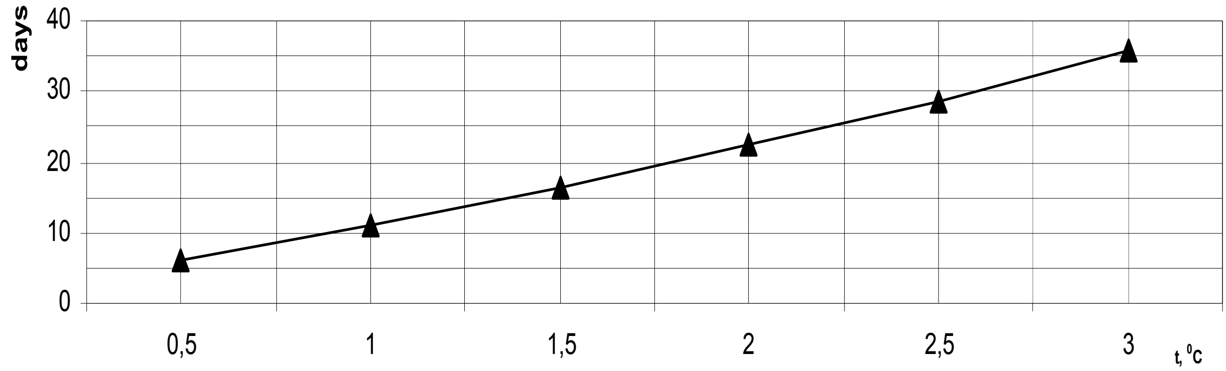


Fig.. 4.3. Reduction in heating period vs mean annual temperature

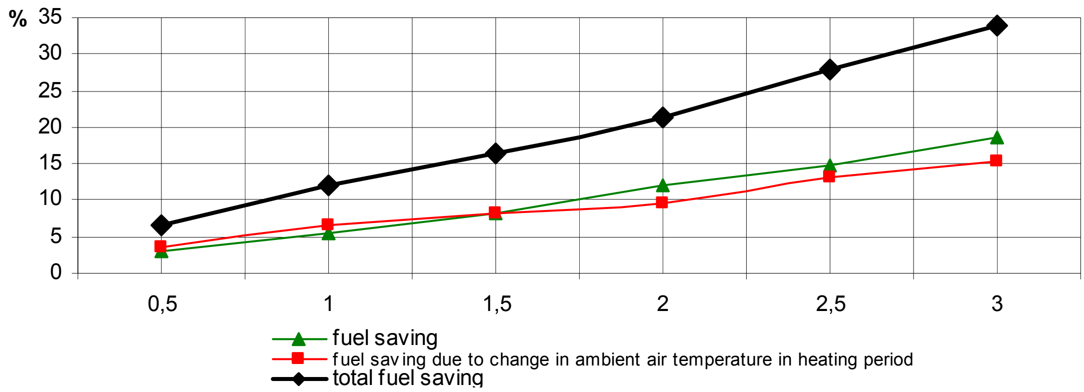


Fig. 4.4. Reduction in heating period and fuel saving

Table 4.4 Mean Monthly and Mean Annual Air Temperature, ^{0}C

Period	Mean temperature, month-wise												Mean annual	Range of mean annual temperature rise
	1	2	3	4	5	6	7	8	9	10	11	12		
1991–2000	-3.6	-3.3	0.3	7.5	12.8	16.7	18.1	17.2	11.8	6.4	-0.1	-3.6	6.7	
1981–2000	-4.4	-4.3	0	7.1	13.3	16.3	17.7	16.8	11.7	6.6	0.2	-3.3	6.5	
1964–1969	-9.2	-7.2	-2.1	6.2	12.5	17	17.4	16.1	12.2	7	0.7	-4.7	5.5	
1989–1993	-1.5	-1.3	2	7.1	12.9	15.9	17.4	17	11.5	6.2	-0.4	-2.1	7.1	
Forecast	-2.7	-1.9	1.6	8.4	13.3	16.8	18.2	17.3	12	6.6	0	-3.4	7.2	0.5
	-1.8	-0.9	3.4	9.1	13.7	17.1	18.1	17.6	12.4	6.8	0.1	-3.1	7.7	1
	-1	0.3	4.3	9.8	14.2	17.3	18.7	17.8	12.6	7	0.2	-2.8	8.2	1.5
	-0.4	1.1	5.4	10.7	14.5	17.5	18.9	18	12.8	7.2	0.5	-2.6	8.7	2
	0.2	2	6.2	11.5	15	17.7	19.1	18.2	13.1	7.4	0.8	-1.6	9.2	2.5
	1	3	7.2	12.3	15.8	17.9	19.3	18.4	13.3	7.6	1	-1	9.7	3

4.2. Assessment of Climate Impact on Health

The most important aspect of the climate change problem is human health. Globally, the change in natural ecosystems may lead to the increased number of ecological refugees, probable health deterioration, propagation of diseases, thereby increasing the mortality rate among them. Global warming is expected to create favorable conditions for specific pests and diseases that would adversely affect the communities' health [9].

Depletion of the ozone layer by 1% which is also related to climate warming may increase incidence in melanoma by 2 %, non-melanotic cancer by 3 %, and cataract by 0.6 - 0.8% [12].

Comfort of work, recreation and living significantly influences health. Providing comfort as climate changes will allow adverse socio-economic effects to be mitigated. The weather and climate effect depends on the value (and sign) of deviation of actually observed values of climatic factors from their specific combination which is considered to be "comfortable".

A direct effect of these factors may be "instantaneous", i.e. caused by the prevailing weather and may also depend on the sequence of events, i.e. synoptic situation. The effects may be cumulative and occur as a result of a long-term exposure to different conditions.

Effect of Temperature Change on Human Organism. Ambient temperature is the major factor directly effecting a human organism. Respiratory depth and rate, blood circulation rate, hematogenesis character, supply of cells and tissues with oxygen and, hence, intensity of oxidation processes, as well as specifics of carbohydrate, salt, fat and water metabolism and muscular work are temperature-dependent.

For majority of healthy people being at rest an air temperature from 15 to 25°C produces normal heat sensations [13, 14] and forms a comfort zone. Impeded heat loss because of high temperatures may contribute to suppression of important functions of the organism, reduction in its vitality and predisposition to infectious diseases. A significant decrease in air temperature may also lead to imbalance of thermoregulation in limbs and mucous membranes of respiratory tract, thereby causing chill. Cardiovascular disease-related mortality in middle and high latitudes is invariably the highest in the cold period of the year – January-February and the lowest in warm months – July-August. This is likely to be related to the effect of thermal factors on elasticity and peripheral resistance of blood vessels, activity of sympathetic nervous system and physical and chemical blood condition (viscosity, coagulation time).

Extreme heat and cold, that is excessive thermal stresses are undoubtedly hazardous: lukewarm climate makes the organism more prone to intestinal diseases, while boreal climate – to respiratory tract diseases. Such conditions as asthma, bronchitis, allergic rhinitis, rheumatic diseases (in particular, rheumatoid arthritis), cardiac diseases (in particular, myocardial infarction and stenocardia), insult, specific eye diseases (for example, acute glaucoma, acute conjunctivitis) and vascular disturbances may be categorized as moderate thermal stress type.

The temperature regime, most comfortable for a human and favorable for conducting climatic therapy, is observed in Belarus during a warm period of the year, when mean daily temperatures reach 15-25 °C. Summer months, namely, June (mean temperatures 15-17 °C), July (17.5-18.5 °C) and August (16-17.5 °C) are most comfortable for a human. The temporal summer temperature variability is minimal. The summer month temperature may reduce to 13 °C and lower only in 5% of years and it increases above 20 °C in July only in 5% of years. This is characteristic of only southern regions in June and August. In addition to these months, the 2nd and 3rd decades of May when the transition of mean daily temperatures passes through 14 °C and the first decade of September are most favorable in terms of air temperature. In May and September, 65-75% of warm days with a mean daily temperature of 10-20 °C favorable for climatic therapy are observed [15].

Abrupt temperature variations significantly effect morbidity and mortality rate. It has been found that the interdiurnal change in temperature by 6 °C and higher causes negative sensations in the human.

Large interdiurnal temperature variability is related to circulation processes and change of air masses over Belarus. A minimum interdiurnal temperature variability is observed in July-August (1.4-1.8 °C). As circulation processes increase, it grows by winter to reach the maximum in January-February (2.5-3.0 °C). Interdiurnal temperature variability (above 6 °C) unfavorable for the human health is observed mainly in winter – about 6% in south-west and 10-11% in north-east – and it reduces significantly only in summer (3-5%).

Therefore, a warm period of the year (2-3 decades of May – 1 decade of September) is characterized by optimum air temperature resulting in a minimum meteopatic responses. In specific cases, however, it is reasonable to temper and train the organism even at lower temperatures.

Effect of Air Humidity Change on Human Organism. The effect of air humidity on the human organism is primarily related to the water metabolism regulation. An abrupt increase in air humidity leads to kidney diseases and pulmonary bleeding [14]. Extremely dry air, however, is also hazardous, since it may cause irritation of a respiratory tract, coughing, dyspnea, general excitation, headaches and insomnia. Average air humidity (50%) in the absence of abrupt variation creates comfortable conditions.

Belarus is characterized by higher air humidity over the entire year. During the cold season of the year (from October to March), mean monthly relative humidity is within the range of 80-90%, and the change in humidity throughout Belarus is not observed. Maximum air humidity is observed in November-December (87-90%).

In spring, rising air temperature reduces relative humidity from 77-83% in March to 65-70% in May reaching minimum in the annual variation.

The diurnal variation of the relative humidity in winter is almost not expressed. In summer, the difference between its limiting values within 24 hours is 15-25% (over 30% in the south-east). The maximum humidity is observed before the sunrise, when temperature reaches the lowest values.

The minimum values of relative humidity are observed in the afternoon when air temperature reaches maximum.

Dry days with humidity less than 30% are rarely observed in Belarus – mainly in April-May, about 5% in the south and even less in the north.

Therefore, most favorable conditions for the human in terms of the relative humidity regime are observed in the spring-summer period (May-August) under conditions of excessive humidity throughout the year in Belarus. However, even in these months up to 10% of humid days are observed.

Effect of Atmospheric Pressure Change on Human Organism. In medical terms, an absolute pressure value is not of great significance, but rather its abrupt variations [16].

Drop in atmospheric pressure even by 5-6 mbar leads to respiratory disturbances, reduce pulmonary and tissue gas exchange and oxygen starvation in blood and tissues, thereby increasing probability of cardiovascular diseases.

In Belarus, atmospheric pressure changes smoothly from day to day in most cases: in 30-50% of cases not more than by 2 mbar a day. Pressure drops unfavorable for human health above 10 mbar a day are observed in 25-35% of cases in winter, in 60% of cases in spring and 10-30% of cases in fall. During the intensive cyclonic activity in the cold period, interdiurnal change in atmospheric pressure reaches maximum values up to 30 mbar and in summer up to 12-16 mbar.

Effect of Wind Change on Human Organism. The dependence of human organism condition on wind direction is defined by physical and chemical properties of moving air. To exclude possible negative impact of industries and large industrial centers on air quality, the prevailing wind direction needs to be taken into account.

Of great importance is the wind force. The stronger the wind, the more it impedes proper respiration causing dyspnea, fatigues and irritates the nervous system causing an anxiety, headaches and insomnia [14]. Wind regulates blood-filling of skin vessels acting directly on skin receptors, reflexly increases metabolism and effects the gas exchange. At low temperatures, it strongly increases body heat dissipation that may lead to body hypothermia. This increases the risk of catching cold. A complete absence of wind during the warm period of the year, creates a relaxation effect and leads to susceptibility of the organism, while a weak wind increases skin evaporation, tones up and stimulates the organism. The wind speed up to 2 m/s is considered to be rather favorable for climatic therapy [16].

The wind regime in Belarus is defined by a general atmospheric circulation over the Euroasia. This determines the prevalence of winds of the south-western quarter of horizon (S, SW, W – 45-50%) in winter, and the western component in the summer season (NW, W, SW – 50 %). In spring and fall, air streams are not so pronounced than in summer and winter. Winds of all directions are almost equiprobable, although winds of the south-eastern direction are more expressed in spring, while winds of south-western and western direction – in fall.

The character of the earth surface both in macro and microclimatic terms (specifics of relief, vegetation, water bodies, structures availability, etc.) primarily effects the values of the ground wind speed being significant for sanatorium treatment.

Belarus is located in the zone of very weak and weak winds. Calm conditions and very weak winds (0-1 m/s) occur in 14-30% of the entire year, on the average, in the Republic. The highest frequency is observed in forested river plains and the lowest – in the upland area and open space. Weak winds (2-5 m/s) are most characteristic of the republic. Their frequency is 60-75% of the year time. It is minimum in Polessie and maximum in open flatland and upland of the middle region of Belarus. The fraction of strong winds in Belarus is low (up to 1-3%), and they are observed only on open spaces in the cold season.

The fall-winter season is characterized by maximum wind speeds when cyclonic activity becomes more intensified, while minimum speeds are observed at the end of summer when frequency and depth of cyclonic formations decreases.

Effect of Cloudiness on Human Organism. Cloudiness effects the light regime: clouds impede passage of solar radiation toward the earth and its favorable effect is strongly limited; it is also a source of precipitation abruptly changing the daily temperature and air humidity. Specifically these two factors, if they are clearly expressed, may unfavorably effect the organism during the cloudy weather [17].

In medical climatology, cloudiness is considered as one of the major factors defining duration of helioprocedures, since it directly effects passage and intensity of solar radiation and sunshine duration.

In Belarus, the sunshine is observed approximately in 40% of time, on the average, when the sun is over the horizon. For the rest of the time, it is shrouded with clouds and only diffuse sky radiation reaches the earth surface. The total mean annual cloudiness reduces from the north, north-west to the south and south-east from 7.0-7.2 to 6.6-6.9 amount of clouds. An average number of overcast days in a year reaches 145-155 in the south-east and 165-175 in the north-west.

The annual variation in cloudiness is characterized by a clear maximum in November-December and minimum in June. In winter, overcast days make up approximately 80%. Cloudiness reduces in summer to 40-50%. The number of clear days increases from the north-west to south-east.

Some differences are observed in the diurnal variation of cloudiness depending on the seasons of the year, and in spring and fall cloudiness minimum is close to the midday, while in summer it shifts by 10-11 hours, and in winter cloudiness is minimum in the afternoon (12-14 hours). It should be also noted that the sunshine duration during these hours in summer is 42 minutes/hour, on the average, and in winter only 17-20 minutes. This effects the duration of heliotherapeutic procedures in different seasons of the year.

Finally, it should be pointed out that the above environmental factors effect the human organism not separately, but comprehensively. The effect would differ depending on the combination of these factors.

Currently, it is presumed that intensity of the weather change plays an important role in the integrated climate effect on the human organism. Occurring weather responses aggravate the course of a disease and adversely effect the general state and mood of a human being. Among a great number of elements characterizing the physical state of the bottom layer, the factors directly effecting the organism – temperature, air humidity, atmospheric pressure and wind – are available. Their effect on the organism arises no doubts. Of significance are both periodic and aperiodic changes in the elements of the bottom layer physical state to maintain rhythm of physiological functions and metabolic processes (during the year). Specifically aperiodic processes effect the organism to a greater extent in case of pathology. The research data provide evidence that exacerbation is observed in up to 80% of patients as response to unstable weather.

Given the above, the effect of weather conditions on the organism may be considered as multiply repeated periodic and aperiodic physical elements with the bottom layer in specific amplitude relations, with the major role being attributed to the general elements. Periodicity of physiological functions, metabolic processes and biological responses characterizing the human vital activity corresponds to the change of these elements, while their effect on occurrence of meteotropic responses, morbidity and death rate is defined by the degree of insufficiency of the organism compensatory and adaptive mechanisms.

The load related to the adaptive activity of the organism may be reduced or increased, the organism may be trained to increase and improve functioning of its protective mechanisms by using peculiarities of that or other climate (solar radiation, air properties, landscape and other climatic medical factors). Given that these protective mechanisms of the human organism play a crucial role in controlling various hazards (infections, regenerative processes, toxicosis, oxygen starvation, etc.), a great practical importance of using spa medical factors for health rehabilitation becomes evident.

Let us consider the change in the pathogenicity index (PI) of temperature, humidity, wind speed, interdiurnal changes in pressure, as well as annual variation in the complex index of pathogenicity over the last 30-40 years.

To assess weather conditions in bioclimatic terms, the method of calculating the PI of individual weather indicators and their set has been used (by V.G. Bokshe). The pathogenicity indices allow for determining the degree of irritating effect of individual weather elements and weather as a whole on a human, the character of its change and pathogenicity level. Analyzing the PI of weather in the area makes possible to identify from which meteoelements it forms, as well as the character of the weather change and its possible effect on the human organism. In analyzing the IP, the relationship between the prevalence of the cardiovascular system and primarily the value of interdiurnal pressure variation has been identified. The air humidity regime effects most the dynamics of respiratory organs prevalence. The air temperature PI and wind velocity PI also significantly effect the dynamics of respiratory organs prevalence, since low temperature and wind speed at high humidity overcool the organism causing an intensive heat transfer, thereby leading to the increased number of chill cases.

