Ministry of Natural Resources and Environmental Protection of the Republic of Belarus

SECOND, THIRD, FOURTH NATIONAL COMMUNICATION

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SYNOPSIS

NATIONAL COMMUNICATION, GREENHOUSE GASES, EMISSIONS, SINKS (ABSORPTION), EMISSIONS COEFFICIENT, CARBON UNITS, ENERGY SECTOR, INDUSTRIAL PROCESSES, USE OF SOLVENTS, AGRICULTURE, LAND USE, FORESTRY, WASTE, VULNERABILITY AND ADAPTATION, GREENHOUSE GAS EMISSIONS REDUCTION STRATEGY.

The objective of the work is to develop the fourth national communication in accordance with the commitments of the Republic of Belarus under the United Nations Framework Convention on Climate Change using the format for countries included in Annex 1 to the Convention; make inventory of greenhouse gases (GHG) for the period 1990-2004 according to the 1996 Intergovernmental Panel on Climate Change Guidelines and determine inputs of each type of GHG to the overall global warming effect (GWE), present information about greenhouse gas emissions reduction policies and measures and their forecast until 2020, and to prepare detailed description of impact assessment of climate change on agricultural, forest, water ecosystems, social environment, as well as to evaluate measures designed to adapt them to climate change.

Pursuant to the goal of the work, inventory of greenhouse gas emissions and sinks has been made in the following sectors: energy; industry; agriculture; land-use change and forestry; waste; the report contains greenhouse gas emissions reduction policy and measures and their forecasts, assessment of vulnerability and adaptation of the national economy to climate change.

The report presents information about the existing national legislation required to set up and ensure the functioning of the greenhouse gas inventory system, and maintain the national carbon unit register.

The research contained herein allows identifying main ways to reduce GHG emission impact on the climate in the future.

Content

LIST OF ABBREVIATIONS

IPCC	–	Intergovernmental Panel on Climate Change
VNMOC	–	Volatile non-methane organic compounds
GHG	–	Greenhouse gas
UNFCCC	–	United Nations Framework Convention on Climate Change
t.r.f.	–	Tonne of reference fuel
GWP	–	Global warming potential
GWE	–	Global warming effect
GDP	–	Gross domestic product
J	–	Joule
FEC	–	Fuel and energy complex
USSR	–	Union of Soviet Socialist Republics
BSSR	–	Belarusian Soviet Socialist Republic
CIS	–	Commonwealth of Independent States
U.S.A.	–	United States of America
MoE	–	Ministry of Environment
U.N.	–	United Nations Organization
BelNIC Ecologia	–	Belarusian Research Centre “Ecologia”
GCM	–	Global climate model
UNEP	–	United Nations Environmental Programme
PI	–	Pathogenicity index
AHPI	–	Air humidity pathogenicity index
IAPVPI	–	Interday atmospheric pressure variability pathogenicity index
WSPI	–	Wind speed pathogenicity index
ATPI	–	Air temperature pathogenicity index
CPI	–	Complex pathogenicity index
LCZ	–	Landscape-climate zone
AREFS	–	Automated regional ecological forecasting system

Prefixes and multiplier coefficients

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

INTRODUCTION

The signing and ratification of the United Nations Framework Convention on Climate Change (UNFCCC) by the Republic of Belarus, as well as the accession to the Kyoto Protocol indicate that the government of the country pays serious attention to the problem of greenhouses gases and their impact on climate change.

The ultimate goal of the UNFCCC is to stabilize the concentration of gases that have a greenhouse effect at such a level that would prevent the harmful anthropogenic intervention into the climatic system.

The cardinal commitment of the Republic of Belarus under the UNFCCC is to reduce the anthropogenic emissions of greenhouse gases, first of all CO_2; develop, periodically update, publish and make available to the Conference of the Parties national inventories of anthropogenic emissions by sources and removals by sinks (except those that deplete the ozone, Art. 4.1a, UNFCCC). Inventories should be made using methodologies of the Intergovernmental Panel on Climate Change (IPCC), adopted by the Conference of the Parties, and submitted in a transparent and verifiable format.

In accordance with the above, the development of national inventories aims to determine the current level of greenhouse gas emissions in order to identify policies and measures to mitigate impacts on climate change in the future.

The following methodological documents were used in developing the Fourth National Communication of the Republic of Belarus:

1) Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part I: UNFCCC reporting guidelines on annual inventories (Document FCCC/CP/1999/7);

2) Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part I: UNFCCC reporting guidelines on national communications (Document/CP/1999/7);

3) UNFCCC reporting guidelines on global climate observing systems (Document/CP/1999/7);

4) Revised 1996 IPCC guidelines for national greenhouse gas inventories;

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

6) Climate Change 2001: IPCC Synthesis Report.

7) 1994 IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations, UNEP/WMO.

8) 1998 Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies, UNEP.

Apart from those listed above, national normative and methodological documents dealing with inventories and calculation of specific emissions, etc. were used. The contributors to the report also relied on many years of experience, materials and results of previous surveys conducted as part of national assignments.

The information presented covers six sectors:

1) GHG emissions in the energy sector (CO_2, CH_4, N_2O, NO_x, CO, NMVOCs, SO_2) ;

2) GHG emissions in industrial processes (CO_2, CH_4, N_2O, NO_x, CO, NMVOCs, HFCs, SO_2). GHG emissions in use of solvents (NMVOCs);

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

4) Land-use change and forestry (removals of CO_2);

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

The inventory has been made for the period of 1990 – 2004 which encompasses all salient points in the development of the national economy of Belarus.

The elaboration of the national emission reduction strategy built upon relevant experiences of other countries, national development specificities, and the results of work related to greenhouse gas inventories, assessment of vulnerability and social and economic adaptations to climate change, and other materials.

The communication contains detailed information regarding assessment of likely impacts on:

– agricultural, forest, aquatic ecosystems;

– climate-dependent sectors (agriculture, forestry, water management);

– social sector,

as well as the assessment of measures to facilitate their adaptation to climate change.

The information has been collected and analyzed in accordance with the requirements it should meet: consistency, transparency, comparability, completeness and accuracy .

All calculations have been made using the IPCC software product. Tables containing cumulative data on greenhouse gas inventories are presented in a special IPCC-designed format.

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SUMMARY

With approximately 9.8 million of population, the Republic of Belarus is situated in Central Eastern Europe occupying an area of 207,600 sq km. Similar to many other FSU republics, Belarus is an economy in transition.

Belarus keeps the problem of climate change in tight focus, as evidenced by the country's accession to all the major international conventions in this field. On 11 June, 1992, the Republic of Belarus signed the United Nations Framework Convention on Climate Change (UNFCCC) ratifying it on 11 May 2000 and becoming a full party to the UNFCCC on 9 August 2000.

On 26 August 2005, the country signed an instrument of accession to the Kyoto Protocol to the UNFCCC becoming a full party to the Protocol on 24 November 2005. By the Decision 10/CMP.2 of the second session of the Conference of the Parties acting as the Council of Parties in Nairobi, 6-17 November 2006, the Republic of Belarus was included in Annex B to the Kyoto Protocol undertaking greenhouse gas reduction commitments in the amount of 92% to the 1990 emissions for the first commitment period 2008 - 2012 ("Proposal from Belarus to Amend Annex B to the Kyoto Protocol" (draft decision FCCC/KP/CMP/2006/L.9)). The inclusion of Belarus in the list of Annex B countries is the primary condition for the country's participation in the Kyoto Protocol economic mechanisms and attraction of financial resources into the country under the flexible mechanisms.

Belarus submitted its First National Communication covering the period 1990 to 2000 in 2003. This National Communication contains information that demonstrates further development of the country and encompasses the period 1990 to 2005, inclusive.

Since the accession to the Kyoto Protocol, the country has enthusiastically embarked on a mission to create conditions conducive to meeting commitments undertaken by the country. Legislative, institutional and technical frameworks are being developed for full and effective participation of Belarus in the flexible mechanisms stipulated by the Kyoto Protocol. The National Action Plan on Climate Change has been approved, the National Sustainable Development Strategy and the Fourth National Communication have been developed.

An analysis of greenhouse gas emission trends and forecasts (see Part 2 below) indicates that the Republic of Belarus is likely to meet its greenhouse gas reduction commitments compared to the base year (1990). Nevertheless realizing its responsibility for climate change and considering future commitments within the next commitment period, the Government plans respective activities designed to stabilize emissions and increase removals of greenhouse gases during the period of economic growth. In accordance with the 2005-2012 Action Plan for the Implementation of the Kyoto Protocol to the United Nations Framework Convention on Climate Change, this strategy should, among other things, include development and integration of greenhouse gas emission reduction and sink expansion activities in sectoral programs of wise nature use and environmental protection for 2006–2010 and subsequent years by providing for greenhouse gas emission reduction in 2008–2012.

PART I. NATIONAL CIRCUMSTANCES

1.1 Geographic location of Belarus

In terms of its size and population, Belarus is an average European state. It is situated in the centre of Europe (56°10' and 51°16' north latitude, 23°11' and 32°47' east longitude). It extends for 560 km from the north to the south and for 600 km from the west to the east. The capital of Belarus is the City of Minsk. The city is situated in the central part of the country at the meeting point of major transportational routes.

Belarus borders on five states: the Russian Federation in the north and east (990 km or 33.4%), the Ukraine in the south (975 km or 32.8%), Poland in the west (399 km or 13.4%), Lithuania in the north-west (462 km or 15.6%) and Latvia (143 km or 4.8%). The total length of borders is 2,969 km. Belarus is a landlocked country.

By the size of its area (207,650 sq km) Belarus ranks the 13th among European states (2.1% of Europe's total area). It is greater than Lithuania, Latvia and Estonia taken together and approximately the same territory occupied collectively by Portugal, Austria and Belgium (206,300 sq km). In terms of population (9,849,100 as of January 1st, 2004) Belarus is the 14th in Europe ahead of Austria, Bulgaria, Sweden. The density of population is 47.4 persons per sq km.

The most important features of the country's geography are its compact configuration, central and transit location. A number of important railways and motorways, air corridors, oil- and gas pipelines connecting economically developed countries of Western Europe and resources-rich Asia meet here. Belarus provides the shortest way from the central and eastern parts of Russia to Western Europe, and from the Baltic to the Black Sea.

Thus, from the global geoenvironmental perspective, Belarus is a country of regional importance that affects the ecological situation in Europe by redistributing transboundary air and water flows.

1.2 Government and legislation

As the Constitution reads, the Republic of Belarus is a unitary, democratic, socially-oriented rule-of-law state. The head of the state is the President of the Republic of Belarus. Various governmental functions are executed by the Parliament, Government, Presidential Administration, judicial authorities, Prosecutor's Office and the State Control Committee. The Parliament (the National Assembly of the Republic of Belarus) consists of two chambers: the House of Representatives and the Council of the Republic. The Government (the Council of Ministers of the Republic of Belarus) exercises executive power and is the central body of public administration. The Judicial Power is executed by courts.

The system of public administration is sector and territory-based. It includes 24 ministries, 12 sectoral committees, 6 regional and 118 district executive committees, as well as town and village committees.

The governmental institutions responsible for environmental protection are the President, the National Assembly, the Council of Ministers, and local committees. Local authorities directly execute state and regional programmes for environmental protection. The Ministry of Natural Resources and Environmental Protection is a body of special competence, which reports to the Council of Ministers. Other institutions that have the right to supervise the state of environment are the Ministry for Emergencies, Health Ministry and the State Property Committee of the Republic of Belarus. Certain environmental functions are assigned to the Ministry of Forestry, Ministry of the Interior, State Customs Committee and the Directorate of the Presidential Affairs.

1.3 Environmental and climate change legislation

According to the Constitution, the mineral resources, water, forests are owned exclusively by the state. Agricultural lands are the property of the state. The Constitution guarantees every citizen's right to healthy environment and full indemnification if this right is violated. The state executes control over the sustainable use of natural resources to ensure improved living standards, environmental protection and remediation.

The national environmental legislation system has been modelled upon the legislation of the industrially developed countries and is generally up to international standards. The Constitution of the Republic of Belarus declares every man's right to healthy environment and full indemnification if this right is violated. The first environmental law adopted in independent Belarus was the "Environmental Protection Act" (1992). It regulates the whole business of environmental protection and forms the basis for sectoral environmental acts, such as "On State Environmental Expert Review" (1993, amended in 2000), "On Specially Protected Areas and Sites" (1994, amended in 2000), "On Animal Protection and Use" (1996), "On Radiation Safety" (1998), "On Waste" (2000), etc. The relations in the field of nature use are regulated by the "Mineral Resources Code" (1997), "Water Code" (1998), "Land Code" (1999), "Forest Code" (2000) and others.

The Constitution declares that everyone ought to contribute to the protection of our environment, and this way it stresses the role the citizen and the society play in opposing environmental threats. At the same time, Belarus is a party to a number of international environmental agreements to control global environmental changes.

In order to comply with the Convention on Biological Diversity (Rio de Janeiro, 1992), Belarus adopted "The National Strategy and Action Plan for the Conservation and Sustainable Use of Biodiversity in Belarus" (1997). In 1995, Belarus was among the European states that approved the Pan-European Biological and Landscape Diversity Strategy in Sofia. In 1999, Belarus joined the Ramsar Convention on Wetlands. The Republic of Belarus is a party to the Convention on Long-Range Transboundary Air Pollution and of three protocols to it.

Since Belarus signed the UNFCCC, it has exerted active effort to develop legislation regulating greenhouse gas emissions and establishing legislative and institutional frameworks to carry out activities related to climate change. The key normative and legal acts defining the climate policy of the country are as follows:

- Environmental Protection Act of the Republic of Belarus dated 26/11/1992, Article 56 – Obligations of legal entities and individual entrepreneurs engaged in economic and other activities related to greenhouse gas emissions into the air; Article 57 – Climate impact control.
- Air Protection Act of the Republic of Belarus dated 15/04/1997, Article 43 – Weather and climate impact control.
- Law on Hydrometeorological Activities of the Republic of Belarus dated 10/05/1999, Article 16. Terms of reference of the national administrative body in the fields of hydrometeorological activities (maintenance of climate inventory).
- Presidential Edict No 177 on the "Approval of the United Nations Framework Convention on Climate Change" dated 10/04/2000.
- Presidential Edict No 370 on the "Accession of the Republic of Belarus to the Kyoto Protocol to the United Nations Framework Convention on Climate Change" dated 12/08/2005.
- Resolution No 1582 of the Council of Ministers of the Republic of Belarus on the "Implementation of the Kyoto Protocol to the United Nations Framework Convention on Climate Change" dated 30/12/2005.

Resolution No 1582 adopted the 2005–2012 National Plan for the Implementation of the Kyoto Protocol to the United Nations Framework Convention on Climate Change. Pursuant to the Resolution, the following normative and legal acts have been submitted, reviewed and adopted by the Council of Ministers of the Republic of Belarus in due manner:

- Resolution No 485 of the Council of Ministers of the Republic of Belarus on the "Approval of the Regulations for the Procedure of Maintaining the National Greenhouse Gas Inventory" dated 10/04/2006. This document defines the procedure for maintaining a national inventory of anthropogenic emissions by sources and removals by sinks of greenhouse gases. The inventory is maintained to assist the Republic of Belarus in meeting its commitments with regard to annual reporting under the UNFCCC and Kyoto Protocol, development of National Communications of the Republic of Belarus on Climate Change for submission to the UNFCCC Conference of the Parties, and analysis of trends and emission and sink targets. The Ministry of Natural Resources and Environmental Protection is responsible for maintaining the national greenhouse gas inventory based on information provided by other government bodies defined by the said Resolution. The IPCC guidelines approved by decisions 2/CP.3, 4/CP.1 и 18/CP.8 inform the process of inventory development.

- Resolution No 585 of the Council of Ministers of the Republic of Belarus on the "Approval of the Regulations for the National Greenhouse Gas Inventory System" dated 4/05/2006. This act determines how the national greenhouse gas inventory system put in place to assist Belarus in meeting its obligations under article 5 of the Kyoto Protocol should be organized and function. The inventory system incorporates all institutional measures for greenhouse gas inventories carried out in Belarus on the basis of the guidelines for national greenhouse gas inventories developed by the Intergovernmental Panel on Climate Change and approved by decisions 2/CP.3, 4/CP.1. The main objectives of the national system are to create an information system for monitoring greenhouse gas emissions and removals, maintain the national greenhouse gas inventory, establish a database for developing programmes and activities to reduce greenhouse gas emissions and increase removals by sinks.

- Resolution No 1077 of the Council of Ministers of the Republic of Belarus on the "National Carbon Unit Register of the Republic of Belarus" dated 25/08/2006. This resolution charges the Ministry of Natural Resources and Environmental Protection with the responsibility to develop and maintain the National Carbon Unit Register. The National Carbon Unit Register of the Republic of Belarus is established to control the introduction, storage, transfer, procurement, cancellation and withdrawal of emission reduction units, certified emission reduction units, assigned amount units and removal units, as well as to transfer emission reduction units, certified emission reduction units and assigned amount units for the next commitment period under the Kyoto Protocol to the UNFCCC.

- Resolution No 1144 of the Council of Ministers of the Republic of Belarus on the "Approval of the Regulations on the Procedure of Submitting, Reviewing and Monitoring Joint Implementation Projects" dated 05/09/2006. These regulations establish the procedure concerning the submission, review and monitoring of joint implementation projects. In accordance with the Regulations, the Ministry of Natural Resources and Environmental Protection keeps track of all such project proposals.

- Resolution No 1145 of the Council of Ministers of the Republic of Belarus on the "Approval of the Regulations on the State Interdepartmental Commission on Climate Change" dated 05/09/2006. This document determines the composition, objectives and competencies of the Commission put in place to regulate relations relating to climate impacts and meeting commitments under the international agreements that address the global problem of climate change. In particular, the commission acting on behalf of the Government may review and endorse activities under the Kyoto Protocol mechanisms (emission trading, joint implementation and clean development mechanism projects), greenhouse gas inventory reports, and performs other necessary procedures in accordance with the Kyoto Protocol. The Commission is headed by Deputy Prime Minister of the Republic of Belarus.

- Resolution No 1155 of the Council of Ministers of the Republic of Belarus on the "Approval of the 2007-2012 Strategy for Reducing Emissions and Enhancing Removals by Sinks of Greenhouse Gases in the Republic of Belarus" dated 07/09/2006. The National Climate Change Strategy reflects a government policy which the Republic of Belarus should pursue to meet its commitments undertaken under the UNFCCC and Kyoto Protocol. The Strategy aims to identify main activity areas allowing to ensure assigned reduction of anthropogenic pressure on climate alongside effective development of economic sectors and meeting population needs using economically justified and ecologically balanced solutions. It is also necessary to take into account future commitments under the Kyoto Protocol in the next commitment period 2013-2017, when allowed emissions and removal enhancements will be noticeably reduced.

Edicts of the President of the Republic of Belarus No 177 (10/04/2000) and No 370 (12/08/2005) devolved power on the Ministry of Natural Resources and Environmental Protection (MoE) to conduct the national policy in the field of climate change.

By Order No 417 of the MoE dated 29/12/2005, the subordinate organization "BelNIC Ecologia" was designated as the National Centre for Conducting Inventories and Maintaining Greenhouse Gas Inventories. In accordance with the Centre Regulations, its main functions include making inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol on substances that deplete the ozone layer, maintaining the national greenhouse gas inventory, developing and contributing to the implementation of activities designed to reduce emissions and enhance removals by sinks of greenhouse gases.

1.4 Natural resources

Geologically, Belarus is situated within the Eastern-European Platform; physical and geographic features of the territory are determined by its location within the western part of the Eastern-European Plain. The country lies on the water divider between the basins of the Baltic and Black Sea, and this indicates its continental location. The topographical surface is generally plain-like: hills, rolling plain and lowlands here alternate with marshlands and lakes. The present relief features are generally determined by Quaternary glaciations.

There were at least five major glaciations recorded in Belarus during the Quaternary period: Günz, Mindel, Riss I, Riss II and Würm. Riss II was most important for the geomorphology of Central Belarus; the Würm glaciation was present only in the North (Poozerie) where, therefore, the country's youngest geomorphologic features occur.

The average elevation in Belarus is around 160 m a.s.l. The highest point of the country, the mountain of Dzerzhinskaya, is just about 345 m; the lowest point is in the valley of the River of Neman next to the Lithuanian border is 80 m a.s.l.

In respect to physical geography, Belarus can be divided into five provinces: Poozerie, Western Belarus, Eastern Belarus, Sub-Polesie and Polesie.

Poozerie (46,700 sq km) occupies the north. Its typical features are lakes, rolling moraine and limno-glacial plains of the Würm origin. Western Belarus (50,300 sq km) is dominated by the Belarusian Ridge with the adjoining plains. It is a hilly area, elevated over the rest of the country, typical of the eroded forms of glacial accumulation. Eastern Belarus (15,100 sq km) is a plateau built by loess clays; other typical features are the flat relief and fertile soil. Sub-Polesie (37,400 sq km) is basically a plain of fluvio-glacial and moraine origin. Polesie (58,100 sq km) is the largest province covering the south of the country. It is the lowland underlain by alluvial, secondary fluvio-glacial and secondary moraine rocks. Polesie is famous for its marshlands.

A diversity of natural conditions such as this presupposes different land use systems for different parts of the country appropriately adapted to local landscapes.

1.5 Climate

Belarus is situated in the region of temperate climate. The specific features of the climate are conditioned by the country's location in the average latitudes, relative proximity of the Atlantic Ocean and prevailing westerly winds that meet no topographical barriers within the country. These conditions contributed to the predominance of temperate continental climate in Belarus.

Total solar radiation gradually increases from the north (3,500 MJ/m2) to the south (4,100 MJ/m2); around 50% of the radiation comes during May-July, and around 5% during November-January.

Mean annual duration of sunshine largely corresponds to the cloudiness and increases from the north and north-west to south and south-east from 1,750 to 1,870 hours.

Mean air temperature in Belarus increases from the north-east (4.5º) to south-west (7.0º), mean temperature in January (the coldest month) increases in the same direction from -8.0 to -4.5ºC, and mean temperature in July (the warmest month) increases towards south-east from 17.0 to 18.5ºC. The absolute temperature maximum is recorded in the south-east of Belarus, in the Gomel Region (+38ºC), and the absolute minimum is in the north-east, in the Vitebsk Region (-44ºC). During the recent decade the coldest periods of winters shift from January to December, which is considered to be a characteristic feature of the current warming period.

The growing period (with temperatures over +5ºC) lasts 209 days in the south-west and 180 days in the north-east.

The national agriculture suffers very much from temperature drops down to 0ºC and lower during growing periods. The probability of frost sharply decreases from the first decade of May (20-45%) to July, and quickly rises from the third decade of August (1-3%) to the third decade of September (25-50%). The frequency of temperature drops varies little in the west and east increasing mostly from the south to north. Autumn frost is more likely to occur in the east; its distribution is close to longitudinal in September. The area of frost distribution greatly varies. Air frost never covers over a third of the country at the same time and is very limited territorially in the summer. In May and September, the temperature drops on the soil surface may occur within up to 70% of the country with the likelihood of 20-25%.

Amount of precipitation a year is, on average, 600 – 700 mm. The warm half-year accounts for approximately 60% of precipitation, while 40% are 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 sections (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 has 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 or anticyclones.

Numbers of days with a stable snow cover vary from 75 in the south-west to 125 in the north-east. The average thickness of the snow layer changes in this direction from 15 to 30 and more cm; water capacity of the snow cover respectively changes from 35 to 80-100 mm. Duration of the stable snow cover has been decreasing in the recent decade within the whole country.

The climate is influenced by the western air circulation that brings to Belarus slightly transformed Atlantic air masses and western winds strongly prevailing during winter (due to local topography there can also be south-western or even southern winds). The frequency of south-western winds is 45-50%; south-eastern winds, related to Siberian or, rarer, some Eastern European anticyclones, have frequency of 15-20%.

In summer the frequency of winds from western directions (also included NW and SW) is around 50%; the frequency of winds from east, south-east and north-east is roughly 30%.

In spring and autumn the winds from all directions have nearly the same frequency, with south-eastern winds just a bit more common during spring, and south-western and western more common during autumn. The peak wind frequency shifts during a year clockwise.

Mean annual wind velocity in Belarus reaches 3.5-4.0 m/sec on plains and uplands and 3.0-3.5 m/sec in lowlands and valleys. The frequency of slow winds (2-5 m/sec) is 60-70%, for moderate winds (6-9 m/sec) it decreases to 6-25%, and for strong winds occurring mainly during the cold period (over 10 m/sec), it is just 2-3%.

The prevailing westerly winds bring to Belarus large portions of transboundary pollutants: around 180,000-190,000 tonnes of sulphur, 60,000-70,000 tonnes of nitrogen oxides, 150,000-170,000 tonnes of reduced nitrogen, over 400 tonnes of lead and 5 tonnes of mercury annually.

1.6 Water resources

The Republic of Belarus is supplied with water resources sufficiently to meet the current and future consumption needs. Belarus has around 20,800 rivers, 10,800 lakes, 153 water reservoirs and 1,500 ponds. The total length of rivers is 90,600 km; the rivers of the Black Sea (Dnieper, Sozh, Pripyat) and Baltic Sea (Western Dvina, Neman, Vilia, Western Boug) basins collect on average 55% and 45% of the accumulated river runoff, respectively.

In a year of average water content, the river runoff is 57,900 km3; depending on the year’s climate it can vary from 37,200 to 92,400 km3. Most of the runoff is generated within the country (34,000 km3 or 59%). The water inflow from Russia and the Ukraine is equal to 23.9 km3 a year (41%).

The longest rivers usually collect a portion of their runoff outside the country: in Russia (Dnieper, Sozh, Western Dvina), the Ukraine (Pripyat, Western Boug) and Poland (Western Boug). Crossing the Belarusian boundary the large transboundary rivers enter the Ukraine (Dnieper), Lithuania (Neman and Vilia) and Latvia (Western Dvina).

Over 10,000 Belarusian lakes are for the most part distributed between Poozerie (over 4,000) and Polesie (6,000). The deepest and most picturesque lakes are situated in Belarusian Poozerie, including the Naroch Lake – the biggest lake in Belarus (80 km2). 75% of lakes are smaller than 0.1 km2 and classified as small ones.

There are 153 water reservoirs in Belarus with the total volume of 3.1 km3 and effective storage of 1.24 km3. Their water resources are primarily intended for irrigation and water supply of big cities (Vileika and Soligorsk Reservoirs); they also serve as coolers for power plants (lakes of Beloe and Lukomlskoe).

Belarus possesses large resources of groundwater, including drinking water (with salt content below 1 g of dissolved matter in 1 dm3), mineral water (table water and spa) and brine (35-500 g of dissolved matter in 1 dm3). Available annual supply of renewable groundwater resources is 15.9 km3; predicted annual supply is 18.1 km3. Fresh groundwater is the major source for industrial and drinking water consumption. To date, there are 251 explored water fields with the total potential production of 6.5 million m3 a day.

Consumption of drinking water in Belarusian cities is 180-370 l/day per capita. This exceeds levels achieved in many European countries (120-150 l/day). The average level of the consumption of drinking water is 218 l/day per capita.

The average supply of locally generated water in Belarus is 3,600 m3; including 1,400 m3 accumulated in groundwater. This exceeds per capita water resources available in England (respectively 2,600 and 1,000), the Netherlands (700 and 250), the Ukraine (1,000 and 200), but lower than in Norway (89,000 and 27,500) and Russia (9,000 and 2,000).

18 hydropower plants are currently in use in Belarus generating around 3% of the potential national hydropower supply and accounting for over 0.13% of electric energy produced in Belarus (10MW) by plants of all types.

The economically available hydropower is 1.3 bln kW/year, which is less than capacity available in Lithuania (1.5), Poland (7.0) and the Ukraine (19 bln kW/year).

Belarus is principally a plain, therefore only low-head hydropower plants can be constructed here. Hydroelectric development on the Dnieper and Pripyat Rivers would lead to the inundation of large areas. However conditions are in place to build economical and environmentally-safe plants in the basins of Western Dvina and Neman. Prospects for hydropower development in Belarus are related to multifunctional systems integrating runoff regulation, power production, water supply, water transportation, irrigation and water protection.

Rational solutions include construction of tandem reservoirs in river channels that do not provoke land inundations. Such projects fit better the rivers with the banks elevated over water edges.

It is also expedient to build micro-hydropower plants (capacity below 100 kW) on small streams; such plants can secure power supply of nearby settlements.

1.7 Mineral resources and feedstock

At present, over four thousand mineral deposits represented by 30 types of mineral resources are known in Belarus.

Most of the fields and deposits were fully surveyed and incorporated in the national list of mineral reserves. Average annual extraction of mineral resources is as follows (mln tonnes): oil - 1.84, peat - 5.0, potassium - 3.4, salt - 1.35, dolomites - 3.2, chalk - 3.6, chalky clay – 1.02, building stone – 3.1, building sand and gravel – 11.0, brick and lightweight aggregate earth - 2.0; 170,000 tonnes of glass-melting sand, 500,000 tonnes of moulding sand; over 1 billion m3 of fresh groundwater, 350,000 m3 of mineral groundwater, etc.

Available deposits of mineral resources are sufficient to cover the national consumption of peat, potassium, salt, dolomites, limestone, building stone, sand and gravel, brick earth, fresh groundwater, mineral groundwater etc.

However, due to limited supplies or under-explored deposits, the country still imports bulks of raw materials, such as oil, natural gas, coal, shale oil, glass-melting sand, tripoli earth, modelling clay, gypsum, kaolin, soda ash, high-strength crushed rock, etc.

In spite of some oil, associated gas, brown coal, peat and oil shale fields, Belarus is not self-sufficient in terms of fossil fuels. Oil supply available for industrial production is 65 mln tonnes, while probable reserves are just around 189 mln tonnes; over 100 mln tonnes have been extracted to date. Explored resources of associated gas are 8.1 bln m3 and annual production is about 252 mln m3. Probable reserves of lignite are over 1.3 bln tonnes, and industrial reserves are 124.4 mln tonnes. These fields are available for strip mining and can supply all households with fuel, however they are not used for production for environmental considerations. Probable reserves of shale oil are over 10 bln tonnes, however they have a high ash percentage, and therefore are not economically sound to extract.

One of the most common and best-explored fossil fuel in the country is peat. It is broadly used in agriculture and as household fuel. There are over 9,000 peat fields, including 100 fields with annual production around 5 mln tonnes. However peat production has been constantly dropping recently.

Sapropel reserves have been found in over 500 lakes as well as under peat deposits making up about 3 bln m3.

Potassium is the major mineral resource in Belarus. The total reserves of the two well-explored deposits – Starobino and Petrikovo – are 6.7 bln tonnes of raw salt or 1.194 mln tonnes of potassium oxide. Currently, the Starobino reserve (5.698 bln tonnes of raw salt) is under production; the ore is extracted by “Belaruskalij” that annually produces over 2.3 mln tonnes of potassium.

There also three explored salt deposits with the total supply of 22 bln tonnes: Mozyrskoe, Davidovskoe and Starobinskoe. The salt extraction plant based on the Mozyrskoe deposit annually produces around 290,000 tonnes.

There is the Ruba dolomite deposit near Vitebsk (industrial reserves - 750 mln tonnes) used for the production of dolomite powder for soil liming.

Belarus possesses large deposits of building stone (576.6 mln m3), cement materials (460 mln tons), building sand (476.1 mln m3), ballast sand and gravel (685.4 mln tonnes), and carbonate materials (945 mln tonnes).

Belarus is rich in brine that can be used for extraction of iodine, bromine, potassium, magnesium and other rare and trace elements. There are indications of industrial deposits of glauconite, pyrophyllite, materials for industrial fibre, amber, diamonds, rare and non-ferrous metals.

A supply of reserves by major types of mineral resources will cover long periods, furthermore many of them have good prospects of building up, including for industrial purposes.

Currently, the projected supply of major mineral resources stands at: oil (2004 production levels) – 34 years; potassium – from 17 years at ore facility 1 to 101 years at ore facility four; rock-salt – practically inexhaustible reserves; dolomite – over 50 years; peat – over 50 years; sapropel – over 60 years; moulding material – enough to provide current enterprises that do require high-quality raw materials; glass-melting sand – over 50 years; cement – long-term provision by current cement plants; building stone – explored reserves allow building up production capacities for high-strength crushed rock from 15 to 20 mln m/y; lime chalk – 8 to over 50 years; refractory clay – over 30 years; fusible clay – 1 to over 25 years; building stone – from 18 to over 30 years; sand and gravel – 5 to 25 years.