The analysis results have shown that the annual PI variation is characterized by maximum values in a cold season of the year (harsh weather) and by minimum values in summer. The PI gradually increases in spring and fall toward winter months (irritating weather). This is confirmed by the annual variation in the morbidity rate indicators reaching maximum in winter and minimum in summer.

The tendency toward the general reduction in the mean annual complex pathogenicity index (CPI) of weather is observed throughout the area under study.

The annual variation revealed a tendency toward reduction in CPI in the cold season resulting from the changeover of the temperature and humidity regime.

The change in the regime of the general atmospheric circulation led to the change in dynamics of partial pathogenicity indices. A stable tendency toward reduction of mean annual pathogenicity indices of air temperature (PIAT) and wind speed (PIWS) has been observed over the last 30-40 years throughout Belarus.

The maximum reduction in the PIAT is observed in the northern part of Belarus (spa Letsy, Vitebsk Oblast). The reduction in PIWS is less expressed only in the south-west of the country (spa Bug, Brest Region). The reduction in the pathogenicity index of air humidity (PIAH) is also maximum in the north of Belarus where it reduced by more than 1.5 units over the observation period (spa Letsy). This reduction is not so expressed in the middle and south-western regions. On the contrary, a significant increase in mean annual indicators is observed in the dynamics of the PIAH in the south-east of the republic (Gomel). A stable increase in the pathogenicity index of the interdiurnal change in atmospheric pressure (PIICAP) is also observed throughout Belarus.

The annual variation in partial pathogenicity indices is also subject to specific changes. The PIAT shows a tendency toward reduction in winter and spring seasons of the year from December to April, when they are maximum, throughout the area under study. In summer months, the PIAT is the lowest and actually remains unchanged over the period of study. However, these values slightly reduce in August specifically in the north and north-west of the country (spa Naroch). On the contrary, the PIAT shows the tendency toward the increase in fall that in combination with the increased PIWS makes the fall period actually unsuitable for climatotherapeutic procedures starting from the third decade of September. The maximum increase in the PIAT is observed in the fall season in November, and it is close to winter months by absolute pathogenicity indices and in a number of years is the most unfavorable month of the year. This is most pronounced in the northern part of Belarus.

The PIWS reduction is also observed in the northern part of Belarus. This is specifically pronounced in the spring-summer period. The change in the PIWS somewhat smoothes toward the central regions of the republic, while in southern regions it is not expressed at all and even demonstrates a slight tendency to growth (Gomel).

The dynamics of the PIAH shows the reduction in indicators in northern parts of the country mainly due to the spring-summer period, however, the tendency toward the reduction in PIAH is also observed in the fall period in the north-east (spa Letsy). This creates prerequisites for improvement of climate healing properties (in terms of heat and humidity), since the reduction in PIAH allows high temperatures to be much easier tolerated in the warm period of the year - it is very important for patients with respiratory organs diseases – and conditions of the winter recreation and rehabilitation to be improved. The reduction in the PIAH in southern and south-western regions (spa Bug) allows for spa treatment there for a major part of the year and this is the most favorable region for climatotherapy in terms of temperature and humidity regime.

The PIICAP in the northern (spa Letsy, spa Naroch) and in central (Minsk) regions of Belarus shows the tendency toward increase, thereby significantly deteriorating the rehabilitation conditions for patients with the cardiovascular pathology in these regions. Only in the south of Belarus (Brest, Gomel) the PIICAP remains actually unchanged and only in spring a slight increase in indices is observed.

The above information regarding the weather effect on the human organism allows meteorological factors leading to health deterioration to be distinguished from other causes.

The predicted temperature rise, reduction in wind velocity, increase in atmospheric pressure variability and air humidity contribute to multidirectional character of trend changes in pathogenicity indices.

It should be pointed out that in analyzing aspects of the climate effect on health, the following circumstances need to be paid attention to. A comparatively minor increase in summer temperatures currently observed has already resulted in a substantial increase in frequency of high temperatures, thus an average number of days with a maximum temperature > 30 °C has changed as follows over the summer months (Table 4.5).

Table 4.5 Change in Summer Temperatures in Different Belarusian Cities and Time Periods, °C

Years	Temperature	Vitebsk	Minsk	Brest
1881 – 1990	T from 20.1 °C to 25.0 °C	13.0	15.0	22.4
1989 – 2001		18.0	20.4	25.6
1881 – 1990	T from 25.1 °C to 30.0 °C	0.11	0.18	0.59
1989 – 2001		1.24	1.38	3.31

Table 4.6 Change in Summer Maximum Temperatures (T > 30 °C) in Different Belarusian Cities and Different Time Periods, °C

Years	Vitebsk	Minsk	Brest
1881-1990	1.7	1.9	4.6
1989-2001	3.3	3.5	9.2

The data provided in Table 4.6 demonstrate almost 2-fold increase in frequency of maximum summer temperatures. The similar conclusion may be also made for temperatures above 20 °C (Table 4.5). The further increase in summer temperatures would entail even more differences, since maximum temperatures correlate well with mean monthly temperatures. The increased number of days and periods with high temperatures creates an additional load on the organism, specifically for patients with cardiovascular diseases, and reduces capacity for work. Protective measures need to be taken in premises, in particular (air conditioners, ventilators, architectural solutions may be also applied).

Characteristics of thaws substantially changed during the warming period which is mainly related to the increased temperatures in winter months. The number of thaw days increased, as well as the continuous duration of thaw periods. While in the past the occurrence of thaw periods with duration over 10 days made up 9% of the total number of such periods, in the last years - nearly 14%. Thaw intensity also increased – maximum and mean daily temperatures became higher during thaws. Frequency of thaws with maximum temperature over 4 °C increased from 13 to 21% and that with the mean temperature increased 1.5 times.

All this creates an additional load on the organism, since its adjustment is required with the commencement of thaws and subsequent cooling. This leads to the increase in chill cases.

A direct effect of weather factors is supplemented by indirect climate impact, since climatic conditions define to a great extent the pattern of the food consumed, sanitary techniques, structure of dwelling buildings, offices and industrial enterprises, effect the social and family structure, as well as viability of insects and animals being carriers of pathogenic microorganisms in their habitat.

Of great concern are the diseases not characteristic of Belarus, namely, infections that have been diagnosed over the last 40 years. Recently, the mass media has informed about propagation of tropical viruses and the scientists explain their emergence by changes occurring in the nature: malaria and the “West Nile fever virus” reached the United States, outbreak of Ebola disease in London, tropical fever in Moscow, malaria plaguing Italy, typhoid fever outbreak in Portugal and cholera outbreak in Madrid. Recently, locally transmitted benign tertian malaria centers have again emerged in Russia, while for several decades this disease was brought to the country from outside only. Extensively developing traffic – in particular, the frequency of air flights increased – significantly contribute to the virus propagation. Climate warming on the earth creates favorable conditions for life and reproduction of hazardous insects: warm springs are currently observed even in the countries where tropical diseases always were a rather rare phenomenon. It has been proved by medical scientists that populations of infestants causing such dangerous diseases as plague, cholera, malaria and dirofilariosis are able to mutate. Cells adapt to changing environment and maintain viability in unfavorable conditions. The OECD Conference stressed that if the pharmaceutical industry of developed countries fails to focus on tropical diseases in developing countries, these diseases will freely propagate to the Northern hemisphere.

Investigating blood-sucking mosquitoes in Belarus allowed the antigen of the West Nile fever (WNF) virus to be found in 1998. Mosquitoes were collected in all landscape and climatic zones (LCZ) of Belarus. 7.1% of mosquitoes were infected with this virus in Belarus. The highest infection contamination (12%) was observed in the southern LCZ; in the middle LCZ this indicator amounted to 11.8% and in the northern - only 2.8%. Among the Oblasts, the highest mosquito infection contamination was observed in Gomel (15.0%) and Minsk (11.8%) Oblasts; the lowest indicator was recorded in Vitebsk Oblast – 2.8%. In Grodno Oblast, the WNF virus antigen in mosquitoes was not found.

Tick-borne encephalitis (TBE) remains a pressing problem; of insect-transmitted diseases, small tick-borne typhus centers exist in eastern and central part of Siberia.

Studies in Russia have shown that TBE morbidity indicator per 100 thousand persons varies from 53.7 (1964) to 4.8 (1985). Over the last decade, morbidity stabilized, and higher morbidity was observed in specific years (1987, 1990, 1993, 1996). The mathematical analysis shows that the situation is not likely to improve in the near future due to the continuous activation of natural centers of this disease. The prime causes of epidemiological concern during the periods of higher morbidity are primarily the changes in natural factors and, hence, in the population of rodents and ticks and their virophoresis directly effecting the sick rate. 1,225 cases (40.7 per 100,000) were recorded over the 1996 epidemic season, and the number of cases increased 4.7 times compared to the previous season.

The so-called pasture tick that may be a carrier of two infestants, namely tick-borne encephalitis and lime disease is common in Belarus. Dozens of cases are diagnosed annually in Belarus. Actual morbidity rate, however, is much higher. The most unfavorable areas in terms of these diseases are Belovezhskaya Pushcha, Berezinsky Reserve, Borisovsky and Dokshitsky Districts, some Districts of Mogilev and Gomel Oblasts. 61 tick-borne encephalitis cases (of them, 5 children) were recorded in Belarus in 2001. The situation with lime disease causes more concern – 181 cases in 2001, of them, 18 children were infected.

Given the Siberian-type encephalitic and possibility of replacing a European type of disease characterized by less expressed clinical picture with stronger strains having more severe clinical manifestation, it may be considered that encephalitis is rather a serious problem that needs to be studied in detail.

Therefore, the projected climatic changes will entail significant changes in human health.

4.3. Adaptation of Social and Economic Systems to Climate Change

To date, only some papers on assessment of social and economic effects of the forecast climate change are available, therefore, the proposed conclusions are based primarily on the expert assessments that need to be further refined.

Unfortunately, Belarus has not studied the aspects of the consumer strategy selection, has not assessed average consumer losses and weather losses, i.e. losses sustained by the consumer resulting from noncompliance of the taken economic decision with actual weather and climatic conditions, as well as the aspects relating to selection of criteria of the optimum strategy (average weather losses, minimum of loss probability exceeding the preset level, maximum of average income), making climatically optimal decision, determining the economic effect from using weather and climatic data.

Potential loss induced by unfavorable weather and climatic conditions is the largest in the agricultural sector (nearly 70%) for countries in the temperate zone. It may be reduced by 35-40%, provided countermeasures are taken. The potential loss in the aviation, construction, power engineering, heating, manufacturing industry, transportation and other sectors is within the range from 0.1 to 2% of the gross national income, and avoidable loss varies from 20 to 40% of the total loss.

It has been found that wind velocity reduced by 15-20% over the last 20-25 years, thereby diminishing prospects of using wind energy. The water use problem is of critical importance for the development of the republic under climate warming conditions. The fresh water demand significantly grows, while a relative reduction in fresh water quantity and quality is predicted. As climate is warming, the guaranteed yield becomes more dependent on irrigation, while investments in developing the irrigation system amount to nearly USD 1 thousand per 1 ha. As is known, production of 1 tonne of grain on irrigated land requires 1-3 thousand tonnes of water.

The most significant effects of the climate warming are expected in highly urbanized areas. Such effects may manifest themselves in lower water supply, increased thermal loads and emergence of unfavorable conditions for propagation of various infections [1, 5].

The change in climatic characteristics being observed will require adjustment of parameters of the construction climatology and *Construction Norms of Belarus*.

The assessment of change in pathogenicity indices of temperature, humidity, wind speed, interdiurnal pressure drop, as well as of the annual variation in the complex pathogenicity index over the last 40 years has demonstrated the multidirectional character of trend changes in the above pathogenicity indices. Pathogenicity indices of air humidity and that of interdiurnal variability of atmospheric pressure increase, thereby adversely effecting the community's health. At the same time, wind speed decreases and temperature rises, thereby contributing to positive dynamics of the pathogenicity index of wind speed and temperature.

Climate warming will allow people to spend more time in recreational zones (in forests, at the rivers, lakes, water reservoirs) and, thus, a higher anthropogenic load on these ecosystems and, hence, lower water quality and aggravation of the epidemiological situation may be expected.

Therefore, the predicted climatic changes will entail significant changes of human health.

In conclusion, it has to be underlined that ecosystems (aquatic, forest, agricultural) should not be considered separately, as they are integrated in the nature. The state of environment mainly defines human health, that is why it is of critical importance to make integrated assessments of the climate effect on ecosystems, economy and community's health. This would allow for choosing most beneficial adaptation measures not only at the national level, but also disseminating them to the intergovernmental (regional) levels.

PART V. RESEARCH AND SYSTEMATIC MONITORING

1. General Policy

Measures aimed at reducing greenhouse gas emissions should become an integral part of the programs of the national economy sector's development. Some of them already provide for major spheres of the medium and short-term development. To formulate the National Strategy of reducing gas emissions causing the greenhouse effect, there is a need to expand the forecast earliness for existing programs, prioritize in them most critical measures relating to the effect of different factors on the climate, to assess the degree of effect and also to integrate the set of measures to reduce GHG emissions in the newly devised programs.

The major target within the "greenhouse effect" problem is to reduce production energy intensity. Belarus consumes much more energy per GDP unit compared to the developed countries. Currently, energy intensity of the GDP and national income is more than twice as large as that of European Community countries. Currently, the short and long-term energy policy is being formulated in Belarus to set the following targets:

- energy saving in all sectors of the economy;
- use of unconventional and renewable energy sources and secondary energy resources;
- predominant use of natural gas;
- development and implementation of ecology-friendly novel processes and equipment;
- development of the regulatory and legislative framework enabling operation of the energy economy.

Developing a system of measures to mitigate possible climate change effects by different sectors of economy is an important sphere of activity.

2. Research

There is reason to believe that warming has been determined to a great extent by the human activity over the recent 50 years, and the anthropogenic "signal" is highlighted against the background of natural climate variability.

Over the last 140 years, global climate warming amounted to 0.6±0.2 °C, the 1990s were the warmest years, and 1998 – was the warmest year since 1861. Recent positive temperature fluctuation in 1979–2000 was most intense over the instrumental observation period. Of 11 most expressed positive temperature anomalies, 10 fall on the last 20 years. The recent positive climate fluctuation was also most intense in the last millennium [17].

Main space-time characteristic features of the global temperature change are as follows [17]:

The highest rate of the change in temperature falls within two periods: 1910–1945 and 1976–2001. In both cases the increase rate of temperature over one decade is 0.15 °C. In the last 25 years, maximum climate warming has been observed in continental regions of the Northern hemisphere high and middle latitudes. Previous warming (1910–1945) was most intensive in the Northern Atlantic, while chilling was observed in those regions in the years that followed (1946–1975).

Warming was most intensive in the Southern hemisphere in 1946–1975, and in the Northern hemisphere in 1976–2000. Mean annual temperature trends were positive in most regions of the globe from 1901 to 2000 suggesting of the global warming.

Since the 1950s, the frequency of extremely low temperatures reduced, while frequency of extremely high temperatures increased, respectively.

The precipitation increased by 0.5–1.0% predominantly in middle and high continental regions in each decade of the XX century over the instrumental observation period.

In the last half of the XX century, 2–4% increase in frequency of heavy precipitation in the Northern hemisphere middle and high latitudes was found.

2% increase in cloudiness in the Northern hemisphere middle and high latitudes was found in the XX century. This correlates with the reduced range of the diurnal temperature variation in the majority of regions.

Satellite observations revealed 10% decrease in the snow cover area since the late 1960s. Deglaciation in mountains also occurred in the Northern hemisphere. There are grounds to assume that duration of ice cover on rivers and lakes reduced by two weeks in the Northern hemisphere middle and high latitudes in the XX century. Since 1950s, the percentage of ice cover of the Northern hemisphere seas has reduced by 10–15% in the warm season of the year.

In the XX century, the World ocean level increased by 0.1–0.2 m. Satellite observations indicate that the World ocean level rose at a rate of 5.8 mm a year from 1993 to 1996.

Frequency and periodicity of droughts have increased in recent decades in a number of regions of Europe, Asia and Africa.

Change in Temperature and Precipitation in the Republic of Belarus

Observations of air temperature and precipitation at 50 stations of the Department of Hydrometeorology from 1881 to 2001 have been used as source data [8, 13]. The length of observation series ranged from 60 to 121 years.

Given a high temperature space correlation, the analysis may be limited to an averaged temperature of Belarus for each month and year in general. The change in precipitation due to its higher space variability are presented for northern, central and southern regions of Belarus.

Fig. 2.1 shows the change in monthly mean and seasonal temperatures.

Most significant characteristic features of the temperature change over the instrumental observation period reside in the following [8, 13].

The temperature rise was observed since the mid 1960s actually in all months of the year except December, May and September (Fig. 2.1 a-p). It was most significant in January-April. Compared to January-April, the temperature rise in summer was recorded only in the 1980s, i.e. almost twenty years later. It was most expressed in July of the last decade (Fig. 2.1 i-l).