1.8 Soil and land resources

Several factors contribute to the modern state of soil cover in Belarus. The primary ones include: composition and properties of soil-forming minerals, climate features, vegetative cover and animal world, relief of the surface of the ground, geological age of the crust, manufacturing.

Dominant soil types in Belarus are: sod-podzol, marshy sod-podzol, sod and sod-carbonated soil, peat soil, sod soils of floodplains. 42.5% of arable lands are loamy sands, 37.6% are clays and loamy clays, 13.6% are sands and 6.3% are peat soils.

In terms of soil moisture, 45.3% of arable lands are automorphic (normal level of moisture), 40.3% are semihydromorphic (high level of moisture for long periods), 14.4% are hydromorphic (permanently high level of moisture). Thus, automorphic and semihydromorphic soils (85.6%) dominate the stock of arable lands in Belarus.

The total land stock in Belarus is 20,759,800 ha as of the end of 2005; agricultural lands are

9,011,500, and 5,542,300 ha of them are arable lands. However, the structure of land stock undergoes certain changes as far as the purpose and types of land are concerned.

The distribution of the national land stock by category of land, land owners and actual land users in 2005 is shown in Table 1.1 and Figure 1.1, and by type of land – in Table 1.2.

Table 1.1

Distribution and dynamics of the national land stock by category, land owners and actual land users

Land type	Area, thousand ha				Changes over 1990-2005
	1990	1995	2000	2005	
Lands in agricultural use and in private ownership	12,096.0	11,894.0	10,741.1	10,204.4	-1891,6
Lands of state forestry enterprises	6,812.7	6,873.3	7,770.0	8,299.5	+1,486.8
Lands used for industry, transport, defence, communications and other purposes	1,056.8	914.0	808.5	690.1	-366.7
Lands owned by the entities related to environmental protection, public health, recreation, culture and historical heritage	338.8	477.8	817.4	879.2	+540.4
Lands occupied by hydraulic and other water-engineering facilities	39.4	36.4	35.0	39.9	+0.5
Public lands of settlements	247.5	377.7	364.9	355.2	+107.7
Land reserve	168.3	186.4	223.0	291.5	+123.2
Total land:	20,759.5	20,759.6	20,759.9	20,759.8	+0.3

Over the last 15 years (1990-2005) the agricultural and privately owned lands have been reduced in size by 1,891,600 ha or from 58.3 to 49.2% of the national land stock. This was due to a transfer of the land to forestry enterprises, for industry and construction activities, areas of nature conservation, and also because of shrub overgrowth of hayfields and pastures within floodplains, etc. Lands used for industry, transport, defence, communications and other purposes have been reduced during this period as well (by 365,700 ha). At the same time, there has been a noticeable increase in the area of the land of state forestry enterprises (by 1,486,800 ha), land owned by the entities related to environmental protection, public health, recreation, culture and historical heritage (540,400 ha), land reserve (123,200 ha) and public lands of settlements (107,700 ha). The lands occupied by waterworks have extended slightly - by 500 ha.

It is worth mentioning that over the last 15 years there was a reduction of agricultural land (by 403,300 ha), land used for streets, squares and other public places (by 190,600 ha), degraded and other land (38,700 and 287,800 ha, respectively) and marshlands (by 48,700 ha).

The land-use groups that grew in the area most during the period were forest and other forested lands (extended by 663,100 ha) and land under buildings and yards (by 250,200 ha). There was some growth of land occupied by roads, passages, clearings and pipelines (by 37,500 ha) and covered with water (by 18,600 ha).

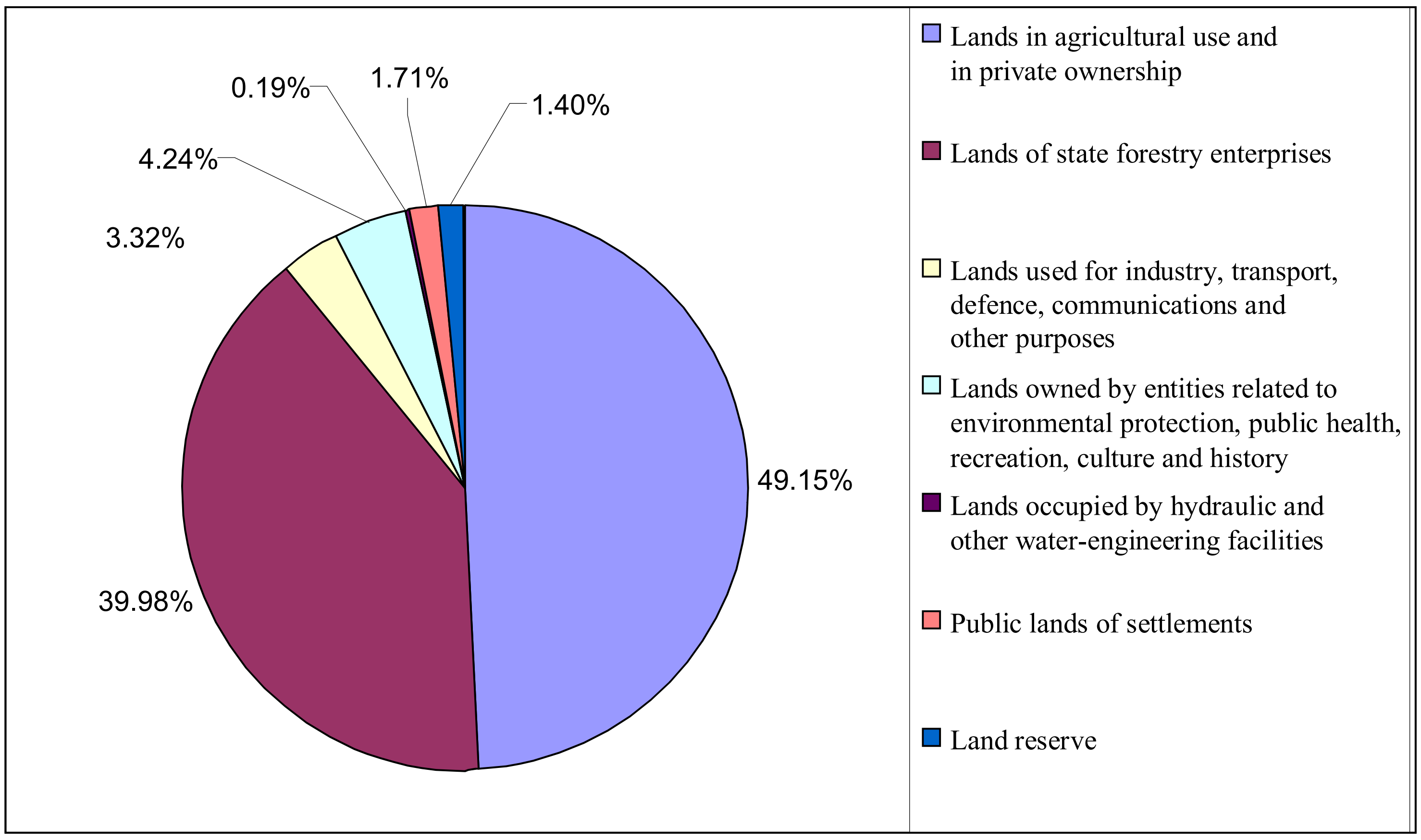

Figure. 1.1. Distribution of the national land stock of Belarus in, %

Table 1.2

Distribution and dynamics of the national land stock by type of land

Type of land	Area, thousand ha				Changes over 1990-2005
	1990	1995	2000	2005	
Total area	20,759.5	20,759.6	20,759.9	20,759,8	+0.3
Agricultural lands, total	9,414.8	9,338.8	9,257.7	9,011.5	-403.3
Forests and other covered with forest	8,229.2	8,277.5	8,436.8	8,892.3	+663.1
Marshlands	948.8	957.6	964.3	900.1	-48.7
Covered with water	458.1	473.2	475.2	476.7	+18.6
Under roads, passages, clearings, pipelines	326.9	350.2	358.1	364.4	+37.5
Under streets, squares and other public places	338.9	190.7	154.7	148.3	-190.6
Under buildings and yards	73.7	295.5	328.7	323.9	+250.2
Degraded lands	44.6	42.1	24.1	5.9	-38.7
Other	924.5	834.0	760.3	636.7	-287.8

The overall dynamics of agricultural lands in Belarus over the last 30 years, including the arable, drained and irrigated lands, is described in Tables 1.3 and 1.4.

Table 1.3

Dynamics of the area occupied by agricultural lands, thousand ha

Agricultural lands	1975	1980	1990	1995	2000	2005
Total	9,892.9	9,727.9	9,414.8	9,338.8	9,257.7	9,011.5
including arable land	6,154.5	6,211.3	5,637.4	6,232.0	6,133.2	5,542.3

Table 1.4

Dynamics of the area occupied by drained and irrigated lands, thousand ha

Type of land improvement	1975	1980	1990	1995	2000	2005
Drained lands	2,282.6	2,716.7	3,229.3	3,394.6	3,416.0	3,411.7
Irrigated lands	139.4	161.9	148.9	114.7	115.0	114.1

Table 1.4 shows a dramatic decrease in the amount of land improvement projects recently. While the pace of drainage was considerable between 1975 and 2000, during the last five years the area of drained lands decreased by 4,300 ha. The drainage systems are in poor working order.

The nationwide tendencies of the reduction in the area of agricultural lands and simultaneous increase of forests and areas covered with forests differ from region to region (Table 1.5). These differences are chiefly expressed in the intensity and direction of these processes.

Table 1.5

Dynamics of the national land stock with respect to administrative regions over the period of 1970-2005 (%)

Administrative region	Type of land					
	Agricultural land			Forests and other covered with forest		
	1970	1990	2005	1970	1990	2005
Brest	44.8	45.1	44.2	38.2	36.2	38.0
Vitebsk	48.5	43.7	39.9	37.1	41.8	46.1
Gomel	42.1	36.3	34.5	46.5	46.1	50.6
Grodno	50.8	51.8	50.6	34.2	34.5	37.1
Minsk	48.1	47.4	47.3	39.3	39.3	41.4
Mogilev	55.2	52.0	48.4	36.1	36.4	40.2
Republic of Belarus	47.8	45.4	43.4	39.1	39.6	42.8

The table demonstrates that the agricultural lands are most widespread in the regions of Grodno (50.6%) and Mogilev (48.4%), and least widespread in the regions of Gomel (34.5) and Vitebsk (39.9%). The highest percentages of forested lands are in the regions of Gomel (50.6%) and Vitebsk (46.1), while the lowest percentages are in the regions of Grodno (37.1) and Brest (38.0%).

The analysis of agricultural lands' dynamics over the period of 1970-2005 reveals the most significant reductions in the regions of Vitebsk (by 8.6%), Gomel (7.0) and Mogilev (5.6%).

During the same period, forested lands have grown in size in all regions, except for the Brest Region. Here they reduced by 0.6%. The growth was most pronounced in the regions of Minsk (by 10.7%) and Vitebsk (by 8.7%).

Continuous growth of urban population leads to the extension of city boundaries. The processes contributing to this are not just the regular growth of bedroom communities, but also the development of large suburban residential areas (cottage communities) at the expense of agricultural lands and, to a lesser extent, the state forest stock. This growth will only intensify in the future because of the growing amount of motorists that stimulates commutation and increasing public wealth. Such trends are typical of other European states. The building density is expected to increase within the city boundaries in the future.

Thus, the land resources capacity is high in Belarus. Recent changes in the distribution of the national land stock are mostly associated with the restoration of their ecological and economic capacity, provision of land parcels to individuals, transfer of low-fertility lands to forestry enterprises, improvement of agricultural use, land allotments for construction purposes, etc. In 2005, the development of agricultural land in Belarus was 43.7%, including 26.7% of arable lands. This indicates a high human pressure on the national land stock. The area taken by land-use groups that contribute to environmental stability (forest, meadows, shrubbery, fens and water) is over 50% of the land-stock. Compared to Western Europe, forests and marshlands are better preserved in Belarus. Besides, the per-capita supply of agricultural lands (including arable) are also higher here (0.92 and 0.57 ha, respectively), which is 1.5-2 times higher than similar parameters European countries. This tendency will prevail in the future.

The Chernobyl Nuclear Power Plant disaster resulted in the contamination of over 1.3 million ha of agricultural lands and 1.6 million ha of forests. As of end of 2005, 248,900 ha are considered to be contaminated by radiation. Most radionuclides are contained in the upper layer (inhabited by roots) and will be available to vegetation in the long term as a result of a lengthy half-life period and a slow speed of percolation deep into the ground, in particular for Cesium-137. Nevertheless, due to some protective measures and lower mobility of Cesium-137, it has become less available to the vegetation (factor of 10-12 during the post-disaster period). The contaminated area is expected to lessen down to 30,000 sq km (15% of the total area) versus 43,500 sq km (21%) now by 2020.

In 2005, Belarus had 1,445 specially protected areas (SPAs) (excluding the Polesski Radiation-Ecological Reserve), with a total area of 1,728,000 ha or 8.3% of the country's territory (Table 1.6). Compared to 2004, the total area of SPAs increased by 40,600 ha, while the number of SPAs decreased by 11. The establishment of new SPAs and elimination of several local zakazniks whose territories were consolidated explain these changes. The SPA area is expected to increase up to 9-10% of the country's territory by 2020.

Table 1.6

Specially protected areas in Belarus (as of January 1, 2006)*

Conservation status	Number	Area, thousand ha	Share in the total SPA area, %
Reserves*, national parks	5	480.1	27.8
Zakazniks, total	527	1,231.3	71.2
including national zakazniks	99	936.3	54.2
local zakazniks	428	295.0	17.1
Nature monuments, total	913	16.6	1.0
including national nature monuments	337		
local nature monuments	576		
Total	1,445	1,728.0	100

* excluding the Polesski Radiation-Ecological Reserve.

Marshlands and wetlands are very common for Belarus. Prior to their economic exploitation they occupied up to 2.9 million ha or over 14% of the country. They were most common in the basin of the Pripyat River. Around 4.5 million ha of fens and wetlands were situated in the basins of Berezina, Western Dvina, Dnieper, Sozh and Neman. The total area of wetlands was 8.1 million ha; 3.1 million ha were assessed as unsuitable for drainage works.

At present, the total area of drained lands constitutes 3,411,700 ha (16.4% of the country); of them, 2,895,100 ha are agricultural lands, including arable lands - 1,235,100 (42.7%) and hayfields and pastures – 1,646,500 (57.3%). Drained lands are a predominant typical feature of the Belarusian Polesie.

Despite ongoing measures to conserve ameliorated lands, 223,000 ha of peatlands are degraded, mostly in the Polesie Area, where a peat layer is totally destroyed or is smaller than 30 cm. Therefore outdated drainage systems require upgrading.

Not only drained lands, but also preserved wetland ecosystems call for the support from the state. This can be done through the implementation of the National Strategy and Action Plan on the Use, Renaturalization and Protection of Marshlands and Peatlands, as well as measures under the UN Convention to Combat Desertification.

1.9 Biological Resources

Biological diversity of Belarus is not only of national, but international relevance as well, as it contributes to the maintenance of the global ecological balance and gene pool. The national natural and socio-economic conditions favour the conservation of many rare ecosystems and animal and plant species, otherwise extinct or endangered in Europe. Large landscapes containing precious gene pool are preserved in the country.

Belarus has considerable biodiversity capacity in terms of animal and plant diversity.

According to the 2005 data, natural vegetation occupies 62.2% of Belarus. The plant world is represented by forest (7.8 million ha), grassland (3.3), scrub (0.49), mire vegetation (0.92) and aquatic vegetation (0.48). Vegetation is a principal component of the nature that creates the landscape, influences micro- and meso-climate and makes a large share of the country's natural resources.

The flora consists of 11,500 species, including 2,100 higher species, 9,000 – 9,400 lower species. To date, there are 1,638 vascular species known to science amply dominated by grass species (1,550). The tree species include 107 wild indigenous species; 28 of them are trees and the rest are various shrubbery species. The mosses are represented by 430 species, lichens by 477, algae by over 2,200 and mushrooms by 7,000.

Endemic species are absent in the flora, however there are species of the past floras. 130 vascular species (8%) belong to relict flora.

Belarus is situated on the edge of the Boreal and the Nemoral vegetation zones; the former is dominated by coniferous forests, and the later – by deciduous forests. There are three geobotanic sub-zones, namely the sub-zone of oak and dark coniferous forests of the south taiga, the hornneam, oak and dark coniferous forests of the sub-taiga, and the broad-leaved and pine-tree sub-zone.

The forest is the national treasure of Belarus and its major natural resource. The forests are mostly coniferous: dominated by pine-trees (50.2%) and spruce (10.0%). Small-leaved forests are mostly birch (20.8%), black almond (8.2%), grey almond (2.3%) and asp (2.1%) groves. The broad-leaved forests occupy just around 3.9% of the area, including 3.3% of oak forests

Belarus is well provided with wood resources. Over the last statistical period (2001-2005) the total area of forest stock increased by 81,000 ha making up 9.3 million ha. The changes were attributable to the withdrawal of 1,400 ha to be used permanently for government and public needs, as well as the inclusion into the forest fund 47,100 ha of land, including 27,700 from the Ministry of Forestry companies. Age distribution has also significantly improved: 27.5% of the forest is young, 45.5% is of middle age, 19.1% is coming to the old, and 7.9% is old. The average indices have also improved: the total annual harvest is 27.4 million m^3, annual harvest per 1 ha of the forest is 3.58 million m^3, the average age is 49 years, supply per 1 ha is 174 m^3. The total wood supply has increased by 245 million m^3 and at present makes 1.3 billion m^3, the same indices for old forests are respectively 55 million m^3 and 135 million m^3. The forested area has extended up to 37.8% of the country and therefore achieved nearly the optimal value.

Per capita wood supply is 130.4 m3, which is over the average European level by the factor of 2.2. Belarus is in the sixth (the highest) group of countries classified with respect to the integrated index for forest resources. Forests account for a large share of the national recreational resources.

However the national forestry faces a number of problems requiring addressing. The species composition is still far from optimum. The area covered with hard leaved species is 1.5-2 times below the available capacity; percentage of soft leaved species is very high. The woodiness varies from 10.1% in the district of Nesvizh to 65.9% in the district of Lelchitsy. Average forest supplies per 1 ha are just 50-60% of the optimal. The utilization rates are still low in the forestry making up 1% of the total supply or 50% of average annual increment. Although the estimated principal cutting area is not utilized fully, the rate of utilization by Forestry Ministry companies generally increased in 2005 by 80.9% (in 2004 – 76.9%, in 2003 – 70.2%). For coniferous trees the estimated cutting area is utilized 97.4% (96.9% in 2004), for hard-leaved trees – 92.1% (89.9% in 2004), for soft-leaved trees – 68.4% (61.4% in 2004). Higher utilization of the estimated cutting area is a result of active work by the forestry and improvement of the economic situation in the country.

By 2010, the estimated principal cutting area is projected to make 8-9 million m^3, and by 2020 – 12-15 m^3.

Reforestation is a positive factor, with an area of 51,500 ha in 2005 including 45,000 ha of forest planting.

It should be noted that the 1st- group plantations that primarily perform ecological functions constitute 46,601,000 ha or 50% of the total forest stock. Of them, the largest areas are covered by water protective forests (31%), green zones (30%), protective forests (26%), reserves and national parks (10%). Specially protected areas make up 1,159,000 ha or 15% of the forest stock, which is greater than in most of Europe.

Annually up to 400,000 tons of pollutants fall out into the forest leading to its degradation. The Chernobyl Nuclear Power Plant accident contaminated 25% of the Belarusian forests.

The latter are also prone to fire: every year brings 2,000-3,000 forest fires that spread over large areas in some years (up to 20,000 ha).

The shrub vegetation is represented by groups of hydrophytic willow growing in mires (52.5%) confined to sandy wasteland of xerophytic juniper and exceptionally rare tangles of blackthorn (34.2%), as well as floodplain mesohygrophytic shrubbery (13.3%).

The meadow vegetation of Belarus is represented by a wide variety of grass communities of upland, lowland, river and lacustrine valleys. All but floodplain meadows are secondary. They get overgrown with scrub, forest and are flooded when no economic activities are in place, i.e. scything, cattle grazing, land care. The ecological role of meadow communities is to create favourable conditions for the support of numerous plants and animals that require open spaces to survive, including rare, endangered and economically valued. The mosaic of forested and unforested (meadows and wetlands) areas creates an auspicious ecological and aesthetic situation increasing the biotope capacity of the environment. Humus-rich turf is formed beneath the meadow grass stand. It has an instrumental role to play against erosion and abrasion, and to protect water, which is used in biological reclamation of degraded lands.

The aquatic vegetation is particularly typical of the Belarusian Poozerie. Bur-reed, reed and arrowheads are commonly found in rivers, lakes, water reservoirs and ponds. Macrophytes form waterside strips of varying width. Hundreds of algal species live in the depths of water, at the bottom of water reservoirs.

The mire vegetation is dominated by formations of eutrophic mires (fen mires) with a 61.1% share of their total area, followed by mesotrophic (transitional) mires - 20.7%, and then oligotrophic mires (raised bogs) – 18.2%. Eutrophic mires are predominant in the Polesie Area, oligotrophic mires – in the Poozerie Area, mesotrophic mires are mostly confined to the country's central part.

Over recent decades the mire vegetation has undergone some major changes. Mires were the key target of a drainage campaign that subsequently transformed them into land suitable for agricultural uses. Open and scrub-overgrown fen mires bore the brunt of that campaign, to a lesser degree – transitional mires and raised bogs. The Belarusian Polesie Area and central parts of the country were most intensively reclaimed. Here the area of open and scrub-overgrown mires was more than halved in 40 years. The size of raised bogs also shrank considerably due to their reclamation for peat extraction purposes.

In the context of the global warming problem mire landscapes of Belarus have recently started playing a special role as effective sinks of CO2. While removing carbon from the atmosphere, mires produce methane, thereby regulating climate to a certain extent. While carbon dioxide sources are tropical countries (India, Brazil, Australia), Belarus is one of the strongest CO2 sinks in terrestrial ecosystems. This indicates how important mires are in the carbon cycle and stresses the need for sustainable use and protection of mire ecosystems.

Ecologically, oligotrophic raised bogs of the Belarusian Poozerie are particularly valuable: their largest groups (Yelnya, Osveyskoe, Yukhovichskoye, Golubitskaya Pushcha, Domzheritskoe, etc.) are included in the current or planned national reserves.

The Belarusian fauna is represented by 453 vertebrates and over 30,000 invertebrate species of different groups. There are 6 orders of mammals, where insectivorous include 10 species, bats - 16, predators - 16, lagomorphs - 2, rodents - 26, artiodactyls - 6 species. There are 298 bird species, of which 225 nest within the country. 46 species of vertebrates in Belarus are included in the IUCN Red List. Natural complexes have an exceptionally important role to play to protect these species: European Bison, Lynx, European Otter, European Mink, Aquatic Warbler, Great Snipe, Ferruginous Duck, White-tailed Eagle, Corncrake, Greater Spotted Eagle, Sterlet, European Cisco, etc.

In order to conserve biological and landscape biodiversity, a modern SPA network has been established. It includes the Berezinsky Biosphere Reserve, four national parks (Belovezhskaya Pushcha, Braslav Lakes, Pripyatsky and Narochansky), 99 national zakazniks, 428 local zakazniks, and 337 and 576 monuments of nature of national and local importance

(Table 1.6). All of these are under the protection of the state.

Forest and open mire ecosystems are represented by 31 SPA sites with the total area of 2,283,200 ha or 22.5% of the total area of national SPAs. This group comprises major sites such as the Berezinsky Biosphere Reserve, hydrological reserves Yelnya (23,200 ha) and Dikoe (9,800 ha), landscape reserves Olmany Mires (94,219 ha), etc.

Numerous SPA sites represent forest ecosystems: 32 sites (the Belovezhskaya Pushcha National Park and 31 zakazniks) with the total area of 273,400 ha or 21.7%.

The main purpose for the establishment of 16 SPAs having a total area of 306,700 ha (24.4%) was to ensure the protection of forest-and-lake ecosystems. These include the national parks Narochansky and Braslav Lakes, unique lakes Richi, Dolgoe, Krivoe, Osveya, Selyava, etc.

The backbone of the Belarusian SPA system are natural territories recognized internationally: the Belovezhskaya Pushcha National Park (World Heritage Site, transboundary biosphere reserve) and Berezinsky Biosphere Reserve. National landscape reserves Olmany Mires and Mid-Pripyat as well as the biological reserve Sporovsky have been designated as the Ramsar sites of international importance.

Belarus consistently increases the number and area of its specially protected areas (Table1.7).

Table 1.7

Changes in the number of and area of national Specially Protected Areas between 1980 - 2005 (exclusive of monuments of nature)

Parameter	Year						
	1980	1985	1990	1995	2000	2004	2005
Number of sites	58	63	67	80	102	102	104
Area, ha	884,600	882,900	900,700	799,300	974,400	1,258,100	1,416,400
% of the country's area	4.2	4.2	4.3	3.8	4.7	6.1	6.8

1.10 Population

Sustainability of a country's socio-economic development hinges upon the number and quality of population, its labour potential, the extent to which staffing skills and labour force demand are balanced, its competitiveness on the labour market.

As of January 1st, 2006, the population was 9,750,500 persons, the average density of population - 47 persons per sq km, urban population – 72.4%. Demographic patterns are shown in Table 1.8.

Table 1.8

Demographic parameters (as at January 1st for each year)

Parameter	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006
Population, mln people.	10.2	10.2	10.1	10.0	10.0	9.9	9.9	9.8	9.8	9.8	9.8
Urban population, mln people (%)	6.7 (66.1)	6.9 (67.9)	6.9 (68.8)	6.9 (69.3)	7.0 (69.7)	7.0 (70.2)	7.0 (70.6)	7.0 (71.1)	7.0 (71.5)	7.1 (72.0)	7.1 (72.4)
Population movement, ‰	+3.2	-3.2	-4.4	-4.9	-4.1	-4.9	-5.9	-5.5	-5.2	-5.2	-5.3

Population activities generate solid household waste and sewage pollution, whose decomposition and disinfection lead to GHG generation. The population of Belarus creates a demand for commodities and services that require the use of fuel, wood and agricultural materials to be produced. This leads to GHG emissions. In such ways the population contributes to the emission of greenhouse gases into the atmosphere directly and indirectly. Between 1990 and 2005, changes in the number of population affected these processes in a relatively favourable fashion. Over this period, the population decreased by 0.4 million people which is seen as the extensive limitation of domestic consumer demand. This somewhat curbed the household waste growth, as well as an increase in output for domestic needs thereby contributing to GHG emissions reduction.

Over the past 15 years, Belarus has been facing a demographic crisis. First of all, it manifests itself in declining birthrate and rising death rate, and consequently – a general population decrease. The population loss was caused by two major factors: a worsened socio-economic crisis by the mid-90's and deterioration of reproductive properties of the population's age structure which led to falling birthrate and rising mortality. This trend is true for both rural and urban population. However, population in the city increases due to the drift of labour from the village.

The demographic situation in Belarus is distinguished by a low birthrate – 8.9 per mille (9 – 11 in Europe) and a high death rate untypical of developed countries (14.6 and 10 – 11 per mille, respectively). As a result, the natural loss of population (- 5.6 per mille) is much higher than in Western Europe (0.1 – 0.7 per mille.

The urban population is highly concentrated. 1.8 million live in Minsk (25.2 % of urban population). Five regional cities (250,000 to 500,000 inhabitants each) concentrate 25.6% of urban dwellers. There are 9 large towns with the population from 100,000 to 250,000 where 17.6 % of urban population live. Belarus has 197 small and medium-sized urban villages with the population under 100,000 each.

The life expectancy in Belarus was 68.8 years in 2005, which is 2.3 years lower than the 1990 level. The life expectancy for rural population was still lower than for urban population.

Negative demographic developments caused the reduction in the number of children leading to the "ageing from below", i.e. the number of people of senior ages exceeds that of children and adolescents.

Simultaneously the "ageing from above" was developing in the 90's as a result of a relative increase of elderly people in the population's age structure. According to the UN scale, a country's population is generally considered old if a share of persons above 65 in the overall structure exceeds 7%. In Belarus, this share was 14.6% in 2005.

It is difficult to assess unequivocally how urbanization affects GHG emissions into the atmosphere. On the one hand, rural population is the primary consumer of wood, peat briquettes and other fuel, which, when used in personal households, has a lower efficiency vis-à-vis CHP plants in the city. Besides, production of household fuels for rural population negatively affects the condition of greenhouse gas sinks (forest and peatlands). On the other hand, urban dwellers use transportation services more heavily, earn higher income and economically their demands provide a stronger stimulation to consume fuel and agricultural produce across the country. As a consequence, GHG emissions increase.

Recently noticeable changes have taken place in migration processes: refugees, immigrants, relocatees from FSU republics emerged. Still, the main migration exchange of Belarus was with Russia, Ukraine and Kazakhstan (90% of arrivals to Belarus originated from these countries). The in-country migration flow was primarily from the village to the city resulting in the annual loss of up to 1.5% of the rural population.

The amount of employed population in 2005 was 4,349,800 versus 5,151,000 in 1990 and 4,441,000 in 2000, i.e. the number of employed shrank by 15.6 % and 2.1%, accordingly. The employment pattern has changed. In the first half of the 90's, there was an expansion of the service sector and a reduction of industry and construction shares, whilst in the second half of the nineties an increasing share of employment in the service sector was accompanied by the stabilization of the employment level in industry and decreasing employment in agriculture.

Labour resources serve as the resource base to support sustainable development. Belarus possesses a considerable labour potential. The labour strength reached 6.2 million in 2005 or

63.7 % of the country's population. Economics make adaptations to market relations by a smaller demand for and greater supply of labour force on the market. The economically active population was 4,426,300 in 2005, and the employment level continues to be quite high making up 73.2 % of the able-bodied population.

At this stage the government policy mainly seeks to keep the HR potential and maintain employment as much as possible, which explains a consistently low level of registered unemployment compared to other economies in transition – 1.7% to the number of economically active population in 2005.

The projected decrease in population will create conditions to reduce environment pressures in general. Taking into account differences within regions, these preconditions will present themselves to their maximum in the Vitebsk and Mogilev Regions and to their minimum – in the Minsk and Brest Regions.

Growing contrast in the distribution of population across the country with higher concentrations in areas with large cities, on the one hand, and declining population in peripheral areas, on the other hand, will give an impetus to similar changes in spatial allocation of environmental loads.

The forthcoming substantial expansion of low-density areas within the country will make it difficult to exploit their natural resources, but ensure more favourable conditions to conserve biological and landscape diversity, and develop specially protected areas here.

1.11 Economy

At the moment Belarus is considered to be an economy in transition. Before the early 90's, Belarus had been one of the most industrially developed entities of the USSR. According to a share of industry in the employment structure (35 %) and national income production (47 %), Belarus is in the lead together with Russia and Latvia. The industry used newer tools and equipment than other Soviet Republics on the average. In the end of the 1980's, economic growth slowed down, socio-economic contradictions sharpened resulting in rising inflation, shortages of consumer goods and services, and overproduction of capital goods. In 1991, the dissolution of the USSR severed the well-established economic links Belarus had with other Soviet Republics. A high level of specialization in machine building, chemical, petrochemical and consumer industries that existed in the USSR, strong reliance on Russia as a source of raw materials and major market, political and socio-economic disturbances of 1991 contributed to accelerated economic crisis in the first half of the 90's. Economic parameters around that period were down across-the-board.

In 1994, the government adopted an emergency relief plan to ride out the crisis. Some major policies were elaborated in 1996, i.e. the 1996-2000 Main Areas of Socio-Economic Development of Belarus, the National Strategy of Sustainable Development of Belarus until 2010, the 1996-2000 Economic Management Master Plan, etc. They laid the foundation of the Belarusian model of socially-oriented market economy with active government influence. Establishment of an effective agroindustrial complex, heavy housing construction and building export potential were given top economic priority. The implementation of this economic model enabled the country to reverse the slump, reach a positive dynamics of key macroeconomic processes, ensure annual GDP and industrial products growth, stabilize the domestic consumer market. Further economic development will be guided by the 2001-2005 Socio-Economic Development Program adopted by the Government and approved by the President. Experts generally noted that the economic situation stabilized in the period of 1996 - 2000. However, fixed capital expenditures dropped by over 200% in 2000 vis-à-vis 1990 giving grounds for alarm. The active part of fixed assets is worn out 70 - 75%. Changes that took place in the GDP structure in 2000 - 2005 are presented in Figure 1.2.

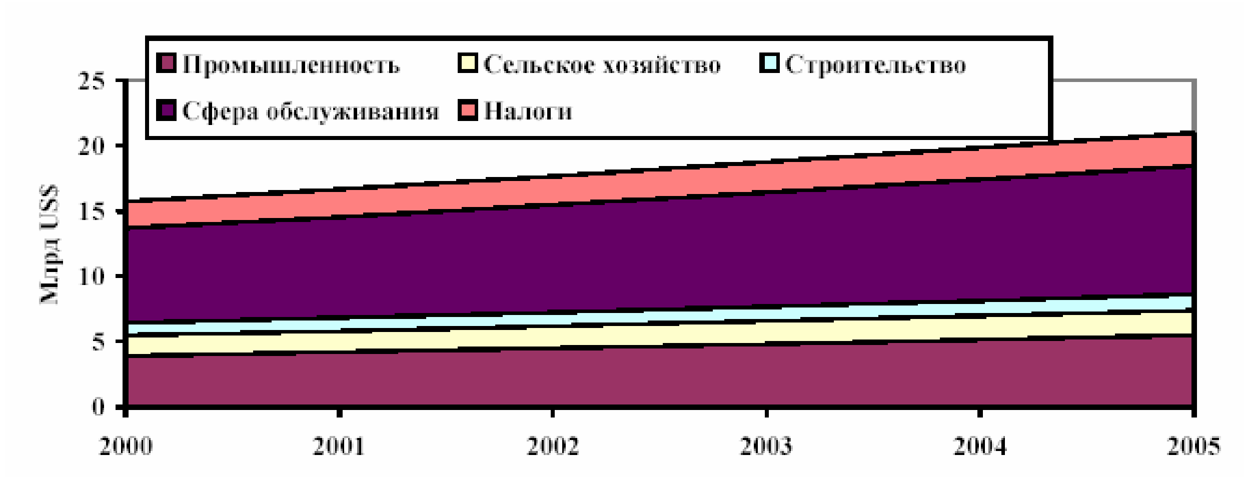

Figure 1.2 GDP structure changes

Between 2001 and 2005, the Belarusian economy entered the stage of sustainable growth after a long crisis and stabilization period. In the last years of the pentad, the amount of GDP, industrial output and investments grew, the living standards of the population showed improvement. The average annual GDP growth rate was 9%. The 2003 GDP output matched the 1990 level, and in 2005 it was already 27% higher.

The industry grew at a faster pace – 11% annually starting from 2003. It reached the 1990 industrial output level already in 2000, and in 2005 the industrial output growth index was 152% vis-à-vis 1990.

Positive changes took place in the development of the country's construction complex where the average annual amount of contract work and building materials' industry increased by 10%. The building industry is still export-oriented, practically all materials and products critical for consumer properties of housing have been certified, renewal of fixed assets is underway.

The agroindustrial complex developed at a slower pace due to a strong influence of natural reproduction conditions. In 2005 agricultural output was only 90% of its 1990 level. In the last five-year period, the salient features of the agroindustrial complex were deeper specialization of farming production, improvement of organizational and economic mechanisms, strengthening of the material and technical basis, reforming loss-making farms with debt restructuring, development of cooperation and integration. Belarus is ahead of other CIS countries in terms of growth rate of agricultural output and production of agricultural staples per capita.

The economic growth in Belarus helped improve the living standards of the people. For example, while GDP rose 1.3 times in 1991-2005, consumer goods output increased 1.7 times, real income of the population – 1.8 times, retail commodity turnover – more than doubled.

The population of Belarus is better supplied with milk and meat, eggs, potatoes compared to large CIS countries (Russia, Ukraine, Kazakhstan). The state support policy of agricultural production through subsidies helped maintain a relatively high level of food consumption. At present it has a significant social value. The country's open economics largely depends on external processes. While the openness of economies around the world generally constitutes about 40 % (ratio of foreign commodity turnover to GDP), for Belarus this parameter is over 130%. The foreign trade volume was USD 15.972 billion in 2000. Exports made up USD 7.326 billion, imports – 8.646; there was a negative foreign trade balance of USD 1.32 billion. In 2005, the foreign trade volume constituted USD 32.687 billion, exports - USD 15.979, imports – USD 16.708 billion, the balance was still negative USD 729 million. Russia is the key trade partner of Belarus. In 2000, it was responsible for 65 % of imports and 51 % of exports of Belarusian goods, and in 2005 – 61% of imports and 36% of exports. The export structure is dominated by machine building sectors (26.3 %); mineral products (20.1 %), where potassium fertilizers have a prominent share (2.8 million t); chemical products (19.7 %). The key import staples are mineral products (31.2 %) and, first of all, oil

(12.0 million t) and natural gas (17.1 billion cu m); machinery, equipment and vehicles (18.3 %), and chemical products (15.3 %).

The Belarusian economy developed predominantly on an extensive basis in the past pentad by utilizing fixed capital stock inherited from the former USSR. It is indicated by its high depreciation and inadequate fixed capital investments: in 2001 they reached only 50% of the 1990 level and in 2005 – 99%. Their share in GDP increased from 17.8% in 2001 to 23.3% in 2005. This is lower than in rapidly developing economies (25% and more).

The National Sustainable Socio-Economic Development Strategy until 2020 was adopted in 2004. It was elaborated in accordance with the Law on Development of Socio-Economic Forecasts and Programmes. The National Strategy projects 4-5% GDP growth per annum across sectors, with higher growth rates in services (Figure 1.3).

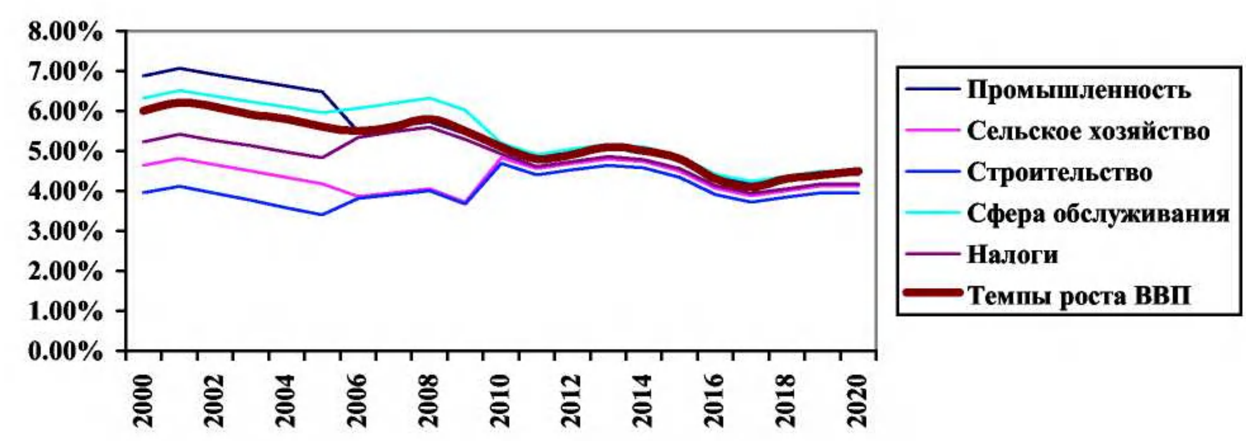

Figure 1.3. GDP growth rate on a sector-by-sector basis

1.12 Energy

The main source of greenhouse gases is the combustion of carbon-containing fuel. The burning of fuel releases CO_2, CO, NOx, H_2O and other substances of direct and indirect greenhouse effect. Until 1995, gross fuel-and-energy consumption steadily tended to decrease, then it stabilized at 35 - 37 mln t.r.f. The main challenges of the energy sector are high dependence on energy imports and a huge backlog of energy payments built up by domestic consumers. Rising import prices cause energy tariffs to grow, which in turn exacerbates the problem of nonpayments. Consequently there is an acute shortage of intersectoral investment in the energy park's fixed assets. The extraction of own energy resources was dropping from 1990 to 2000: from 2.1 mln tonnes to 1.9 million tonnes for oil, from 297 mln cu m to 257 mln cu m for natural gas, from 3.5 mln tonnes to 2.0 mln tonnes for peat.

The Belarusian economy is characterized by a high level of GDP energy intensity. Energy intensity is best described by the ratio of energy equivalent to GDP in comparable prices, which takes into account real price proportions between production and consumption. This indicator has been falling in the 90's. By 1995, GDP energy intensity had dropped by 14% versus 1990 due to reduced energy consumption caused by the economic crisis. In the second half of the 90's, energy intensity dropped another 28% compared to 1995 because of economic recovery and energy saving policies pursued by the state.

An analysis of major economic parameters and fuel consumption volumes during the period under review allows identifying two stages characterized by different tendencies of GDP energy intensity pattern and GHG emissions in Belarus.

Stage 1 covers 1990 - 1995. This period was marked by a sharp reduction of GDP and fuel consumption. What's more, the pace of consumption reduction outstripped that of GDP decline. The level of fuel consumption fell by 44%, and GDP – by 35%. This led to a reduced energy intensity of the economy. Naturally, GHG emissions generated by the energy sector over that period declined mainly as a result of lower fuel consumption and to a certain extent changes in the structure of fuel used.

Stage 2 covers 1996 - 2000. This is when the state undertakes serious steps to overcome the crisis and carry out energy saving policies as envisaged by the 1996-2000 Main Areas of Socio-Economic Development of Belarus, Main Areas of Energy Policy until and the National Energy Saving Programme till 2000. As a result, GDP rose by 36% over five years, with fuel consumption volume stabilizing. So, energy intensity continued to decline. Between 1995 and 2000, there was a reduction in GHG emissions originating from the energy sector, albeit not as considerable as between 1990 and 1995. GHG emissions reduction was connected with, firstly, a 1.1% drop in fuel consumption, and, secondly, an increasing share of natural gas in the fuel structure.

The 2001-2006 period is characterized by a fairly stable condition of the energy sector, energy-related greenhouse gas emissions continued to drop.

Between 1990 and 2005 the structure of fuel and energy resources used for energy generation purposes has changed. Natural gas moved well to the foreground squeezing out crude oil. A share of coal used for heat production decreased. Belarus typically uses a lot of peat briquettes for energy purposes (totally, about 2 mln t.r.f.). Another distinguishing feature of Belarus is that it has a low supply of hydroelectric resources, which made up a mere 0.01% in 1990 and 0.02 % in 2000 in the primary energy consumption structure.

No major changes have occurred in the structure of fuel use by consumption area. Fuel resources are mainly used to generate heat and power energy, plus as a process fuel in industries. A share of population in fuel consumption has considerably increased, as more and more people buy cars and build houses.

The fuel and energy complex of Belarus 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 houses. 22

combined heat and power (CHP) stations and public district power plants (PDPP), Belenergo company's 25 district boiler houses, 8 isolated generating plants and 22,100 small boiler houses (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 1.10.

Table 1.10

	2000	2001	2002	2003	2004	2005
BELENERGO						
Electrical energy mln kWh						
Production	26101	25063	26455	26627	31211	30961
Import	9975	10989	10068	10818	7975	9100
Export	2764	2718	3513	3987	4723	5100
Heat energy, mln Gcal						
Production	28.1	29.6	29.1	30.2	31.6	32,1
Municipal and industrial boiler houses						
Heat energy, mln Gcal						
Production	38.1	41.4	39.5	39.4	37.5	38.0

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 fuel and energy complex. 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 end-use gas-filling stations – by vehicles.

1.13 Transport

As a greenhouse gas source, 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 1990–2005, the road network expanded 1.7-fold, while the length of railways remained virtually unchanged. Since 1990 until 2005 the passenger and freight turnover by all modes of transport reduced by 42.9% and 40.9%, respectively. Data on freight and passenger carriage is given in Tables 1.11 and 1.12.

The structure of passenger traffic by all modes of transport substantially changed. The share of the railway transport of the total passenger turnover (excluding electrical municipal transport) increased from 39.5% in 1990 to 42.5% in 2005, while the share of the bus and air transport reduced from 46.4% and 12.9% to 37.9% and 2.8%, respectively, over the same period. The structure of freight turnover by key modes of transport changed very slightly. The railway (73–78 %) and motor transport (22 – 27%) are dominant modes.

Table 1.11.

Freight transportation mln ton-kilometres

Year	Total	By rail	By road	By air	By water
1990	99,634	75,430	22,361	38	1,805
1991	89,460	65,551	22,128	34	1,747
1992	75,024	56,441	17,569	23	991
1993	58,200	42,919	14,839	8	434
1994	40,614	27,963	12,488	68	95
1995	35,242	25,510	9,539	60	133
1996	34,887	26,018	8,658	123	88
1997	39,888	30,636	9,065	84	103
1998	40,180	30,370	9,686	12	112
1999	39,830	30,529	9,232	13	56
2000	41,214	31,425	9,745	18	26
2001	40,037	29,727	10,241	28	41
2002	45,665	34,169	11,400	37	59
2003	51,306	38,402	12,710	34	160
2004	54,531	40,331	13,969	49	182
2005	58,763	43,559	15,055	59	90

Table 1.12

Passenger traffic, mln passenger-kilometres

Year	Total	By rail	By water	By road	By air
1990	42,618	16,852	30	19,787	5,510
1991	40,782	15,795	25	18,949	5,611
1992	37,625	18,017	5	15,921	3,458
1993	35,692	19,500	6	14,329	1,732
1994	29,600	16,063	3	12,014	1,390
1995	25,989	12,505	2	9,308	1,228
1996	23,083	11,657	1	7,620	1,085
1997	25,268	12,909	1	8,040	910
1998	27,084	13,268	2	8,752	729
1999	31,686	16,874	3	9,312	578
2000	32,449	17,722	2	9,235	513
2001	30,345	15,264	2	9,493	546
2002	29,281	14,349	2	9,397	553
2003	28,165	13,308	2	9,768	565
2004	28,172	13,893	2	9,382	674
2005	24,354	10,351	2	9,231	684

The size and structure of the public and private fleet changed over the period in question. The total number of vehicles increased 2.7-fold from 720,300 units in 1990 to 1,920,100 in 2005. 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 80.5% in 1990 to 94.3% in 2005.

1.14 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 processing raw materials chemically and thermally. 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. The current proportions in the industrial output structure are as follows: machine building and metalwork (22.4%), fuel industry – 21.7%, food industry 16.2%, chemicals and petrochemicals – 11.3%. A share of electrical energy reduced considerably from 13.8% in 1995 to 6.2 % in 2005.

Since the middle 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 labour 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.

1.15 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 after-harvesting crop residue, greenhouses and reclaimed land tillage are the main sources of GHG emissions. They generate N_2O, CO_2, CH_4. The main indicators of agriculture performance are given in Tables 1.13,1.14, 1.15.

Table 1.13

Gross harvest of agricutlrual staples, thousand tons

Year	Rye	Barley	Oats	Legumes	Peas
1990	2,652	2,908	806	88	164
1995	2,143	1,965	638	75	112
1996	1,794	2,194	707	129	181
1997	1,788	2,359	822	219	273
1998	1,384	1,623	501	153	181
1999	929	1,181	368	108	123
2000	1,360	1,378	495	168	123
2001	1,294	1,700	530	178	103
2002	1,600	1,681	575	188	91
2003	1,152	1,608	594	239	94
2004	1,397	2,031	765	316	110
2005	1,155	1,864	609	280	51

Table 1.14.

Application of mineral fertilizers, thousand tons

Year	For grain and legumes	For sugar beet	For potato
1990	277	397	329
1995	109	219	151
1996	136	251	194
1997	184	288	228
1998	195	309	242
1999	193	315	244
2000	200	324	245
2001	171	306	212
2002	171	306	235
2003	174	385	251
2004	183	401	255
2005	213	435	279

Table 1.15

Livestock population

Year	Thousand heads				Million heads
	Cattle	Pigs	Sheep and goats	Horses	Fowl
1990	7,166	5,204	510	219	49.8
1991	6,975	5,051	445	217	50.6
1992	6,577	4,703	424	212	51.7
1993	6,221	4,308	381	215	48.9
1994	5,851	4,181	323	215	33.2
1995	5,403	4,005	284	220	30.9
1996	5,054	3,895	262	229	26.4
1997	4,855	3,715	214	232	27.4
1998	4,802	3,686	186	233	27.5
1999	4,686	3,698	162	229	28.1
2000	4,326	3,566	150	221	27.4
2001	4,221	3,431	154	217	27.4
2002	4,085	3,372	149	209	26.2
2003	4,005	3,329	137	202	25.2
2004	3,924	3,287	126	192	24.5
2005	3,963	3,407	125	181	25.1
2006	3,980	3,545	121	168	28.5

Agricultural output somewhat reduced in 1990–2005. The sown area pattern has not substantially changed over that period. Cereal and leguminous crops (42.3%) and fodder crops (41.8%) dominate in it. The yielding capacity of cereal crops reduced from 27.2 cwt/ha of sown area in 1990 to 19.4 cwt/ha in 2000, and then gradually increased to constitute 28.1 cwt/ha in 2005. The situation is the same with other crops. The enhanced application of fertilizers starting from 2001 largely contributed to yield growth. The agricultural animal population reduced considerably: cattle - by 44.7%, pigs - by 34.5%, and goats/sheep - by 75.5%. In general, a steady tendency of key GHG source reduction could be observed in farming industry due to a certain setback in agricultural production.

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 stock area amounted to 9,329,000 hectares as of 1 January 2005, of which 7,812,000 ha are forested, or 37.6% 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. Approaches to sustainable forestry management are stipulated in the Strategic Forestry Development Plan formulated in 1997. It is planned to increase the percentage of forested land in Belarus to 40% by 2015. 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.

Between 2000 and 2005, positive changes took place in the way forest resources are used. In 2005, reforestation was carried out in the area of 51,500 ha or 1.3 times larger than in 2000 including 45,000 ha by way of planting and sowing.

Felling produces the most significant impact on forests. In 2005, 14,109,000 m^3 of merchantable wood were harvested in Belarus from all types of felling, which is 2% less in 2004. In 2005 principal felling was held in the territory of 25,100 ha, which resulted in the harvesting of 5,213,000 m^3 of merchantable wood, which is 7% more than in 2004.

The forest cutting structure changed: while in 1990 principal felling (clear cutting) dominated, starting from 2000 approximately 60% of wood comes from intermediate cutting (improvement thinning, selective sanitary felling) and other types of cutting.

1.16 Waste

In 1990–2005, the economy-related negative impact on the environment reduced.

Main water use indicators drastically reduced in 1991–1997 and even stabilized in the recent years. 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 is 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, some 20 mln tonnes of solid industrial waste are generated. Nonrecycled industrial waste is accumulated at 80 industrial waste disposal sites. Halite waste (86.3%) and halite sludge (10.1%) prevail in the bulk of accumulated waste. Currently, the level of waste utilization is low due to low content of valuable components in waste, shortage of processing capacities and necessary technologies.

The current level of waste utilization, excluding halite waste and sludge, is 72%. There is a high level of utilization for waste of plant and animal origin: food waste is used in agriculture; wood processing waste is used for different purposes; overburden waste is almost entirely used to fill quarries and restore degraded land. The use of halite waste was 3.8% in 2005. Clay-and-salt sludge is not used so far. There is practically no use for production waste similar to household waste, where industrial and building waste, sewage sludge belong.

Annually, over 2 mln tonnes of solid municipal waste are generated. Almost all of it is 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 stored annually at solid municipal waste disposal sites.

Sewage sludge is accumulated at sludge drying beds of treatment facilities in the amount of about 80,000 tonnes of dry residue. High toxicity level makes sewage sludge utilization difficult.

PART II. NATIONAL INVENTORY OF GREENHOUSE GAS SOURCES AND SINKS

2.1 General information

This National Communication contains information about GHG inventory for 1990-2004 prepared by the National Unitary Enterprise BelNIC Ecologia with support from the EU/TACIS project in accordance with the commitments of the Republic of Belarus under the UNFCCC and Kyoto Protocol.

To make inventories, Belarus created and is currently improving the National GHG Inventory System, while BelNIC Ecologia under the Ministry of Natural Resources and Environmental Protection established the National GHG Inventory Centre.

The 2004 National Cadastre presented here comprised inventory for 6 sectors:

1. Energy: CO_2, CH_4, N_2O, NO_x, CO, VNMOCs, SO_2;
2. Industrial processes: CO_2, CH_4, N_2O, NOx, CO, VNMOCs, HFCs, SF_6, SO_2;
3. Solvent and other product use: N_2O, VNMOCs;
4. Agriculture: CH_4, N_2O;
5. Land-use change and forestry: CO_2, CH_4, N_2O, NOx, CO;
6. Waste: CH_4, N_2O.

2.1.1 General information about GHG emissions by source category in the Republic of Belarus

The main greenhouse gas in Belarus is carbon dioxide (CO_2), whose share in greenhouse gas emissions (without net CO_2 removals of the LUCF sector) was 73.9 % in CO_2 equivalent in 2004, followed by methane (CH^4) – 17,0% and nitrous oxide (N_2O) – 9.05%, the share of HFC, PFC and SF_6 is approximately 0.03%.

The largest amount of greenhouse gases is emitted by the energy sector – 74.07%, agriculture – 16.6%, waste – 6% and industrial processes – 3.3%, solvent use emissions make up 0.1%.

The aggregate CO_2 equivalent greenhouse gas emission without the LUCF sector is 74,306.56 Gg and decreased in 2004 by 41.66% compared to 1990 levels (127,361.43 Gg) (for HFC, PFC and SF_6, the year 2003 is the base year).

Between the years 1990 and 2004 methane emissions decreased by 16.38%, and those of nitrous oxide – by 34.68%.

The aggregate CO_2 equivalent greenhouse gas emission (including emissions, but excluding CO_2 sink in the LUCF sector) was 87,317.46 Gg in 2004 compared to 141,185.92 Gg in 1990 (Table 2.1).

Table 2.1

Greenhouse gas emission changes by sector 1990 -2004, Gg, CO_2 equivalent

Source category	1990	2004	1990-**2004** trend, %	Share in aggregate emissions (excl. LUCF), 2004	Share in aggregate emissions (excl. CO_2 sinks), 2004
Energy	102097,70	55078,92	-46,05	74,07	63,04
Industrial processes	2249,29	2363,86	5,09	3,18	2,71
Solvents	74,40	80,91	8,75	0,11	0,09
Agriculture	20364,89	12320,92	-39,50	16,57	14,10
Waste	2574,73	4461,95	73,30	6,00	5,11
Total (excluding LUCF)	**127361,00**	74306,56	-41,66	**100,00**	**85,10**
LUCF	-11307,18	-11900,32	5,25		
Sinks	-25132,10	-24911,22	-0,88		
Emissions	13824,92	13010,9	-5,89		14,89
Total, including LUCF	**116053,82**	**62406,24**	**-46,23**		
Total, excluding CO_2 sinks	**141185,92**	**87317,46**			**100,00**

In general, greenhouse gas emissions in Belarus are determined by the sectors of energy, agriculture and LUCF.

It should be mentioned that the primary emission reduction between the years 1990 and 2004 took place in the energy and agriculture sectors.

The industrial processes and LUCF have shown no major changes.

A sharp reduction in greenhouse gas emissions in the energy sector was largely connected with fuel consumption changes. Practically all large district power plants, CHPs and boiler houses switched to gas, while fuel oil is used in small quantity, as a backup fuel.

2.1.2 Evaluation and trend overview for different source and sink categories

In 2004 energy-sector CO_2 equivalent emissions were 55,078.92 Gg or 74.1% of aggregate national emissions excluding the LUCF sector. Energy sector emissions have generally decreased by 46% between 1990 and 2004.

Industrial processes CO_2 equivalent emissions were 2,363.86 Gg growing by about 5.09% compared to the base year.

Solvent use emissions in 2004 made up 80.91 Gg in CO_2 equivalent or 0.1% of aggregate emissions.

Agriculture CO_2 equivalent emissions in 2004 were 12,320.92 Gg or 16.6% of aggregate national emissions excluding the LUCF sector. This is the second largest greenhouse gas emitting sector. At the same time, in 2004 emissions from this sector reduced by 39.5% versus 1990.

Waste GHG emissions constituted 6% of aggregate emissions in 2004. In this category CO_2 equivalent emissions increased between 1990 and 2004 by 73.3% from

2,574.73 Gg to 4,461.95 Gg.

With the exception of the LUCF sector, GHG emissions in five sectors reduced from 127,361.00 Gg in CO_2 equivalent in 1990 to 74,306.56 Gg in 2004 or by 41.66%.

Within the LUCF sector throughout the entire period 1990-2004 sinks prevailed emissions rising by 5.3% in 2004 versus 1990.

Table 2.2

CO_2 equivalent greenhouse gas emissions in the Republic of Belarus (excluding net CO_2 of the LUCF sector), Gg

Year	CO_2	CH_4	N_2O	HFC	SF_6	GWE
1990	101946,79	15125,64	10298,86			127371,29
1991	95302,07	14323,16	9888,49			119513,72
1992	88105,53	14207,62	8482,26			110795,41
1993	75752,25	13475,98	7725,80			96954,04
1994	63273,17	12241,80	5773,72			81288,69
1995	56233,42	11725,38	4991,87	2,84	0,01	72950,68
1996	57078,08	11951,32	5800,75	3,68	0,05	74833,88
1997	59245,05	12012,39	6469,65	5,34	0,24	77732,67
1998	56761,00	11877,37	6630,55	7,12	0,28	75276,32
1999	54043,71	11514,93	6254,21	7,98	0,37	71821,20
2000	51910,88	11484,01	6408,55	9,35	0,41	69813,20
2001	50987,98	11300,62	5895,25	12,90	0,46	68197,21
2002	51231,29	11250,45	5690,63	16,38	0,50	68189,25
2003	51396,28	12134,92	6218,90	19,24	0,69	69770,03
2004	54919,64	12648,50	6727,09	23,14	1,03	74319,40
1990-2004 trend,%	-46,13	-16,38	-34,68			-41,65
Share in total 2004 emissions	73,90	17,02	9,05	0,03	0,001	100

2.1.3 Evaluation and trend overview of indirect greenhouse gases and sulphur dioxide

Evaluation of indirect greenhouse gases and sulphur dioxide is given in Table 2.3.

Table 2.3

Greenhouse gas emissions in the Republic of Belarus (excluding net CO_2 of the LUCF sector) in 1990-2004, Gg

Year	CO_2	CH_4	N_2O	HFC	SF_6	Nox	CO	VNMOC	SO_2
1990	101946,79	720,27	33,22			336,13	1525,36	311,73	1080,70
1991	95302,07	682,06	31,90			315,30	1418,79	295,77	999,76
1992	88105,53	676,55	27,36			282,36	1145,27	231,34	763,72
1993	75752,25	641,71	24,92			238,91	828,57	171,31	617,58
1994	63273,17	582,94	18,62			186,85	566,08	133,18	522,77
1995	56233,42	558,35	16,10	2,84	0,30	164,52	513,65	126,07	457,29
1996	57078,08	569,11	18,71	3,68	1,96	164,77	494,57	118,39	431,45
1997	59245,05	572,02	20,87	5,34	10,06	166,29	453,26	127,06	360,70
1998	56761,00	565,59	21,39	7,12	11,62	158,08	410,38	112,50	330,36
1999	54043,71	548,33	20,17	7,98	15,56	146,91	345,18	104,77	279,01
2000	51910,88	546,86	20,67	9,35	17,00	137,97	300,84	126,38	221,26
2001	50987,98	538,12	19,02	12,90	19,40	136,10	296,03	132,39	212,49
2002	51231,29	535,74	18,36	16,38	20,72	138,79	323,62	101,65	191,39
2003	51396,28	577,85	20,06	19,24	28,90	137,20	290,58	105,13	174,89
2004	54919,64	602,31	21,70	23,14	42,92	149,46	311,90	117,14	172,37
1990-2004 trend, %	-46,13	-16,38	-34,68			-55,53	-79,55	-62,42	-84,05

Between 1990 and 2004 there was a considerable reduction in indirect greenhouse gases, especially SO_2 (by 84.1%) and CO (by 79.6%).

A dramatic reduction in SO_2 emissions is primarily linked to using less liquid fuel (more than fourfold) and fuel oil (nearly ninefold).

2.2 Institutional inventory mechanism

2.2.1 Organizations responsible for greenhouse gas inventory

The Ministry of Natural Resources and Environmental Protection of the Republic of Belarus takes full responsibility for preparing and submitting the National Communication and greenhouse gas inventories to the UNFCCC Secretariat.

The focal organization responsible for carrying out greenhouse gas inventories and coordinating all activities on the greenhouse gas problem is BelNIC Ecologia.

BelNIC Ecologia develops the necessary scientific and methodological documents concerning data collection, processing and analysis, and calculations as part of inventory taking and preparing a national inventory report.

Institutes of the National Science Academy of the Republic of Belarus and researchers from other ministries and institutions are also used in this work.

Representatives of 15 ministries and institutions are involved in one way or another in the work relating to the UNFCCC and Kyoto Protocol implementation.

2.2.2 National inventory system

At present the legal basis for sustainable development of the inventory process has been already put in place in Belarus. The following documents have been adopted:

Regulations on the State Interdepartmental Commission on Climate Change;

Regulations on the National Greenhouse Gas Inventory System;

Regulations for the Procedure of Maintaining the National Greenhouse Gas Inventory;

Regulations of the Ministry of Natural Resources and Environmental Protection of Belarus “On the Approval of the Regulations on the National Greenhouse Gas Inventory Centre”.

The national inventory system comprises all institutional, legal and procedural activities inside the country for the estimation of anthropogenic emissions and sinks of all greenhouse gases, not controlled by the Montreal Protocol, and for reporting and archiving inventory data.

The national inventory system should ensure transparency, consistency, comparability, completeness and accuracy of inventories, and a high quality of work during inventorization (i.e. during data collection, selection of emission methodology and factors).

Its main functions (in accordance with the IPCC Guidelines) are to:

- create and support institutional, legal and procedural linkages between governmental structures and other organizations;
- ensure adequate working efficiency for prompt submission of inventories;
- designate a single national authority to be fully responsible for the national system;
- prepare annual national inventories and supplementary information as per the timeframe;
- provide information that meets reporting requirements.

Specific functions include: inventory planning, preparation and management.

The Republic of Belarus aims to create a national inventory system that would meet the Kyoto Protocol requirements and work efficiently to meet all other commitments undertaken by the country concerning air emissions.

2.2.3 Inventory preparation process

To carry out and maintain inventories BelNIC Ecologia created a team where each member is assigned a specific section of the inventory. It has been decided which ministries and institutions are to provide initial data, what kind of data it should be and contact persons. If necessary, BelNIC Ecologia sends formal requests to obtain additional information.

The most important data comes from the Ministry of Statistics and Analysis which harmonizes all data and publishes a Statistical Yearbook where data is incorporated. Normally published data is not changed and no amendments can be made unless authorized by the Ministry of Statistics and Analysis.

BelNIC Ecologia analyzes and processes initial data, and incorporates it in the database and makes calculations. During inspections activity data and emission coefficients are compared vis-à-vis parameters from the previous years, IPCC data and data from countries with similar conditions.

2.2.4 Description of methodologies and data sources used

Inventories are prepared in accordance with the methodological documents:

1. Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part I: UNFCCC reporting guidelines on annual inventories (document FCCC/SBSTA/2004/8 after the inclusion of the provisions of Decision 13/CP/9);
2. Revised 1996 IPCC guidelines for national greenhouse gas inventories;
3. Good practice guidance and uncertainty management in national greenhouse gas inventories, IPCC, 2000;
4. Good practice guidelines for the land-use change and forestry sector.

Besides, national normative and methodological documents dealing with inventories, calculation of specific emissions, materials and results of previous surveys conducted as part of national assignments are used.

The main source of activity data is the Ministry of Statistics and Analysis of the Republic of Belarus. Additional information is provided by other ministries and institutions based on formal requests.

In this greenhouse gas inventory report default emission coefficients were mainly used as per the IPCC Guidelines, and in certain cases – the industrial processes and LUCF modules – national coefficients.

Table 2.4

Organizations that provided initial activity data

Sector	Data provider	Emission calculator
Energy	Ministry of Statistics and Analysis, Ministry of Energy, Oil and Chemistry Concern	BelNIC Ecologia TACIS Project
Industrial processes	Ministry of Statistics and Analysis, Oil and Chemistry Concern, Ministry of Industries, Ministry of Construction and Architecture	BelNIC Ecologia TACIS Project
Solvent Use	Ministry of Health, Oil and Chemistry Concern	BelNIC Ecologia TACIS Project
Agriculture	Ministry of Statistics and Analysis, Ministry of Agriculture and Food	BelNIC Ecologia TACIS Project
LUCF	Ministry of Forestry, Ministry of Statistics and Analysis, Committee for Land Resources and Cartography, Ministry of Energy, National Science Academy of Belarus	BelNIC Ecologia TACIS Project
Waste	Ministry of Natural Resources and Environmental Protection, Ministry of Statistics and Analysis, Ministry of Housing and Utilities	BelNIC Ecologia TACIS Project

2.2.5 Summary of key source categories

The evaluation of the most important source categories has been made according to

GHG emission levels and trend using the level 1 basic approach.