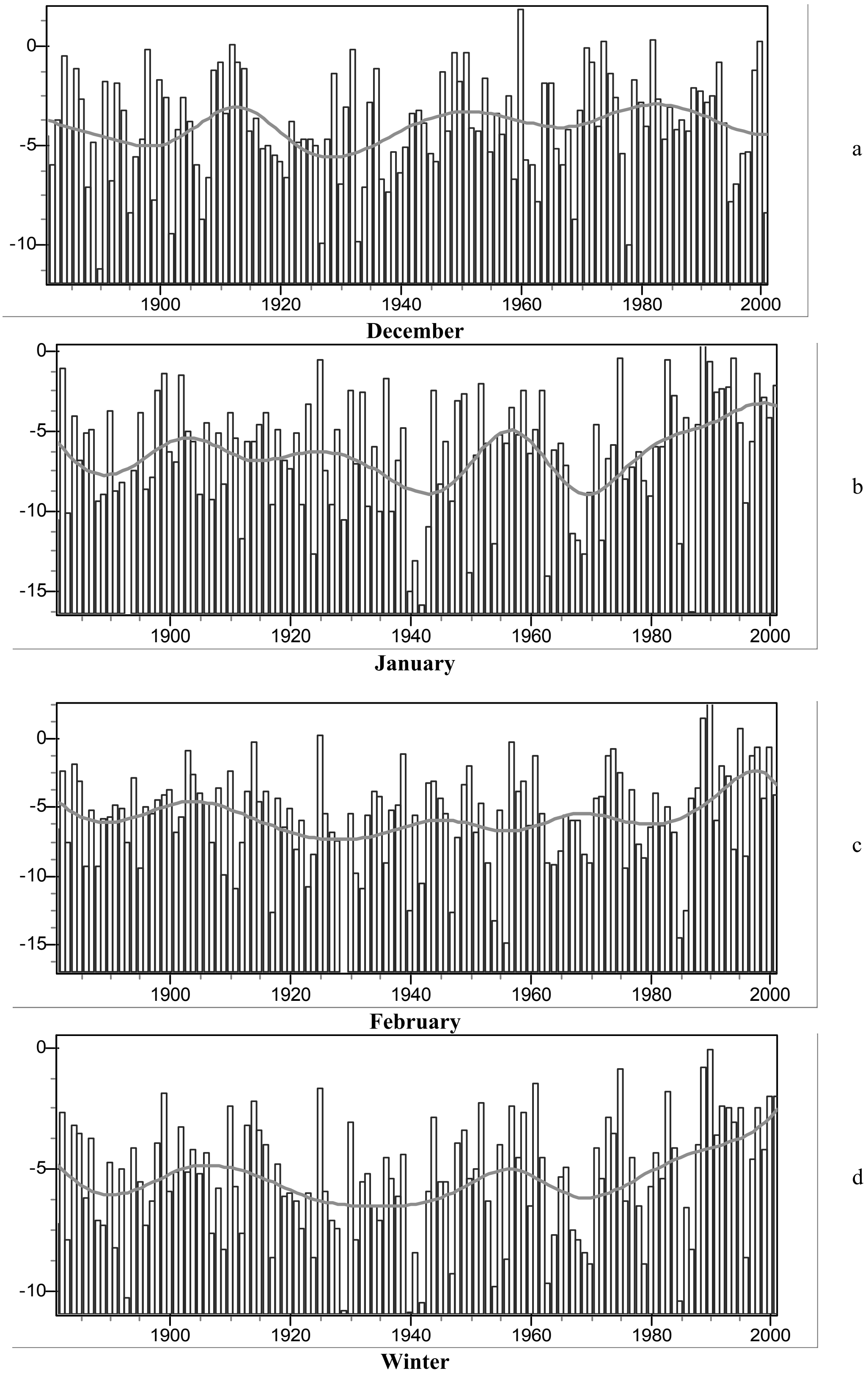
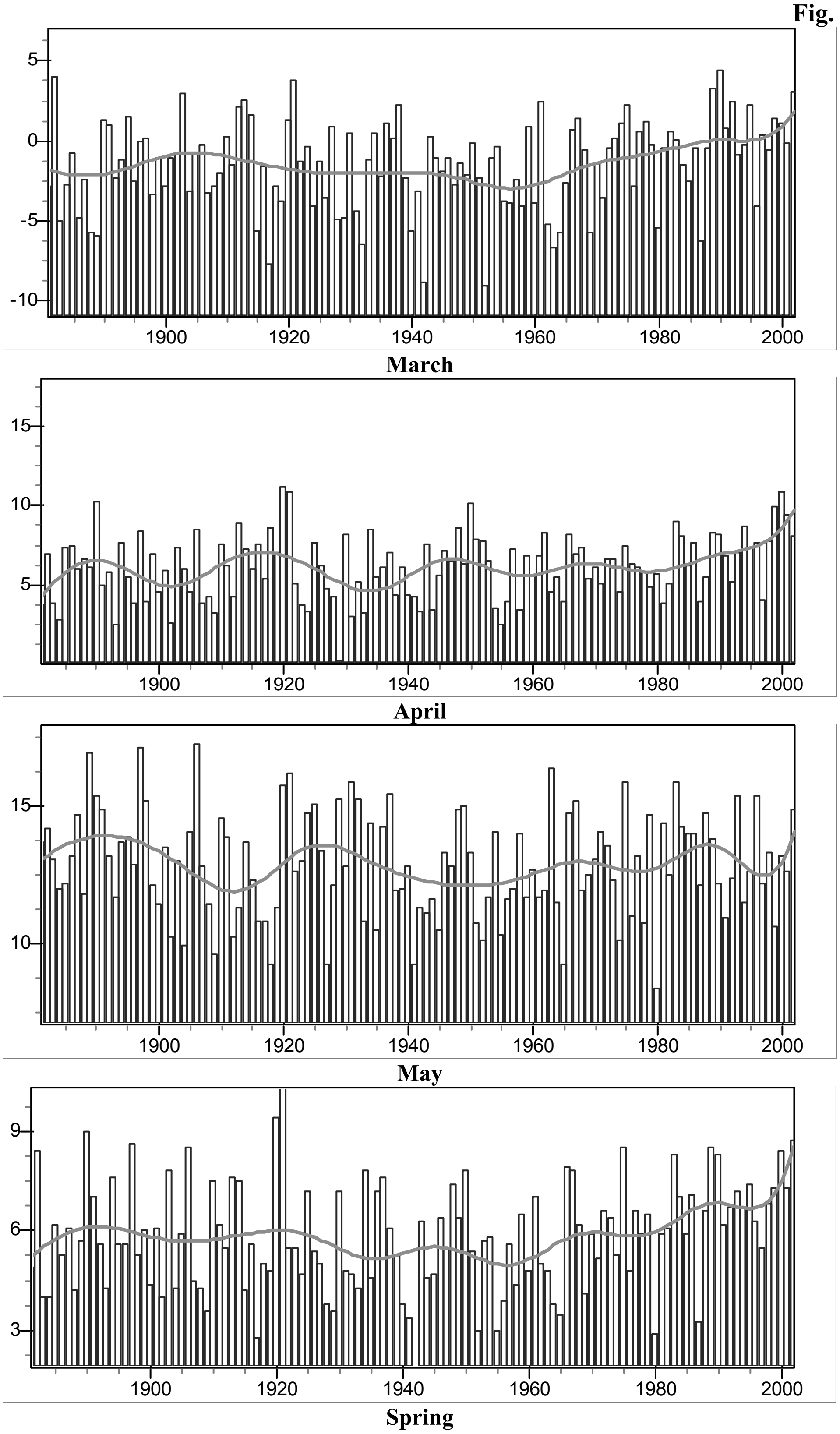


Fig. 2.1 . Change in mean monthly temperature in Belarus in winter (a–d), spring (e–h), summer (i–l) and fall (m–p)

Fig. 2.1 (continued)



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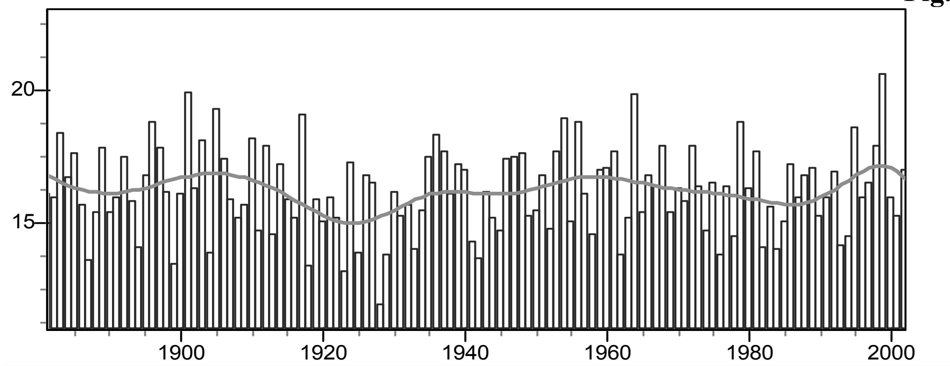

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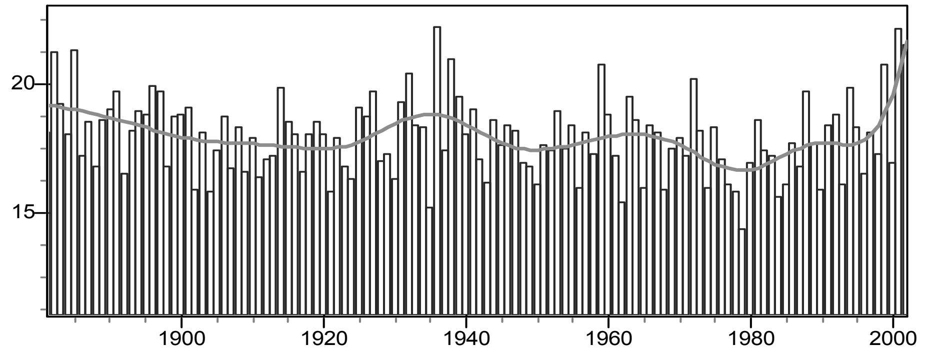
June



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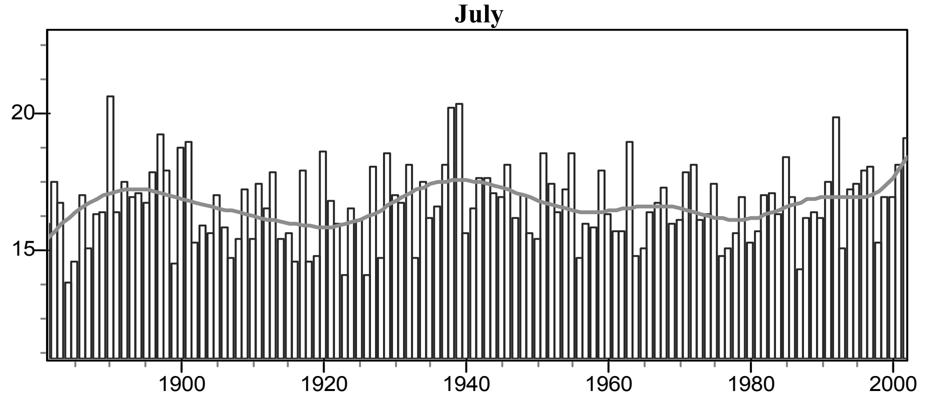
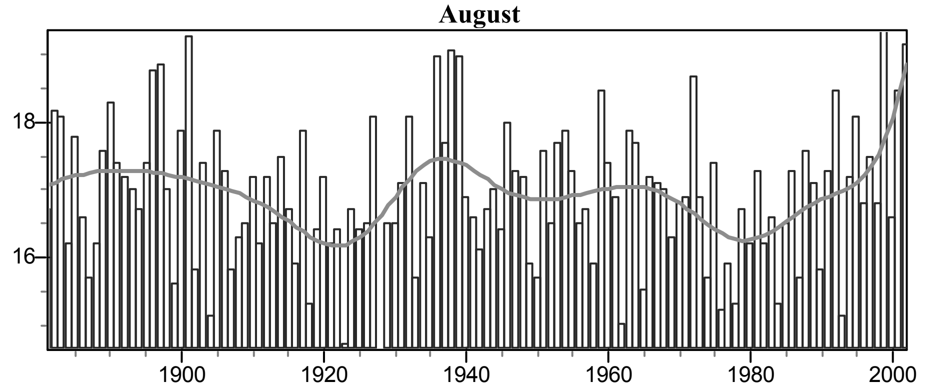
July



k

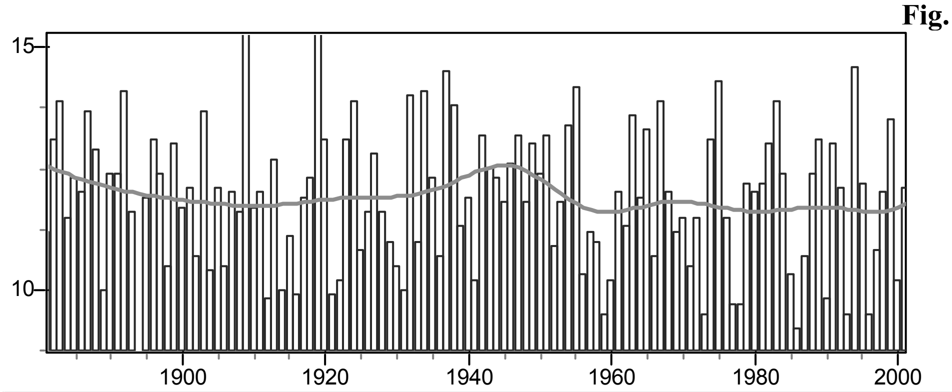
August



l

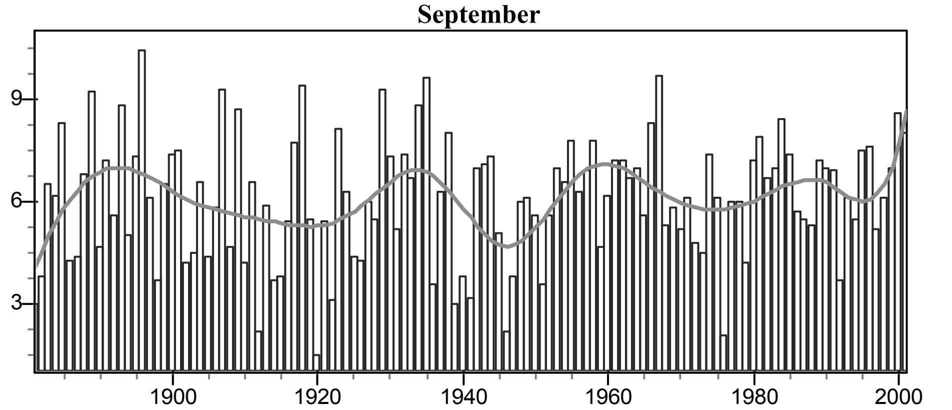
Summer

Fig. 2.1 (continued)



m

September



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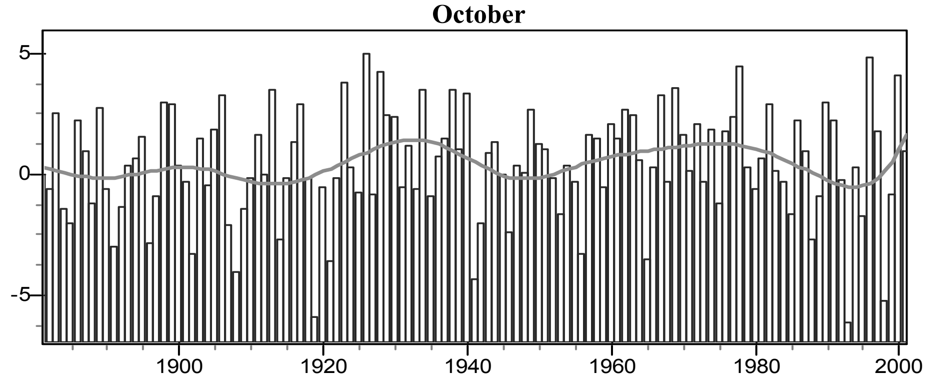
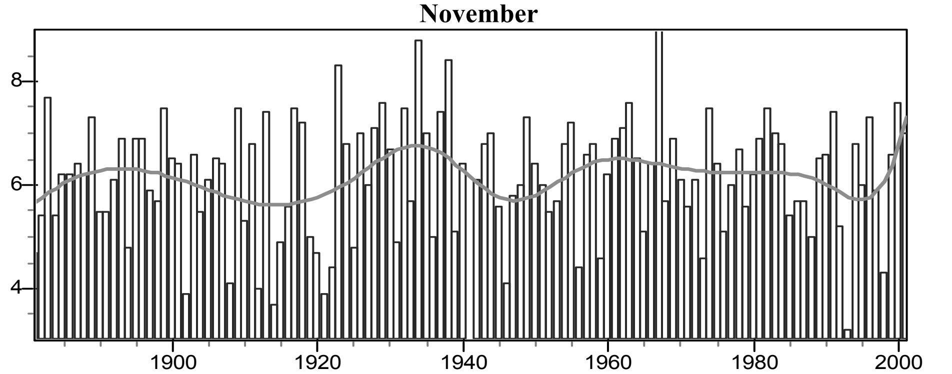
October



o

November



p

Fall

The most lengthy and high temperature rise was observed in summer of the 20–30s of the XX century. July and August temperatures were extremely high in 1936–1939. The recent positive temperature fluctuation (1997–2002) in July is comparable by the range with the positive temperature fluctuation of the same month in 1936–1939. Summer temperatures of somewhat lesser duration, but similar in values were observed at the end of the XIX century (specifically in July).