The analysis is based on the level of detail of subcategories presented in CRF tables. When data for certain categories was lacking, they were presented at a higher level of aggregation. Emission sources, untypical of Belarus, and those that were not evaluated were excluded from the analysis.

The evaluation was made separately for each greenhouse gas from each source, all in all 50 categories. The analysis of key categories was made using CO_2 equivalent emissions calculated on the basis of Global Warming Potential (GWP) for each greenhouse listed in the UNFCCC Guidelines.

The level evaluation (Table 2.5) resulted in the identification of 15 key sources covering 95% of total national emissions.

The main key categories are sources of the energy sector - 8 categories and the agriculture sector - 5 categories.

Electricity and heat production is the first key source of greenhouse gas emissions in Belarus (44.0% of total emissions). CHPs and boiler houses, manufacturing industries and construction, automobile transport have been defined in accordance with the level evaluation as three main key categories each of which accounts for 44.0%, 10.7 %, 5.9%, respectively, in the national aggregate GHG emissions and together these sources cover 60.6% of total emissions. Cement production is also subsumed under the main key source making up 1.7% of total emissions.

Three most important key sources of emissions apart from CO_2 in Belarus are CH_4 emissions from locations of solid waste disposal (5.7%), emissions from non-dairy cattle (enteric fermentation) (3.7%) and emissions from dairy cattle (3.7%).

The largest key source of N_2O emission is the direct emission from soils (use of organic soils) – 2.8%.

Table 2.5

Key source categories by type of activity

Module	Greenhouse gas sources and removals CATEGORIES		GHG	1990 evaluation CO_2 equivalent, Gg	2004 evaluation CO_2 equivalent, Gg	Level evalua-tion, %	Aggregate total, %
1. Energy	1A1	A Fuel combustion 1 Energy – fuel processing, energy production and transmission	CO_2	65140,9	32567,4	43,83	43,83
1. Energy	1A2	A Fuel combustion Manufacturing industries and construction	CO_2	7214,8	7911,4	10,65	54,48
1. Energy	1A3	A Fuel combustion Transport	CO_2	12909	4381,2	5,90	60,37
6. Waste	6A2	A. Location of solid waste disposal	CH_4	2348,4	4232,6	5,70	66,07
1. Energy	1A4b	A Fuel combustion Housing sector	CO_2	6776,9	4045,7	5,44	71,51
4. Agriculture	4A1b	A. Enteric fermentation /Non-dairy cattle	CH_4	5425,1	2763,3	3,72	75,23
4. Agriculture	4A1a	A. Enteric fermentation /Non-dairy cattle	CH_4	4017,9	2743,5	3,69	78,92
1. Energy	1A4c	A Fuel combustion Agriculture/Forestry	CO_2	3655,8	2301,3	3,10	82,02
4. Agriculture	4D 15	D. Direct emissions from soil/use of organogenic soils	N_2O	2226,2	2075,2	2,79	84,81
4. Agriculture	4D 1 1	D. Direct emissions from soil/use of mineral fertilizers	N_2O	3746,9	1897,9	2,55	87,37

1. Energy	1B 2	B Oil and gas system leakage 2 Oil and natural gas	CH_4	1234,1	1633,8	2,20	89,57
4. Agriculture	4D3	D. Indirect emissions from soil	N_2O	2833,5	1435,4	1,93	91,50
2. Industrial processes	2(I)A1	AProduction of mineral products 1 Cement production	CO_2	965,8	1261,2	1,70	93,19
1. Energy	1A4a	A Fuel combustion Commercial sector	CO_2	3794,2	1225,8	1,65	94,84
1. Energy	1A5	A Fuel combustion Other	CO_2	579,2	599,7	0,81	95,65

2.3 Greenhouse gas emission trends

2.3.1 Aggregate greenhouse gas emission trends

Primary greenhouse gas emissions come from fuel combustion in various sectors of economy, first of all the energy sector. This is where the bulk of carbon dioxide CO_2 is generated – up to 59.3% during power and heat production and 96.6% generally across the sector.

The bulk of methane is formed in the agriculture sector – 50.9%, in the energy sector – 15.3%, mainly as leakages during pipeline transportation and use of natural gas.

In the waste sector methane is formed at household waste landfills making up 33.5% of national methane emissions.

Nitrous oxide is mainly emitted by the agriculture sector – 87.4%, industrial processes - 6.1%, waste – 3.4%, and partially by the energy sector - 1.7 %.

Generally in Belarus, GHG emissions (excluding the LUCF sector) break down as follows: CO_2 -73.9%, CH_4 – 17.0% and N_2O – 9.0 %. In 1990 it broke down as 80.0 %, 11.9%, 8.1%, respectively. The reason for changes was a sharp reduction in fuel consumption in the energy sector, with emissions in other sectors changing insignificantly.

CO_2 emissions in the LUCF sector are 13,010.9 Gg. Removals of carbon dioxide take place in the LUCF sector - 100% or 24,911.22 Gg. Total sinks of greenhouse gases in the LUCF sector are 11,900.32 Gg. Over the period 1990-2004, total CO_2 equivalent GHG emissions by sector are presented in Table 2.6.

Table 2. 6

Total greenhouse gas emissions by sector, Gg, CO_2 equivalent

Source category	1990	19901	1992	1993	1994	1995	1996	1997	1998	1999	200320	2001	2002	2003	2004
Energy	102097,70	95240,34	88429,56	76076,86	63920,11	56962,37	57835,43	59338,33	57132,99	54424,91	52470,90	51603,66	51649,35	51638,30	55078,92
Industrial processes	2249,29	2141,70	2085,83	1889,34	1415,64	1 209,28	1 259,24	2 138,28	1 838,96	1 790,93	1 683,01	1 659,45	1 916,20	2 114,87	2 363,86
Solvents	74,40	72,39	70,38	66,36	64,34	62,33	60,32	58,31	69,47	87,42	76,04	83,36	80,66	79,30	80,91
Agriculture	20364,89	19478,40	17549,47	16341,57	13785,28	12569,04	13066,84	13563,68	13490,40	12583,40	12612,70	11837,58	11423,56	11850,32	12320,92
Waste	2574,73	2572,52	2570,52	2568,31	2091,50	2137,64	2589,99	2623,44	2732,49	2921,76	2955,57	3000,88	3092,44	4068,46	4461,95
Total (excluding LUCF)	**127361,00**	**119505,35**	**110705,75**	**96942,43**	**81276,87**	**72940,7**	**74811,8**	**77722**	**75264,3**	**71808,4**	**69798,2**	**68184,9**	**68162,2**	**69751,3**	**74306,6**
LUCF	-11307,18	-13315,74	-12256,58	-13590,89	-15128,89	-15429,26	-14769,13	-12819,65	-13123,67	-13801,12	-14126,24	-14405,89	-13297,83	-11985,32	-11900,32
Sinks	-25132,10	-26889,50	-25758,63	-26719,99	-27654,00	-28137,89	-27930,76	-26520,60	-27144,08	-27953,49	-28226,66	-28223,80	-26893,68	-25295,45	-24911,22
Emissions	13824,92	13573,76	13502,05	13129,10	12525,11	12708,63	13161,63	13700,95	14020,41	14152,37	14100,42	13817,91	13595,85	13310,13	13010,90
Total including LUCF	**116053,82**	**106189,61**	**98449,17**	**83351,54**	**66147,98**	**57511,4**	**60042,7**	**64902,4**	**62140,6**	**58007,3**	**55672**	**53779**	**54864,4**	**57765,9**	**62406,2**

2.3.2. Emission trends on a gas-by-gas basis

A sharp reduction of CO_2 emissions by the energy sector led to substantial reduction of CO_2 equivalent emissions in 2004 compared to 1990 by 46.1%. The reduction was caused by a combination of factors where production decrease and energy-saving policies, including a change in the fuel consumption structure played a prominent role.

CH_4 and N_2O emissions over this period haven't changed dramatically: they reduced by 16.4% and 34.7%, respectively.

Such substances as HFC, PFC and SF_6 are not produced in the country, nor are they used in manufacturing. They mainly enter the country with equipment. Due to insignificant usage, their emission input is small.

In the LUCF sector greenhouse gas emissions and sinks haven't shown major changes over the period 1990-2004.

Table 2.7

Main greenhouse gas emissions in the Republic of Belarus, Gg, CO_2 equivalent (excluding net CO_2 sinks in the LUCF module)

GHG	1990	2004	Share in total emissions	
			%, 1990	%, 2004
CO_2	101946,79	54919,64	80,04	73,90
CH_4	15125,64	12648,50	11,87	17,02
N_2O	10298,86	6727,09	8,09	9,05
HFC		23,14		0,03
SF_6		1,03		0,001
Total:	127371,29	74319,40	100,00	100,00

2.3.3 Emission trends by source category

Between the years 1990 and 2004 the number of key sources increased from 13 to 15 in greenhouse gas source categories. Similar to 1990 the three main key sources are connected with fuel combustion: energy production and transmission, manufacturing industries and construction, and transport. In 1990 a share of these three key sources was 66.9%, and in 2004 – 60.3%.

The increasing number of key sources is attributed to a greater level of detail in the agriculture sector and separation of cement and lime in the industrial processes sector.

In 2004 there were 50 source categories as opposed to 31 in 2003 (excluding the LUCF sector).

2.3.4 Indirect greenhouse gas emission trends

Indirect greenhouse gas emissions mainly come from the energy sector, which is related to NOx, CO and SO_2 production during fuel combustion. These emissions decreased in 2004 versus 1990 due to fuel consumption reduction.

The energy sector share in NOx, CO, VNMOCs and SO_2 emissions is 98.8%, 94.4%, 29.4% and 93%, accordingly. Shares of the industrial processes and solvent use in VNMOC emissions are 30.4% and 40.2%, respectively.

Table 2.8

Indirect GHG emissions in the Republic of Belarus, 1990-2004, Gg

Year	NOx	CO	VNMOC	SO_2
1990	336,13	1525,36	311,73	1080,70
1991	315,30	1418,79	295,77	999,76
1992	282,36	1145,27	231,34	763,72
1993	238,91	828,57	171,31	617,58
1994	186,85	566,08	133,18	522,77
1995	164,52	513,65	126,07	457,29
1996	164,77	494,57	118,39	431,45
1997	166,29	453,26	127,06	360,70
1998	158,08	410,38	112,50	330,36
1999	146,91	345,18	104,77	279,01
2000	137,97	300,84	126,38	221,26
2001	136,10	296,03	132,39	212,49
2002	138,79	323,62	101,65	191,39
2003	137,20	290,58	105,13	174,89
2004	149,46	311,90	117,14	172,37
1990-2004 trend, %	-55,53	-79,55	-62,42	-84,05

2.4 Energy

2.4.1 Sector summary

After 1990 GHG emissions in the Belarusian energy sector reduced. Since the energy sector makes the heaviest contribution to aggregate emissions in the country, they analyzed main reasons explaining a considerable discrepancy between GDP growth and GHG emissions between the years 1995-2004. Structural changes took place in the GDP due to an increasing share of less energy-intensive sectors, such as services and commerce in 2004 compared to 1990; active introduction of energy-efficient technologies practically in all the sectors; a switch from coal and oil to natural gas as a fuel; more active use of biomass in housing and industrial sectors.

Over the period in question the number of enterprises in the fuel industry reduced from 44 in 1990 to 37 in 2004. There was a slight reduction in the production of oil and natural gas, and substantial reduction in the production of fuel oil in 2004 versus 1990. To meet needs of the economy, natural gas and oil are mainly exported from Russia. Starting from 1997 until 2004 the amount of gas, oil and oil products transported by pipelines increased, including by transit, which is one of the reasons of GHG leakage and emission growth.

On the whole, the energy sector consumed an increased amount of natural gas to meet industrial needs and those of the population.

2.4.2 Emission trends

Total CO_2 equivalent direct greenhouse gas emissions during fuel combustion and methane leakages from pipelines were 55,078.92 Gg. CO_2 emissions make up the largest share - 96,3%, with district power stations, CHPs and boiler houses of the Energy Ministry delivering the bulk of emissions during fuel combustion for power and heat production. Generally, the sector's emissions decreased by 46.1% in 2004 compared to 1990.

Over the same period there was a considerable emission reduction of all greenhouse gases except methane, whose emissions rose by 8.3% due to leakages from pipelines (Table 2.9).

The declining trend of greenhouse gas emissions could be observed in the sector up until 2003 because of a sharp reduction in fuel oil consumption as one of the reasons.

Indirect greenhouse gas emissions as a result of fuel combustion also decreased dramatically compared to 1990.

Table 2.9

Changes in GHG emissions (Gg)

Year	CO_2	CH_4	N_2O	NOX	CO	VNMOC	SO_2
1990	100 071,27	85,00	0,78	334,77	1 506,50	195,90	1 059,39
1991	93 470,55	73,99	0,70	314,01	1 401,29	184,03	981,54
1992	86 328,65	91,43	0,58	280,22	1 126,51	146,59	752,23
1993	74 136,49	85,03	0,50	237,69	810,15	100,93	610,00
1994	62 161,97	77,42	0,43	185,78	550,97	68,48	517,21
1995	55 297,70	73,50	0,39	163,49	494,37	62,09	449,25
1996	56 063,50	78,59	0,39	163,56	474,26	59,89	421,38
1997	57 422,53	85,35	0,40	165,04	436,69	54,72	342,48
1998	55 276,30	82,52	0,40	156,72	395,38	49,42	318,52
1999	52 608,85	80,91	0,38	145,56	330,75	41,13	267,63
2000	50 556,82	85,79	0,36	136,47	283,49	34,77	210,47

2001	49 692,85	85,59	0,37	134,63	280,17	33,85	202,59
2002	49 746,36	85,36	0,36	137,12	301,89	36,46	181,54
2003	49 685,84	87,80	0,35	135,59	271,59	31,49	164,03
2004	53 032,36	92,09	0,36	147,69	293,01	34,48	160,26
1990-2004 trend, %	-47,01	8,48	-53,29	-55,73	-80,55	-82,40	-84,87

2.4.3 Fuel combustion

In 2004 Belarus used 906,401.63 TJ of fuel on all types of activities based on the sectoral approach adopted for such calculations. According to the base option, it was 916,110.11 TJ. The 2004 difference was 1.1%, which is quite acceptable.

For all activities in 2004 they used solid fuel – 3.0%; liquid fuel – 21.3%; gaseous fuel -71.1%; biomass fuel – 4.4%; other fuels – 0.2%. In 1990 the breakdown was as follows: solid fuel – 7.3%; liquid fuel – 56.8%; gaseous fuel – 34.3%; biomass fuel – 1.5%; other fuels – 0.1%

Compared to 1990, the year 2004 saw a sharp reduction in consumption of solid fuel by about 4 times, liquid fuel – by over 4 times. Consumption of gaseous fuel rose slightly over 1.3 times and biomass fuel – by approximately 1.9 times. All of this contributed to a substantial emission reduction.

Apart from energy-related purposes, 819,233.74 TJ of fuel is used for non-energy purposes: conversion into other fuels; industrial production in the chemical industry, etc.

Emissions from these activities were taken into account in emission calculations in respective sectors.

Table 2.10

Emissions of CO_2, CH_4 and N_2O in CO_2 equivalent by source category in the energy sector (Gg)

Year	Energy production	Industry and construction	Transport	Commercial sector	Housing sector	Agriculture/ Forestry	Other	Total
1990	65 307,26	7 239,50	14 230,99	3 828,64	7 214,76	3 683,58	579,72	**102 097,70**
1991	58 626,61	7 767,40	13 912,41	3 832,36	6 579,33	3 969,02	553,25	**95 240,34**
1992	54 536,07	7 228,61	12 052,62	3 603,58	6 626,10	3 820,80	561,80	**88 429,56**
1993	45 539,33	6 849,37	9 933,12	3 246,53	6 098,24	3 829,23	581,07	**76 076,86**
1994	39 217,44	6 485,80	6 632,14	2 644,81	5 642,47	2 674,36	623,11	**63 920,11**
1995	33 443,71	6 481,68	6 047,18	2 572,61	5 196,76	2 626,75	593,71	**56 962,37**
1996	33 519,15	6 786,62	6 118,27	2 729,47	5 057,65	2 867,14	757,15	**57 835,43**
1997	35 441,71	6 858,34	5 807,01	2 538,23	5 057,25	2 993,47	642,36	**59 338,33**
1998	33 351,16	7 139,57	5 443,79	2 558,46	4 829,53	3 143,12	667,40	**57 132,99**
1999	32 025,59	7 041,45	4 695,92	2 276,80	4 759,09	2 959,27	666,82	**54 424,91**
2000	30 635,92	6 836,91	4 562,09	1 734,86	4 964,60	2 922,86	813,68	**52 470,90**
2001	31 080,01	6 386,83	4 557,51	1 593,53	4 700,63	2 465,88	810,48	**51 603,66**
2002	30 767,34	6 568,84	5 640,85	1 351,87	4 559,40	2 185,28	574,32	**51 649,35**
2003	30 598,95	7 131,72	5 383,66	1 338,55	4 426,87	2 166,70	591,86	**51 638,30**
2004	32 622,97	7 944,67	6 026,34	1 255,57	4 284,00	2 334,59	610,82	**55 078,92**
1990-2004 trend, %	-50,05	9,74	-57,65	-67,21	-40,62	-36,62	1,92	-46,06
Share of source category, 2004, %	59,23	14,42	10,94	2,28	7,78	4,24	1,11	100,00

The main greenhouse gas is the energy sector is carbon dioxide, whose share in aggregate national emissions in 2004 was 71.8% compared to 78.8% in 1990, i.e. decreasing by 47% versus 1990. The reason is a sharp reduction in fuel consumption compared to other greenhouse gas emission sources.

The heaviest CO_2 emission is attributable to fuel combustion at CHPs and boiler houses for heat and power production – 61.4% of total CO_2 across the sector. Compared to 1990, emissions from this source halved.

The second largest emitter is the industry and construction subsector (14.9%,) whose share compared to 1990 rose by 9.7%.

A share of transport is 8.3% dropping 66% versus 1990 as a result of a sharp reduction of freight traffic and freight by motor transport.

Although the number of cars increased, its share in CO_2 increased moderately because cars have become more economical and are used to a smaller extent during winter.

The housing share is 7.6% dropping 40.3% compared to 1990 because of a reduction in consumption of liquid and solid fuel, and considerable share growth of gaseous fuel – connection to gas supply of towns and rural communities, as well as efficiency measures.

A reduction in fuel consumption in the commercial subsector by 67.7% is also linked to a switch to gas and efficiency measures like in the housing subsector.

Agriculture and forestry also showed a sharp emission reduction by 37% as a result of fuel combustion for the same reasons.

In general Belarus has a fairly high percentage of residential communities connected to a gas supply grid.

Basic and sectoral approach to CO_2 emissions

CO_2 emissions as per the basic and sectoral approaches do not differ greatly. This is because, firstly, original data on fuel usage for different approaches was submitted by the Ministry of Statistics and Analysis where it was carefully analyzed and verified, therefore the maximum spread in 2004 is 1.1 %.

Secondly, emission coefficients for fuel types of main source categories were adopted using the IPCC guidelines, and the same coefficients were used for similar fuels.

The national energy balance was also presented by the Ministry of Statistics and Analysis.

Table 2.11

Comparison of basic and sectoral approaches, CO_2, Gg

Year	Basic approach	Sectoral approach	Difference, %
1990	99 673,20	100 071,27	**-0,40**
1991	94 136,12	93 470,55	**0,71**
1992	86 466,85	86 328,65	**0,16**
1993	74 424,12	74 136,49	**0,39**
1994	62 401,18	62 161,97	**0,38**
1995	55 538,02	55 297,70	**0,43**
1996	56 322,42	56 063,50	**0,46**
1997	57 691,32	57 422,53	**0,47**
1998	55 592,22	55 276,30	**0,57**
1999	52 981,16	52 608,85	**0,71**
2000	51 070,91	50 556,82	**1,02**
2001	50 096,85	49 692,85	**0,81**
2002	49 845,03	49 746,36	**0,20**
2003	50 361,93	49 685,84	**1,36**
2004	53 380,28	53 032,36	**0,66**

2.5 Industrial processes

2.5.1 Sector summary

Greenhouse gas emissions in this sector are caused by various industrial processes not related to energy. The main sources of such emissions are production processes where chemical or physical transformation of materials takes place. During such processes different greenhouse gases are emitted including: CO_2, CH_4, N_2O, NO_x, CO, NMVOCs, HFCs, SO_2, SF_6.

The sector's GHG emissions make up 3.18% of the total national emissions. The largest contributions are made by carbon dioxide, nitrous oxide and SF_6, their methane equivalent shares are 79.84%, 17.48% and 1.66%, respectively.

Original data was provided by the Ministry of Statistics and Analysis, Ministry of Health, Belarusian State Oil and Chemistry Concern.

2.5.2 Emission trends

Since 1996 greenhouse gas emissions in the industrial processes sector tended to increase as a result of production capacity growth in the country.

Table 2.12

Total greenhouse gas emissions in the Industrial Processes, CO_2 equivalent

Year	CO_2	CH_4	N_2O	HFCs	SF_6	Global warming effect
1990	1 875,52	24,07	349,70			2 249,29
1991	1 831,52	24,07	286,11			2 141,70
1992	1 776,89	22,83	286,11			2 085,83
1993	1 615,76	19,25	254,32			1 889,33
1994	1 111,20	18,32	286,11			1 415,63
1995	935,71	16,40	254,32	2,84	0,01	1 209,28
1996	1 014,58	18,40	222,53	3,68	0,05	1 259,24
1997	1 822,52	24,07	286,11	5,34	0,24	2 138,28
1998	1 484,70	28,95	317,91	7,12	0,28	1 838,96
1999	1 434,86	29,81	317,91	7,98	0,37	1 790,93
2000	1 354,06	33,08	286,11	9,35	0,41	1 683,01
2001	1 295,13	33,04	317,91	12,90	0,46	1 659,45
2002	1 484,93	32,91	381,49	16,38	0,50	1 916,20
2003	1 710,44	34,80	349,70	19,24	0,69	2 114,87
2004	1 887,29	39,13	413,28	23,14	1,03	2 363,86
Trend 1990-2004, %	0,63	62,58	18,18			5,09
Share in total emissions 2004	79,84	1,66	17,48	0,98	0,04	100,00

In this sector total CO_2 equivalent greenhouse gas emissions are 2,363.86 Gg. Carbon dioxide is responsible for about 79.84%, nitrous oxide -17.48%, methane -1.66%, HFCs – 0,98% and SF_6 – 0.04% (Table 2.12).

2004 witnessed a slight increase of carbon dioxide, methane, nitrous oxide, carbon oxide and nitric oxide emissions; NMVOC, SO_2, HFCs and SF_6 emissions reduced (Table 2.13).

Since 1996 industries have started showing improvement in terms of output growth, so greenhouse gas emissions increased. As a result CO_2 emissions more than doubled versus 1995 reaching the 1990 level.

A share of methane in the sector's total emissions is 1.66%. Methane emission growth since 1995 is mainly attributed to growing production of electric furnace steel.

Nitrous oxide emissions somewhat increased since 1995 as a result of increasing production of nitric acid, and it CO_2 equivalent share generally makes up 17.48%.

A HFC and SF_6 share in total emissions is 1.02%.

Table 2.13

Greenhouse gas emissions in the Industrial Processes, Gg

Year	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2	HFC	SF_6
1990	1 875,52	1,15	1,13	0,96	8,06	49,58	21,31		
1991	1 831,52	1,15	0,9230	0,93	7,87	51,53	18,22		
1992	1 776,89	1,09	0,9230	0,87	7,03	47,76	11,49		
1993	1 615,76	0,92	0,820	0,74	5,28	44,98	7,58		
1994	1 111,20	0,87	0,9230	0,70	4,40	42,71	5,56		
1995	935,71	0,78	0,820	0,64	5,15	41,30	8,04	2,84	0,30
1996	1 014,58	0,88	0,7179	0,70	5,48	37,21	10,07	3,68	1,96
1997	1 822,52	1,15	0,9230	0,93	7,87	51,53	18,22	5,34	10,06
1998	1 484,70	1,38	1,03	1,05	6,90	42,92	11,84	7,12	11,62
1999	1 434,86	1,42	1,03	1,09	7,31	43,27	11,38	7,98	15,56
2000	1 354,06	1,58	0,9230	1,16	8,04	37,76	10,79	9,35	17,00
2001	1 295,13	1,57	1,03	1,17	7,94	37,64	9,91	12,90	19,40
2002	1 484,93	1,57	1,23	1,22	7,99	36,74	9,85	16,38	20,72
2003	1 710,44	1,66	1,13	1,23	8,25	35,52	10,85	19,24	28,90
2004	1 887,29	1,86	1,33	1,40	8,94	35,60	12,10	23,14	42,92
1990-2004 trend, %	0,63	62,58	18,18	45,87	10,82	-28,19	-43,21		

2.6 Solvents

2.6.1 Sector summary

Solvents belong to substances that release non-methane volatile organic substances into the air when used.

The solvent use sector makes up a very small part in greenhouse gas emissions in Belarus, a mere 0.1 %.

NMVOC emissions during solvent use in the production and processing of chemical products constitute 47.063 Gg or 99,4%, and nitrous oxide emissions from solvent use for medical purposes – 0. 261 Gg or 0.6% (Table 2.14).

In 2004 total NMVOC emissions reduced by about 29% compared to 1990.

Table 2.14

VNMOC emissions during solvent use in the production and processing of chemical products, N_2O from solvent use for medical purposes

Year	Oil processing	Xylenes	Benzol	Resin-based varnishes	Resin-based enamels, primers and fillings	Dimethyl -tereftalat	Long glass fibre	Tires	Use of paints	Grease removal and dry cleaning	TOTAL	Nitrous oxide used for medical purposes
	VNMOC emissions,											N_2O emissions, Gg
1990	57,98	4,599	0,744	0,851	0,220	0,398	0,583	0,872	0,000	0,000	66,247	0,240
1991	52,58	4,360	0,698	0,670	0,158	0,384	0,626	0,736	0,000	0,000	60,213	0,234
1992	30,24	4,032	0,494	0,550	0,120	0,378	0,520	0,651	0,000	0,000	36,984	0,227
1993	20,81	2,909	0,295	0,294	0,054	0,303	0,282	0,455	0,000	0,000	25,401	0,214
1994	18,39	2,423	0,239	0,152	0,026	0,270	0,212	0,272	0,000	0,000	21,988	0,208
1995	19,02	2,243	0,330	0,164	0,027	0,248	0,339	0,314	0,000	0,000	22,681	0,201
1996	17,81	1,968	0,208	0,206	0,032	0,229	0,398	0,437	0,000	0,000	21,286	0,195
1997	17,06	2,172	0,215	0,239	0,039	0,264	0,397	0,426	0,000	0,000	20,808	0,188
1998	16,82	1,863	0,100	0,189	0,030	0,234	0,411	0,512	0,000	0,000	20,156	0,224
1999	16,85	1,987	0,140	0,212	0,028	0,231	0,495	0,419	0,000	0,000	20,363	0,282
2000	19,76	2,504	0,310	0,224	0,034	0,247	0,599	0,485	0,217	29,463	53,845	0,245
2001	19,55	2,145	0,241	0,160	0,030	0,244	0,747	0,583	0,188	37,019	60,901	0,269
2002	22,39	2,387	0,207	0,144	0,023	0,223	0,774	0,468	0,232	1,598	28,451	0,260
2003	23,04	2,485	0,299	0,141	0,021	0,206	0,859	0,664	0,248	10,145	38,110	0,256
2004	27,03	2,616	0,323	0,138	0,019	0,183	0,900	0,600	0,255	15,000	47,063	0,261

2.7 Agriculture

2.7.1 Sector summary

In 2004 the agriculture sector accounted for 16.57 % in total greenhouse gas emissions in the Republic of Belarus (excluding the LUCF sector). Between 1990 and 2004 emissions decreased by 39.5% in this sector (Fig.1 and Fig.2.15) as a result of a slowdown in the farming sector.

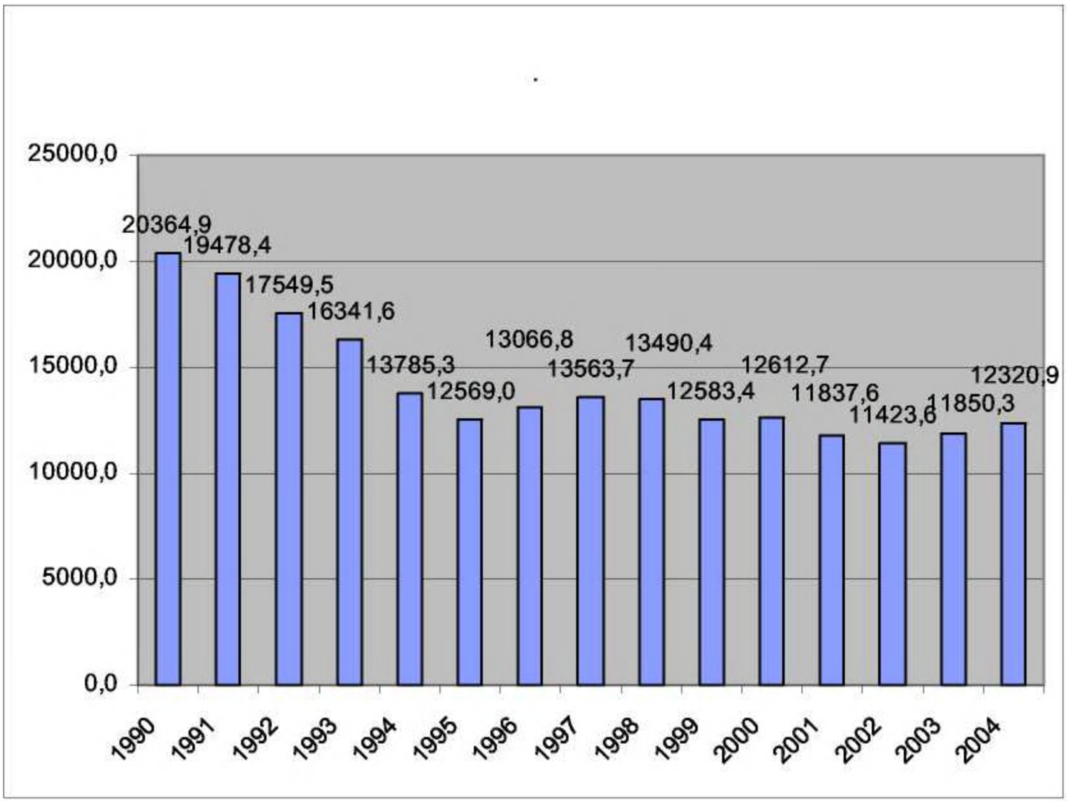

Fig.1 - Greenhouse gas emissions, 1990-2004, Gg, CO_2 equivalent.

Emission changes over this period are mainly attributed to a change of CH_4 emissions from domestic animals N_2O emissions from agricultural soils.

Emission trends by gas

CH_4 emissions in the *Agriculture* reduced by 41.3 % compared to the base year as a result of decreasing emissions from enteric fermentation and manure due to cattle reduction. N_2O emissions reduced by 37.5% due to decreasing emissions from agricultural soils (direct and indirect emissions) mainly as a result of the amount of applied mineral fertilizers and a reduced area of drained peaty soils used in agriculture. Trends are reflected in Table 2.15.

Table 2.15

Greenhouse gas emissions and trends, 1990 – 2004, in the Agriculture

Year	Greenhouse gas emissions, Gg	
	CH_4	N_2O
1990	522.09	30.33
1991	494.79	29.32
1992	468.19	24.89
1993	443.10	22.70
1994	414.39	16.40
1995	391.13	14.05
1996	375.40	16.72
1997	370.65	18.65
1998	362.06	18.99
1999	337.80	17.71
2000	329.59	18.36
2001	319.16	16.57
2002	312.01	15.71
2003	305.02	17.56
2004	306.65	18.97
Change vis-à-vis the base year, 1990 - 2004	-41.3%	-37.5%

Emission trends by category

Table 2.16 shows total greenhouse gas emissions in the *Agriculture* and trends over 1990 – 2004 by subcategory and their share in total national emissions. The main sources are subcategories 4A 'Enteric fermentation' (7.66%), 4D 'Agricultural soils' (7.9%) and 4B 'Manure storage' (1.0%).

As seen from the Table 2.16 data, there is an emission reduction trend across all subcategories. Reduction from categories 4 A *Enteric fermentation* and 4 B *Manure storage* takes place as a result of livestock population reduction (mainly cattle and pigs). Emission changes in category 4D *Agricultural soils* were caused by changes in activity data for the period in question (chiefly, application of nitrogen fertilizers and cultivation of organogenic soils).

Table 2.16

Total greenhouse gas emissions and trends (1990 – 2004) in the Agriculture totally and by subcategory

Year	Greenhouse gas emissions, Gg, CO_2 equivalent				
	4 Total	4A Enteric fermentation	4B Manure storage	4D Agricul-tural soils	4F Burning agricultural residues on fields
1990	20,364.9	9,756.39	1,204.20	9,394.06	10.24
1991	19,478.4	9,246.42	1,140.88	9,081.37	9.73
1992	17,549.5	8,758.95	1,068.93	7,710.88	10.72
1993	16,341.6	8,299.54	1,000.13	7,029.62	12.27
1994	13,785.3	7,752.06	946.71	5,077.36	9.15
1995	12,569.0	7,314.76	895.14	4,349.62	9.53
1996	13,066.8	7,018.16	860.76	5,177.58	10.34
1997	13,563.7	6,928.13	852.10	5,774.93	8.51
1998	13,490.4	6,758.52	841.85	5,882.32	7.71
1999	12,583.4	6,295.04	796.49	5,485.13	6.74
2000	12,612.7	6,143.58	774.32	5,686.56	8.24
2001	11,837.6	5,946.03	753.14	5,130.62	7.79
2002	11,423.6	5,810.78	737.99	4,866.77	8.01
2003	11,850.3	5,678.21	723.73	5,440.31	8.07
2004	12,320.9	5,699.27	735.72	5,876.26	9.67
Share in total GHG emissions in Belarus	16.57%	7.66%	0.99%	7.90%	0.01%
Change vis-à-vis the base year, 1990-2004	-39.5%	-41.6%	-38.9%	-37.4%	-5.6%

2.8 Land use change and forestry

2.8.1 Sector summary

In accordance with the new UNFCCC guidelines for preparation of annual inventories (FCCC/SBSTA/2004/8) and good practice guidance for the land-use change and forestry sector (IPCC, 2003) this chapter contains information about the estimation of emissions and sinks for CO_2 and other greenhouse gases in the sector *Land-Use Change and Forestry (LUCF)* according to the general IPCC reporting format taking into account Decision 13/CP/9 – category CRF 5.

2.8.2 Emission trends

In 2004, net sinks from this sector made up 16% of total greenhouse gas emissions in the Republic of Belarus. The amount of sinks compared to the base year practically remained unchanged: it reduced by 0.9% mainly as a result of increased losses of forest biomass from cutting.

Table 2.17 shows CO_2 equivalent greenhouse gas emissions and removals in the sector *Land-Use Change and Forestry.*

Table 2.17

CO_2 equivalent greenhouse gas emissions and sinks in the LUCF sector, 1990-2004.

Year	Emissions, Gg CO_2 equivalent	Sinks, Gg CO_2 equivalent	Balance
1990	13,814.63	-25,132.10	-11,307.18
1991	13,565.40	-26,889.50	-13,315.74
1992	13,412.39	-25,758.63	-12,256.58
1993	13,117.49	-26,719.99	-13,590.89
1994	12,513.29	-27,654.00	-15,128.89
1995	12,695.78	-28,137.89	-15,429.26
1996	13,139.59	-27,930.76	-14,769.13
1997	13,690.33	-26,520.60	-12,819.65
1998	14,008.39	-27,144.08	-13,123.67
1999	14,139.58	-27,953.49	-13,801.12
2000	14,085.44	-28,226.66	-14,126.24
2001	13,805.61	-28,223.80	-14,405.89
2002	13,568.82	-26,893.68	-13,297.83
2003	13,291.34	-25,295.45	-11,985.32
2004	12,998.07	-24,911.22	-11,900.32
Change, 1990-2004	-5.91%	-0.88%	5.26

As seen from the table, the LUCF sector is a net sink in the Republic of Belarus. The most important category is *5 A Forest,* in particular subcategory 5 A 1 Forest land remaining to be forest land. This subcategory is a CO_2 while the other subcategories are sources of greenhouse gas emissions.

2.9 Waste

2.9.1 Sector summary

In the waste sector the main greenhouse gas emission sources are disposal and incineration of solid waste, and wastewater treatment.

In Belarus, like in most countries, solid waste is disposed of at waste disposal locations. At the moment waste is not incinerated, because the only recycling plant of the country ceased to burn solid communal waste in 1990.

Wastewater is treated at treatment facilities biologically in aerobic conditions.

The most considerable input to greenhouse gas emissions is made by waste disposal at solid waste landfills (CH_4 emissions) and to a lesser extent – waste of human activities (N_2O emissions).

2.9.2 Emission trends

Total greenhouse gas emissions in the waste sector in 2004 were 4,461.95 Gg in CO2 equivalent or 6% of aggregate greenhouse gas emissions in Belarus (excluding net sinks of the LUCF sector).

Greenhouse gas emission trends over the period 1990 - 2004 are presented in Table 2.18.

Table 2.18

Greenhouse gas emissions in the waste sector, 1990-2004.

Year	CH_4, CO_2 eq.	N_2O, CO_2 eq.	GWE
1990	2,348.43	226.30	2,574.73
1991	2,352.42	220.10	2,572.52
1992	2,356.62	213.90	2,570.52
1993	2,360.61	207.70	2,568.31
1994	1,890.00	201.50	2,091.50
1995	1,945.44	192.20	2,137.64
1996	2,385.39	204.60	2,589.99
1997	2,409.54	213.90	2,623.44
1998	2,509.29	223.20	2,732.49
1999	2,689.26	232.50	2,921.76
2000	2,723.07	232.50	2,955.57
2001	2,765.28	235.60	3,000.88
2002	2,856.84	235.60	3,092.44
2003	3,842.16	226.30	4,068.46
2004	4,232.55	229.40	4,461.95
Change, 1990-2004, %	80.23	1.37	73.30
Share in total emissions for the sector, 2004	94.86%	5.14%	100

In 2004 emission in the waste sector exceed the base-year emissions by 73%. The chief contributor is CH_4, whose emissions in the sector's total emissions are about 95%.

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

3.1. Environmental protection strategy, GHG emission reduction policies and measures

3.1.1. GHG emission reduction policies and measures

In order to preserve and ensure wise use of natural resources and environmental protection in Belarus, comprehensive measures should be envisaged with respect to air protection, protection and sustainable use of land, forest and water resources, sustainable agriculture, environmentally friendly use of biotechnologies and toxic chemical substances, and disposal of all kinds of waste. The national laws on the “Environmental Protection” (No126-3 of 17/07/2002), “Air Protection” (No29-3 of 15/04/1997), “Waste” (No444-3 of 26/10/2000) and others seek to give priority to ecological concerns and balanced nature use over the production economy and nature use economy.

Being aware of its responsibility for climate change in accordance with the UNFCCC and Kyoto Protocol commitments, Belarus, as a party to these international agreements, shall not allow exceeding planned GHG emissions during the commitment period 2008-2012. Hence, the implementation of home policy should provide for strategic measures to stabilize GHG emissions and removal enhancement in the context of rapid economic growth taking into account a possible increase of fuel consumption, as well as other factors, that go along with economic development leading to GHG emission growth and removal reduction. Simultaneously it is necessary to consider future commitments under the Kyoto Protocol for the next commitment period (2013 – 2017). To address these tasks, the 2007-2012 National Emission Reduction Strategy has been developed.

The Strategy development built upon the following core documents:

- National Sustainable Development Strategy for the Period until 2020, endorsed by the National Commission on Sustainable Development of Belarus;

- Dedicated programme designed to ensure that at least 25% of domestic energy production comes from local fuels and alternative energy sources for the period until 2012, approved by Resolution No1680 of the Council of Ministers of Belarus dated December 30, 2004;

- Energy Security and Energy Independence Enhancement Concept, and State Comprehensive Programme to Modernize Foxed Assets of the Belarusian Energy System, Energy Saving and Increased Share of Domestic Fuel and Energy Resources in Belarus in 2006-2010, approved by Presidential Edict No 399 of August 25, 2005;

- 2006-2010 National Energy Saving Programme, approved by Resolution No 137 of the Council of Ministers of Belarus dated February 2, 2006;

- 2006 – 2010 National Action Plan on the Wise Use of Natural Resources and Environmental Protection of Belarus, approved by Presidential Edict N 302 of May 5, 2006;

- 2006-2010 Socio-Economic Development Programme of Belarus approved by Presidential Edict No 384 of June 12, 2006.

In accordance with the National Sustainable Development Strategy-2020, the essential principles of ecological policy should include:

- support of ecosystem integrity through effective management of natural resources;
- reduction of environmental pressure on the part of economy (during its growth);
- environmentl protection as an integral part of development process;
- social and ecological interplay for improved quality of life;
- expansion of cooperation taking into account global ecological interdependency.

Based on these principles, a system of directions and measures has been developed to implement the ecological policy. The remaining key task is to minimize the consequences of the Chernobyl disaster in terms of ensuring safest living conditions possible for people and rehabilitation of natural complexes. It is necessary to ensure safe ecological living conditions for people in towns and areas with dangerous levels of air pollution, water sources, etc. To implement the ecological policy, relevant activity plans have been developed that aim to:

> reduce the amount of pollutant emissions into the air from fixed and mobile sources in large cities and industrial centres;

> improve the system of environmental quality standards taking into consideration international requirements and national commitments under international conventions and agreements;

> improve methods to assess pollutant emissions and content in the air, including greenhouse gases;

> develop an environmental monitoring system in large cities and industrial centres.

3.1.1.1 Socio-economic development strategy

The primary means and indicator of national economy development and solution of social problems is the gross domestic product (GDP), which takes into account product and service consumption, available resources, efficiency of their use with a compulsory provision of favourable ecological situation. To reach set socio-economic targets the GDP production over 2001-2020 needs to be increased 2.7-3.0-fold. A gradual reduction of commodity share (from 45.6% in 2000 to 40-41% in 2020) and increase of services share from 39.9 to 45-46%, respectively, should take place in the growth structure. As for the GDP structure, the goal by 2020 is to bring a share of capital formation to 30-31% versus 25.7% in 2000 and a share of investments from 19.8 to 24-26%. It is envisaged that the level of production efficiency and competitiveness, reduction of anthropogenic pressures on the environment should develop on the basis of smaller consumption of raw materials and energy, less labour, more rational structure, technology improvement and innovation, and prioritization of ecologically safe and alternative technologies.

The main objectives of the public employment policy are to develop a rational employment structure in tune with economic reform needs and increase labour force efficiency.

Implementing this policy will require a balanced investment policy to create new jobs, more active intersectoral re-distribution of workers into social spheres of the economy, effective tax incentives to develop private business. It is necessary to develop effective mechanisms to further improve social protection of the people against unemployment.

Main macroeconomic parameters of socio-economic development

As mentioned above, the ‘status’ of GDP is the fundamental instrument and indicator of sustainable development of national economy, and solution of social and ecological tasks. For the socio-economic development of the country the 2000-2005 pentad was a stage of economy stabilization and sustainable development support.

In accordance with the National Sustainable Development Strategy, the services sector is expected to develop at a faster pace than other sectors in the future. Projected structural changes in the Belarusian economy are given in Table 3.1.

Table 3.1

GDP structure forecast

	1990	**2006**	2008	2010	2012	2014	2016	2018	2020
Industry									
Billion $US	**9.29**	**5.84**	**6.50**	**7.25**	**7.99**	**8.81**	**9.70**	**10.54**	**11.48**
Share in GDP	38.2	**26.3%**	**26.3%**	**26.3%**	**26.3%**	**26.3%**	**26.4%**	**26.4%**	**26.4%**
Agriculture									
Billion $US	**5.76**	**2.01**	**2.17**	**2.34**	**2.57**	**2.82**	**3.08**	**3.33**	**3.61**

Share in GDP	23.7	**9.1%**	**8.8%**	**8.5%**	**8.5%**	**8.4%**	**8.4%**	**8.3%**	**8.3%**
Construction									
Billion $US	**1.88**	**1.23**	**1.33**	**1.43**	**1.57**	**1.71**	**1.87**	**2.01**	**2.17**
Share in GDP	**7.7%**	**5.6%**	**5.4%**	**5.2%**	**5.2%**	**5.1%**	**5.1%**	**5.0%**	**5.0%**
Service sector									
Billion $US	**6.78**	**10.42**	**11.74**	**13.23**	**14.60**	**16.13**	**17.77**	**19.34**	**21.09**
Share in GDP	**27.9**	**47.0%**	**47.5%**	**48.0%**	**48.1%**	**48.2%**	**48.3%**	**48.4%**	**48.5%**
Taxes									
Billion $US	**0.63**	**2.68**	**2.98**	**3.31**	**3.64**	**3.99**	**4.38**	**4.73**	**5.13**
Share in GDP	**2.6%**	**12.1%**	**12.1%**	**12.0%**	**12.0%**	**11.9%**	**11.9%**	**11.8%**	**11.8%**
GDP, billion $US	**24.34**	**22.19**	**24.72**	**27.57**	**30.36**	**33.47**	**36.80**	**39.97**	**43.49**

Based on the overall long-term industrial development strategy seeking to rely on resource economy and science intensity the priority sectors and productions are as follows:

- information technologies;
- microelectronics and equipment to make it;
- instrument engineering, precision engineering;
- new materials for different purposes;
- household and health care equipment;
- biological and high chemical technologies;
- agricultural machinery, equipment and products;
- high-precision equipment and technology for defence applications.

The prospective core areas of industrial policy are: promotion and government support of the most advanced “growth point” sectors, individual enterprises and productions; all-out focus on best practices that deliver fastest possible results in competitive, import-replacement and export production. Generally, industrial sectors should develop in accordance with the 1998-2015 Industrial Complex Development Concept and Programme of Belarus (approved by Presidential Edict No 246 of May 14, 1998).

The main trends and prospective development areas of industrial sectors of Belarus can be characterized in the following way:

Fuel and energy complex (FEC) of the Republic of Belarus includes production, transportation, storage and distribution of all types of energy carriers: gas, oil and processing products, solid fuels, power and heat energy. They are responsible for 25.6% of capital investment in industry, 20% of basic production assets and 13.8% of industrial output.

The basis (core) of the Belarusian FEC is *electrical and heat energy sectors,* whose generation capacity is represented by 23 large power plants with a total capacity of 7.6 million kWh (totally, the country generates 7.8 million kWh), and district boiler houses with a capacity up to 10,000 Gcal/h, about 7,000 km of high-voltage grid power lines and over 10,000 km of heat supply network. It is envisaged that the retrofit of oil refineries (Mozyr Oil Refinery and ‘Naftan’) will bring the oil processing depth to 85%, i.e. getting close to world standards. This will help increase exports and simultaneously improve quality and expand the oil product range, and, most importantly, reduce GHG emissions (first of all carbon dioxides) both during primary processing and end-use stages. An important FEC component is *the fuel industry.* In Belarus it is represented by oil and peat production enterprises, dominated by largest oil refineries with 40 million tonne annual capacity. Due to raw material shortages, capacities are utilized only around 25%. One of the priority areas for *the peat industry* is to develop the production of peat-lignin briquettes through full utilization of lignin – production waste from Rechitsy and Bobruisk hydrolysis plants.

The prospective development of *the fuel and energy complex* will aim to address the following tasks:

➢ meet fuel and energy needs of domestic producers to the maximum extent possible, predominantly at the cost of local resources;

➢ ensure energy security of the country and improve its energy independence on the basis of FEC optimized structure (higher share of secondary energy resources, local fuels, alternative and renewable energy sources: wind, sun, water, bioenergy), broad application of new effective power generation technologies, implementation of energy-saving measures across all the sectors of economy, including the social sector; development of advanced oil processing technologies;

➢ improve the FEC/environment interaction in order to reduce anthropogenic pressures on the nature. The structure of power generation facilities will be optimized through the introduction of steam-and-gas and turbine technologies, increased production of electrical energy by the heating cycle, conversion of boiler houses into small CHPs. All of this will help satisfy the increasing power demand to the maximum extent possible and enhance efficiency of residential heat supply. *In the chemical and petrochemical industries* the priority areas include: creation of new-generation chemical products, above all latest chemical fibres and threads, plastic masses, elastomers, advanced mineral fertilizers and chemical ingredients of fodder blends, products of primary and small-tonnage chemistry, and consumer goods taking into account modern world innovation trends and current challenges facing the chemical industry of Belarus. Products will be made on the basis of newest technologies that ensure the use of clean materials and are designed to improve consumer properties of goods, expand their range, reduce production costs, first of all it refers to the production of clean (safe) polymers, chemical fibres and threads, synthetic rubber, catalysts and other products;

➢ retrofit and put into operation new capacities to produce enamels, varnishes, paints, glass fibres, glass wallpapers, thin tissue for printed circuit cards, polyester thermoelastolayers, plasticizers, polymer materials, glues, low-pressure polyethylene of different density, nitrogen-containing fertilizers, cord tissue, caprolactam and other products;

➢ starting from 2006 (following radical modernization of many enterprises) the main development area of the sector is the systematic introduction of new technologies designed to save resources and minimize environmental impact of industries, wise nature use;

➢ special attention will be paid to complex material processing and waste utilization. This will require putting in place essentially new aggregates for treating gaseous, liquid and solid substances capable of reducing anthropogenic pressure on the environment; expanding the range of new-generation catalysts and reaction initiators and technological processes on their basis, which will lead to increased production of polyolefins, organic synthesis and other clean products. In the *machinebuilding complex,* production growth was accompanied by progressive structural intrasectoral shifts at the cost of preferential development of science-intensive and high-technology, export-oriented and import-replacement sectors. This is supported by the selective government support of enterprises and productions chosen as "growth points", as well as active enterprise management development.

The main tasks of *the construction complex* are: to the extent possible, meet needs of economy in efficient building products; create new and modernize the existing manufacturing facilities; ensure export growth of building materials, constructions and services; renew manufacturing capacity.

The following long-term sectoral programmes will be implemented to enhance efficacy of the construction complex:

➢ Main Development Areas of the Construction Material and Technical Basis in Belarus for the period 1998-2015;

➢ Programme for the Creation of National Legislation in the Field of Construction;

> Ministry of Architecture and Construction's Action Plan for the Implementation of Long-Term Investment Policy until 2015;

> State Sci-Tech Programme "Creating and Introducing New Materials, Energy-Saving Technologies and Resource-Saving Structural Systems of Residential Houses That Reduce Consumption of Resources and Energy during Housing Construction and Use".

Agroindustrial complex. Key goal: to ensure fuller and more reliable supply of food products for people and raw materials for the primary processing industry; boost agricultural exports thereby enhancing food security of the country.

According to key parameters the priority areas for *transport* development should be:

> adaptation and modernization of major communications, sites and systems;

> compliance with EURO 3-4 standards;

> renewal and restoration of industrial potential, replacement of worn-out and obsolescent tools and transport machinery;

> creation of the necessary conditions to attract transit flows;

> improvement and severization of vehicle ecological control.

A comprehensive system of ecologically-oriented measures (more specifically, conversation to natural gas) should in the foreseeable future ensure reduction of negative transport impact on people and their environment.

3.1.1.2 Main areas of the national climate programme

Effective economy planning and management requires analyzing and keeping track of a lot of economic, social and natural parameters. This work should rely on the establishment and effective operations of an extensive information base for the benefit of planning and managing various aspects of economic activities. Climate-related information is an essential element of the information base. Climate has always produced great impact on human societies. The history of civilizations knows quite a few examples from the past, when the effect of a changing climate on many countries and peoples was disastrous. Despite increasing human independence from the elements, the influence of climate and weather changes on human activities is still considerable. Generally speaking, key economic sectors have come to depend on climate, in absolute terms, even to a greater extent. At the times of unfavourable climate conditions world grain supplies shrank from 20 to 5-10%, and the price of grain tripled or quadrupled.

As the fact that natural resources are limited and need conservation sinks in public mind deeper and deeper, the problem of climate change acquires overriding importance. Climate debates in national parliaments and at interparliamentary assemblies confirm this point. This is mainly because a number of economic sectors become more dependent on the changing climate conditions in absolute terms as production grows. Nearly all economic activities and life of people, plants and animals are connected with natural and climatic conditions. They can be favourable, but can also make life very difficult causing devastation, inflicting damage and jeopardizing health and even life. Experts attach the maximum loss factor to the following three groups of extreme weather events: floods, droughts, tropical hurricanes.

Developing an independent economy requires a detailed study of climate resources in order to optimize agricultural production, create more possibilities for using climate in the energy and construction sectors and, finally, develop an appropriate strategy to facilitate industrial and agricultural response to climate change.

The National Sustainable Development Strategy of the Republic of Belarus projects 10-15% GDP growth by 2010 versus the 1990 level. This will require appropriate measures to reduce emissions of greenhouse gases and their precursors, and to adapt economy to climate change, first of all to develop the National Climate Programme.

National Climate Programme: goals and objectives

The main goals of the programme are to:

> create an effective system to provide government bodies, ministries and agencies, population with reliable hydrometric information and forecasts of possible climate changes to prevent negative effects of such changes for the economy and public health;

> reduce damage from negative climate changes;

> implement international commitments of Belarus under the UNFCCC and Kyoto Protocol regarding the reduction of anthropogenic climate changes through GHG concentration stabilization (reduction).

The achievement of these goals is possible by addressing the following objectives:

> develop a network of hydrometeorological observation, improve a system to collect, analyze, control, store and distribute climate-related information to keep government and other bodies, and individual citizens fully and promptly informed;

> make an inventory of GHG sources and sinks; conduct a national policy and adopt appropriate measures for limiting anthropogenic emissions and enhancing GHG sinks;

> ensure effective use of climate resources by all sectors of economy, public health, etc.;

> improve the application of climate information for the benefit of various sectors of economy;

> improve the understanding of processes and factors that affect climate;

> obtain more comprehensive assessments regarding the impact of natural and anthropogenic factors on regional and local climate;

> develop forecasts (scenarios) of climate change and climate extremes (droughts, floods, severe and warm winters);

> develop recommendations on assessment of possible socio-economic and ecological consequences of climate change in Belarus to facilitate adaptation of the country's economy to new climate conditions; improve the use and protection of natural resources that depend on climate conditions;

> create scientific, technical and legislative frameworks to prevent dangerous climate changes and adapt economic development of the country to climate changes.

3.1.2. Energy sector

The energy sector, which includes all processes of energy activities related to production, storage, transportation and use (combustion) of organic fuel, is responsible for the following shares in the direct GHG emission structure by category of source (excluding CO_2 removal):

carbon dioxide (CO_2) ~78 %

methane (CH_4)-15.3%

nitrous oxide (N_2O) - 1.6 %

The energy sector's CO_2 emission structure, according to the 2000 data, was: fuel processing, energy production and transmission (64.3%), transport (~11%), industry (~7%), housing and utilities (~10%). Due to an overriding role of CO_2 emissions from energy-related fuel use (combustion) in the overall national GHG emissions, the key provisions of the GHG reduction strategy first of all relate to the problems of CO_2 emission limitation in the energy system.

In the Belarusian economy, which lacks energy resources of its own, the fuel and energy complex is instrumental in developing productive forces and improving living standards of people.

3.1.2.1 Energy complex development forecast

The country's energy needs are covered 15-18% by domestic resources produced within Belarus (oil, associated gas, fuel peat, wood, etc.), the rest comes from imports. In 2004, Russia's share in the total import was 97.1%. A ratio of local and imported energy resources keeps changing to show a growing share of local fuels (mainly wood and wood waste). Pursuant to the National Sustainable Development Strategy Concept 2020, the development aim of the fuel and energy complex is to meet country's fuel and energy needs on a sustainable basis and use energy resources rationally. Priority areas should include:

> ensured energy security for the country, and its greater energy independence based on an optimised structure of fuel and energy balance (increased share of waste energy, local fuels, unconventional and renewable energy, wind and solar energy, bioenergy and small hydro power plants), massive introduction of new efficient energy-generation technologies, further development of the power system, implementation of the energy efficiency policy in all areas, including the social sector;

> development of advanced technologies of oil refining, which would upgrade the level of its use and enhance the quality of oil derivatives; improvement of interaction of the fuel and energy complex with the environment for mitigation of the negative environmental impact;

> diversification of fuel supply by type and supplier. The National Sustainable Development Strategy Concept 2020 stipulates industrial restructuring, which must contribute to further strengthening and development of up-and-coming industries based on the introduction of new equipment and advanced resource- and energy-saving environment-friendly technologies; deceleration of the development of conventional, mostly metal- and energy-intensive, industries; certain decrease in the share of machine-building and metalwork. The GHG emission reduction activities in Belarus rely on the provisions of the general national policy on how to mitigate the negative impact of the expected climate change.

The main requirements for such activities are:

1. The national climate change mitigation activities must be well co-ordinated with the general action plan of the National Sustainable Development Strategy Concept 2020, in order to avoid a negative impact of such activities on the society's living standards.

2. The priority activities in the field shall contribute (at minimum cost) to implementation of Belarus' obligations under the UNFCCC. Just like other sectors of economy, the fuel and energy complex suffered from the crisis in the '90s. Until 1995, the total fuel consumption had been steadily decreasing, and thereafter it stabilised at the level of 35-37 million tons of reference fuel.

The main goal of the State Programme is to identify specific activities, timeframe of their implementation, and required investments, which would ensure the country's energy security, positive dynamics of fixed assets renewal, reliable, efficient, and environmentally sound supply of energy to accommodate the needs of economy and population.

The State Programme built on the following basic documents:

- Main directions of the Energy Policy of Belarus for 2001-2005, and for the period until 2015, as approved on 27 October 2000 by Resolution of the Council of Ministers of Belarus No. 1667;

- Target Programme of Ensuring Not Less Than 25% of Power and Heat Production by Local Fuels and Alternative Energy Sources by 2012, as approved on 30 December 2004 by Resolution of the Council of Ministers of Belarus No. 1680;

- Draft Concept of Energy Security of Belarus.

The goal shall be achieved through implementation of a range of activities, including:

- centralised management of all the stages of energy production, transportation, and consumption;

- state control over power and heat tariffs, and fuel prices;

- balanced modernisation and development of power generators as well as power and heat transmission and distribution networks of the Belarusian Energy System;

- change of the age structure dynamics of the Belarusian Energy System's fixed assets, at first for stabilisation of the achieved level, and then for their continuous renewal;

- logistic/economic mechanism stimulating an ultimate introduction of energy-efficient technologies and equipment in all the economic and social sectors;

- reduction of costs related to production (extraction, harvesting), transmission and distribution of all kinds of fuel, heat and power sources;

- development and enforcement of national sectoral and regional programmes of energy efficiency;

- gradual diversification of suppliers of different types of fuel;

- maximisation of the economically feasible share of local fuels, unconventional and renewable energy in the fuel and energy balance.

Implementation of the State Programme shall help:

the energy sector:

- to enhance the level of energy security for Belarus through renewal of the fixed assets of the Belarusian Energy System, efficient use of fuel and energy resources, and increased share of local fuels, unconventional and renewable energy;

- to increase reliability of the Belarusian Energy System as a whole through renewal of its fixed assets;

the social sector:

- to create more jobs for new energy sites, all stages of extraction, generation, transmission, and distribution of local and alternative fuels;

- to increase tax payments to the national and local budgets;

the industrial sector:

- to increase production and consumption of local fuels to the level of 6.17 tons of reference fuel by 2010, including:

wood and logging waste	2.24
peat and lignin	1.18
other fuels	0.69
which include:	
industrial wood residue	0.37
hydro	0.07
heat recovery	0.78
solid waste and wind power	0.02

- to renew the fixed assets of the energy system as a whole by 15%;

- to decrease the energy consumption of GDP by 25-30% compared to the level of 2005.

Table 3.2

Main outcomes of the State Programme

	Expected economy, in 1,000 t.r.f.	Outcome
Modernisation of the fixed assets including:	900.0	reduction of depreciation by 14.9 %
generators	751.5	reduction of depreciation by 21.8 %

power grids	99.3	reduction of depreciation by 12.3 %
heat T/D network	29.7	reduction of depreciation by 17.9 %
others	19.5	
Energy efficiency	4,600.0	decrease of energy consumption of GDP in 2010 vis-à-vis 2005 by no less than 25%
including power generating equipment	344.9	
Local fuels	6,170.0	replacement of the imported fuels for heat and power generation by 22.7 %
Total	5,167.5	

The expected outcomes for 2010 are:

- decrease of energy consumption of GDP by no less than 25% vis-à-vis 2005;
- the aggregate fuel savings in the energy system in 2006-2010 amounting to 900 thousand tons of reference fuel, while the renewal of the energy system's total fixed assets reaching 14.9%;
- increase of the share of local fuels, unconventional and renewable energy up to 22.7% in the total boiler and furnace fuel needs of the country. Introduction of nuclear energy shall:
- substitute organic fuels in the fuel and energy balance of the country;
- make it possible to purchase nuclear fuel in other countries, and stockpile it for future needs;
- increase energy security of the country.

Table 3.3

Expected structure of boiler and furnace fuel consumption in Belarus in 2004-2010, in millions of tons of reference fuel

Type of fuel	2004	2010	2006	2007	2010	2009	2010
Natural gas	22.8	22.8	22.4	22.51	22.75	22.77	22.7
including natural gas used as raw material	1.4	1.46	1.5	1.8	2.2	2.2	2.2
Fuel oil	2.14	1.60	1.7	1.7	1.75	1.73	1.55
including fuel oil produced from own resources (including solid residue of oil refining, starting from 2008)	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Coal, including coke	0.28	0.15	0.16	0.17	0.18	0.19	0.20
Liquefied natural gas	0.33	0.33	0.32	0.32	0.31	0.31	0.30
Oil refinery gas	0.64	0.45	0.45	0.45	0.45	0.45	0.45
Domestic furnace oil	0.11	0.09	0.09	0.09	0.09	0.09	0.09
All other types of fuel	2.25	2.56	2.80	3.16	3.47	3.80	4.11
including:							
peat and lignin	0.60	0.75	0.94	1.07	1.13	1.15	1.18
firewood	1.07	1.18	1.22	1.44	1.67	1.97	2.24
others	0.58	0.660	0.63	0.6	0.67	0.68	0.69
Total boiler and furnace fuel:	28.6	28.0	27.9	28.4	29.0	29.3	29.4
without raw materials	27.1	26.4	26.4	26.6	26.8	27.1	27.2
including own boiler and furnace fuel with gas Oil refinery, domestic furnace fuels and other products	3.55	3.86	4.09	4.45	4.75	5.07	5.37
same in percentage	13.1	14.6	15.5	17.7	17.7	18.7	19.7
Heat-recovery systems	0.62	0.64	0.69	0.72	0.74	0.76	0.78
Solid waste, wind turbines		0.01	0.01	0.01	0.02	0.02	0.02
Total consumption of local fuels for energy production	4.17	4.50	4.79	5.18	5.51	5.85	6.17
same in percentage	15.4	17.0	18.1	19.5	20.5	21.6	22.7
Power consumption, in billions of kWh	34.46	34.7	35.0	35.5	36.0	36.5	36.9
Heat consumption, in millions of Gcal	73.0	73.2	73.9	74.5	75.2	75.9	76.5

3.1.2.2 Main directions of the Energy Policy of Belarus for 2001-2005, and for the period until 2015

In the past few years, the fuel and energy complex's impact on the environment continued to decrease due to the overall reduction of boiler and furnace fuel consumption, increase of natural gas consumption due to fuel oil phase-out, introduction of environment-friendly technologies and equipment. The continuous reduction of NO_X, carbon, and sulphur emissions helps Belarus meet its obligations under the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, although for Belarus this effect is rather modest because more than 70% of NO_X fallout is the result of transboundary transfer from the western countries. This, however, does not belittle the responsibility of the energy complex on reduction of hazardous emissions.