A slight decline in temperature in the fall was observed from the 1960s to the mid 1990s. In general, a slight temperature rise has been observed in recent years in October, November and fall. No significant change in temperature was recorded in September (Fig. 2.1 m-p).

The deviations of the mean annual air temperature from the mean long-term temperature in the Republic of Belarus are provided in Figs. 2.2. The Figure shows that the temperature was above the normal (except 1996) from 1988 to 2002. This recent positive temperature fluctuation was the strongest over the whole instrumental observation period. Probability of randomness of two 7-year series of positive temperature anomalies is less than 5%. Of 7 largest yearly positive temperature anomalies, ($\Delta t > 1.5$ ºC), 5 fall on the last 14 years. Judging by the change in mean annual temperature anomalies, warming of the 30s of the XX century is weakly expressed.

Therefore, the main feature of the change in temperature resides in two most significant warmings in the last century. The first warming, known as the Arctic warming, was mainly observed in the warm season of the year from 1910 to 1939. Then, a strong negative temperature anomaly followed in January-March in 1940–1942. Those years were the coldest over the whole instrumental observation history. The mean annual temperature anomaly in those years was about -3,0 ºC, and in January and March of 1942 the mean monthly temperature anomaly was about -10 ºC and -8 ºC, respectively. Current warming is expressed most in the majority of months of the cold season of the year and it appeared to be more intense than the previous one; in specific months of the cold period of the year the temperature increased by several degrees over 30 years. Warming was most intensive in January (nearly 6 ºC in specific years). Over the last 14 years, only one winter was cold (1996) (Fig. 2.1 d). Below are provided additional details of climate change in Belarus in the recent years.

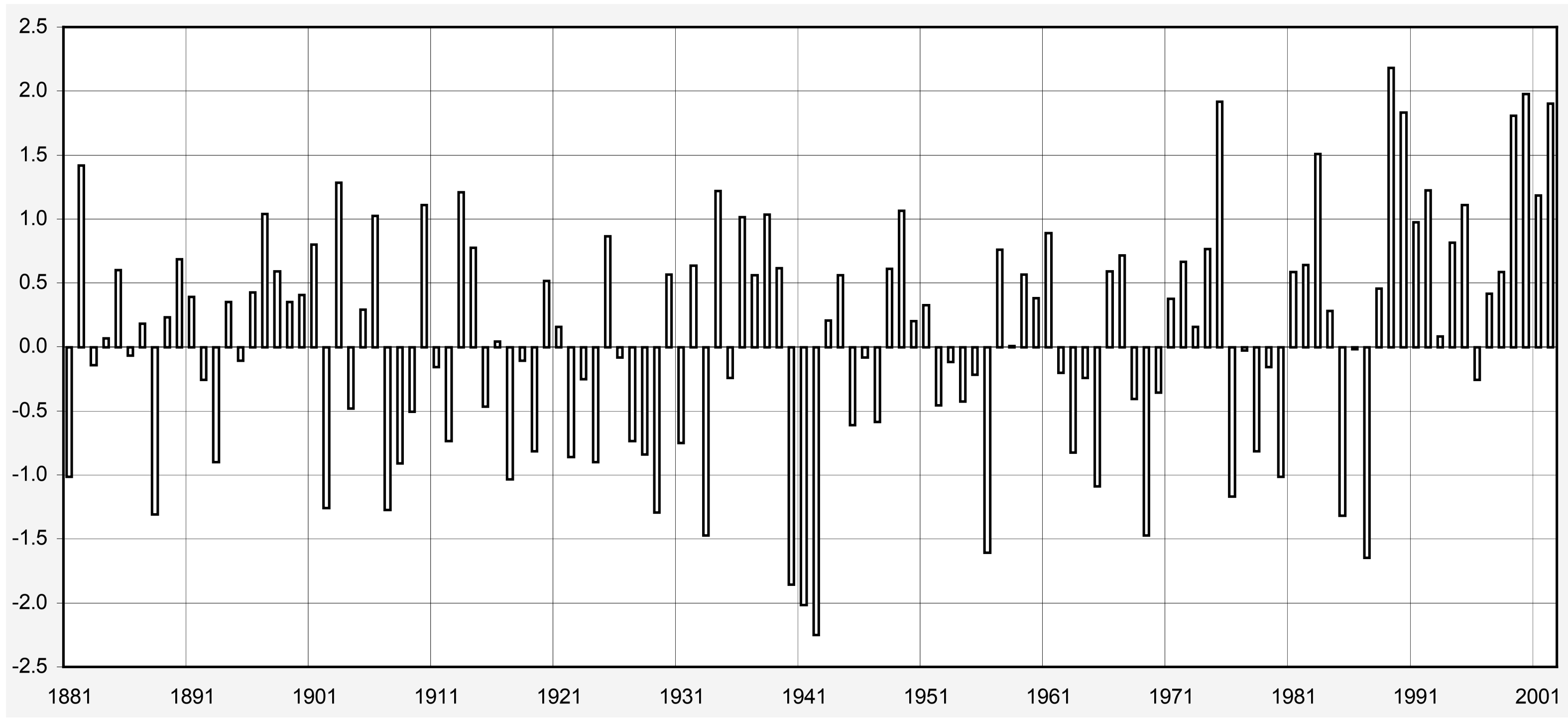


Fig. 2.2. Deviation of mean annual air temperature from mean long-term air temperature in the Republic of Belarus

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The most essential feature of the climate change in Belarus is the change in the annual temperature variation (I–IV months) in 1988–2001 (Fig. 2.3).

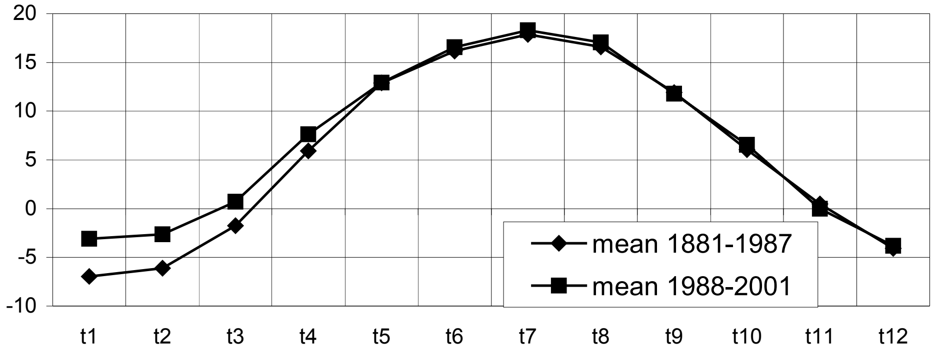


Fig.. 2.3. Change in temperature in Belarus (1881-1987 and 1988-2001)

Current warming began in 1988 and was characterized by extremely warm winter of 1989 when January and February temperature exceeded the normal by 7.0–7.5 ºC. 1989 mean annual temperature was the highest over the whole instrumental observation history. Positive mean annual temperature anomaly was 2.2 ºC. Temperature was, on the average, higher than normal by 1.1 ºC from 1988 to 2002. Warming was more expressed in the north of Belarus that correlates with the main conclusion of the numerical temperature modeling, being supportive of a higher temperature rise in high latitudes.

In the recent years, the trend has been toward higher temperature in the temperature change in Belarus not only in the cold season, but also in summer, specifically in the second half of summer. 1999, 2000 and 2002 were extremely warm. Given that the mean-square temperature deviation is almost 2.5 times higher in winter than in summer, July and August temperature anomalies, normalized to the mean-square deviations, approximate to the winter ones. However, July of 1936 and August of 1938–1939 were extremely warm. In transitional seasons, several months (May, October, November) are available when a minor decrease in temperature (about 0.5 ºC) was observed. The most characteristic feature of the temperature change in Belarus is the maximum increase in temperature in January resulting in the shift of winter core to December and sometimes even to late November. The winter December temperature (2002/2003) was substantially lower than the normal, i.e. the above feature in the temperature change of winter months persisted.

Positive March and April anomalies led to early snow cover melting and temperature transition through 0º two weeks earlier on the average. In specific years, the temperature transition through 0º in the warmest years (1989, 1990 and 2002) was observed even in January.

The change in precipitation in the Republic of Belarus is of a mixed character both in terms of space and time.

Due to this, precipitation has been analyzed separately for the northern, central and southern regions.

The above regions have been selected with due regard to Oblasts' agroclimatic boundaries. To save space, precipitation values are given for the cold and warm periods of the year of each of the regions (Figs. 2.4, 2.5 and 2.6), while the change in precipitation is dealt with in more detail.

The highest precipitation in the Belarusian northern, central and southern regions was observed in the majority of winter and spring months from 1893 to 1918; the summer/fall precipitation peak shifted to 20–30s of the XX century in the northern and central regions of Belarus, while short-duration secondary precipitation peak was observed in the majority of months in the southern and central regions in the early 90s of the XIX century.

In the recent 25–30 years, increased precipitation was observed in the winter season. This increase is particularly expressed in February in the northern and central regions of Belarus. A slight decline in winter precipitation from the mid 60s to the mid 90s of the XX century was recorded in the southern region of Belarus. Minimum precipitation in February was observed in the 80s of the XX century throughout Belarus.

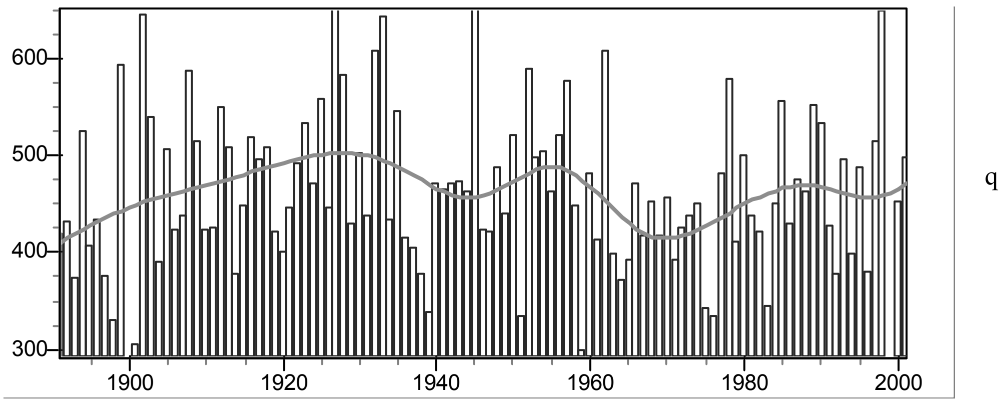
From the 1910s to the mid 80s of the XX century, precipitation reduced in spring in the northern and central part of Belarus, while precipitation decline was discontinued by a minor positive precipitation fluctuation in the south in the late 1960s. A slight increase in precipitation followed by its reduction in recent years was also observed in the 1990s.

Precipitation behavior in the summer season is characterized by large spatial inhomogeneity. A drastic drop in precipitation throughout Belarus was observed in August since the late 1950s. A weak and short-duration positive precipitation fluctuation was recorded against that background of reduction in precipitation in the late 1980s. The fluctuation was expressed most in the north of Belarus. Somewhat higher precipitation was observed in June in the late 1980s followed by the drop in precipitation in the recent 10–15 years. Two positive precipitation fluctuations were observed in July (1970s and 1990s).

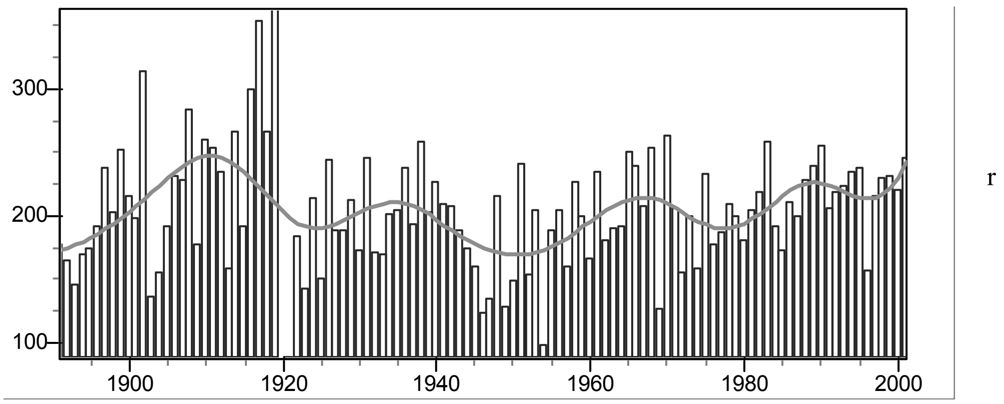
The precipitation minimum in July in the south of Belarus fell in the late 1980s – early 1990s. In 2001-2002, the precipitation amount was below normal, specifically in the east of Belarus.

The recent decade saw the reduction in precipitation in the fall. The previous precipitation minimum was observed in October and November in 1980s. A prolonged increase in precipitation was observed in September (1965–1995).

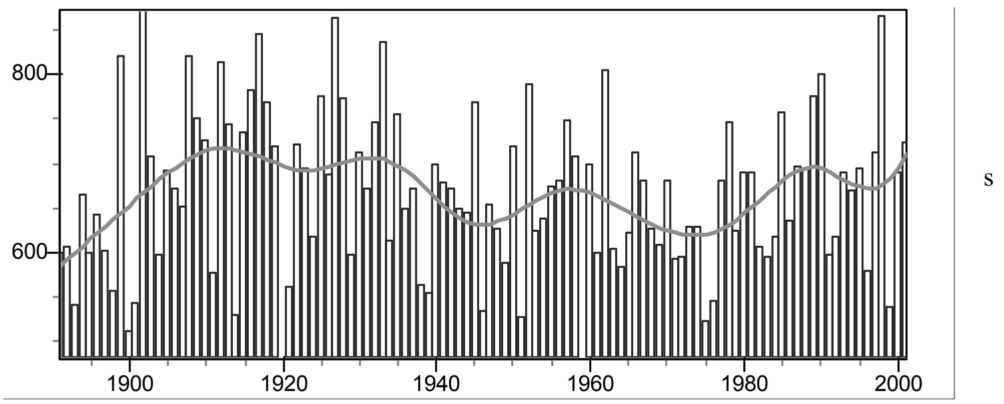
The analysis of precipitation in the warm and cold half-year and over the year as a whole demonstrates that mean annual precipitation reduced by nearly 60 mm from 1950 to 1990 compared to the 1891-1935 period in the south of Belarus. The fall in precipitation in the north of Belarus is less expressed and it terminated in the mid 1970s. Asynchrony of the change in mean annual precipitation in the north and south of Belarus was observed from 1891 to 1910 when high precipitation values were recorded in the south and low – in the north. Asynchrony of the change in precipitation in the north and south was observed for the second time in the 1970–1980s, i.e. 80 years later. Specific asynchrony of precipitation in the north and south is expressed less in the change in warm half-year precipitation. In the cold season, a rapid synchronous change in precipitation was observed in the north and south till the mid 1960s. Precipitation was above normal in the north and below normal in the south in the recent 20–25 years. The exception is recent 5 years when precipitation reached nearly normal, on the average, in the south and north.



Warm period (April-October)

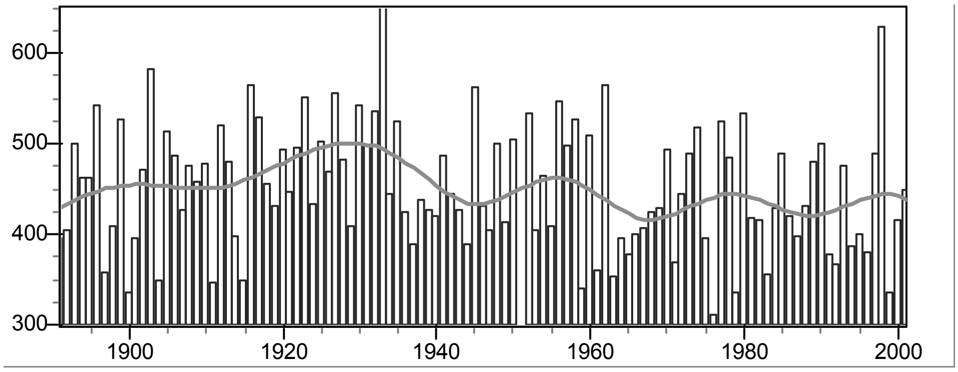


Cold period (November–March)



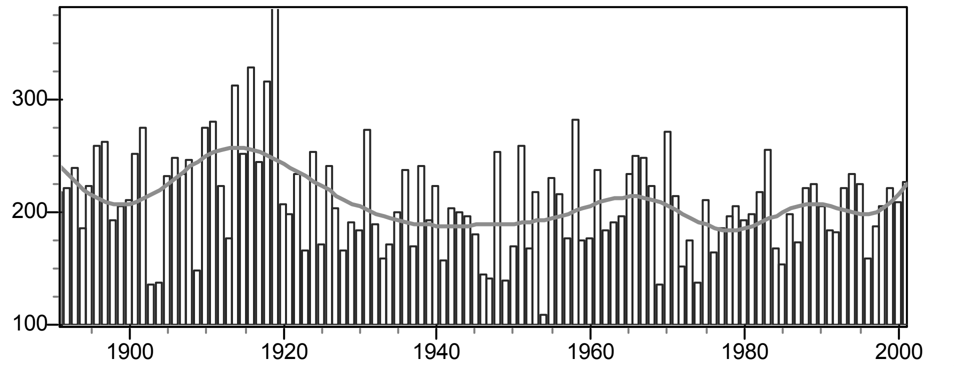
Year

Fig. 2.4. Change in precipitation in warm and cold periods of the year in northern region



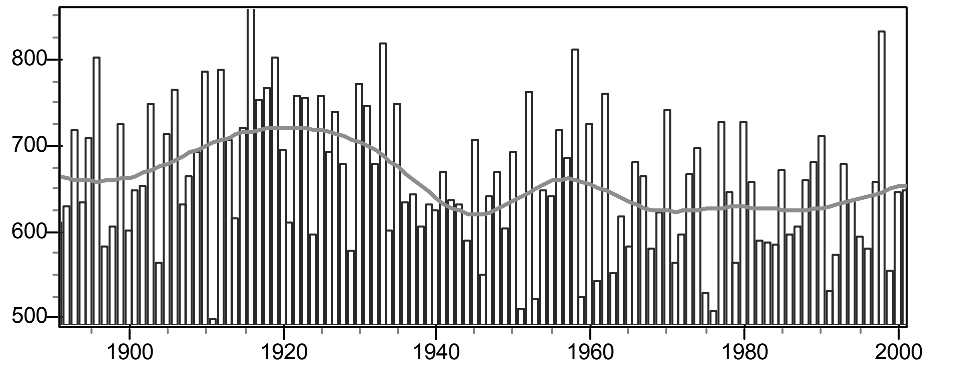
q

Warm period (April–October)



r

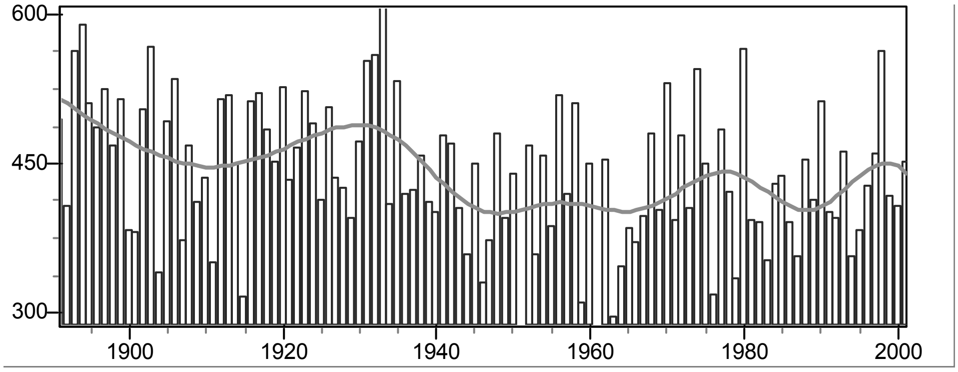
Cold period (November-March)



s

Year

Fig. 2.5. Change in precipitation in warm and cold period of the year in central region



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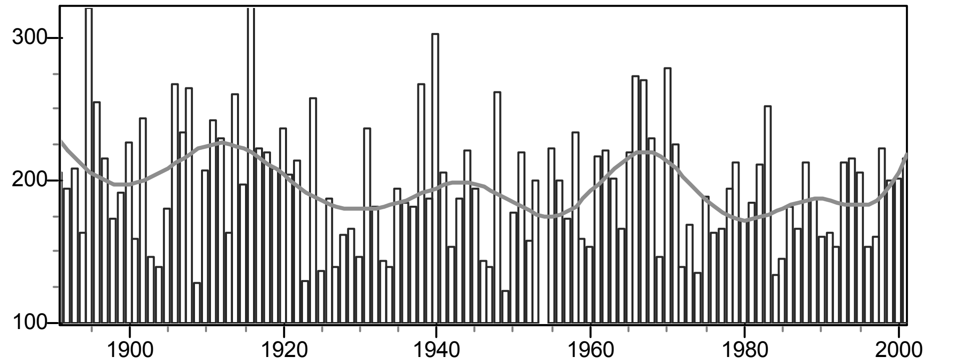
Warm period (April–October)



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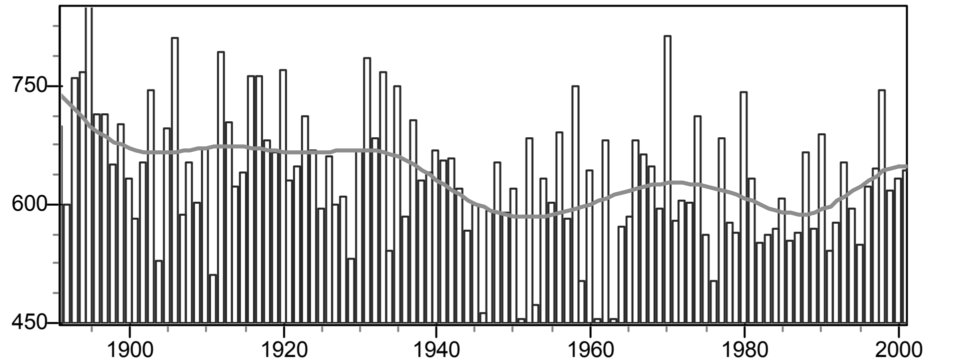
Cold period (November–March)



s

Year

Fig. 2.6. Change in precipitation in warm and cold period of the year in southern region

The precipitation in the central region of the Republic of Belarus is more closely correlated with the precipitation in its southern region. The exception is the 1891-1910 period when the change in precipitation in the south better correlates with the change in precipitation in the north.

The analysis of precipitation difference at meteorological stations located in the western (west of 28º of easterly longitude meridian) and in the eastern part of Belarus showed that precipitation was higher in the western region of the country in cold time of the year over the last 50–60 years; the opposite situation was observed at the end of the XIX – first third of the XX century when precipitation was higher in the east of Belarus. More precipitation was observed in the warm period of the year in the western region in the 40–80s of the XX century. The situation reversed at the end of the XIX – first third of the XX century and in the 90s of the XX century when precipitation was higher in the eastern region of Belarus. Precipitation differences are ±25 mm/month, on the average, but in specific years they exceed that value 2-3-fold.

These peculiarities of the change in precipitation difference in the western and eastern region of Belarus are most clearly pronounced in winter and fall, specifically in November. Such character of the change in precipitation difference in the western and eastern regions of Belarus is associated with the change in geographical position of high altitude ridges and troughs and atmospheric circulation forms respectively. It is well known that regions of positive pressure anomalies, negative temperature anomalies and precipitation deficit form underneath eastern parts of high-altitude ridges and western parts of troughs at the Earth surface. The eastern region of Belarus had higher precipitation amount compared to the western region in the years of dominance of the G.Ya. Vangengeim western atmospheric circulation form (1891-1928).

At that time, the trough's western part was located above the eastern region of Belarus resulting in the precipitation deficit in that region. In the post-WWII time, the eastern and meridian G.Ya. Vangengeim circulation form progressed most.

Therefore, the change in precipitation in Belarus is characterized by greater space and time variability compared to that of temperature. The specific feature of the precipitation change resides in reduced precipitation in the post-WWII period compared to the pre-WWII period. Precipitation differences were most pronounced in the 1905-1935 period, when precipitation was by 60–70 mm higher compared to the 1950–2002 period. The mean annual total precipitation has not significantly changed in the current warming period, but mean monthly precipitation somewhat reduced in August, April and May and somewhat increased in June and September. Space specifics of the precipitation change over the last 20-30 years reside in:

- increase in precipitation in winter in the north of Belarus and in specific months of the warm period of the year (June and September);

- fall in precipitation in the southern and central region of Belarus, particularly in Brest, south of Minsk and south-east of Gomel Oblast. The areas where precipitation reduced below 600 mm (Bragin) have expanded.

Higher space inhomogeneity of precipitation has been noted in the recent years compared to the previous periods. New areas where mean annual precipitation exceeded 700 mm emerged. This includes northern areas of Vitebsk Oblast and also Zhitkovichy District.

The character of precipitation variation in the warm period of the year has changed. The precipitation difference in the first (May-June) and second (July-August) half of the warm period has a positive trend related to greater extent to the reduced precipitation in the second half of the summer season after Polessie intensive reclamation. These findings are not in contradiction with the established experimental fact of the increased total evaporation and air humidity on swamps intensively reclaimed for expanding crop areas, specifically in the first half of summer - after crop harvesting, air becomes warmer and drier on the reclaimed swamp. Increase in arid spells in the second half of summer also supports the found feature of the change in precipitation and temperature after intensive reclamation in the southern region of Belarus and neighboring regions of Ukraine and Poland.

Local peculiarities of the change in precipitation have also been found. Precipitation, for example, is higher by 40–50 mm/year at Zhitkovichy station than at Lelchitsty and Polesskaya stations which is likely associated with specifics of the underlying surface in the area in question, namely, availability of the large Chervonoe lake contributing to some extent local evaporation to general hydrological cycle.

Therefore, precipitation substantially changed within a year and in specific years over the instrumental observation period. This is specifically characteristic of August, when monthly precipitation values reduced by one fifth. A significant deficiency of precipitation was observed in April-May, while precipitation began to increase in February, June and September in the last years. Extremely humid years were recorded (1998, first half of 1991 summer, second half of 1993 summer, etc.). Precipitation fluctuation has increased in July over the recent decade.

Scenarios of Global and Belarusian Climate Change

The global climate change implies its cumulative regional changes in different time and space scales. Due to this, forecasts (scenarios) of climate change in the specific region need to be developed with consideration made for global changes and in relation to global macroprocesses.

The factors inducing the regional climate change are both global and regional in scale. Therefore, the climate change in Belarus should be diagnosed and projected within the context of the global change of atmosphere, hydrosphere, cryosphere, lithosphere and biosphere. Possible scenarios of the global climate change prepared by a team of scientists under the auspices of the WMO and UNEP are reviewed in brief below [17].

Current multiple model estimates [17] show the rise in global temperature by 1.4–5.8° in 1990-2100. The predicted temperature rise rate would be higher than in the XX century and last thousand years. Anthropogenic warming would be within the range of 0.1–0.2 °C over the decade. Warming in continental regions would be more intensive, specifically in high latitudes and during cold seasons. Warming in the northern part of the North America, North and Central Asia would exceed mean global warming by more than 40%, while in the South and South-East Asia in summer and in the south of the South America in winter warming would be less intensive than the mean global warming.

Warming in the southern part of the Pacific Ocean tropics is predicted to be more intensive than that in the western part of the Pacific Ocean tropics. This is likely to be associated with the *El Nino-South Vibration* phenomenon.

Increase in air humidity and precipitation in the XXI century is projected. The precipitation would increase in middle and high latitudes of the Northern hemisphere and in Antarctica in winter by the second half of the XXI century. Precipitation might both increase and decline in low latitudes in continental regions.

Assessments of change of extreme climatic phenomena in the XXI century are less definite. Higher frequency of extreme temperatures and hot days in continental regions, increased minimum temperatures, less number of cold and frosty days, reduced diurnal temperature variation over the larger part of continental regions are most likely. The number of dry days and dry spell frequency are likely to increase in continental regions in temperate latitudes. Higher frequency and intensity of hurricanes, increased wind speed and higher precipitation in some tropical regions are less probable.

Frequency, range and space features of the El Nino are not quite clear, but it is obvious that number of droughts and floods associated with this global phenomenon would increase in many regions.

Asian monsoons-related increase in summer precipitation variability is most likely. The predicted change in monsoon duration and intensity is defined by the emissions scenario used in preparing the forecast.

Snow and ice cover area in the Northern hemisphere would reduce accompanied by deglaciation in the XXI century. Behavior of the Antarctic and Greenland ice sheets in the XXI century is not absolutely clear.

The World ocean level would rise from 0.09 to 0.88 m by different estimates over the 1990-2100 period. Thermal water expansion, glacier and ice sheet melting would contribute to this.

The anthropogenic climate change may persist for many decades and probably for several centuries, since the GHG lifetime is dozens of decades or even hundreds of years. The temperature and ocean level also would rise for several hundred years after GHG concentration stabilization due to large thermal lag of the World ocean deep layers. Ice sheets and World ocean level would response to climate warming for several thousand years more after its stabilization. Naturally, that after GHG concentration has stabilized, an average rate of the global temperature rise would be reducing.

A significant spread of estimates regarding the climate change in the XXI century suggests that our understanding of climate-change mechanisms and factors is not exhaustive [2, 15, 18]. Furthering research, including unaccountable and poorly accountable natural and anthropogenic climate-forming processes and also physical and biogeochemical feedbacks in the climatic system into models, developing more substantiated emissions scenarios, developing more sophisticated mathematical climatic models for forecasting climate variability, regional climatic changes and extreme phenomena would allow for significantly reducing the scatter of predicted climate change and its effects. Of not less importance is to further improve the climatic data management system including acquisition, processing, control, storage and dissemination of implicit data on the climate change, GHG and aerosol’s content in atmosphere, change in the subsurface layer properties, solar and geomagnetic activity, etc.

Statistical forecasting schemes are most frequently used in forecasting. Predictors characterized by a large "memory" are typically used in such schemes. The main mechanism responsible for the long-term climatic anomaly is defined by the "ocean-atmosphere" system interaction. Self-induced vibrations occur in this system. The former may be modulated by external periodic or quasiperiodic sources, for example, solar, volcanic activity, etc.

In the recent years, the anthropogenic activity leading to the change in atmosphere gas and aerosol composition and also underlying surface properties began to be considered as one of the major predictors. It is responsible for trend components in the climate change.

One of the most important goals in developing climate forecasts (scenarios) is to assess the deterministic-random components ratio in the climate change. Natural processes may be represented as the sum of deterministic and random functions.

Currently, the atmospheric processes predictability limit is determined based on the "instantaneous" atmosphere condition as the time interval within which the forecast of individual processes provides additional information in excess of that provided by their statistical description [11]. It is the maximum lead period estimated at 3–4 weeks in which the forecast error variance becomes equal to the mean square predicted characteristic variance. Processes inducing climate changeability define the predictability limit.

The predictability limit of the climatic system may be increased by using averaged data, applying regularities of the successive microprocess development, and accounting adjointness of atmospheric processes, character of ocean-atmosphere interaction, various cyclicities of atmospheric processes and phenomena associated with influence of external factors [7]. For lengthy periods of time, great importance is attributed to supply of heat from external sources inducing boundary atmosphere activation.

Two approaches to developing the future climate scenarios, namely, geographical and time analogs and also computer estimates have been applied.

The European part of Russia, on the one hand, and Poland, on the other hand, were taken as geographical analogs for the region (country as a whole); to analyze internal differences in warming scenarios, the Baltic Region was taken as an analog for the northern part of the country, and the Ukrainian Polessie – for the southern. It should be taken into account that the inferences by analogy are related to the class of plausible inferences.

As it has been noted above, according to assessments, the change in the global climate toward warming is predicted for the near 20-50 years. In the near 10-15 years, a transition period is forecast during which intra-annual (interseasonal) and interannual temperature and precipitation fluctuations would abruptly increase against the background of general warming, i.e. abnormally strong frosts in winter against the background of abnormally hot summer with an extremely unstable weather in winter and fall. The most probable warming estimates for the Northern hemisphere are 3.0-5.0 °C.

P.M. Khomyakov in his model estimates of climate-warming impact on the Russia's farming was specifically guided by those figures. He points out that the observed warming is not of a long duration and it occurs against the background of a global cooling associated with the change in the Earth orbital parameters and which would change the current trend, but the issue of cooling, as not urgent, has not been considered by him in a short and medium-term [16].

The Russian scientists have developed the method of paleoanalogs which is based on the selection of paleoclimatic analogs for scenario values of temperature change (Table 2.1) [12]. It was used to identify the effects of the climate change on the Russia's farming. It has been demonstrated that negative aspects in a number of regions would be accompanied by the improved climatic conditions for farming and other activities.

Table 2.1 Paleoclimatic Analogs of Scenario Values

Paleoclimate	Analog (year)	Change in temperature, °C	CO_2 concentration, mln t^{-1}	
			In the past	presumed
Holocene optimum	2000	+1	280	380
Interglacial period	2025	+2	280	420
Pliocene	2050	+4	500–600	560

To forecast moisture storage in soils in the Eastern Europe [1], two paleoanalog-based warming scenarios have been considered. The authors consider the conditions of the Holocene optimum as a scenario of increase in the mean global temperature by +1.0 °C and the optimum of the last Mikulinsky (Muravy) interglacial period as a scenario of warming by +2 °C. The trend toward a certain increase is characteristic of precipitation during these periods. This increase did not exceed 50 mm for the Mikulinsky interglacial period in altitude of Belarus.

When designing the interventions to adapt the Poland's economy to possible climate change using *GISS* and *GFDL* (USA) models of the total atmosphere circulation, 4 scenarios have been developed which may condition the farming development up to 2030 (Table 2.2) [20].