Environmental section of the Energy Policy includes:

1. Reduction of hazardous emissions by the energy complex through relatively inexpensive activities, i.e. introduction of multi-tip burners, multi-stage combustion with recirculation of flue gases, replacement of fuel oil with natural gas, development of systems for continuous control and emission regulation.
2. Investments for implementation of environmentally advanced activities must be made based on the integrated environmental and economic calculations with prioritisation of costs per emission reduction unit.
3. Shaping up of the tariff and price policies that encourage all economic entities to develop and introduce environment-friendly technologies and equipment.
4. Continued introduction of the deep conversion technology at oil refineries, which would ensure production of fuel oil with adjustable sulphur content.
5. Improvement of the air monitoring system and the operating management system, which includes economic and administrative impact control, and covers all emission sources.
6. Improvement of the legislation in accordance with the world standards and the economic capacity of the country.

The fuel consumption forecast for the period of 2006-2010 has been made based on four scenarios with the use of BALANCE application. All the scenarios derive from the State Integrated Programme for Retrofitting of the Fixed Assets of the Belarusian Energy System, Energy Conservation, and Increased Share of Local Fuels in Belarus. This Programme regards coal as a poor alternative for power and heat production due to the high transportation costs.

Baseline Scenario

The baseline scenario serves as a reference for comparison of alternative scenarios. The growing rates of various economy sectors' inputs into GDP are based on the National Sustainable Development Strategy 2020. The GDP growth rates used in the calculations are separate for each economy sector, and build on the data from Table 3.1.

Intensive Development Scenario (optimistic)

The intensive development scenario foresees higher GDP growth rates in all the economy sectors, with 5-6% annual average, and the respective structure of the used primary energy resources.

Intensive Development Scenario With Nuclear Power Plant

This scenario foresees same sectoral growth rates of inputs into GDP as in the optimistic scenario.

Table 3.4 shows the fuel consumption forecasts for the selected scenarios. According to the estimates, the intensive development scenario would require additionally 3 million t.r.f. of natural gas, mostly for heat and power production. All the scenarios foresee increase in the use of wood as fuel up to 6.3 million t.r.f. The calculations relied on the wood fuel price in the range of 40-45 USD per t.r.f., and also included capital investments for procurement of the necessary equipment. It can be expected that, within the proposed scenarios, wood fuel can be quite competitive. The estimates also show decrease in the share of fuel oil in the fuel balance of the country from 2.8 million t.r.f. to 2.1 million t.r.f. Introduction of nuclear power generating facilities would reduce the natural gas consumption by about 3 million t.r.f.

Based on the climactic, geographical, and meteorological conditions in the country, such sources as hydropower, wind and solar energy, biogas, solid waste, phytomass, crop residues, ethanol fuel, biodiesel fuel, and geothermal energy can be considered as potential renewable and unconventional sources of energy.

Although those fuels together can replace only a small portion of the currently used fuel, their expanded use in the nearest future in Belarus is very important due to a number of reasons. First, the use of alternative fuels would contribute to the development of own technologies and equipment, which can subsequently become an important export element; second, these sources are as a rule environment-friendly; third, their use in itself educates people to give preference to rationalism over wastefulness.

Hydropower resources. The aggregate capacity of all the watercourses of Belarus amounts to 850 MW, including the technically accessible 520 MW, and the economically feasible 250 MW. The main area of small hydropower development is the construction of new, and reconstruction or rehabilitation of the existing hydropower plants.

Table 3.4

Primary fuels consumption forecast for different scenarios, in 1,000 t.r.f.

	2000	2005	2010	2015	2020
	Baseline Scenario				
Natural gas	16,071	15,572	17,882	18,618	19,28
Liquefied natural gas	431	473	511	546	581
Fuel oil	2,821	2,248	2,163	2,127	2,134
Gasoline	1,348	1,339	1,469	1,560	1,696
Diesel fuel	2,394	2,455	2,517	2,736	2,992
Peat	1,104	949	1,024	1,098	1,151
Coal	602	333	338	352	382
Wood	2,566	3,548	4,514	5,443	6,356
Total	27,337	26,918	30,417	32,480	34,577
	Intensive Development Scenario				
Natural gas	16,071	15,572	18,622	19,924	21,209
Liquefied natural gas	431	473	511	546	581
Fuel oil	2,821	2,248	2,163	2,127	2,134
Gasoline	1,348	1,339	1,504	1,643	1,802
Diesel fuel	2,394	2,455	2,631	2,834	3,084
Peat	1,279	1,151	1,253	1,358	1,444
Coal	902	764	796	839	881
Wood	2,566	3,548	4,514	5,443	6,356
Total	27,812	27,551	31,994	34,714	37,491
	Baseline Scenario With Nuclear Power Plant				
Natural gas	16,071	15,572	17,882	17,524	16,098
Liquefied natural gas	431	473	511	546	581
Fuel oil	2,821	2,248	2,163	2,127	2,134
Gasoline	1,348	1,339	1,469	1,560	1,696
Diesel fuel	2,394	2,455	2,517	2,736	2,992
Peat	1,279	1,151	1,253	1,358	1,444

Coal	NA	1,014	1,057	1,108	1,160
Wood	2,566	3,548	4,514	5,443	6,356
Nuclear fuel	0	0	0	1,217	3,347
Total	28,039	27,801	31,365	32,403	32,460
	Intensive Development Scenario With Nuclear Power Plant				
Natural gas	16,071	15,572	18,622	18,181	18,115
Liquefied natural gas	431	473	511	546	581
Fuel oil	2,821	2,248	2,163	2,127	2,134
Gasoline	1,018	828	916	1,031	1,104
Diesel fuel	2,560	2,695	2,907	3,068	3,370
Peat	895	1,112	1,259	1,420	1,527
Coal	NA	1,014	1,057	1,108	1,160
Wood	2,566	3,548	4,514	5,443	6,356
Nuclear fuel	0	0	0	1,217	3,650
Total	27,492	27,490	31,949	33,624	34,346

Turboexpanders. Due to the existence of a well-developed natural gas infrastructure in Belarus, with continued use of significant amounts this resource, there is a virtually unused energy potential derived from the pressure drop in natural gas. This potential is estimated at the level of 60 MW. It can be retrieved by installing turboexpanders at a number of gas-distribution stations of the country, as well as at the gas-distribution plants of major gas consumers.

Wind energy. As of 1 January 2005, the total installed capacity of wind turbines equalled 1.1 MW, with the replacement rate of 400 t.r.f.

The available technologies of wind energy conversion into power with the conventional propeller-type wind turbines are economically unfeasible for Belarusian conditions and under the existing power tariffs. However, recent technological advancements make it possible to create wind turbines for the start-up wind speed as low as 3 mps, and nominal operational speed of 7-8 mps. Such wind turbines cost 800-1,200 USD per kW of installed capacity, which makes them far more appealing for customers. Moreover, the growing prices for imported natural gas shall invariably increase the costs of power generation, thus making it economically feasible to use wind energy technologies.

The wind energy role in the overall power generation system of Belarus is estimated for 2010 at the level of 7.34 million kWh (2,050 t.r.f.) with a total installed capacity of 4.1 MW; and for 2012 - 9.31 million kWh (2,610 t.r.f.) with a total installed capacity of 5.2 MW. The indicated amounts shall be annually corrected based on the updated prices of energy resources.

Biogas. The testing of biogas plants extracting biogas from livestock waste confirmed the need for an integrated assessment of their viability, because their biogas extraction alone is economically unfeasible compared to other types of fuel, but the combined effect of the resultant side products – fertilisers and better environment around the farms – make it worthwhile.

The total production of commercially viable biogas by all the sources is estimated at 160,000 t.r.f. per year.

Solar energy. According to the weather service of Belarus, on the average the country has in any given year 250 overcast days, 185 cloudy days, and 30 clear days, while the annual average of solar energy, taking into account nighttimes and cloudiness, is estimated at 243 cal per m^2 per day, which is equivalent to 2.8 kWh per m^2 per day, and with the conversion efficiency rate of 12% it comes down to 0.3 kWh per m^2 per day. Yet, based on the foreign experience, the specific investments into solar power plants and the prime cost of the generated power greatly exceed power generation costs of other sources. The technological progress in that area shall naturally reduce the costs, but for Belarus the share of solar energy will remain virtually unseen within the timeframe in question.

The main solar energy applications shall be solar water heaters and various solar dryers and heaters for agriculture and domestic purposes.

Under favourable economic and production conditions, within the timeframe in question, the solar energy can potentially replace 5,000 t.r.f. of organic fuel per year.

Solid waste. The potential energy contained in solid waste, which is accumulated on the territory of Belarus, is equal to 470,000 t.r.f. The bioprocessing of solid waste for gas extraction has the efficiency of no more than 20-25%, which is equivalent to 100,000-120,000 t.r.f. Another aggravating factor is the existence of old landfills in all the major cities, which have little room left for the incoming wastes. In the regional centres annual conversion of solid waste would generate 50,000 t.r.f. of biogas, and up to 30,000 t.r.f. for Minsk alone. Efficiency of this technology is manifested not only in the amount of generated biogas, but also in the environment rehabilitation factor, which in this case would be more important. The existing landfills in Belarus had been designed and constructed without taking into consideration the biogas potential, and the lack of knowledge in the field opens up new opportunities for additional research and work.

Phytomass. The phytomass of fast-growing plants and trees, which is considered to be a periodically renewable energy source, can be used as a feedstock for production of liquid and gaseous fuels. Under the climactic conditions of the country, one hectare of the energy plantation can yield up to 10 tons of dry matter, which is equivalent to about 4 t.r.f. With application of some agricultural techniques this yield can be doubled or trebled. It is more reasonable to cultivate the raw material on depleted peat-lands with poor conditions for agricultural crops. The total area of such abandoned peat-lands in the country is about 180,000 ha, which in future can become a stable and environment-friendly source of the energy feedstock. Lack of experience in massive conversion of phytomass into energy makes it difficult to make an accurate analysis of costs and calculate future fuel prices, because the whole operation requires specifically designed equipment, proper road infrastructure, conversion plants, and other activities. Experts predict that by 2010 this source of energy can account for 50,000-70,000 t.r.f.

Crop residues. Conversion of crop residues into energy is a brand-new direction for energy efficiency. The practical experience of crop residues conversion is available in Belgium and Scandinavia, while our country has never practiced it on a mass scale. The total energy potential of crop residues is estimated at 1.46 million t.r.f. per year. By the end of the forecast period, the amount of converted crop residues is likely to reach 20,000-30,000 t.r.f.

Ethanol and biodiesel fuel. Belarus has a considerable potential to introduce technologies for production of ethanol and biodiesel fuel from rapeseed and soybeans.

In future, biodiesel fuel from rapeseed and soybeans will be re-evaluated from the standpoint of its competitiveness in comparison with conventional fuels, because at the moment its prime cost is higher than that of the conventional diesel fuel, and its use in developed countries is justified by a very low negative impact on the environment.

Massive introduction of the ethanol production technologies requires first of all a proper reconstruction of distilling plants, which would minimise the investments.

Combustible waste fuel. Their total output in Belarus is assessed at the level of 580,000 t.r.f. per year, including 162,000 t.r.f. of methane-hydrogen fraction for polyethylene production, 14,500 t.r.f. of X-oil, 9,200 t.r.f. of concentrated bisulphite liquor, 36,900 t.r.f. of flax shive, and 2,400 t.r.f. of fuel-oil waste. The use of combustible waste fuels by processing plants and boiler houses is at the level of 70-100%.

The stockpiles of lignin (about 2 million tons) of the Bobruisk and Rechitsa hydrolysis plants are still used for these purposes, although on a limited basis.

Waste heat energy. The total waste heat energy output amounts to 17.9 million Gcal per year, including the technically accessible 10 million Gcal per year, and the actually used 2.9 million Gcal per year in 2003, or 17.2%, which is predicted to grow up to 4.5 million Gcal per year by 2010. The biggest waste energy output (about 96.5%) is produced by the enterprises of the Belneftehim Concern (11.1 million Gcal), the Belenergo Concern (2.72 million Gcal), the Ministry of Construction and Architecture (1.77 million Gcal), and the Ministry of Industry (0.97 million Gcal). Against the background of a higher reclamation level of other waste energy resources, the low level of use of this type of energy is conditioned by virtually no exploitation of the heat generated by such low-potential source as recycling water, which currently accounts for 50.2% of all the waste energy resources of Belarusian enterprises.

The low level of use of waste energy resources in most of the cases occurs due to the irregularity and seasonal nature of their output, lack of consumers, financial constraints related to the procurement of heat-recovery equipment (especially for low-potential waste energy recovery), and lack of a smoothly running mechanism for interdepartmental use of waste energy.

With the required amount of financing of about 70 million USD, the use of waste energy can be enhanced by 2010 through installation of heat-recovery systems:

- high-potential systems equivalent to about 200,000 t.r.f.;
- medium- and low-potential systems equivalent to about 60,000 t.r.f.

The main sources of waste heat energy are:

- Open Joint Stock Company GrodnoAzot;
- sulphuric acid plants of the Gomel Chemical Factory;
- Petrochemical Enterprise Naftan, including its hydrogen production facilities that generate significant amounts of waste heat energy;
- Mozyr Oil Refinery.

The source of waste heat energy is the energy generated as a result of chemical reactions during technological processes. The predicted increase in the use of waste heat energy can be ensured only if the long-term quantitative plans for oil refining and production of mineral fertilisers are fulfilled.

3.1.3. Industrial processes

The main industrial GHG emitters are metallurgy, chemical and petrochemical industries, construction material producers. The above industries generate and emit virtually all the greenhouse gases, but the actual contribution of different sectors can vary considerably.

The share of industrial processes in the aggregate GHG emissions equals ~3%. The biggest industrial GHG emitters are cement producers (CO_2, SO_2) and lime producers (CO_2). In 1990-1995 GHG emissions dropped due to the decline in production, while the recent years are characterised by a certain increase in emissions.

3.1.3.1 Industrial sectors development forecast

The National Sustainable Development Strategy Concept 2020 and the Belarus Industrial Complex Development Concept and Programme 1998-2015 envisage a serious restructuring of industrial sectors. The restructuring must be directed at the development of up-and-coming sectors and industries through introduction of new equipment and advanced energy- and resource-efficient environment-friendly technologies. There is an evidence of decelerated development of conventional, mostly metal- and energy-intensive, sectors and industries, and accelerated development of hi-tech export-oriented industries. Such sectors as food industry, forestry, wood processing, pulp and papermaking industry, are expected to demonstrate the highest rate of development.

3.1.4. Agriculture

Agriculture consists of two sub-sectors: livestock farming and crop farming.

The Belarusian agriculture specialises in cultivation of crops that are traditional for temperate latitudes. Cereal crops like barley, rye, wheat, potatoes, and fodder crops dominate crop farming. Livestock farming is mostly characterised by breeding cattle for meat and milk, also pig breeding and poultry farming.

As of 1 January 2006, agricultural lands occupied 9,012,000 ha or 43.4% of the land reserves of Belarus, including 5,542,300 ha of arable lands and 3,289,200 ha of meadowlands.

Belarus has the following types of agricultural emission sources:

- cattle breeding and poultry farming, which provide emissions caused by the internal (digestive) fermentation of agricultural and domestic animals, and also emissions induced by collection, stockpiling and use of the waste products of cattle and fowl (manure and poultry droppings);
- agricultural soil-induced emissions;
- incineration of agricultural wastes on the fields.

The emission forecast focuses mostly on the above-listed sources with due consideration of possible changes in the agro-industrial complex.

3.1.4.1 Agriculture development forecast

Cattle inventory is the basic indicator for livestock farming. Thus, two scenarios have been considered for the livestock farming development. The first (baseline) scenario postulates that the livestock population stabilises at the level of 2003.

The second alternative development scenario in its assessment of the emission range relies on the indicators stipulated by the Forecast of Socio-Economic Development of the Agro-Industrial Complex of Belarus 2015, which envisages a certain increase in the livestock population.

Crop farming contributes to the GHG emissions mainly during the disposal of crop residues.

The existing crop farming forecasts predict growing production of grain, potatoes, sugar beet, flax, and other cultures. However, as long as the production increase is planned to be ensured through the yield enhancement, one may expect that the amount of crop residues will not increase considerably, and therefore, the predicted emissions will remain at the level of 2000.

Nitrogen fertilisers' application forecast.

According to the Belarusian Research Institute of Soil Studies and Agro-Chemistry, the annual consumption of nitrogen fertilisers is specified at the level of 600,000 tons. Nitrogen fertilisers' application rate shall remain the same within the period until 2020.

3.1.5. Land-use change and forestry

In accordance with the Strategic Forestry Development Plan for Belarus, the country is moving towards the permanent forestry and introduction of the information system for forestry management. The changing size of the areas under forests lies within the statistical and forecast specifications of 37.6% to 39% of lands under forests.

Implementation of activities for reduction of CO_2 emissions from degraded wetlands:

1. Governmental resolution about transfer of the decision-making authority as regards the management of depleted peat-lands from the national to local level.
2. Environmental rehabilitation of the degraded wetlands through re-inundation and resumption of the peat-formation processes.
3. Harmonisation of the structure of drained peat lands under crops with the drainage

plans and scientifically justified recommendations.

4. Transition towards environmentally and economically justified use of peat soils.
5. Fire prevention activities on peat-lands.

The Belarusian forestry has the following long-term plans for improved forest protection and conservation:

- to optimise the composition and structure of forests for their greater sustainability by transition from single-species and single-age plantations to mixed, composite, and all-aged forests, including their adaptation to the climate changes;
- to intensify the work on fire prevention, pathological and environmental monitoring of forests, also with the application of remote probing equipment;
- to implement the programme of optimisation of drained and degraded forests through reconstruction of efficient forest drainage systems, and re-inundation of the forested lands that had been wrongly drained or affected by peat extraction activities.

3.2. Prospective estimation of greenhouse gas emissions and efficiency evaluation of reduction measures

3.2.1. Energy sector

3.2.1.1 Prospective estimation of greenhouse gas emissions and efficiency evaluation of reduction measures in the energy complex

The GHG emission forecast has been developed for four scenarios of economy development. The scenarios are based on the State Integrated Programme for Retrofitting of the Fixed Assets of the Belarusian Energy System, Energy Conservation, and Increased Share of Local Fuels in Belarus, and the Energy Security Concept. Description of the scenarios can be found above in Section "Energy sector" Part III. It is expected that the total fuel consumption in 2020 will be:

- as per baseline scenario – about 35 million t.r.f.;
- as per intensive development scenario – about 37 million t.r.f.;
- as per baseline scenario with nuclear power plant – about 32.4 million t.r.f.;
- as per intensive development scenario with nuclear power plant – about 34.3 million t.r.f.

Thus, the fuel consumption is not expected to grow significantly until 2020, it is going to be about 80% from the level of 1990. Furthermore, the energy consumption of GDP is expected to decrease annually by 3-4%.

For the reasons of energy security and transportation costs, the Energy and Environment Security Concept does not foresee construction of any coal-fired power plants. There is expected to be no increase in fuel oil-based heat or power production either. In view of the growing natural gas prices up to 120-150 USD per 1,000 m^3, the Concept anticipates construction of a nuclear power plant for 2,000 MW with the commissioning of the first block in 2015.

The GHG emission forecasts for all the scenarios have been made separately for the selected economy sectors with due understanding of the fact that organic fuel combustion for heat and power generation is done with varying efficiency by different sectors of economy. We also made a forecast for GHG emissions associated with the vehicles-induced combustion of gasoline, diesel fuel, compressed and liquefied natural gas. Table 3.5 describes CO_2 emission forecasts for all the scenarios.

Table 3.5

CO_2 emissions on the basis of fuel consumption forecasts, Gg

	1990	2000	2005	2010	2015	2020
	Baseline Scenario					
Agriculture	3,890.88	2,847.13	3,001.50	3,164.76	3,337.42	3,520.01
Heat and power generation	53,324.37	41,505.05	42,788.18	50,482.83	53,850.63	57,003.42
Housing and utilities	8,043.76	4,831.43	4,989.22	5,154.82	5,328.63	5,511.05
Industry	14,940.26	6,893.42	7,212.06	7,464.52	7,678.67	7,871.36
Service sector	6,432.58	4,271.20	4,462.65	4,674.19	4,908.60	5,166.29
Vehicles	17,852.21	5,786.51	6,325.25	6,982.61	7,708.30	8,509.39
Total	104,484.06	66,134.75	68,778.87	77,923.73	82,812.24	87,581.51
	Intensive Development Scenario					
Agriculture	3,890.9	2,847.1	3,001.5	3,164.8	3,337.4	3,520.0
Heat and power generation	53,324.4	41,505.1	42,788.2	51,874.8	56,234.4	61,185.3
Housing and utilities	8,043.8	4,831.4	4,989.2	5,154.8	5,328.6	5,511.0

Industry	14,940.3	6,893.4	7,212.1	7,464.5	7,678.7	7,871.4
Service sector	6,432.6	4,271.2	4,462.6	4,674.2	4,908.6	5,166.3
Vehicles	17,852.2	5,786.5	6,325.3	6,982.6	7,708.3	8,509.4
Total	104,484.1	66,134.7	68,778.9	79,315.6	85,196.0	91,763.4
Baseline Scenario With Nuclear Power Plant						
Agriculture	3,890.9	2,847.1	3,001.5	3,164.8	3,337.4	3,520.0
Heat and power generation	53,324.4	41,505.1	42,788.2	50,482.8	51,770.8	51,078.0
Housing and utilities	8,043.8	4,831.4	4,989.2	5,154.8	5,328.6	5,511.0
Industry	14,940.3	6,893.4	7,212.1	7,464.5	7,678.7	7,871.4
Service sector	6,432.6	4,271.2	4,462.6	4,674.2	4,908.6	5,166.3
Vehicles	17,852.2	5,786.5	6,325.3	6,982.6	7,708.3	8,509.4
Total	104,484.1	66,134.7	68,778.9	77,923.7	80,732.4	81,656.1
Intensive Development Scenario With Nuclear Power Plant						
Agriculture	3,890.9	2,847.1	3,001.5	3,164.8	3,337.4	3,520.0
Heat and power generation	53,324.4	41,505.1	42,788.2	51,874.8	54,355.9	54,849.3
Housing and utilities	8,043.8	4,831.4	4,989.2	5,154.8	5,328.6	5,511.0
Industry	14,940.3	6,893.4	7,212.1	7,464.5	7,678.7	7,871.4
Service sector	6,432.6	4,271.2	4,462.6	4,674.2	4,908.6	5,166.3
Vehicles	17,852.2	5,786.5	6,325.3	6,982.6	7,708.3	8,509.4
Total	104,484.1	66,134.7	68,778.9	79,315.6	83,317.5	85,427.4

3.2.1.2 Methane emission forecast

The main methane emission sources are the volatile emissions from oil and gas systems (they account for 85.9%). Volatile methane emissions have been calculated based on the anticipated needs for oil and natural gas in accordance with the methodology of the Intergovernmental Panel on Climate Change. As long as all the scenarios have little difference in the calculated needs for oil and natural gas, Tables 3.6 and 3.7 display expected methane emissions only for the baseline scenario.

Table 3.6

Volatile methane emissions from oil and gas systems, Gg

Year	Oil			Gas				Total
	Recovery	Refining	Storage	Recovery	Transportation	Other leaks		
						by energy and industrial sectors	by other sectors	
2005	0.17	0.5	0.09	2.23	76.06	50.75	2.81	132.6 1
2010	0.14	0.53	0.1	2.03	83.32	55.61	3.07	144.8
2015	0.12	0.59	0.11	1.75	86.78	57.92	3.2	150.47
2020	0.11	0.63	0.12	1.6	87.3	58.34	3.22	151.32

Table 3.7

Methane emissions from fuel combustion, Gg

	1990	2000	2005	2010	2015	2020
Agriculture	0.304	0.228	0.241	0.256	0.271	0.287
Heat and power generation	0.906	0.644	0.651	0.761	0.804	0.845
Housing and utilities	17.097	9.150	9.455	9.776	10.112	10.465
Industry	0.399	0.259	0.286	0.306	0.322	0.335
Service sector	16.425	11.880	12.306	12.777	13.300	13.873
Vehicles	3.105	1.270	1.388	1.533	1.692	1.868
Total	38.24	23.43	24.33	25.41	26.50	27.67

3.2.1.3 Nitrous oxide emission forecast

Nitrous oxide emissions in Section "Energy sector" constitute less than 1%, thus making it inexpedient to make any serious chronological forecast, while the absolute values lie within the range of 0.36-0.50 Gg.

Table 3.8 displays the chronological forecast of GHG emissions from organic fuel combustion. As long as the GHG emissions, with the exception of CO_2, have little variation in different scenarios, the results listed below correspond only to the baseline scenario.

Table 3.8

GHG emissions from organic fuel combustion

	Economy sectors	1990	2000	2005	2010	2015	2020
N_2O	Agriculture	0.0307	0.0226	0.0239	0.0252	0.0266	0.0280
	Heat and power generation	0.1093	0.1854	0.2075	0.2474	0.2701	0.2921
	Housing and utilities	0.0810	0.0416	0.0430	0.0445	0.0461	0.0477
	Industry	0.0745	0.0425	0.07450.0	0.0551	0.0588	0.0616
	Service sector	0.0646	0.0453	0.0473	0.0494	0.0519	0.0545
	Vehicles	0.1450	0.0463	0.0507	0.0559	0.0617	0.0681
	Total	0.5050	0.3837	0.4223	0.4775	0.5151	0.5522
VNMOC	Agriculture	14.12	10.62	11.24	11.90	12.60	13.34
	Heat and power generation	4.53	3.22	3.25	3.80	4.02	4.22
	Housing and utilities	10.97	5.28	5.47	5.66	5.87	6.08
	Industry	7.04	2.85	2.61	2.47	2.41	2.39
	Service sector	7.52	5.21	5.47	5.76	6.08	6.44
	Vehicles	177.08	69.74	76.22	84.13	92.85	102.48
	Total	221.26	96.91	104.26	113.73	123.83	134.95
NO_X	Agriculture	38.09	28.41	30.03	31.75	33.56	35.48
	Heat and power generation	143.00	114.41	119.00	140.97	151.14	160.75
	Housing and utilities	7.75	4.61	4.76	4.91	5.08	5.24
	Industry	59.21	27.10	27.67	28.24	28.82	29.41
	Service sector	6.85	4.63	4.83	5.04	5.28	5.54
	Vehicles	177.36	55.84	61.05	67.39	74.40	82.13
	Total	432.25	235.01	247.34	278.30	298.27	318.55

SO_2	Agriculture	11.35	8.21	8.64	9.09	9.57	10.07
	Heat and power generation	175.47	158.50	161.01	176.81	183.83	189.54
	Housing and utilities	14.63	9.92	10.19	10.47	10.76	11.07
	Industry	93.72	27.90	27.46	27.45	27.71	28.13
	Service sector	28.17	21.29	21.75	22.25	22.81	23.42
	Vehicles	36.44	9.95	10.87	12.00	13.25	14.63
	Total	359.77	235.77	239.91	258.07	267.92	276.86

3.2.2. Industry

3.2.2.1 Prospective estimation of greenhouse gas emissions and evaluation of efficiency measures in industry

Industry makes a small contribution to the GWE – roughly 3.1% according to the 2000 level. Greenhouse gas emissions in industry mainly depend on the size of industrial output. However due to the enforcement of green policies and measures with regard to industrial processes, the growth rate of greenhouse gas emissions will be smaller than the growth rate of industrial output. Development targets of main GHG emitting sectors in the aforementioned documents are approximately the same, so a forecast of greenhouse gas emissions follows one scenario.

3.2.2.2 Carbon dioxide emission forecast

Carbon dioxide emissions are composed of two sources: cement and lime production. In cement production CO_2 appears at the stage of making clinker – an intermediate product. Estimations show that by 2020 carbon dioxide emissions may increase with a 15% range versus 2000.

3.2.2.3 Sulphur dioxide emission forecast

The main sources of SO_2 emissions are production of cement, ammonia and sulphuric acid. Since sulphuric acid production is responsible for 94-96% of SO_2 emissions, this particular source will determine the overall emission trend. According to obtained data, by 2020 SO_2 emissions level will be about 84% of the 1995 emissions level. Due to planned increase of sulphuric acid production compared to 2000, forecasted emission growth will be over 45%.

3.2.2.4 Carbon oxide emission forecast

The main sources of carbon oxide emissions are production of caprolactam, ethylene and propylene, ammonia and a number of metals. According to obtained data, by 2020 CO emissions may amount to 7.8 Gg, i.e. compared to 2000 taking into account green policies a possible increase of this compound will be less than 3%.

3.2.2.5 Nitric oxide emission forecast

The main sources of nitric oxide emissions are metallurgy and a number of chemical productions. Since the main source of NO_2 emissions is production of nitric acid, a level of forecasted emissions by 2020 will practically remain unchanged. A possible slight reduction of emissions may be linked to planned modernization of obsolete equipment.

3.2.2.6 Methane emission forecast

Estimations show that a minor increase of methane emissions is expected in the future due to plans to scale up steel production. Vis-à-vis the 2000 level methane emissions will make up about 9% by 2020.

3.2.2.7 VNMOC emission forecast

The main source of VNMOC emissions is production of ammonia, whose input to aggregate VNMOC emissions is over 82%. Estimations show that over the period 2000 - 2020 the total GWE from industrial processes may increase by 11.7% mainly due to output growth.

However taking into consideration planned ecologization of economic activities in the country, greenhouse gas emissions will be increasing much slower than the volume of output.

3.2.3. Agriculture

3.2.3.1 Prospective estimation of greenhouse gas emissions and evaluation of efficiency measures in agriculture

A forecast of greenhouse gas emissions from agriculture built upon available targets of animal husbandry development, application of mineral fertilizers, areas of agricultural land on organogenic soils. Since there are two possible scenarios for animal husbandry development, two methane emission scenarios have been considered. As for nitrous oxide, primarily emitted by nitrogen mineral fertilizers and organogenic soils, only one emission scenario was considered, since the usage of nitrogen fertilizers met needs in 2005 and will be stabilized from now on; there is also one forecast scenario for how fast ameliorated organogenic soils will be degrading.

3.2.3.2 Methane emission forecast

Calculations show that under various scenarios of livestock breeding development no increase of methane emissions will take place in the future.

By 2020 they won't reach the 1995 level (much less the 1990 level) making up 337,000 tons under the baseline scenario and 393,000 tons under the best-case scenario. Compared to 1990, methane emissions in 2020 will be: under the baseline scenario - 64%, under the best-case scenario - 74%.

3.2.3.3 Nitrous oxide emission forecast

According to available data, nitrous oxide emissions in 2020 may constitute 26,500 tons or 86% of the 1990 level. Compared to 2000 there is a possible increase of emissions by approximately 1.4 times. Since the main sources of nitrous oxide emissions are nitrogen fertilizers and peaty soils, a ratio of these particular sources will determine the general emission trend. With regard to the use of peatlands in agriculture, one may say with a fair amount of certainty that their areas will be decreasing, and so will emissions. At the same time the use of nitrogen fertilizers tends to increase, and according to various estimates their consumption may reach the required level already within the coming years.

3.2.4. Land-use change and forestry

3.2.4.1 Forecast of greenhouse gas emissions and sinks in forestry

The main CO_2 sink in the territory of Belarus is its sequestration by forest biomass. In order to evaluate it, data about typological structure of forest vegetation and distribution was used. CO_2 estimations were made based on specific increases of forests and their areas for each species and age category identified.

Estimation is made for 2001, 2005, 2010, 2015 and 2020. Middle-aged coniferous and small-leaved forests, as well as 2nd-group underwood and maturing treestands of these forest formations have a key role to play in CO_2 removal. The forest area substantially expanded in 2005 compared to 2004 not only because of planting activities, but also due to the inclusion of part of the previously contaminated land and forest into the forest stock. In 2015 forecasted forest utilization will amount to 18 million m^3 versus 10.8 million ^{3} in 2000.

In 2005 forestry organizations conducted reforestation and afforestation in the area of 51,471ha, forest planting and sowing – in the area of 45,031ha. As for the contaminated areas, reforestation and afforestation covered the area of 12,184ha (110.5% of the 2004 level). Facilitation of natural reforestation took place in the area of 6,440ha, which is 4.4% more than in 2004.

Two groups of natural and economic processes need to be mentioned as measures contributing to greenhouse effect reduction at a country scale:

- those that reduce CO_2 emissions into the atmosphere from forest ecosystems and certain changes in the land-use sector;

- those that increase productivity (increase) and thus increase biomass stock in forest ecosystems, and certain changes in land use.

Blanket logging basically puts forest ecosystems into a condition of minimum productivity and a heavy stock of mortmass. Two practices are effective here: 1) forest regeneration through protection of underwood during felling and new tree planting, blanket or selective; 2) economic use of remaining mortmass to the fullest extent possible. This ensures a conditional transformation of felling into 1st-age group underwood in some areas.