Table 2.2 Possible Climate Change Scenarios (Poland)

I. *Warm and humid climate* Increase in precipitation ≈ by 20% (up to 700 mm) Increase in temperature ≈ by 2 °C CO_2 concentration – 450 mln t^{-1}	III. *Warm and dry climate* Decrease in precipitation ≈ by 20% (down to 450 mm) Decrease in temperature ≈ by 2 °C CO_2 concentration - 450 mln t^{-1}
II. *Very warm and humid climate* Increase in precipitation ≈ by 20% (up to 700 mm) Increase in temperature ≈ by 2 °C CO_2 concentration – 600 mln t^{-1}	IV. *Very warm and dry climate* Decrease in precipitation ≈ by 20% (down to 450 mm) Increase in temperature ≈ by 2 °C CO_2 concentration – 600 mln t^{-1}

Of computational approaches used in developing global and regional climate forecasts (scenarios), building statistical and dynamic models may be distinguished. Among statistical approaches, the time series extrapolation method is the simplest. The skill in forecasting based on the time series extrapolation is defined by the stationarity of series and value of quasiperiodic variation determined by external and internal factors. Attractiveness of the periodicity (cyclicity) method is that it allows the climate to be projected well in advance. Although the method does not allow the years of extreme climatic phenomena to be highlighted, it makes possible to foresee systematic climate change trends. Currently, data accessibility is not a critical constraint for such forecasts. In the recent years, theoretical and empirical periodicities have been found in many works, and while the contribution of these periodicities to the general changeability of climatic characteristics is minor, using them in superlong-term forecasts may hold some physical validity.

Forecasts may be made more correct if hydrometeorological elements are calculated as average across the area and not for individual stations. In this case, the skill in forecasting reduces as the extrapolation period increases, since associations between the past and future gradually erode with time due to inclusion of new factors or altered character of their effect.

The research demonstrates that the amplitude of separated cycles is small and it changes with time, thereby not allowing for skill in temperature forecasting using known spectral methods, periodogram methods and maximum entropy methods [9].

The search for the modulation function describing the change in cycle amplitude has not yielded specific results.

Multiple correlation methods allowed equations to be derived to forecast temperature in Belarus and obtain justifiability of temperature forecasts slightly above the random ones using identified predictors.

The climate forecast for Belarus developed by using linear extrapolation needs to be continuously updated. Such climate anthropogenic factor as GHG responsible for upward temperature trend in the recent decades is not the only one. The upward temperature trend may be transformed through continuous increase of man-made aerosol content in atmosphere and also through short-term, but frequently intensive emission (emissions) of aerosols of natural (volcanic) origin. The change in supply of solar activity-related radiation and presence of the secular and other cycles determined in many works [3, 4, 5, 14, 18, 21] need to be also accounted. This factor does not offer hope for high justifiability of climate extrapolation forecast.

The data of simulating climate in the time scales from decades to centuries using the general atmospheric circulation model (GACM) serve as the subject of discussion.

A number of works [15] suggests that GACM data should be considered not as forecasting, but as heuristic only to assess climatic system sensitivity to effect of specific disturbing factors. However, given that models are made based on the available level of knowledge of natural system behavior, there is no reason to rule out using the GACM for forecasting climate estimates.

In making estimation forecasts of change in climatic indices, the results provided by the Information Distribution Center of the International Panel of Climate Change (IPCC) have been used.

Data of several GACM were compared with experimental data on Belarus for the 1961-1990 period chosen as the base one in [10] using the method described in [5]. It was found that the *HadCM2* model (Great Britain) most efficiently simulates the base period data, the main variant of external impact – combined increase in GHG and sulfate aerosols by 0.5%/year. This scenario is the lower limit of the known *IS92* scenario in which the range of annual change was presumed to be from 0.5 to 1.2%. Such option corresponds to later adjustments of assumed external impacts. It should be noted that the *HadCM2* model is the only one considering such "soft" emissions variant among those provided by the IPCC. The *CSIRO Mk2* model (Australia) demonstrates somewhat worse results. The *CGCM1* model (Canada) provides data being far short of actual ones.

Scenario estimates of the change in precipitation and air temperature variables obtained by authors using the *HadCM2* model at the "mid XXI century» horizon are given in Table 2.3 [10].

Regression dependencies of different agroclimatic indices on average monthly temperatures have been established by processing base period data. Among such indicators are the dates of a stable air transition through 0º, 5º, 10º and 15 ºC in the spring and fall, duration of periods with a temperature above these limits, as well as respective total active temperature. Forecasts made for 2010-2039 show the increase in mean air temperature by 1 ºC, with the mean annual day-time temperature increasing by 0.92 ºC, and night-time by 1.15 ºC. Increments of total temperature above 0º, 5º and 10 °C is expected to be approximately equal and are nearly 200–220 C°, increment of total temperature for 15 °C is substantially greater - higher in Minsk (387 °C) than in Vasilevichy (294 ºC).

Table 2.3 Scenario of Possible Change in Mean Annual Indices of Climate of Belarus for XXI Century Using HADCM2 Model (Great Britain)

Variable	Impact	Time period	
		2010–2039	**2040–2069**
Mean air temperature, ºC	GHG	1.37	2.28
	GHG/SA	0.99	1.84
Maximum air temperature, ºC	GHG	1.31	2.17
	GHG/SA	0.90	1.75
Minimum air temperature, ºC	GHG	1.52	2.51
	GHG/SA	1.13	2.03
Precipitation, mm/month	GHG	1.5	2.7
	GHG/SA	1.5	2.1
Water vapor pressure, hPa	GHG	0.757	1.355
	GHG/SA	0.596	1.040
Wind speed, m/s	GHG	0.06	0.11
	GHG/SA	-0.01	-0.01

Note: GHG – greenhouse gas effect only;
GHG/SA - combined effect of greenhouse gases and sulfate aerosols.

Therefore, conducted numerical experiments provide evidence of a high rate of change in mean annual night-time temperatures compared with day-time ones. This conclusion is supported by the current meteorological observation data. The forecast estimates of agroclimatic indices are as follows: the onset of periods with a temperature above 10 °C may be expected in spring 3–7 days earlier and in fall 2–6 days later that would increase the vegetation period duration almost by two weeks in the 2010 – 2039 period.

PART VI. PUBLIC EDUCATION AND AWARENESS ENHANCEMENT

The scientific and technical progress has allowed favorable conditions to be created for the people to live, while it contributed to emergence of acute global problems on the Earth challenging the existence of humanity itself. One of the global problems relating to the Republic of Belarus is the problem of climate change.

The current environmental condition may be characterized as a specific borderline at which the need in a new social organism and new world perception has emerged. To this end, there is a need to reorient objectives of the society, namely, to change over from a rapid growth in excessive consumption based on the wasteful economy to sustainable development when needs of the people should be commensurable with the ecological capacity of a country, a continent and, finally, the planet of Earth. This necessitates the change in environmental consciousness and mentality. The main methodological premise of reorienting the environmental mentality is to switch from anthropocentrism to ecocentrism and follow conditions of the sustainable development.

Capability of any state to lay the foundation for the sustainable development depends on the willingness of the population and state administrative bodies to comprehend a complex process of the economic activity management, with considerations being made for the environmental protection requirements under changing climate. The latter is not possible without a system of ecological education highlighting climatic problems and identifying clearly-cut priorities to be consistently implemented.

Belarus, as a Central European region, also faces global ecological problems being specific to it. Its area is exposed to intensive anthropogenic effect manifesting itself in atmospheric air, surface and ground water pollution, plant/animal biocenosis degradation, and soil contamination and erosion. The Belarusian population's state of health is substantially worse than in economically developed countries.

The Constitution of the Republic of Belarus (Section II, Art. 46) stipulates that "each individual has the right to a health environment and damages for infringement of this right" and that "environmental protection is the duty of each individual" (Art. 55). Article 9 *Education and Ecology* providing for ecologization of the educational process at all stages of education has been included for the first time into the Law *On Education* of the Republic of Belarus. This regulation has been further developed in the *Concept of Education and Training in Belarus*, *Concept of Education in the National Schools of Belarus*, Draft of the *Concept of the Ecological Education and Training of Students*.

The right of access to the ecological information is guaranteed by the Constitution of the Republic of Belarus Art. 34 of which reads, "The citizens of the Republic of Belarus are guaranteed the right to receive, store and disseminate the complete credible and timely environmental information".

1. Ecological Education

Improving the ecological education is one of the priority spheres of the national education system development. The ecological education and training is based on succession of the curricula and consistency of education levels for all education system stages from preschool to postgraduate education institutions.

The Belarusian ecological education system is developing. To form a community being conscious of the environment and its problems, the Council of Ministers of the Republic of Belarus approved the Republican Program of Ecological Education for 1991-1995 by adopting Resolution No. 85 on March 14th 1991. That first Republican Program formulated specific targets of each form of the education system:

- preschool, general secondary, out-of-school education and learning;
- vocational and technical education;
- higher and secondary specialized education;
- retraining and advanced training.

The objective of the Program was to teach a person to take ecologically informed decisions in the nature management sphere. A unified continuous process comprised preschool education, education of school inmates, training highly-skilled workers in vocational and technical schools, training environmental engineers with secondary special and higher education, environmental training of specialists of other professions, advanced training and retraining of executives, specialists of the national economy and pedagogical staff within the postgraduate education system, and training higher scientific qualification personnel.

The Program implementation was imposed on all institutions in charge, working plans of actions were approved, a series of workshops and conferences on ecological education were held.

Administering the ecological education is a difficult-to-address problem, since it is an intersectoral problem and many governmental and non-governmental organizations and research institutions should be involved to settle it. It should encompass people of all ages at all stages of the formal and informal education. Conventional techniques are not suitable for establishing this education system.

The *preschool education* may be rightfully considered as the starting point of upbringing an ecology-oriented individual, since specifically at this stage initial knowledge is obtained to form conscious attitude toward surroundings. The existing Program of Upbringing and Education in the Kindergarten limits possibilities of the ecological education of the preschool-age children not allowing ecological consciousness and ecological culture to be adequately formed. The time decrees to progress, to profoundly review this problem bearing in mind that modern preschool-age children would be the adult generation of the XXI century who is to formulate the strategy of the mankind attitude to the nature.

Given that fact, pedagogical staff of many preschool institutions began the search for innovative approaches to solve the ecological education problem. Belarus has already gained and generalized an interesting experience of solving this problem in the kindergartens. Among the preschool institutions which extensively, purposefully and systematically educate children in the ecological sphere the following institutions progressed most: Nos. 491, 535, 393, 282 (Minsk), Nos. 35, 36 (Mogilev), No. 38 (Borisov), Nos. 42, 77 (Vitebsk), No. 3 (Novolukoml), No. 1 (Dokshitsy, Nos. 23, 27, 30, 50 (Grodno) and others. Some of them implement their own ecological education programs.

Specific progress has been reached in solving this complicated problem.

The course of ecological education of preschool children was prepared to be lectured at the institutes for advanced training of teachers. The program of ecological education of preschool children (author - AA. Petrikovich, employee of the preschool and family education laboratory), being an integral part of the National Program of education and training in the *Praleska* kindergarten (Section *Nature and Ecology*), will be of great support for teachers in solving the preschool children ecological education problem. The main message of the program is unity of the man and nature.

Currently, kindergartens experience shortage of special preschool-children ecological education literature. One of the sources most accessible to them to receive data pertaining to that problem is still the *Praleska* journal publishing a special *Ecological Path* column.

The *general educational school* should provide even higher ecological literacy level of children and youth. The environmental general secondary education is the process of learning common scientific knowledge about the nature, society and human, forming a creative, moral, psychically and physically healthy individual. Forming knowledge about the environment, skills of informed and responsible attitude to the nature, and high general and also ecological culture is the priority target of the modern school. The general secondary education is implemented at three levels, namely, primary, basic and secondary.

The ecologization of all disciplines being taught is of critical importance for the general educational school, arranging special elementary and advanced courses, cooperation with industrial enterprises, ecological governmental, research and non-governmental organizations is also an option.

The current secondary school biology curricula aims at teaching the ecological aspects at such courses as botany (6 – 7th forms), zoology (7 – 8th forms), human being and his/her health (9th form), general biology (10th form). The specialist subject and advanced level of study include the discipline *Principles of Ecology and Environmental Protection* which is taught in the 10th form. Using school component hours, the teachers use such optional courses programs as *Environmental Protection, Society and Nature, Principals of Ecology and Environmental Protection, Human*

Health and Environment, Technology and Environment, etc., and also inter-discipline courses in chemistry, geography and physics. The education system reforms provide for ecological education and training starting from the first form.

Since 1996/97 school year, a stage-wise change-over to a new biological education content began when the *Universe* course was introduced. It is planned to introduce a special discipline *Ecology* in 10-11th forms (speciality and advanced level, 2 hours a week).

Belarusian lycees and gymnasiums began to introduce speciality classes (chemical and biological, natural and geographic), thereby focusing on ecologization of the entire educational process. The institutions of education that progressed most in this sphere are Ecological Gymnasium (Baranovichy), Polytechnic Gymnasium No. 1 (Minsk), schools Nos. 84, 65, 144 (Minsk) and others. The Domzheritsky Ecological Lycee was established in Lepel District. A number of basic and secondary schools has embarked on ecologization of the entire educational process. Among them, Borkovskaya and Orekhovskaya secondary schools (Brest Oblast), Proshkovskaya secondary school (Vitebsk Oblast), Babichskaya secondary school (Gomel Oblast) and many others.

In addition, some regions of the republic take the initiative to develop *Comprehensive Programs of Continuous Ecological Education and Teaching Preschool and School-Age Children*. The Program prepared in 1996 by a large team of teachers and tutors of Grodno institutions of higher education may serve as an example, and it is based on the principle of succession of ecological education of preschool children and students of primary, secondary and higher forms.

The Regional Program of Ecological Education of Students for 1997–2000 was also developed in Gomel Oblast, which was an intersectoral document and had a force of the Normative Act in Oblast.

Currently, the students are educated in the ecological sphere based on the Concept of Education and Republican Program of Improving Ecological Education approved by Resolution No. 12/362 dated 21 April 1999 of the Board of the Ministry of Education and Resolution No. 31 dated 19 March 1999 of the Board of the Ministry of Natural Resources and Environmental Protection.

Separate ecology course programs, developed by scientists, tutors of institutions of higher education and school teachers, are available for gymnasiums. The program for gymnasium classes developed by the Minsk Polytechnic Gymnasium and Chair of Ecology of the Belarusian National Engineering University (S.G. Shevtsova, G.G. Parfenova, M. Yu. Kalinin) may serve as an example.

126 institutions of the ecological profile providing general secondary education are available in Belarus. 25 ecological and naturalist/biological Centers, 45 museums of nature and 37 microreserves function in the Belarus. Notwithstanding the obvious progress in promoting the ecological education in preschool and school institutions, the bottleneck resides in insufficient coordination of activities at the republican level, shortage of teachers, inadequate supply of manuals, methodical guidelines, and literature relating to environmental protection and problems of climate change effect on economy and natural ecosystems.

Currently, the ecological education is prioritized in the sphere of reforming all general education systems and that is the reason why the establishment of the continuous ecological education system, namely, family, school, secondary specialized, higher, postgraduate, advanced training and retraining supplemented by dissemination of ecological knowledge among the population is put on the agenda. Out-of-school institutions of ecological and naturalistic profile should play a specific role in this process. In addition, naturalist associations function in other out-of-school institutions.

Nearly 30 thousand students are involved in ecological and naturalist work within the system of out-of-school institutions. Ecological problems are also extensively analyzed in the Engineering Innovations and Tourism Centers. Education in out-of-school institutions significantly supplements and sets off drawbacks of the school basic education in all spheres, in particular, in the ecology sphere (it is not surprising that they are more often referred to as Education Centers). The educational institution – *Republican Ecological Center of Children and Youth* – coordinates the activities of out-of-school institutions in this sphere in Belarus. A specific system of ecological education of students has been established to set the major objective of forming ecological mentality and ecological culture of the rising generation.

Children research teams work in all Oblast out-of–school institutions managed by researchers from the institutions of higher education and research institutions which provide facilities for the out-of-school experimental work. Its results are annually reviewed at the republican conferences and contests of innovations, the prize-winners of which participate in the International Ecological Contest in Turkey and regularly become its prize-winners. Since 1992, representatives of Belarus have been participating in the International Biology Contests of students. Since that time, Belarusian students have won 7 golden, 20 silver and 11 bronze medals. The experience of participation in the international contest, however, has demonstrated that facilities and logistics of the research and experimental institutions are extremely inadequate. The network of scientific student societies has not been actually developing in recent years. Scientific societies usually function mainly in the regions characterized by availability of scientific potential, institutions of higher education and other research institutions offering education by correspondence for many children from remote areas, for example, *Belarusian Minor Forest Correspondence Academy*, schools of young farmers, biologists, and *Computer, Ecology and Biology*. After leaving out-of-school institutions, many high-grade students choose the occupation related to nature and continue the training in institutions of higher education.

The Republican Ecological Center of Children and Youth issues journals *Ekovestnik* and *Geta Ideya* for scientific societies in which members of scientific societies publish their scientific papers. Periodicals *Teachers' Newspaper*, *Out-of-School Education*, *Education and Upbringing, Healthy Style of Life* and other scientific and methodical publications offer their pages for publishing articles relating to ecological education and upbringing.

Secondary specialized educational institutions pay much attention to the ecological education by adjusting curricula, including a special ecology discipline in the learning process, introducing the interdiscipline approach and active forms and methods of educating specialists, with environmental topics being covered in graduation and term thesis. All institutions of education of that type introduced the discipline *Principles of Ecology* (20 hours) for the II-year students to learn ecological definitions, have insight into the legislation in this sphere, review ecological problems from local, regional and global points of view. The integrated discipline *Industrial Ecology* (50-60 hours) has been introduced for senior students in junior technical colleges of the chemical and engineering profile. Grodno Chemical and Engineering Technical College trains environmental specialists in the speciality *Environmental Protection and Natural Resources Management.*

Belarusian institutions of higher education train higher qualification specialists who become managers of industries with time and their ecological competence is a factor determining multiple aspects (prevention of climate change, in particular). Sufficiently large number of institutions of higher education are available in the republic. The institution of education of ecological orientation, the Sakharov International State University, also functions in Belarus.

Ecological projects developed by students within the framework of international educational programs (*Acid Rains, Protection of the Earth Ozone Layer, GLOBLE*, etc.) play important role in the ecological education.

The environmental engineers are trained in compliance with the UN International Ecological Education Program and decisions of the World Conference on Environment in Rio de Janeiro (Global Forum-92) and environmental legislation of the Republic of Belarus.

Introduction of a new list of specialities from 1 September 1994 was the first stage in that sphere. In addition to traditional specialities, such as *Heat Supply, Ventilation and Atmospheric Air Protection, and Water Supply, Sanitation and Water Resources Conservation*, the list included *Ecology, Radioecology, Environmental Protection and Natural Resources Management and Radiobiology and Radiation Medicine.* About 200 students are enrolled each year to be trained in new specialities.

The curricula provide for compulsory ecological training in institutions of higher education through the course of lectures *Principles of Ecology* (54 hours). In addition, the students of non-ecological specialities are lectured different courses such as *Radiation Safety* (34–36 hours*), Ecological Safety* (40–50 hours), *Chemical Principles of Life Activity* (70 hours), *Ecology and Rational Nature Management* (58 hours), *Radiobiology* (20 hours), *Biogeography with Principles of Ecology* (100 hours), *Ecological Problems of Industrial and Agricultural Production* (24 hours), *Legal Principles of Environmental Protection* (18 hours), *Comprehensive Water Resources Conservancy* (22 hours), *Use of Mineral Resources and Geological Environment Protection* (22 hours), *Wildlife use and Conservancy (22 hours), Ecological Monitoring* (22 hours), *Hydroecology of Belarus* (22 hours), *Atmospheric Air Protection* (24 hours), *Land and Plant World Conservancy* (26 hours), *Principles of Ecological Assessment* (24 hours), *Geochemical Ecology* (22 hours), *Ecological Law* (68 hours), *Sociodynamics of Ecological Consciousness* (50 hours), etc.

The ecological education in institutions of higher education pursues the following objectives: provide students with basic knowledge relating to ecology, measures for environmental protection and demonstrate the interrelation between climatic, economic and ecological factors.

To this end, for instance, the manual *Principles of Ecology and Nature Management* is used (published by Polotsk University, 1997, 2000, author - V.F. Loginov). It contains, in particular, the Section *Global and Regional Ecological Problems* (climate change and its socioeconomic effects, assessment of economic, social and ecological effects of extreme climatic phenomena and possible climate change, ozone layer protection, etc.) as one of the major Sections. The Geographic Department of the Belarusian State University trains hydrometeorology specialists.

In the Brest State Engineering University, the climate disciplines are studied at the courses *Engineering Hydrology and Runoff Control*, *Agricultural Hydrotechnical Reclamations* and *General Hydrology and Hydrography of Belarus*.

The scale of ecological problems in Belarus requires that state administrative bodies, scientific, cultural and mass media communities, non-governmental organizations and movements and all citizens should focus on the environmental problems and take immediate measures aimed at environment enhancement, more efficient conservation of all natural complexes, and creation of favorable working and living conditions. One of the most important component of this multicomponent and long-term program of measures is the *postgraduate ecological education.* The general objective of this education is to provide information to executive and specialists regarding the latest achievements in the environmental sphere and related sciences, and techniques of adapting these achievements to their professional activity. There is a need to introduce ecological education components into all types and forms of advanced training of executives, specialists and all categories of employees.

Special emphasis should be placed on retraining executives and specialists working directly in the governmental ecological control system. Republican courses of advanced training of ecological personnel arranged by the Belarusian Research Center *Ecology* of the Ministry of Natural Resources and Environmental Protection of the Republic of Belarus since 1993 is considered as a positive aspect. The courses function in pursuance of the provision of the law *On Environmental Protection* providing for regular upgrading of the ecological knowledge of executives working at different levels, officials and specialists involved in activities effecting the environment and health. Since 2001, training of ecological audit specialists began.

The other positive example of retraining Ecological Services' executives (Oblast, District and municipal level) is periodic training in the Academy of Management of the President of the Republic of Belarus. Senior officials of different ministries and departments, Oblast, Districts and cities/towns also obtain modern ecological knowledge in this Academy.

The sustainable development may be promoted only through ecological literacy of the entire population, that is why education in the environmental sphere should encompass people of all ages. Awareness of the people regarding their involvement in addressing environmental problems should be enhanced and their concern for the stable development both at the global (entire humanity) and local levels (Republic of Belarus and Russia) needs to be stimulated.

There is a need to promote enhanced awareness of the population regarding the problems of environment and climate-change effect through governmental and non-governmental organizations and mass media. To this end, special attention should be paid to devising plans of training journalists, newspaper editors, radio/television producers working in the ecology and natural resources management sphere to professionally cover the environmental problems and promote exchange of programs and films at the governmental and regional levels. Belarus should establish the environmental information system to inform the public of the respective national, regional and global ecological problems, to provide the governmental support to informal ecological culture enhancement measures carried out by youth, tourist and non-governmental organizations, museums, national parks and reserves, international specialized ecological and educational organizations.

Therefore, some progress has been reached in the sphere of ecological education and training ecological specialists, but to further this process, the following measures need to be implemented:

- increasing efficiency of methodological guidance in this sphere by the Ministry of Education and Science, republican Methodical Centers and establishing base Ecological Education Centers in institutions of higher and secondary specialized education to meet this objective;

- establishing Chairs of Ecology (environment protection) in all institutions of higher education;

- developing a consistent and continuous ecological education system for the whole education period by each educational establishment (the scheme designed by the Belarusian National Engineering University is recommended as an exemplary reference model of such training for institutions of higher education);

- arranging universal ecological education among senior officials of the education system and all teachers of different types of educational establishments;

- involving governmental and non-governmental organizations, institutions and mass media into the ecological education process;

- purposefully investing in the ecological education;

- establishing base centers for advanced training of the educational institutions' personnel teaching ecological disciplines;

- focusing on ecological education of students of pedagogical institutions of education, etc.

2. Scientific and Technological Programs

In 1997–1998, the following works related to further improvement of the ecological education in Belarus were implemented within the framework of the National Scientific and Technological Program *Nature Management and Environmental Protection* (Research Manager – NASB Academician I.I. Lishtvan): *Development of the Ecological Education Concept, Development of the Program for Improving Environmental Engineers Training, Development of Recommendations for Improving the System of Advanced Training of the Ecological Personnel, Assessment of the Current State and Development Trends and Development of Software Modules of Training and Game Expert/Information Computer Systems, Development of Game Training Simulators, Computer Reference Aids, Graphical and Animated Cartoon Billboards Promoting Efficient Nature Management and Environmental Protection*.

The above served as the basis for developing the Republican Program of *Improving the Ecological Education* which is aimed at harmonizing the content and institutional structure of all levels of ecological education with the modern requirements. Major provisions of the Ecological Education Concept are being implemented within the framework of this Program.

Scientific and Technological Programs and Systematic Research. The following individual projects are being implemented in Belarus within the framework of governmental and scientific-and-technical *Programs Nature Management and Environmental Protection* (1990 – 2000), *Ecological Safety* (2001–2005), and also in the line with Fundamental Research Programs and Fund:

- Assessment of Emission Factors Associated with Heavy Metals Characteristic of the CIS Countries (Russia, Ukraine, Belarus, Kazakhstan) – mercury, lead, cadmium, nickel, copper, zinc. Responsible organization – NASB INRUE.

- Research into Spectral Composition and Distribution of Heavy Metals by Size of Carrying Aerosol Particulates Emitted by the Industries Characteristic of the CIS Countries (Russia, Ukraine, Belarus, Kazakhstan). Responsible organization – NASB INRUE.

- Assessment of the Effect of Changing Climate on Economic Activity and that of Economic Activity on Climate. Responsible organization – NASB INRUE.

- Assessment of Ecological Tolerance of Minsk Forests and Surroundings Related to the Economic Activity and Current Climate Behavior, Development of Scientific Recommendations to Improve it. Responsible organization – NASB IEB.

- Analysis of Generation of Volatile Organic Compound Emissions in the Republic of Belarus and Development of Scientific, Ecological and Economic Recommendations for Reducing Emissions. Responsible organization – BRC Ecology.

- Assessment of Emission Factors of Persistent Organic Pollutants for Major Emission Sources. Responsible organization – NASB INRUE.

The above projects, however, paid little attention to problems of the climate-change effect on water resources. The problems of the climate effect on the water economy and vice versa, as well as water ecosystems vulnerability and adaptation have not been considered.

3. Internet-Site

The main information of ecological situation is included as a separate Section in the Statistical Yearbook of the Ministry of Statistics and Analysis. The National Report the *State of Environment in the Republic of Belarus* was published in the Russian and English languages in 2001.

MNREP regularly updates the information on the natural environment state in the Republic of Belarus and environmental enhancement measures on its Internet site located on the server of the Administration of the President of the Republic of Belarus at the site www.president.gov.by.

4. Cooperation with Mass Media

The mass media is mainly responsible for informing the population (primarily, children and youth) regarding the natural environment state, environmental protection measures and climate change through the following channels: journals *Rodnaya Pryroda (Native Nature*), *Praleska (Snow Flower*), newspapers *Ecology of Minsk*, *Ecological Bulletin* (Gomel), *Nabat (Alarm*), *Belovezhskaya Pushcha*, weekly radio program *Ecological Bulletin* and *Native Nature*.

Since 1991, the Institute of Natural Resources Utilization and Ecology of the National Academy of Sciences of Belarus and the Ministry of Natural Resources and Environmental Protection has been annually publishing the Ecological Bulletin *The State of Natural Environment in Belarus*. The Belarusian Research Center *Ecology* issues the library of the National Environment Monitoring System of the Republic of Belarus and the Central Research Institute of Multipurpose Utilization of Water Resources publishes the *National Water Resources Inventory* and *Water Resources* journal.

All the above publications cover, although unsystematically, the climate-change problems.

5. Cooperation with Non-Governmental Organizations

Currently, it is getting more evident that global problems of environmental protection and ecological security cannot be successfully solved by efforts of only governmental institutions. One of the critical conditions of pursuing the national policy is to involve general public into the process of taking ecologically informed decisions. It has been noted in many intergovernmental documents, in particular, in decisions of the UN Conference On Environment and Development (UNCED, Brazil, 1992), Conference of Environmental Ministers of Europe in Lucerne (1993), Sophia (1995) and Aarhus Conference of Ministers, that ecological problems may be efficiently addressed, provided all citizens concerned are involved.

The Convention Access to Justice regading environmental aspects (Aarhus Convention) approved in Aarhus (Denmark) 23-25 June 1998 was an important step to further environmental protection and democracy development. Approval of this important document by the President of the Republic of Belarus implies that Belarus is committed to strictly implement all Aarhus Convention provisions.

The Ministry of Natural Resources and Environmental Protection of the Republic of Belarus is implementing provisions of the Aarhus Convention, in particular, by strengthening collaboration with non-governmental ecological organizations and involving them into joint activities aimed at environment enhancement and protection.

In July 2001, to implement provisions of the Aarhus Convention and coordinate activities of the MNREP structural divisions with non-governmental environmental organizations and associations, the Ministry set up the Public Coordinating Ecological Council incorporating 17 non-governmental organizations and associations, namely, *Ecoline, Ecoprovo, Ecodom, Belarusian Society of Nature Conservancy, Protection of Birds of Belarus, Ecological Management, Next Stop – New Life, Belarusian Children and Youth Association, International Non-Governmental Ecological Association Burenko, Green Region*, etc.

Setting up the Council allowed the non-governmental organizations to take part in making ecologically informed decisions, participate in formulating the ecological policy (National Plans of Actions, Bills, regulatory and legal acts, etc.).

6. Conferences

In 1992, the Republican Scientific and Practical Conference *Urgent Issues of Ecological Education* was held to focus the attention of senior officials of the educational bodies, educational institutions and ecological committees on the ecological education. The Conference stated, first of all, the lack of in-depth scientific analysis of the problem, and scientifically substantiated definition of the compulsory scope of ecological knowledge for different stages of education, specific industries and specialities. The underfunding impeded development and publication of a new generation of manuals, teaching aids, methodical and ecological popular-scientific literature.

In 1995, the II Republican Conference *Ecopedagogics: State, Problems, Perspectives* was held to summarize implementation of the Ecological Education Program. The Conference stated that extremely positive progress was reached in solving existing problems and made constructive proposals.

The X Republican Pedagogical Readings were held in Brest the same year and were dedicated to the European Year of Nature Conservancy; 31 papers covering the experience, problems and prospects of ecological education in the Republic of Belarus were presented.

The international television forums *Ecoworld* were held in 1995, 1996, 1997 to demonstrate television films pursuing the goal of ecological education of the general public.

The Republican Scientific and Methodical Workshop *Ecological Education – 96* was held in Minsk in 1996 under the auspices of the MNREP and ME of the Republic of Belarus.

The Republican Methodical Workshop *Innovative Pedagogical Technologies in Ecological Education* was held in the Republican Ecological Students Center in 1997.

The workshop reviewing the involvement of public in taking ecologically informed decisions was held within the framework of the TACIS Program *Enhancement of Public Awareness of Ecological Problems* in 1998.

The International Scientific and Practical Conference *Europe – Our Common Home* was held in 1999.

In 2000–2003, a series of scientific conferences were held to discuss problems of climate effect on natural complexes and economic sectors, as well as of anthropogenic effect on climate change.

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APPENDIX

APPENDIX 1. CO2 emission trends
(Sheet 1 of 5)

Country
Year
Submission

Category of greenhouse gas sources and sinks	Basis year (1)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
	(Gg)											
1. Energy sector	**0,00**	**100 615,00**	**99 700,00**	**96 300,00**	**79 800,00**	**65 700,00**	**60 552,10**	**59 900,00**	**60 200,00**	**57 300,00**	**55 185,00**	**50 741,60**
A. Fuel combustion	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1. Energy sector												
2. Processing industry and construction												
3. Transport												
4. Other sectors												
5. Other												
B. Volatile fuel emissions	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1. Solid fuels												
2. Oil and natural gas												
2. Industrial processes	**0,00**	**1 856,35**	**1 781,71**	**1 725,06**	**1 578,70**	**1 082,80**	**902,65**	**985,14**	**1 248,22**	**1 438,14**	**1 405,65**	**1 277,78**
A. Mineral products		1 856,35	1 781,71	1 725,06	1 578,70	1 082,80	902,65	985,14	1 248,22	1 438,14	1 405,65	1 277,78
B. Chemical industry												
C. Metallurgy												
D. Other production sectors												
E. Porduction of halogenated hydrocarbons & SF_6												
F. Use of halogenated hydrocarbons & SF_6												
G. Other												
3. Use of solvents												
4. Agriculture	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
A. Intestinal fermenation												
B. Waste of agricultural animals												
C. Rice growing												
D. Agricultural soils (2)												
E. Savannah burning												
F. Agricultural remnants burning												
G. Other												
5. Change in land use and forestry(3)	**0,00**	**-12 720,21**	**-14 565,00**	**-15 650,00**	**-16 880,00**	**-17 685,00**	**-18 157,61**	**-18 155,00**	**-18 310,00**	**-18 520,00**	**-19 298,44**	**-18 981,37**
A. Forest changes and other biomass sinks		-35 095,00	-35 025,00	-35 000,00	-35 000,00	-35 025,00	-35 093,74	-35 325,00	-36 000,00	-36 800,00	-38 179,29	-38 199,42
B. Transformation of wood, pasture and meadows		8 412,45	6 650,00	5 800,00	5 000,00	4 900,00	4 705,04	4 700,00	4 750,00	4 900,00	5 219,26	5 638,71
C. Used land		1 347,50	1 310,00	1 300,00	1 260,00	1 200,00	1 155,00	1 080,00	1 020,00	960,00	924,00	885,50
D. Emission and removal of CO2 from soil		2 517,24	2 400,00	2 150,00	1 740,00	1 100,00	845,39	770,00	800,00	820,00	788,09	714,54
E. Other		10 097,60	10 100,00	10 100,00	10 120,00	10 140,00	10 230,70	10 620,00	11 120,00	11 600,00	11 949,50	11 979,30
6. Waste	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
A. Garbage dumpsites												
B. Wastewater												
C. Waste incineration												
D. Other												
7. Other *(indicate)*	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
Total emission/removal taking into account item 5 (4)	**0,00**	**89 751,14**	**86 916,71**	**82 375,06**	**64 498,70**	**49 097,80**	**43 297,14**	**42 730,14**	**43 138,22**	**40 218,14**	**37 292,21**	**33 038,01**
Total emission taking into account item 5(4)	**0,00**	**102 471,35**	**101 481,71**	**98 025,06**	**81 378,70**	**66 782,80**	**61 454,75**	**60 885,14**	**61 448,22**	**58 738,14**	**56 590,65**	**52 019,38**
Note columns:												
International bin	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
Aviation												
Sea transport												
Multilateral Operations (Total)												
Emission of CO_2 from biomass												