Since 2nd-age group underwood, middle-aged and maturing forests have the highest productivity, a noticeable increase of CO_2 sinks with the same forest area will be possible if shares of these three age categories (II, IV) in the total forest area increased. Overmature forest needs to be preserved, if there are historical, conservation or other reasons for that. The scenario suggested by the Forestry Development Strategic Plan of Belarus recommends a strategy of increased forest felling which would make the forest stock "much younger" already in a decade, thereby improving CO_2 removal.

Under this scenario the 'emissions-sinks' ratio shifts in favour of sinks due to carbon sequestration in wood processing products and biomass in general. Stopping agricultural use of low-productivity lands, a particularly clear trend of the past decade, may be accompanied by CO_2 emissions from soil. Ecologically, the wisest thing to do is to afforest these territories. The same logic applies to recultivation of disturbed lands unsuitable for farming use. Here afforestation will lead to greater CO_2 removals over emissions. A forested area becomes a carbon dioxide sink. Lime application – indispensable to farming technology in the country – is a strong source of CO_2 emissions. At present, soil liming needs have appreciably decreased, because over the previous decades they reached a sufficient level of soil deoxidation which needs to be maintained. Nevertheless, the 'optimum' lime application scenario provided earlier (2000 tons and more a year) greatly increases CO_2 emissions from soils. A liming scenario with a stable balance of sinks and emissions at a lower level was considered. By 2020 the optimum percentage of forest land is reached – 39.6%. As a result, land is practically no longer withdrawn from use leading to CO_2 sink reduction.

3.2.4.2 Forecast of greenhouse gas emissions and removals by mire ecosystems

For the purpose of the forecast, the area of natural mires will not change as land drainage stops and the area of peat stock under development stabilizes.

Carbon dioxide emissions from 1 ha of exhausted peat deposits are 22.5 tons a year, from 1 ha of active peat deposits – 11.3 tons. The area of peat stock under development will stabilize at the 2000 level. Methane emissions from 1 ha of restored mires are 0.005 tons a year. So the following conclusions can be drawn:

1. By 2020 carbon dioxide emissions from drained peatlands will decrease by 718,700 tons a year compared to 2000.
2. Carbon dioxide emissions from depleted peat deposits will reduce by 574,000 tons a year.
3. Carbon dioxide removals by restored mires will be constantly increasing due to an expanding area of restored mires on the ineffectually drained peatlands and depleted peat deposits and will increase by 56,800 tons a year.
4. Methane emissions will increase by 350 tons a year due to an expanding area of restored mires.

Table 3.9

Total greenhouse gas emissions (sinks) under different scenarios

	1990	2000	2005	2010	2015	2020
Baseline scenario	105,536	66,726	69,395	78,600	83,529	88,340
Intensive development scenario	105,536	66,726	69,395	79,998	85,923	92,540

Baseline scenario and nuclear power plant construction	105,536	66,726	69,395	78,600	81,439	82,387
Intensive development and nuclear power plant construction	105,536	66,726	69,395	79,998	84,036	86,176
Total CO_2 sinks, Gg	-25,130	-28,200	-28,200	-26,500	-26,450	-24,800

PART IV. VULNERABILITY ASSESSMENT, CLIMATE CHANGE IMPACT AND ADAPTATION MEASURES

4.1. Climate characteristics of Belarus

A series of warm years has been typical of Belarus' climate of late. Throughout the entire last fifteen years, the greatest positive deviations of the air temperature are observed in winter and in the first half of spring (from December to April). There is also a steady, but less substantial positive temperature deviation in autumn. Shortage of precipitation is a distinguishing feature of most months of the warm period of the year.

A temperature analysis in the last five-year periods (1990-2004) showed that during the last pentad (2001-2005) the temperature continued to rise in most months of the year compared to the previous periods. The exception was the temperature in February and June, especially in the north of Belarus. The months of November, December, March, July and August saw considerable rises in temperature. The last pentad was distinguished by increasing temperatures in November and December, the months which in the preceding two pentads often were the coldest months of the year.

Thus, the temperature continues to rise throughout Belarus, although the annual variation pattern has become somewhat different: the warming is more pronounced in the second half of the year (VII - XП), whereas earlier it had been more intensive in January-March. The warmest winters were in 1988-1989 and 1989-1990. A continuous long-term series of the warmest winters over the period of instrumental observation (1881-2005) took place between 1989 and 1995, with the average temperature of 1.6°C.

Other lasting warm-winter series could be observed in the first half of the 1970s, second half of the 1950s and first half of the 1910s. However for these five-year series the average winter temperature ranged between -2.5…-3.5°C. The sharpest difference in the "south-north" temperatures was recorded in the last pentad, especially in February-March and October-November.

Changes in precipitation in the last three pentads are more complex by nature. In the north of the country the amount of precipitation continues to increase similar to the previous two decades. Unlike before, in the last decade increased precipitation could be observed in the central and southern parts of Belarus.

Recently the precipitation growth has been particularly strong in these regions in January. In spring and June, the amount of precipitation in southern Belarus continues to decrease which produces negative impacts on agricultural production. In the central part of Belarus during two out of three spring months (III and V) the precipitation somewhat lessened in the last five-year period. The precipitation growth is particularly considerable countrywide in July, August and October. The precipitation growth is greater in the north of Belarus. Decreasing amount of precipitation in the last 15 years is a typical feature of September.

So, in certain months of the year (V, VIII, X, I, II) in the last decade precipitation tends to increase in the south and centre of Belarus. In the north of the country a precipitation growth trend in most of months covers the period exceeding 30 years.

Recent precipitation variation patterns in the northern, central and southern parts of Belarus share a greater degree of similarity as opposed to 20-30 years ago. It is seen in the general tendency of increased precipitation, whereas previously precipitation dropped in the south and rose in the north noticeably. However the growth value of monthly mean precipitation totals in recent years remains smaller in the south than in the north and central part of Belarus.

Changes in the annual precipitation course over the last five years – reduction in precipitation in May-June (especially in the south), rise in precipitation in July-August (especially in the north and centre) – deteriorated conditions for crop development. However in harvesting terms the conditions are more favourable because the amount of September precipitation has been decreasing in the last 15 years. Increasing precipitation in October over the last pentad (2001-2005) has been conducive to winter crops.

4.2. Agriculture and Change in Agroclimatic Potential

There is a fair amount of contradiction in how climate change is forecasted to impact upon agriculture at a global scale. This is due to great uncertainty, lack of research and development in the field, complexity and ambiguity of the ongoing processes. These forecasts are mainly focused only on natural fertility trends. When viewed from a formal angle of natural sciences, an increase in the CO_2 concentration to a certain point helps biomass growth, because this gas is a raw material for photosynthesis. For example, a group of academicians, namely Y. Israel, M. Budyko and L. Yanshina, predicted back in the 1990s that if the CO_2 concentration doubles, it will help feed an extra billion people.

Due to uncertainty of numerous changes taking place in the nature, it is very difficult to predict qualitative effects of the global climate change for Belarus. In particular, a respective modelling and forecasting system requires improvements. At present, global atmosphere circulation models and their modifications are commonly used worldwide for developing scenarios of agricultural impacts of climate change.

Agricultural industry of Belarus largely depends on possible climate changes. Experts point to mixed impacts of such changes on agriculture, where positive consequences may be combined with negative ones. Many climate-related scenarios and predictions emphasize the point that the transformation of climatic conditions will be related to an alternation in frequency of agriculturally unfavourable events. Risk may be posed by a rising likelihood of poor harvests as a result of more frequent and recurring droughts and increased dryness in the territories of several regions.

The present-day structure of the national land stock undergoes certain changes as far as the purpose and types of land are concerned. Developing best land stock structure is an essential area of activity here. Environmentally friendly use and protection of land is an important element of wise nature use in the agroindustrial complex. This key point will guide and inform a policy of optimized use of agricultural lands in the coming years. Addressing the problems ensuing from the large-scale drainage reclamation of wetlands, mainly peatlands, and control of water erosion and soil deflation will be placed in special focus.

Assessing the agroclimatic resources of Belarus and its regions, A. Vitchenko (1996) considered four arbitrarily assigned climate change scenarios that reflect (with regard to a climate norm), on the one hand, increasing precipitation totals in the context of cold weather, and on the other hand – declining precipitation totals in the context of warm weather (Table 4.1) [7].

Table 4.1

Possible Climate Change Scenarios in Belarus

Parameter	Scenario			
	I	II	III	IV
Air temperature, °C	-1.0	-0.5	+0.5	+1.0
Precipitation, %	+20	+10	-10	-20

Based on an analysis of climate change assessments in Belarus, there is danger involved in an option where the air temperature rises by 1°C and the amount of precipitation drops (already recorded for the central and southern parts of the country). With this option of the numerical experiment, the crop capacity reduction may reach 4-16% for cereal crops, 8-20% for potato and 16-26% for long-fibred flax. The northern areas are an exception (landscapes of the Poozerie Province), where the growing of winter cereal crops may result in a slight yield increase of 1-2% determined mainly by better thermal conditions of the vegetation period (Table 4.2).

Possible rise in air temperature will improve conditions for the growing of winter cereal crops in the landscapes of the Poozerie and Central Elevated Province. In the Pre-Polesie and Eastern Provinces they will remain close to mean multi-year conditions, and in the Polesie Province they will get worse leading to reduced productivity of these crops.

Rise in air temperature will lead to growing discrepancy between intensity of thermal conditions during the vegetation period for barley and potato and to a greater extent − long-fibred flax – and development needs of the said crops and reduce their productivity throughout Belarus.

Increased precipitation in the context of dropping air temperatures leads to a loss of productivity for all crops (down to 10-15%, scenario I, Table 4.3) [7].

Table 4.2

Predicted change in productivity of staple crops, %

Crop	Landscape Province					Belarus
	Poozerskaya	Central Elevation	Pre-Polesie	Eastern	Polesie	
Winter 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
Fibre flax	82.5	78.7	73.1	74.7	66.9	75.5

Table 4.3

Changes in crop productivity under different climate change scenarios, %

Scenario	Region					
	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	ПО	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	1161	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

Temperature rise and precipitation reduction, on the contrary, contribute to certain improvement of agroclimatic conditions for the growing of cereal crops and potato causing productivity to increase by 5-10 and 9-22%, respectively. However a small reduction in precipitation is able to bring about a more frequent occurrence of drought-related phenomena that would lead to poorer yields.

Projected assessment of a bioclimatic potential (BCP) change or, according to the other terminology, primary biological productivity as a total productivity of dry overground biomass of grass agroecosystem over the period of one year with a temperature above 5 °C, based on the GFDL model (U.S.) for doubling CO_2, for Belarus was performed by O. Sirotenko (1991) on the basis of economic regions of the former USSR [50]. In the context of current agricultural background BCP growth is projected at 7%, with optimal mineral nutrition or adequate moisture supply - at 15%, and with the combination of both latter conditions – at 16%. Agroclimatic changes imply a longer vegetation period (plus 54 days), lack of moisture by 0.8 and reduction of Selyaninov’s hydrothermal coefficient by 0.04. According to the 2 × CO_2 scenario, the European part of the former USSR should expect a rise in winter temperatures by 6.8 °C, and summer temperatures – by 3.1 °C.

Modern BCP assessments of arable land in Belarus in the context of global warming based on the HADCM3 scenario are given in Table 4.4. The following trend which might be of much account for agricultural development can be traced: with a high level of intensive farming, i.e. massive application of fertilizers and ameliorants, the productivity of arable land will increase in the context of global warming. The productivity of land containing a low level of fertilizers and ameliorants will conversely deteriorate under the warm climate. A drop in BCP values with a low level of farming intensification will be quite appreciable (down 11%). Table 4.4 data can be construed as follows: fertilizer efficiency will increase in the territory of the Republic of Belarus during climate warming under the scenario in question.

Table 4.4

Changes in bioclimatic potential (BCP) for arable land and climate-dependent yield (CDY) of cereal crops under the HADCM scenario

Region	Current level of mineral nutrition				Adequate level of mineral nutrition and moisture supply			
	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 4.4 also contains data that describes possible changes in climate-dependent yield of cereal crops in the context of global warming. Calculations based on dynamic models of crop productivity confirm, above all, the known data about high efficacy of farming chemicalization in Belarus – yielding capacity may be enhanced from 20 - 26 to 46 - 49 cwt/ha or nearly doubled by introducing better conditions of mineral nutrition. However, under the HADCM3 scenario, yielding capacity decreases during climate warming with both low and high levels of farming technology. The reason for yield decline is a shorter vegetation period (acceleration of ripening) because of a higher thermal background. To a certain degree declining yield of spring cereals may be precluded by choosing earlier planting and/or switching to late varieties capable of taking better advantage of increasing heat resources.

According to O. Sirotenko and co-authors, relying on one climate-change scenario for crucial conclusions is obviously not sufficient even if it bases itself on a well-established global climate model (GCM). The need for continued calculations is stressed using the CLIMATE-SOIL-HARVEST imitation system for other climate-change scenarios, which significantly improves accuracy of calculations. Calculation results for the GFDL (U.S.A.) scenario are provided in Table 4.5.

The data contained in the left-hand side of Table 4.5 is comparable with that for CDY in Table 4.4 by CO_2 level and soil fertility. Scenarios can be found to have essential differences only for the nearest decades. The GFDL scenario expects an increase of climate-dependent yield of cereals (20%) in the early stage of global warming. However taking into account a very small expected yield growth (a mere 1-3%) within the territory of the Baltic States and Ukraine, the result for Belarus may be related to some accidental causes. This conclusion also seems cogent because subsequently yield growth is replaced by yield decrease, and assessments of yield decrease for Belarus and the Baltic States are getting close (see the left-hand side of Table 4.5).

Table 4.5

Expected yield changes (as % of the base level) of cereal crops for the GFDL scenario regarding and ignoring CO_2 growth in the atmosphere

Country, region	Ignoring CO_2			Regarding CO_2		
	Projection 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

Also a role of increasing CO_2 content in the atmosphere should be considered. Admittedly, ignoring direct plant impact of larger CO_2 concentration in the atmosphere makes any assessments of expected changes in agricultural productivity induced by the greenhouse effect unrealistic. The Table 4.5 inputs confirm the relevance of this factor once again. A positive impact of CO_2 enrichment of the atmosphere completely, if not excessively, offsets a possible drop of yielding capacity caused by the warm climate in the territory of Belarus as per the GFDL scenario (see Table 4.5). The HADCM3 scenario may be assumed to deliver a similar inference.

4.2.1 Adaptation of Belarusian agriculture to climate change

The reality of changing climate and farming practices in Belarus requires the elaboration of a proactive dedicated programme designed to facilitate adaptation of the farming sector and its sustainable development under new conditions. It is necessary to continue research to obtain better accuracy of climate change predictions in agricultural areas. These predictions will then become the basis for updated local agricultural development programmes that take into account climate changes. These programmes are not unlikely to envisage changes of regional farming specialization, patterns of sown area, etc. all the way to limitations of agricultural production. At the moment the climate factor is not taken into account, which, as a consequence, may have serious social and economic losses in the country, ineffective investment allocation in the farming industry in the near future.

Under these new circumstances essential farming development principles should include: measures to adapt agricultural development to climate changes, consideration of current and future natural peculiarities of the functioning of land resources, dynamics of natural and economic fertility. Already guided by these principles, the Ministry of Agriculture and Food and respective institutions should take steps to develop farming sector, including by way of mechanization, chemicalization and amelioration, and promote technological innovation. In the light of the above, an appropriate system of regulators should be put in place (preferences, loans, taxes, etc.) for setting new priorities in the allocation of resources and investments in agriculture, and enhancing the role of costs in delivering greater sustainability of the farming sector in the near future.

The following points should be borne in mind in doing so:

> Major losses in agriculture are associated with adverse effects of harmful meteorological events, such as droughts, frosts, heavy rains, hail, etc. There is reason to believe that rising mean annual air temperatures will result in a higher recurrence of extreme heat and moisture levels producing a negative effect on crop growth. A reduction of yielding capacity of agricultural crop staples due to adverse meteorological conditions may reach 50-60%, and in some years even more. Declining yields (especially of spring cereals) are predominantly attributable to dry conditions.

> Greater agricultural risks attributed to climate aridization will lead to shorter periods of adequate moisture supply in spring and summer and worse vegetation conditions.

> Irrigated cropping technology is of very limited distribution in the country.

> The predominance of light (sandy and sandy-loam) soils in the south of the country in the context of warm and dry climate may require the use of extremely expensive adaptation measures and raise the question of profitability in certain districts and regions.

The development of a climate change adaptation strategy bases itself on a number of agreed assessment objectives and principles. The most generalized objectives are to promote continuous development and reduce vulnerability. They acquire specific substance in each single task. Critical climatic impacts are determined through the identification of positive and negative climate effects with the orientation on the subsequent choice of adaptation measures. Vulnerability assessment is conducted to identify impact units when a climate variability risk is involved. It is defined as a level where an impact unit breaks or changes unfavourably. Vulnerable systems, activities, territories are viewed as objects of planned adaptation.

The identification of an adaptation strategy choice includes making a detailed list of possible adequate responses orientated towards negative and positive climatic effects. Six types of adaptation strategies can be distinguished: avoided losses, allowed losses, distributed (shared) losses, changes of use or activity, restoration of the original condition.

There are four groups of strategies: long-term, tactical, contingency, analytical.

Adaptation activities also include such procedures and processes as a limitation study, identification of quantitative measures and formulation of alternative strategies, scoping and premium assessment, recommended measures.

The country has developed and put in place a good system of adaptation to climate events and changes, as well as natural and man-made accidents and disasters. With a moderately continental (transitional) type of climate, adaptation to climate changes takes place in the form of independent responses (embedded, daily and tactical) of agriculture to weather changes and other dangerous phenomena. This area is largely regulated by normative documents.

In order to enhance adaptation capacity of agriculture to climate change and deliver sustainability to the farming sector, it is expedient to implement a set of activities comprising, among others, the following:

> Combating soil erosion;

> Soil-protective technologies, minimization of human-induced impact on soils;

> Moisture-saving technologies;

> Clean fallow;

> Agro-forestry;

> Wide use of organic fertilizers;

> Conservation of the most degraded agricultural lands; selection of new varieties and hybrids of agricultural crops; biotechnology development;

> Use of alternative energy sources including biomass; development of infrastructure (roads, storage facilities, etc.) and agricultural processing companies in areas where natural conditions for farming practices may improve;

> Further farming intensification – use of greater doses of fertilizers and other chemical agents in parallel with deeper soil amelioration bearing in mind that climate warming enhances efficacy of measures designed to improve soil fertility;

> Introduction of slower-maturing varieties (hybrids), that will make better use of growing thermal resources of the territory;

> Expansion of catch crops with a view to exploiting additional heat resources;

> Expansion of planting areas of new (or cultivated currently on limited territories) highly effective crops corresponding to agro-meteorological conditions developed over the last decade (i.e. maize, sugar beet, etc.);

> Selection of species and varieties for newly-laid garden plantations considering climate change tendencies (lower probability of tree frost damage, longer vegetative period, etc.).

> Special training and educational programmes geared for rural workers.

According to estimates of the Belarusian Agrarian Economy Research Institute [61], the Republic of Belarus can secure a sufficient supply of food, fodder and technical grain by planting grain and legumes in all types of farms in the area of 3-3.1 million ha, including for agricultural companies – 2.6-2.7 million ha, and harvesting 48-50 and 50-52 cwt/ha of grain, respectively, from arable land. There are economic justifications for planting areas of certain crops at the level of agricultural companies: winter rye – 730,000-750,000 ha, winter wheat – 250,000-280,000 ha, spring wheat – 100,000-120,000 ha, barley for all purposes – 700,000, oats – under 300,000 ha, triticale (mainly for winter) – 100,000-110,000 ha, buckwheat – 45,000-50,000 ha, leguminous – 350,000-400,000 ha. The grain problem in the country can be addressed by growing short-season maize varieties with yielding capacity of 40-50 cwt/ha. Belarus needs 300,000—400,000 tons of fodder grain and 75,000-100,000 tons of seeds. To meet these needs, maize planting should be expanded up to 100,000 ha.

In order to satisfy export and other needs of the national textile industry in flax, the fibre flax planting area should reach 110,000-120,000 ha with yielding capacity of 10-12 cwt/ha. Obtaining stable yields of sugar beet roots (300-350 cwt/ha) with a limited planting area of 50,000 ha will keep sugar factories operational with a 10-15% capacity increase.

It is necessary to expand planting areas of rape up to 100,000 ha with 15-20 cwt/ha productivity to meet oil needs. Taking into account an increasing potato demand among cities and industrial centres of Russia and other CIS countries, it is advisable to increase its sown areas up to 120,000-130,000 ha with an average yielding capacity of 200-220 cwt/ha.

It is suggested that fodder crops (fodder grain) should have 2.1-2.2 million ha of arable land, including edible roots – 100,000 ha, silage maize -250,000 ha, annual and silage grass (excluding maize) – 550,000, perennial grass -1.200-1.300 million ha.

4.3. Forestry and forest ecosystems

4.3.1 Climate impact assessment

The purpose of assessing impact of the climate on forestry and forest ecosystems is to identify the consequences of climate change during the period until 2050 for forest plant cover (composition, productivity, carbon sinks, potential resources, performance of socially relevant and protective functions by forests) and forest management practices. Additionally it is necessary to identify practical measures to adapt forestry and other sectors of economy linked to it to climate change.

The object of research are the lands belonging to the National Forest Stock of the Republic of Belarus comprising, as of January 1st, 2005, 8,335,100 ha or 40.1% of the country's total area, and forestry as a sector of economy and element of its forest-industrial complex.

Research period: 1980; 1990-2000 – the base period; 2000; 2030-2050 – the analyzed period; a step of assessment depends on a step of perspective sectoral planning and/or a step of model-based assessments.

The research relied on data regarding the assessment of composition, structure and dynamics of forest stock based on materials of a state inventory of forest resources, whereas perspective assessments take into account materials of strategic planning of the sector (forestry) and model-based assessments of local climate dynamics given adaptation measures.

Modelling was the primary research method. Models (biophysical and mathematical, integrated system models) are used to predict climate change parameters relevant for forest ecosystems and forest economics. The results of empirically statistical carbon-content modelling are used to assess carbon content, volume of phytomass, scale of carbon removals from the atmosphere as a result of photosynthesis or, on the contrary, its emissions into the atmosphere due to forest fires and decomposition of the organic substance of mortmass. Original productivity models were not used. The hydrodynamic model of meteorological elements was used to assess diurnal temperature variation under the forest canopy [2].

An impact forecast is based on accepted official forecasts, materials of the National Forest Stock Inventory, other types of assessments and materials (forestry prognosis, climatogenic-chorologic, phonologic materials).

The total stock of stem wood in Belarusian forests is estimated at 1.34 billion m^3, including the stock of mature and overmature stand – 137.15 million m^3 (or 10.2% of the total forest stock), where coniferous wood (common pine and common spruce) represents 63.17 million m^3 (or 46.1% of the mature stock).

The current change of forest stock develops from photosynthesis-induced stock increase minus the amount of fall-off resulting from felling of all kinds and tree loss, natural or caused by manmade and natural disasters: fires, windfalls and windbreaks under the influence of wind (squalls, tornados, hurricanes), mass reproduction of tree pests and diseases, flooding or inundation, etc.

According to V. Baginsky and L. Esimchik's estimates [2], the current (annual) stem wood growth on the average constitutes 6.3 m^3 per 1 ha of forested land. At the same time the average fall-off is equal to 1.8 m^3/ha a year, i.e. the average current change of stock is 4.5 m^3 per hectare. The annual wood growth in Belarusian forests is 35.3 million m^3 as a result. Taking into account the average annual volume of forest exploitation that recently averaged at 10.2 million m^3, the total current change of forest stock is 25.1 million m^3.

The trend forecast of wood stock and, accordingly, carbon in the forest stock relies on the following key principles:

- optimization of forest age structure: attaining an approximately equal ratio of areas in each age category with a share of mature forest slightly above 20% and overmature – above 15%;
- wood replenishment in the forest stock by underutilizing wood growth;
- alteration of species ratio within the forest stock by increasing a share of commercial types of forest formers: pine, spruce, oak;
- expansion of forest-covered areas through afforestation of land transferred from other users;
- afforestation of sparsely closed stand, fire-sites, openings, clearings, etc.
- annual loss of part of the forest to fires and manmade and natural disasters.

Table 4.6

Projected wood growth in Belarusian forests and carbon sink in wood stock for the period till 2070

Projected parameter	Mean annual value of the parameter by decades							
	2000	2010	2020	2030	2040	2050	2060	2070 +
Current stock change, m^3 per 1 ha	4.50	4.66	4.82	4.97	5.13	5.29	5.45	5.60
Forested area, million ha	7.85	8.05	8.15	8.17	8.20	8.22	8.24	8.25
Current stock change in Belarus, million m^3	35.30	37.49	39.24	40.63	42.07	43.46	44.87	46.22
Forest utilization, million m^3	10.25	17.40	20.86	23.23	24.55	24.82	24.94	25.08
Forest stock increase, million m^3/year	25.05	20.09	18.39	17.39	17.51	18.65	19.92	21.14
Carbon sink in stand growth, million tons	8.062	6.466	5.918	5.597	5.635	6.002	6.411	6.804
incl.: in 1st-class underwood	0.136	0.109	0.1080	0.095	0.095	0.1	0.108	0.115
2nd-class underwood	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
maturing	2.194	1.760	1.61	1.523	1.534	1.634	1.745	1.852
mature and overmature	0.845	0.678	0.6290	0.587	0.591	0.629	0.672	0.713

Socio-economic forecast in the absence of climate changes

The optimistic forecast of forest utilization prepared in 1997 is at this point far from being completely true. The total amount of forest exploitation in 2000-2001 was on the average slightly above 10.2 million m^3 of wood. This was a primary result of the economic situation in the country: inability to pay by a considerable portion of wood consumers, their refusal to work with small-leaved kinds of tree (birch, aspen, alder, etc.), first of all in hard-to-reach, excessively moistened land, as well as an unfavourable wood market situation in Europe in the wake of massive windfalls in the forests of Germany, France, Austria. Ecologically, this was however a positive development.

Starting from 2000, in parallel with the transfer of forest that belonged to state-owned farms and other users to Forestry Ministry companies, low-productivity unforested lands have been also added to the forest stock, some of which are in need of afforestation. It has been decided already to transfer 134,600 ha, while a 2010 prediction suggests that the share of this land category will reach 300,000 ha (3.8% of the current area of forested lands), which is a substantial backup for enhancing a percentage of forest land in a number of Belarusian districts. This will also offer additional carbon sink opportunities as far as ground ecosystems are concerned.

These considerations are taken into account above (Table 4.6).

Future climate forecast.

Climate change assessments for the first half of this century in Belarus are based on the results of the atmospheric general circulation according to HadCM2 (Great Britain) [1]. The following aspects are relevant for forest management in Belarus as far as climate changes in the first half of the 21st century are concerned:

- a rise in mean temperatures of all months of the year on the average by 0.6-1.9ºC between 2010 and 2039 and by 1.0-2.9 ºC subsequently;
- temperature rises are most dramatic during winter months, which aggravates wintering conditions for plants by increasing the likelihood of vegetation-provoking thaws;
- change of heat supply during a vegetation period for forest stands, in particular such critical climate parameters as total durations of periods with mean daily temperatures above temperature limits of 5 and 10° C, and temperature totals for the respective periods.
- greater probability of extreme dry events, above all during summer months because in the context of rising temperatures the amount of precipitation remains practically unchanged during that period;
- smaller depth and shorter period of soil frost penetration in winter; in some years frost penetration may not be even pronounced.
- precipitation increase is small or occurs during winter months when its role as a source of moisture for next-year vegetation is marginal.

Table 4.7

Forecast of annual amount of principal and intermediate forest utilization in Belarus (all types of forest users) (scenarios 1 and 2, according to: [3])

Scenario	Utilization amount by decades:							
	2000	2010	2020	2030	2040	2050	2060	2070 +
Primary utilization[a], area, thousand ha								
total cut, million 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 utilization (thinning, sanitary felling) and other; total cut, million 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	12.2812	12.28	12.35
Total projected amount of forest utilization by all types of forest users, million ^{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	10.25	17.4	20.86	23.23	24.55	24.82	24.94	25.08

Notes:

[a] Under scenario one, the age of felling is taken at the level of the middle of the second half of age class 5 (for forest group 2) and 6 (for forest group 1) with the conditionally permanent stock of mature stands; the second option implies a gradual increase of stock per 1 ha of mature stands annually in amount of 0.35%.

[b] Until 2020, the amount of intermediate forest exploitation is set pursuant to the Strategic Forestry Development Plan of Belarus [3], and for subsequent periods — in amount of 65% of the primary utilization volume, which corresponds to the planned ratio of these types of forest management.

[c] An adjusted forecast of forest utilization takes into account sluggish market transformations in combination with a high degree of forest market saturation with inexpensive Russian wood, more difficult access to forest markets caused by forest certification. To consider these negative (in terms of economic consequences) events, a downward coefficient of 0.80 has been introduced in third-option calculations.

Table 4.8 Mean air temperature changes within the forecasting period

Month	Mean air temperature, ° C			Difference between forecast and base period 1961 - 1990, ° C	
	1961-90	forecast			
		2010-2039	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 4.9

Changes of selected heat supply parameters for the period 2010 - 2039 relative to the base period 1960 - 1990

Climate parameter	Temperature limit, °C	
	5	10
Shift of spring date of steady transition over temperature limit, days Duration of period above temperature limit, days Total temperatures above temperature limit, ° C	-3 +7 +201.4	-4 +6 +184.7

Table 4.10

Precipitation changes within the forecasting period

Month	Precipitation totals, mm/ month				
	1961 - 1990	forecast		difference between forecast and 1961 - 1990	
		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

Economic consequences of climate change

Change of the current tree increase pattern as active temperatures rise and growing season increases. Breathing costs increase during vegetative season as a result of higher average nightly temperatures.

Different maturity timing of tree fruit and seeds due to an earlier vegetation start.

10-15-day shift of the starting period of forest silvicultural season.

Longer fire risk periods, wider areas of fire-prone forests, general increase of fire danger in forests and peatlands.

Change of tree stand structure due to a shift of ranges of core forest-forming trees: spruce, hornbeam, speckled alder.

Greater probability of mass breeding of forest pests, both primary (gipsy moth, nun moth, sawfly, burdock borer, tussock moth, tortrix, etc.) and secondary (first of all, eight-toothed bark beetle and its satellites).

Transfer of land rendered agriculturally ineffectual by the widening of drought-related zone under the forest stock.

Reduction/increase in efficiency of hydro forest reclamation systems and emergence of negative side effects of their functioning.

Growing risk of emergence and damage of late spring frost due to earlier beginning of vegetation.

Active shrub overgrowth of mires due to a generally lower level of groundwater and more intense evaporation from mire surface and catchment areas.

Increase in transpiration of forest communities.

Changes in soil conditions of tree stand growing as a result of total reduction of groundwater level.

Worsened conditions of assimilation due to reduced air transparency.

Impoverishment of gene pool of forests' boreal flora and fauna.

Worsened water supply due to a generally lower groundwater level over enormous territories as a result of cumulative effect of man- and climate-induced factors.

Expansion of forest-steppe and steppe flora into forest ecosystems.

Generally accelerated cycle of matter in forest ecosystems, in particular faster decomposition of forest litter.

Biodiversity enrichment through thermo- and xerophilous species of European-Small Asian and European Siberian – Aral and Caspian biotic complexes.

Plant productivity growth as a result of lower CO_2 limitation stemming from its higher concentration in the atmosphere.

Worsened overwintering conditions for forest vegetation in consequence of lack or shorter period of snow cover.

Worse access to waterlogged cutting areas during winter for wood harvesting machines as a result of increased temperatures, shorter snow cover period and forest road freezing.

Change indicators. A change of the current tree increase within a 10% range due to a 15-20% increase of the duration of a vegetation period (from 180-205 days a year to 195-230).

A change of maturity timing of tree fruit and seeds, and forest berries due to an earlier vegetation start is possible with a range of 10-15 days, and in some years even more compared to the average timing of many years. This event already occurred in certain years of the last decade.

A 10-15-day shift of the starting period of the forest silvicultural season should be generally viewed as a favourable development, because it will allow to somewhat extend the duration of a forest planting (sowing) period and start it using a still available winter stock of soil moisture. On the other hand, it is not advisable and under new climatic and meteorological conditions even dangerous to keep it going for too long due to a fast drying of the top layer of the litter and soil in May with little precipitation. A forced early start of forest planting already took place in the 1990s.