APPENDIX 1. CH4 emission trends
(Sheet 2 of 5)

Country
Year
Submission

Category of greenhouse gas sources and sinks	Basis year(1)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
	(Gg)											
Total Emissions	**0,00**	**987,41**	**963,31**	**923,68**	**887,69**	**840,15**	**805,61**	**832,61**	**834,81**	**835,11**	**835,05**	**611,41**
1. Energy sector	**0,00**	**321,04**	**319,00**	**307,00**	**303,50**	**289,50**	**288,05**	**325,00**	**327,70**	**325,00**	**332,50**	**123,26**
A. Fuel combustion	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1. Energy sector												
2. Processing industry and construction												
3. Transport												
4. Other sectors												
5. Other												
B. Volatile fuel emissions	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1. Solid fuels												
2. Oil and natural gas												
2. Industrial processes	**0,00**	**1,15**	**1,15**	**1,08**	**0,92**	**0,87**	**0,78**	**0,88**	**1,20**	**1,38**	**1,43**	**1,61**
A. Mineral products												
B. Chemical industry		0,15	0,14	0,09	0,07	0,08	0,11	0,08	0,10	0,11	0,13	0,15
C. Metallurgy		1,00	1,01	0,99	0,85	0,79	0,67	0,80	1,10	1,27	1,30	1,46
D. Other production sectors												
E. Porduction of halogenated hydrocarbons & SF_6												
F. Use of halogenated hydrocarbons & SF_6												
G. Other												
3. Use of solvents												
4. Agriculture	**0,00**	**529,53**	**508,43**	**481,69**	**456,40**	**429,85**	**403,76**	**384,46**	**374,15**	**367,03**	**350,12**	**333,94**
A. Intestinal fermenation		471,30	452,45	428,70	406,15	382,18	358,73	341,26	332,05	325,87	310,80	296,16
B. Waste of agricultural animals		57,90	55,66	52,45	49,66	47,22	44,72	42,73	41,68	40,80	39,10	37,51
C. Rice growing												
D. Agricultural soils (2)												
E. Savannah burning												
F. Agricultural remnants burning		0,33	0,32	0,54	0,59	0,45	0,31	0,47	0,42	0,36	0,22	0,27
G. Other												
5. Change in land use and forestry(3)	**0,00**	**23,89**	**22,93**	**22,11**	**21,47**	**20,83**	**20,42**	**20,97**	**21,66**	**22,40**	**22,90**	**22,90**
A. Forest changes and other biomass sinks												
B. Transformation of wood, pasture and meadows		6,09	5,10	4,25	3,60	2,95	2,54	3,15	4,00	4,95	5,56	5,56
C. Used land												
D. Emission and removal of CO2 from soil												
E. Other		17,80	17,83	17,86	17,87	17,88	17,88	17,82	17,66	17,45	17,34	17,34
6. Waste	**0,00**	**111,80**	**111,80**	**111,80**	**105,40**	**99,10**	**92,60**	**101,30**	**110,10**	**119,30**	**128,10**	**129,70**
A. Garbage dumpsites		111,80	111,80	111,80	105,40	99,10	92,60	101,30	110,10	119,30	128,10	129,70
B. Wastewater												
C. Waste incineration												
D. Other												
7. Other *(indicate)*	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
Note columns:												
International bin	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
Aviation												
Sea transport												
Multilateral Operations (Total)												
Emission of CO2 from biomass												

APPENDIX 1. N2O emission trends
(Sheet 3 of 5)

Страна
Год
Submission

Category of greenhouse gas sources and sinks	Basis year(1)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
	(Гг)											
Total Emissions	**0,00**	**33,38**	**32,18**	**27,87**	**25,61**	**19,19**	**16,21**	**18,80**	**20,96**	**22,47**	**19,89**	**20,92**
1. Energy sector	**0,00**	**0,77**	**0,75**	**0,73**	**0,70**	**0,53**	**0,44**	**0,43**	**0,48**	**0,49**	**0,40**	**0,36**
A. Fuel combustion	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1. Energy sector												
2. Processing industry and construction												
3. Transport												
4. Other sectors												
5. Other												
B. Volatile fuel emissions	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1. Solid fuels												
2. Oil and natural gas												
2. Industrial processes	**0,00**	**1,12**	**1,06**	**1,01**	**0,95**	**0,89**	**0,84**	**0,88**	**0,92**	**0,95**	**0,99**	**1,01**
A. Mineral products												
B. Chemical industry		1,12	1,06	1,01	0,95	0,89	0,84	0,88	0,92	0,95	0,99	1,01
C. Metallurgy												
D. Other production sectors												
E. Porduction of halogenated hydrocarbons & SF_6												
F. Use of halogenated hydrocarbons & SF_6												
G. Other												
3. Use of solvents												
4. Agriculture	**0,00**	**30,68**	**29,57**	**25,36**	**23,24**	**17,08**	**14,28**	**16,81**	**18,84**	**20,27**	**17,71**	**18,76**
A. Intestinal fermenation												
B. Waste of agricultural animals		0,02	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
C. Rice growing												
D. Agricultural soils (2)		30,66	29,55	25,35	23,23	17,07	14,27	16,80	18,83	20,26	17,70	18,75
E. Savannah burning												
F. Agricultural remnants burning												
G. Other												
5. Change in land use and forestry(3)	**0,00**	**0,04**	**0,03**	**0,03**	**0,02**	**0,02**	**0,02**	**0,02**	**0,03**	**0,04**	**0,04**	**0,04**
A. Forest changes and other biomass sinks												
B. Transformation of wood, pasture and meadows		0,04	0,03	0,03	0,02	0,02	0,02	0,02	0,03	0,04	0,04	0,04
C. Used land												
D. Emission and removal of CO2 from soil												
E. Other												
6. Waste	**0,00**	**0,77**	**0,77**	**0,74**	**0,70**	**0,67**	**0,63**	**0,66**	**0,69**	**0,72**	**0,75**	**0,75**
A. Garbage dumpsites												
B. Wastewater		0,77	0,77	0,74	0,70	0,67	0,63	0,66	0,69	0,72	0,75	0,75
C. Waste incineration												
D. Other												
7. Other *(indicate)*	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
Note columns:												
International bin	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
Aviation												
Sea transport												
Multilateral Operations (Total)												
Emission of CO2 from biomass												

Table 10. Emission trends for CFC, PFC and SF_6
(Sheet 4 of 5)

Country
Year
Submission

Category of greenhouse gas sources and sinks	Basis year[1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
	(Gg)											
CFC emission[5] - in CO_2 эequivalent (Gg)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
CFC-23												
CFC-32												
CFC-41												
CFC-43-10mee												
CFC-125												
CFC-134												
CFC-134a												
CFC-152a												
CFC-143												
CFC-143a												
CFC-227ea												
CFC-236fa												
CFC-245ca												
PCF emission[5] - in CO_2 equivalent (Gg)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
CF_4												
C_2F_6												
C_3F_8												
C_4F_{10}												
$c\text{-}C_4F_8$												
C_5F_{12}												
C_6F_{14}												
SF6 emuission[5] - in CO_2 equivalent (Gg)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
SF_6												

Substance	ПГП
CFC	
CFC-23	11700
CFC-32	650
CFC-41	150
CFC-43-10mee	1300
CFC-125	2800
CFC-134	1000
CFC-134a	1300
CFC-152a	140
CFC-143	300
CFC-143a	3800
CFC-227ea	2900
CFC-236fa	6300
CFC-245ca	560
PFC	
CF_4	6500
C_2F_6	9200
C_3F_8	7000
C_4F_{10}	7000
$c\text{-}C_4F_8$	8700
C_5F_{12}	7500
C_6F_{14}	7400
SF_6	23900

[5] Enter information on the actual emissions. Where estimates are only available for the potential emissions, specify this in a comment to the corresponding cell. Only in this row the emissions are expressed as CO_2 equivalent emissions in order to facilitate data flow among spreadsheets.

APPENDIX 1. Emission trends (REVIEW)
(Sheet 5 of 5)

Country
Year
Submission

Greenhouse gas emission	Basis year[1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
	CO_2 equivalent (Gg)											
Total emission/sink of CO_2	0,00	89 751,14	86 916,71	82 375,06	64 498,70	49 097,80	43 297,14	42 730,14	43 138,22	40 218,14	37 292,21	33 038,01
CO_2 emission (without "Change in land use ..") [6]	0,00	102 471,35	101 481,71	98 025,06	81 378,70	66 782,80	61 454,75	60 885,14	61 448,22	58 738,14	56 590,65	52 019,38
CH_4	0,00	20 735,61	20 229,51	19 397,28	18 641,49	17 643,15	16 917,81	17 484,81	17 531,01	17 537,31	17 536,05	12 839,61
N_2O	0,00	10 347,80	9 975,80	8 639,70	7 939,10	5 948,90	5 024,48	5 828,00	6 497,60	6 965,70	6 165,59	6 483,96
HFCs	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
PFCs	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
SF_6	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total (incl. "Total emissions/sink of CO2")	**0,00**	**120 834,55**	**117 122,02**	**110 412,04**	**91 079,29**	**72 689,85**	**65 239,43**	**66 042,95**	**67 166,83**	**64 721,15**	**60 993,85**	**52 361,58**
Total (without "Change in land use ..") [6] [8]	**0,00**	**133 554,76**	**131 687,02**	**126 062,04**	**107 959,29**	**90 374,85**	**83 397,04**	**84 197,95**	**85 476,83**	**83 241,15**	**80 292,29**	**71 342,95**

Category of greenhouse gas sources and sinks	Базовый год[1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
	CO_2 equivalent (Gg)											
1. Energy sector	0,00	107 595,54	106 631,50	102 973,30	86 390,50	71 943,80	66 737,55	66 858,30	67 230,50	64 276,90	62 291,50	53 441,66
2. Industrial processes	0,00	2 227,70	2 134,46	2 060,84	1 892,52	1 376,97	1 179,43	1 276,42	1 558,62	1 761,62	1 742,58	1 624,69
3. Use of solvents	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4. Agriculture	0,00	20 630,93	19 843,73	17 977,09	16 788,80	14 321,65	12 905,14	13 284,76	13 697,55	13 991,33	12 842,31	12 827,10
5. Change in land use and forestry[7]	0,00	-12 206,12	-14 074,17	-15 176,39	-16 422,93	-17 241,37	-17 722,59	-17 708,43	-17 845,84	-18 037,20	-18 805,14	-18 488,07
6. Waste	0,00	2 586,50	2 586,50	2 577,20	2 430,40	2 288,80	2 139,90	2 331,90	2 526,00	2 728,50	2 922,60	2 956,20
7. Other	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

(6) Information in these lines is for data comparison, since the Parties give different reports on emisison and sink of CO2
for the module "Change in land use and forestry"
(7) Total emissions
(8) Information in these lines is for data comparison, since the Parties give different reports on emisison and sink of CO2
for the module "Change in land use and forestry". Pay attention that these amounts will be different from data given in the Summary table 2 (Summary2),
if the Parties report not about CO2 emisisons in the module "Change in land use and forestry".

Calculation of uncertainty acc. to level 1 of the national greenhouse gas inventory

A	B	C	D	E	F	G	H	I	J
Source category, IPCC	Greenhouse gas	Basis year emissions	Emissions in 2000	Uncertainty of data on activities	Uncertainty of emission factor	Combined uncertainty	Combined uncertainty in % from the total nation emission of 2000	Type A sensitivity	Type B sensitivity
		Gg, CO2 equivalent	Gg, CO2 equivalent	%	%	%	%	%	%
1.1 Coal	CO2	9803	3845	1	5	5,099	0,148	-0,013885	0,019
1.2 Oil	CO2	63301	15630	1	2	2,236	0,264	-0,135878	0,079
1.3 Natural gas	CO2	27287	30426	1	2	2,236	0,513	0,061196	0,154
1.4 Other (waste)	CO2	224	837	1	5	5,099	0,032	0,003479	0,004
1.5 Fuel, total	CH4	356	365	1	5	5,099	0,014	0,000638	0,002
1.6 Natural gas transmission	CH4	6386	2224	1	5	5,099	0,086	-0,010469	0,011
1.7 Other fuel combustion (except transport)	N2O	1296	53	1	3	3,162	0,001	-0,004144	0,000
1.8 Transport	N2O	1023	12	1	5	5,099	0,000	-0,003422	0,000
2.1 Cement production	CO2	996,2	814,76	3	10	10,440	0,064	0,000737	0,004
2.2 Lime production	CO2	860,15	463,02	3	10	10,440	0,036	-0,000582	0,002
2.3 Electrical steel production	CH4	21	30,66	3	5	5,831	0,001	0,000084	0,000
2.4 Ethylene production	CH4	3,15	3,15	1	5	5,099	0,000	0,000005	0,000
2.5 Nitric acid production	N2O	347,2	313,1	1	5	5,099	0,012	0,000405	0,002
3.1 Use of solvents	NMH	1992	1130	35	5	35,355	0,301	-0,001056	0,006
4.1 Internal fermentation	CH4	9897,3	6219,36	8	20	21,541	1,010	-0,002179	0,032
4.2 Manure handling	CH4	1215,9	787,71	8	20	21,541	0,128	-0,000148	0,004
4.3 Incineration in the fields	CH4	6,93	5,67	20	20	28,284	0,001	0,000005	0,000
4.4 Manure handling	N2O	4,96	3,1	8	20	21,541	0,001	-0,000001	0,000
4.5 Agricultural soil	N2O	9505,84	5811,26	5	20	20,616	0,904	-0,002914	0,029
4.6 Incineration in the fields	N2O	0	0,93	20	20	28,284	0,000	0,000005	0,000
5.1 Change in land use and forestry	CO2 (emission)	23676,89	20583,64	15	10	18,028	2,799	0,023667	0,104
5.1 Change in land use and forestry	CO2 (sink)	36397,4	39565,02	15	10	18,028	5,380	0,076434	0,200
5.2 Change in land use and forestry	CH4	127,89	480,9	15	10	18,028	0,065	0,002002	0,002
5.3 Change in land use and forestry	N2O	12,4	12,4	15	10	18,028	0,002	0,000021	0,000
6.1 Solid waste disposal	CH4	2348,43	2723,07	7	10	12,207	0,251	0,005803	0,014
6.2 Wastewater treatment	N2O	246,4	243,2	6	10	11,662	0,021	0,000394	0,001
TOTAL		197336,04	132582,95				6,258		

A (continued)	B (continued)	K	L	M	N	O	P	Q
Source category, IPCC	Greenhouse gas	Uncertainty of national emissions trends due to uncertainty of emisison factors	Uncertainty of national emissions trends due to uncertainty of data on activities	Uncertainty introduced into the national emissions trend	Indicator of the emission factor quality	Indicator of quality of data on activities	Number of references to expert judgements	Number of the explanatory note
					D/M/R	D/M/R		
					%	%	%	
1.1 Coal	CO2	-0,069	0,028	0,075				
1.2 Oil	CO2	-0,272	0,112	0,294				
1.3 Natural gas	CO2	0,122	0,218	0,250				
1.4 Other (waste)	CO2	0,017	0,006	0,018				
1.5 Fuel, total	CH4	0,003	0,003	0,004				
1.6 Natural gas transmission	CH4	-0,052	0,016	0,055				
1.7 Other fuel combustion (except transport)	N2O	-0,012	0,000	0,012				
1.8 Transport	N2O	-0,017	0,000	0,017				
2.1 Cement production	CO2	0,007	0,018	0,019				
2.2 Lime production	CO2	-0,006	0,010	0,012				
2.3 Electrical steel production	CH4	0,000	0,001	0,001				
2.4 Ethylene production	CH4	0,000	0,000	0,000				
2.5 Nitric acid production	N2O	0,002	0,002	0,003				
3.1 Use of solvents	НМУ	-0,005	0,283	0,283				
4.1 Internal fermentation	CH4	-0,044	0,357	0,359				
4.2 Manure handling	CH4	-0,003	0,045	0,045				
4.3 Incineration in the fields	CH4	0,000	0,001	0,001				
4.4 Manure handling	N2O	0,000	0,000	0,000				
4.5 Agricultural soil	N2O	-0,058	0,208	0,216				
4.6 Incineration in the fields	N2O	0,000	0,000	0,000				
5.1 Change in land use and forestry	CO2 (emission)	0,237	2,213	2,225				
5.1 Change in land use and forestry	CO2 (sink)	0,764	4,253	4,321				
5.2 Change in land use and forestry	CH4	0,020	0,052	0,055				
5.3 Change in land use and forestry	N2O	0,000	0,001	0,001				
6.1 Solid waste disposal	CH4	0,058	0,137	0,148				
6.2 Wastewater treatment	N2O	0,004	0,010	0,011				
TOTAL				4,906				