Longer fire risk periods, wider areas of potentially fire-prone forests. A general increase of fire danger in forests and peatlands could be already observed in some years of the last decade (1992, 1999, 2002).

A change of a tree stand structure due to a shift of ranges of core forest-forming trees will be a long-term development that would primarily affect the phytocenotic tolerance of climate change-sensitive forest-forming species, leading to competition on the part of other species, and pest and disease impact. In Belarus this land category includes stands consisting of hornbeam, speckled alder and spruce. In particular, the current southern boundary of the spruce range is determined by a number of days (over 120) with relative air humidity above 80%, + 10 ºC temperature totals and average temperature of May [18]. Due to a northward shift of contours of these parameters, there will also be a shift of a spruce tolerance zone to climate conditions by 150-180 km. Speckled alder will be squeezed out of its southern range by an excessive influx of heat, which at the moment keeps it within its present-day boundaries. A northbound movement of hornbeam will be apparently unequal to a shift of direct-acting factors (temperature, precipitation), and will be associated with an intricate combination of effects, because the current boundary of its range is conditioned in the east of Belarus by the height of snow cover, in the west – by lack of heat, and in the centre – by extreme winter temperatures [18]. This is the reason why its moving towards the north is unlikely to be so considerable and will be limited to a dozen of kilometres.

A greater probability of mass breeding of forest pests, both primary leaf and needle-eaters (gipsy moth, nun moth, sawfly, burdock borer, tussock moth, tortrix, etc.) and secondary (first of all, eight-toothed bark beetle and its satellites). Certain signs of growing mass breeding spots of forest pests and a number of insect species that do considerable harm to tree stands have been already recorded in the last decade of the last century and early this century. For example, there were recorded population explosions of European pine moth (1993-98, 2003, 2004), nun moth (1993-95), pine beauty moth (2001), pine sawfly (1993-96, 1998-99, 2002), fox-coloured sawfly (1994—95 and 2002, 2003, 2005). Between 2001 and 2005, there was heavy winter moth activity in numerous foci in oak groves of Belarus. However under the influence of natural factors and coping measures the number of winter moth foci reduced, their area decreasing from 39,277 ha in 2003 to 11,136 ha in late 2005.

As of early 2006, active nidi of forest pests and diseases occupied the area of 73,613 ha, of which disease nidi constituted 97% (71,413). In general, the area of pestholes and disease centres in territories under the Ministry of Forestry declined by 22,100 ha or 25.7% over the year.

Transfer of land rendered agriculturally ineffectual by the widening of drought-related zone under the forest stock will require producing more planting material, enhancing planting and sowing capacities, developing technology that takes the characteristics of this category of silvicultural areas into account, conducting a set of measures to reduce the population of underwood pests (first of all, cockchafers). These considerations are partly integrated in the programme "Reforestation and Afforestation in Forests of the Republic of Belarus" covering the period until 2015.

Reduction/increase in efficiency of hydro forest reclamation systems and emergence of negative side effects of their functioning are subject to operational assessment and development of relevant recommendations because: a) over considerable areas of these territories renaturalization processes are already developing; b) actively and passively drained peatlands, both covered with forest and unforested, is one of the land categories within the forest stock most liable to fire; c) in a number of cases poorly managed drainage of peatlands (at raised bogs and fen mires) resulted in loss of important biological diversity and degradation of tree stand, not their productivity growth.

Since transpiration largely depends on relative humidity of air and soil, air temperature, and lighting conditions, it is reasonable to expect its intensity to grow, especially between 2040 - 2069 due to a rise of mean monthly air temperature by 1.5 - 2º C vis-à-vis the base period (1961 - 1989) throughout the vegetation period. A certain increase of precipitation and wind speed will also contribute to the processes. Their impact will be stronger upon soils with insufficient moisture content where moisture supply and replenishment need to be regulated by way of improvement thinning [44,55].

A change of water regime of forest soils, where important factors, besides precipitation, are air temperature and transpiration of forest communities [44].

Growing risk of emergence and damage of late spring frost may exercise heavy impact on the current growth of oak (early openers), spruce, linden, some other deciduous species, and occasionally lead to nipped flowers and buds of tree fruit and forest berries. This phenomenon has already occurred repeatedly in Belarus over the last decade leading to almost total crop failures of blackberries, red bilberries, blueberries and as a result – to smaller forest revenues and less food for grouse birds and other birds and animals that feed on berries.

Active shrub overgrowth of mires due to a generally lower level of groundwater and more intense evaporation occurs naturally and can be evaluated as a positive development in terms of increasing forest resources. Although no quantitative analysis of this phenomenon has been undertaken, the available experience from planning a number of reserves indicates overgrowth of all categories of open mires with pine, white birch, willow, black alder, spruce. Normally, there is 15 – 30% overgrowth depending on the type of mire and the extent to which it has been drained. Ecologically, however, this process is likely to be evaluated as a negative one, since it leads to a loss of the most valuable, critical wetlands supporting a considerable number of plant and animal species that are unable to survive in other conditions.

Changes in soil conditions of the tree stand growing as a result of total reduction of groundwater level produce substantial impact on the stand condition within areas with unstable earth nutrition, and in old-age forests of fen mires. In particular, there is ongoing degradation of black alder and ash forests in the Belarusian Polesie Area following a massive drainage campaign aggravated by lack of precipitation during several years of the 1990s. On the other hand, with regard to forests of transitional mires this phenomenon may manifest itself in increased productivity of white birch stand and help introduce there more economically valuable pine, spruce, oak, ash. This phenomenon has not undergone objective evaluation yet, although field observations suggest this process is already underway.

Worsened conditions of assimilation due to reduced air transparency is an event requiring more detailed research and apparently not very significant so far.

Impoverishment of gene pool of forests' boreal flora and fauna in the context of biodiversity enrichment through thermo- and xerophilous species of European-Small Asian and European Siberian – Aral and Caspian biotic complexes, just like the expansion of forest-steppe and steppe flora into forest ecosystems, are all ecologically negative processes, but so far they do not have or predicted to have any forest management implications of economic relevance (direct losses or benefits). As far as ecological and genetic losses are concerned, they are inevitable, therefore it is necessary to study this process and develop a corresponding loss reduction strategy.

Generally accelerated cycle of matter in forest ecosystems, in particular faster decomposition of forest litter, does not have significant economic consequences. Theoretically an increased pace of ground litter mineralization may contribute to somewhat increased stand productivity, but it is one of those phenomena where trying to help or fight it makes no sense.

Changes in overwintering conditions for forest vegetation in consequence of lack or shorter period of snow cover generally represent a rather negative event, because it brings about a sharp increase of heat variability of forest litter and top soil layers, where different forms of life are concentrated. An interchange of thaws and frosts in winter months may have a dramatically adverse effect on resting seeds, small animals, insects, etc. Although with regard to pests wintering in ground litter this may be rated in positive terms, because it reduces their damage capacity.

A smaller depth and shorter period of soil frost penetration during winter will pose and is already a serious obstacle to forest management activities and wood harvesting in waterlogged areas, and on mineral "islands" surrounded by such land. The most difficult part of the problem is the impossibility of utilizing considerable wood stock in mature black alder and white birch groves, some pineries, where felling activities in the past took place exclusively during winter, when peat soils were firm enough to bear heavy lumbering equipment. From the ecological point of view (biodiversity conservation), this phenomenon, conversely, can be viewed as a positive development, because it allows the preservation of the biotic complex of old-age wetland forests over large areas.

Studies carried out using an Automated Regional Ecological Forecasting System (AREFS) with respect to regions having natural and climatic characteristics similar to Belarus showed a generally favourable impact of global warming on forestry. An expected stock increment of standing wood is estimated over 10% by 2050 [18].

Studies conducted on the basis of the Belarusian material suggest complex, interacting impacts of precipitation and rising air temperatures on the index variability of radial spruce increment. These indices tended to decrease as the air temperature rose in the zone of mixed (under-taiga) forests and in the Polesie Area with a generally increasing index variability throughout Belarus. The latter can be interpreted as an influence of worsened climate conditions in the late 20th century. Precipitation growth positively affects the radial increment index for spruce in the zone of under-taiga forest and negatively – in the Polesie Area. A combination of rising air temperature and precipitation produces a positive effect on the stem productivity of the Carpathian variety of common spruce in its extrazonal insular plantations in the Polesie Area near drainage systems [43].

Alongside direct climate factors affecting the community productivity (temperature, humidity, etc.), there is a number of factors that themselves depend on the climate or are indirectly linked to it through intricate feedbacks. Here one can mention higher pest activity, higher dryness, etc., plus changes in the concentration of greenhouse gases, aerosols and ozone. Some of these factors are able to substantially reduce the probable growth of plant productivity.

Productivity growth of plant associations resulting from a higher CO_2 concentration in the air can be evaluated only using specific mathematical models of carbon dioxide changes in the atmosphere and 'responses' of the vegetative cover to a change of its concentration. Preliminary assessments of CO_2 concentration changes in the atmosphere are rather contradictory. For example, a report prepared by Solomon and Leamans who supervised the U.S. biosphere project (1989) indicates that projected rapid climate changes in the 21st century may lead to a considerable reduction of forest areas within the temperate climate zone. A twofold increase of carbon dioxide concentration in the atmosphere will lead to a 40% loss of boreal (northern) forests.

In case the CO_2 concentration changes less rapidly, its impact upon productivity should be positive [44]. For example, according to Italian scientists, if the carbon dioxide concentration hits the projected level for 2050, there will be 25% growth acceleration for pines.

Increasing concentrations of aerosols and ozone are among the factors affecting productivity in a negative way. Apart from reducing the amount of incoming radiation, these gases produce a negative influence on plant physiological processes during the vegetation period. According to model-based assessments by Russian scientists, an anthropogenic increase of near-surface ozone concentration alone was responsible for a 15% reduction of biomass growth of deciduous trees in the first half of the 1990s in some countries of Western and Central Europe. For Belarus this reduction is estimated at 7-9%. Moving eastward brings these figures down to 6-7% in Russian regions Belarus is bounded by [44].

Table 4.11

Estimation of carbon sink in forest growth provided CO_2 concentration in the air increases 1% every year

Projected parameter	Mean annual value of the parameter by decades							
	2000	2010	2020	2030	2040	2050	2060	2070 +
Carbon sink in stand growth given the response to higher CO_2 concentration in the air, million tons	10.150	8.142	7.453	7.049	7.098	7.559	8.073	8.568
incl.: in 1st-class	0.171	0.137	0.126	0.120	0.120	0.127	0.136	0.145
2nd-class underwood	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
maturing	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

Compared to ozone, sulphur dioxide (SO_2) has a small role to play in the anthropogenic reduction of biomass growth of deciduous trees in Belarus. Growth reduction for the same period was estimated at 1% in Belarus.

Temperature and humidity changes will affect the diurnal variation of temperature under the forest canopy. Model-driven assessments of changes of minimum (night), maximum (day) temperatures and ranges of diurnal temperature variations for the period of 2010-2039 versus the base period are given in Table 4.12.

Table 4.12

Mean monthly changes of the parameters of diurnal temperature variation under the forest canopy (1 m) between 2010 and 2039 compared to the base period of 1961–1990

Month		January	February	March	April	May	June	July	August	September	October	November	December
Change, ºC	night 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 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

As nighttime and daytime temperatures generally rise, the range of diurnal temperature variation lessens in the warm season and increases in the cold season. This occurs in general because of a sharper rise of night temperatures in the warm season and day temperatures – in the cold season.

Geographic analysis. Practically all negative developments related to climate change will be most pronounced in the south of Belarus - Brest and Gomel Polesie; to a lesser degree – in the subzone of hornbeam and oak groves, and will have little impact in the Vitebsk Region and northern districts of the Minsk, Mogilev and Grodno Regions. Although, as the 2000-2002 forest pathology analysis showed, these territories may also become subjected to extreme meteorological and climatic events (droughts, hurricanes, etc.), capable of triggering mass breeding outbreaks of forest pests, first of all the most harmful spruce pest – eight-toothed bark beetle. Additionally spruce, as a tree species, will experience a heavier negative impact of climate change compared to pine.

4.3.2. Assessment of adaptation strategies/measures

Objective setting. Adaptation of forestry as a sector and its enterprises to a new climate situation and conditions for the existence of the production staple of the sector – tree stand, and in broader terms – lands belonging to the state forest stock.

Identifying adaptation options. Adaptation of the sector to new meteorological and climatic conditions of the environment should be aimed at both overcoming the negative consequences of these changes and taking fullest advantage possible of them. A set of adaptation measures should include the following primary areas.

Planning and regulation:

- development of a sectoral policy and target programmes to adapt to new climatic conditions;

- critical revision and amendment of the regulatory framework and sectoral reference resources due to the ongoing climate change.

Organization: implementation of a set of interventions defined by the sectoral policy and adaptation programme at the level of the Forestry Ministry, regional forestry associations, sectoral enterprises (forestries, institutions).

Finances and economy: development of a dedicated programme of the sector's economic adaptation to new climate conditions incorporating cost rationale necessary to address and/or prevent negative consequences related to climate change to be covered from the national budget or other sources.

Education and research:

- amending curricula of institutions of higher learning and colleges that produce staff for the sector;

- setting up dedicated refresher courses at the sectoral training centre of the Ministry of Forestry;

- developing training and methodological materials to be used in forestries, the sectoral skills improvement system, etc.;

- implementation of comprehensive research aimed at assessing the consequences of climate change for forest vegetation and forestry and development of adaptation measures for the sector.

4.4. Hydrological cycle, water resources, water management

Water resources and the hydrological regime of Belarusian rivers developed in the context of meteorological peculiarities of several years of the warming period that started in 1988. Uneven distribution and quality of water resources is the most essential problem for Belarus. Unequal water supply of the population and territories, varying levels of intensity of agricultural and industrial production and water needs directly related to them, as well as current approaches to ownership in the water laws of the neighbouring states impart a unique nature to the problem of shared use of transboundary waters. Water resources are highly sensitive to climate change, therefore the development of adaptation measures requires putting in place a common information exchange system to evaluate the water regime of the whole region and individual states.

Belarus has a large number of water ecosystems represented by rivers (20,800), lakes (10,800), water reservoirs (153) and ponds (1,500). The total length of rivers is 90,600 km. They belong to the catchment areas of the Black and Baltic Seas. The main rivers are Berezina, Neman, Sozh, Pripyat, Western Dvina, Dnieper. Out of 146 km^3 of precipitation falling out annually nearly 110 km^3 is evaporated, and only 36.0 km^3 (25 %) is transformed into local flow. 22.2 km^3 of transit waters flow annually from neighbouring territories. Total resources of local flow are 56.2 km^3 a year. The largest lakes are Naroch (80 km^2), Osveyskoe (52.8 km^2), Chervonoe (43.6km^2). The total volume of water reservoirs is 3.1 km^3, effective storage is around 1.2 km^3.

Western Dvina and Neman hold the greatest energy potential. Belarus has 21 small hydroelectric power plants with a total installed capacity of approximately 10 MWh, including 14 hydros with a total capacity of 7.8 MWh. The plan is to put into operation 29 hydros with a total installed capacity of 7 MWh by 2010.

Belarus has a number of artificial water systems. The Berezinskaya system (169 km) is located in the north of the country connecting Western Dvina and Dnieper. The Dneprovsko-Bougsky and Oginsky summit canals run in the Polesie Area, in the south. The former is a part of the Dneprovsko-Bougsky Waterway (ca 735 km).

Surface waters are used by inland water transport which carries minerals, building and wood cargoes, and passengers by the rivers of Pripyat, Dnieper, Berezina, Sozh and Dneprovsko-Bougsky Canal. Until 1986, iron ore was transported from Ukraine to the Brest Port. All cargo shipments from Ukraine were terminated after the nuclear accident at the Chernobyl Power Station.

Relatively regular observations of hydrological parameters of the rivers began in the late 19th century; fragmentary data about the chemical composition of surface waters was obtained in the 1930s.

Rivers and canals now have 125 hydrological stations, 14 more stations are set up on lakes and water reservoirs. Hydrochemical readings are collected by 106 stations from 165 cross-sections within the basin of all the largest rivers. Hydrobiological monitoring takes place at 68 water sites, 128 cross-sections. Systematic observations of the natural groundwater level started in 1949 [11]. Observations of natural and disturbed groundwater regimes are made at 1,656 wells drilled through all aquifers (Figure 4.4.1).

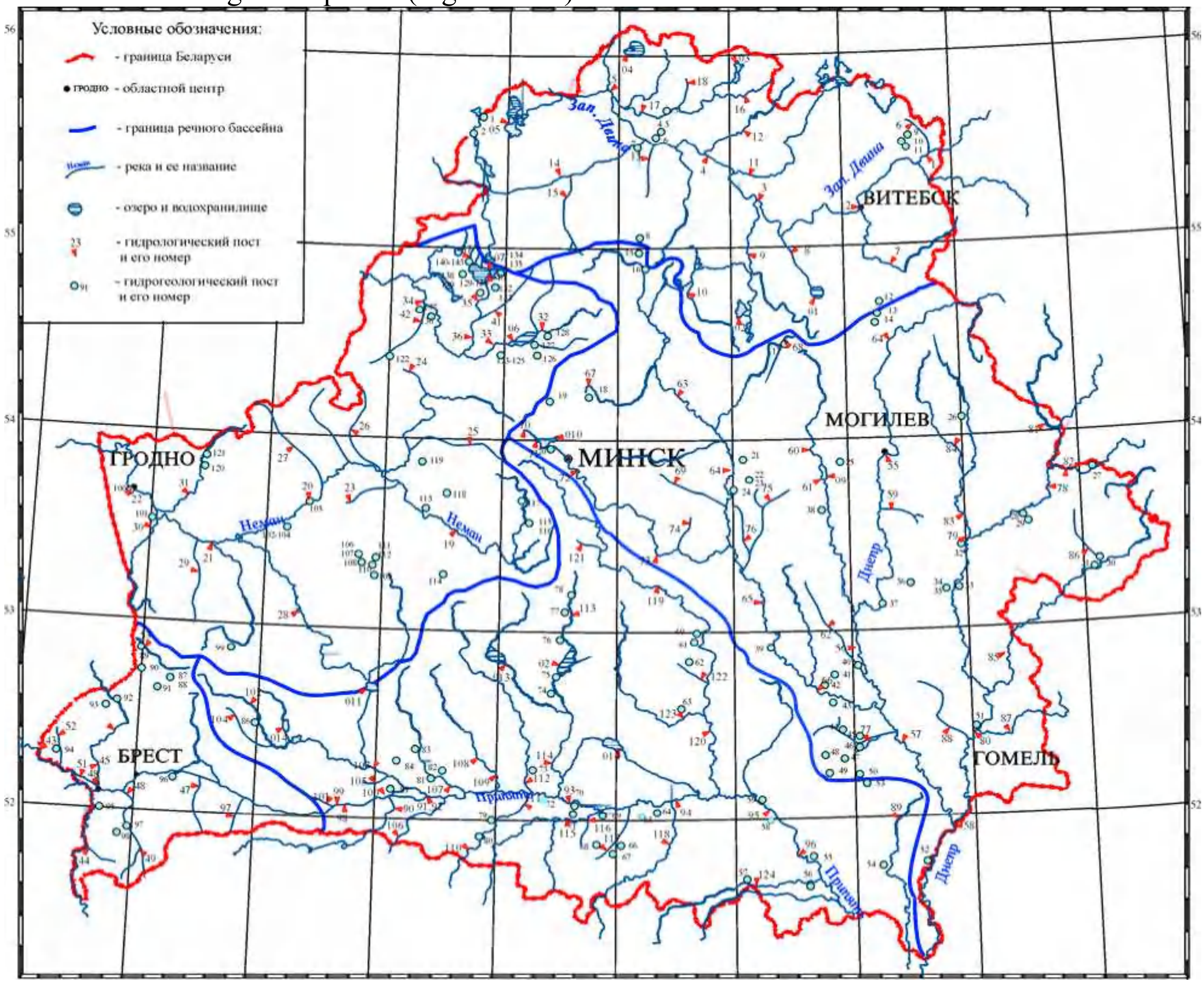

Figure 4.4.1. Location of hydrological and hydrogeological stations.

Hydrometeorological institutions have accumulated sufficient field material regarding hydrological characteristics of rivers, lakes and water reservoirs to date [13,14]. Less hydrological material became available after several hydrometric stations were closed and water regime monitoring of lakes and rivers was suspended.

Hydrological data used in this chapter was borrowed from official documents on hydrology published by the USSR and BSSR Hydrometeorological Service [33,34,48].

The territory of Belarus is divided into 6 regions according to the regime of run-off, its relations with determinants and amount of run-off (Figure 4.4.2). Table 4.13 contains major characteristics of hydrological regions and subregions of Belarus designed for rivers with 1,000 km^2 catchment area for a mean-flow year [13,14].

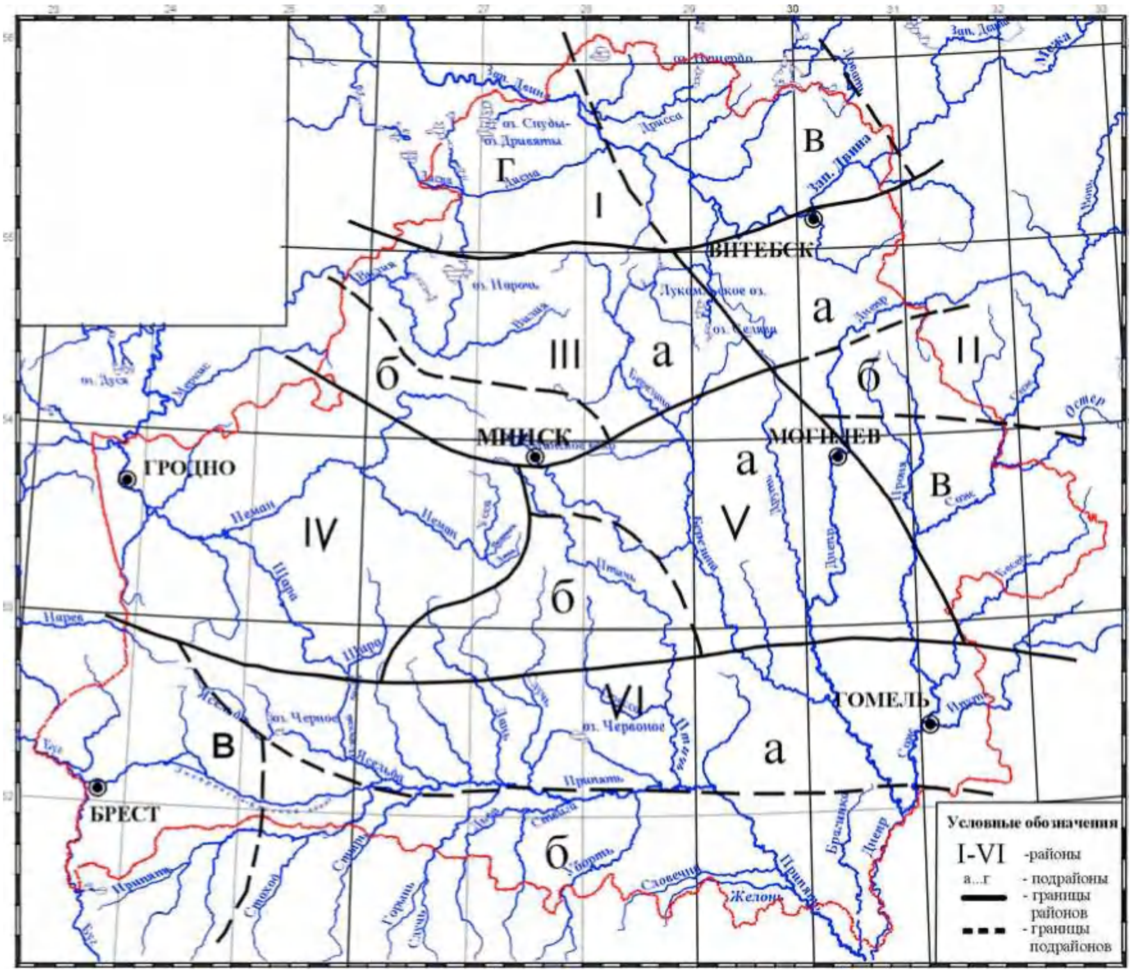

Figure 4.4.2. Hydrological regions and subregions of Belarus

Major characteristics of hydrological regions **Table 4.13**

Region and subregion	Mean long-term annual flow rate, l/(s-km^2)	Seasonal flow, % of annual flow		
		spring (III-V)	summer-autumn (VI-XI)	winter (XIII-II)
Western Dvina Region subregion **a** subregion b	7.0 6.8	61 66	29 23	10 11
Upper Dnieper Region subregion **a** subregion b subregion **c**	607 604 5.5	70 68 68	23 23 22	7 9 10
Vileika Region subregion **a** subregion b	7.2 7.5	48 40	36 40	16 20
Neman Region	6.0	45	35	20
Central Berezina Region subregion a subregion **b**	5.6 4.9	52 60	32 25	16 15

Pripyat Region				
subregion a	4.1	69	19	12
subregion **b**	3.5	59	26	15
subregion c	3.6	49	28	23

Analysis of climate change impact on river run-off and lake levels

In accordance with a latitudinal shift of geographic zones and, hence, change of climate factors, the mean annual run-off also changes territorially. The overall reduction of annual run-off is seen from the north to the south (Figure 4.4.3).

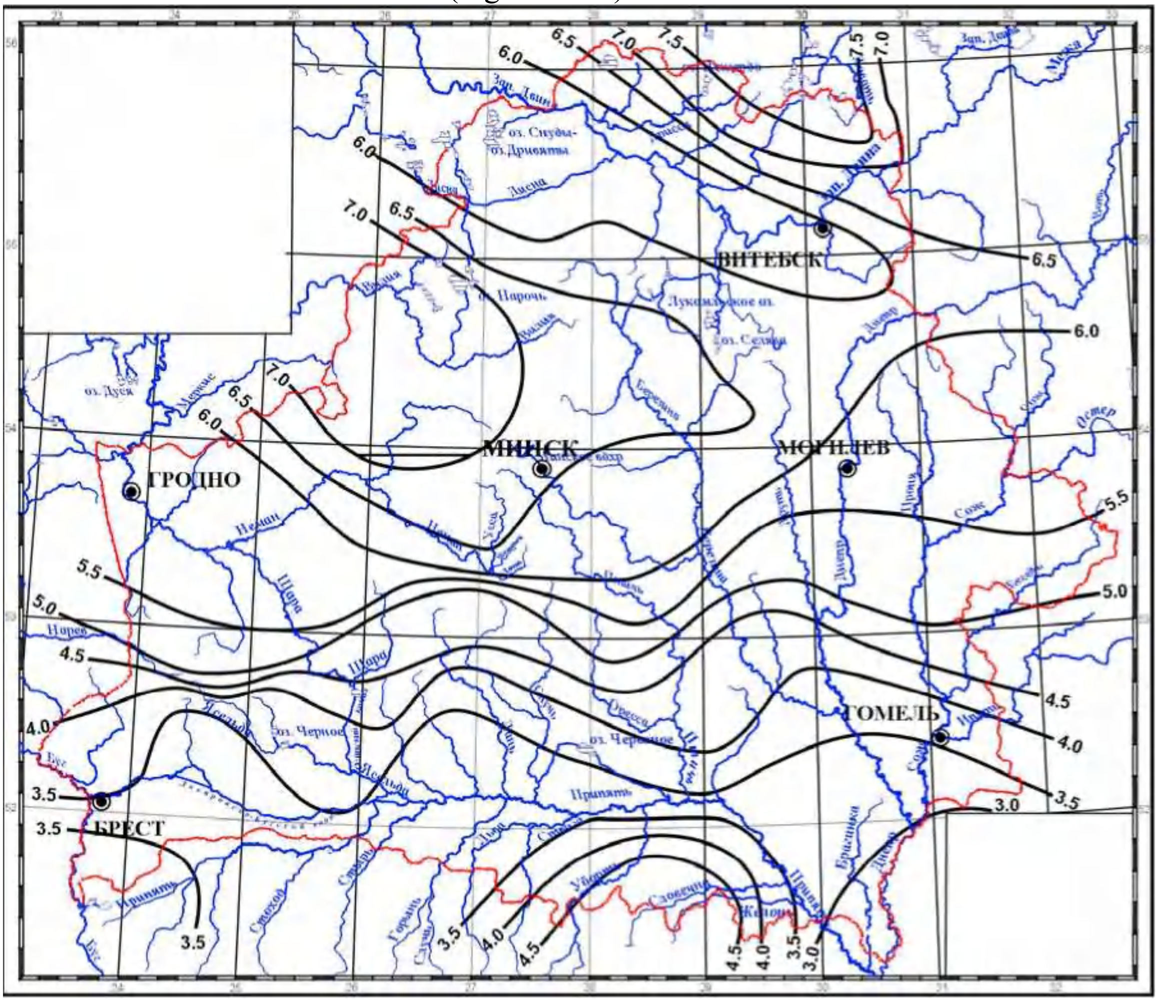

Figure 4.4.3. Map of mean long-term river run-off, l/(s km^2)

Spring flood is the most critical phase of the river water regime in Belarus. In large rivers, the water rises 8.6 – 12.8 m above the normal (mean water) level. In middle-sized and small rivers, the water rises approximately half as high. The flood period lasts 30-120 days. The shortest flood occurs on rivers belonging to the Neman catchment area (30 - 50 days), the longest – within the Pripyat catchment basin (90 - 120 days). The recession of spring waters lasts from 30 to 60 days.

Damaging floods occurred in Belarus 10-12 times over the last 50 - 70 years, the heaviest ones - in 1956, 1958, 1974, 1979, 1993 and 1999. The maximum flood on the Pripyat River was recorded in 1845, when the maximum level was 675cm above the zero mark of the modern water observation station in Mozyr, and water discharge was estimated at 11,000 m^3/s. The biggest flood in recent memory took place in 1999, when the floodplain of the Goryn and Ubort Rivers (Polesie Area) was 1.0 – 3.3*m* under water. The flood brought about considerable economic damage.

River spring flood is followed by a period when water levels are at their lowest in summer and autumn. This low-water period lasts 120 - 140 days on the rivers of the Western Dvina catchment area, 135-165 days on Pripyat and 190 - 205 days on the remaining rivers. In dry years (1939, 1951, 1952), rivers and canals with catchment areas exceeding 1,000 km^2 may even dry up.

Rivers stay frozen for 80 - 140 days starting from the second decade of November. During intense winters some small rivers may freeze to the bottom for a period of up to 4.5 months. No river freeze-up occurs during mild winters.

The current hydrological regime of water bodies in Belarus depends not only on natural fluctuations of meteorological elements, but anthropogenic factors as well [11,13,14,16]. The role of the latter increases every year and failure to take it into account may lead to great errors in estimated characteristics.

A forecasted change of water resources indicates the need to prepare for possible adverse consequences of climate change in advance [11,14].

In terms of water management, taking into account possible transformation of hydrographs of low-water years is most critical of all, especially if the entire amount of forecasted annual flow reduction will fall onto the summer-autumn low-water period. Negative effects of such a scenario for water management are as follows:

1) reduction of actual rated supply of economic entities using surface waters;

2) a drop of minimum water levels in rivers and resultant complications for the operations of river intake, water transport and recreation;

3) groundwater level reduction, especially in near-river areas;

4) worsened quality of river water caused by low dilution of wastewater and other pollution sources;

5) transformation of the hydrobiological regime of rivers caused by a change of rivers' level and speed patterns, rising air temperature and consequently compromised oxygen regime, reduced self-purification intensity.

If we were to elaborate on the consequences of climate change, we would mention the following.

Forecast of climate change impact on river and lake ecosystems. Increasing "thermal pressures" on rivers and water reservoirs are likely to speed up the eutrophication process. Alteration of species composition (groups) of phytoplankton towards species (groups) with a higher temperature optimum (e.g. cyanobacteria) posing great danger to the quality of drinking water.

Warming will affect fish stock. A steady rise of water temperature in shallow reservoirs will lead to weight loss of the fish that prefer to live in cold waters causing numerous fish to die.

Disturbed life cycles of fish, disappearance of stenobiont fish from ichthyofauna, changes in species diversity, numbers and biomass of fish should be expected.

According to experts, at present there is no systematized hydrobiological material upon which to make a statistically significant record of changes in structural parameters of aquatic communities under the influence of certain environmental factors and, more specifically, identify climate change impact. It is necessary to commence long-term "high-frequency" observations of hydrobiological parameters at the most typical water sites as part of research and monitoring.

As water levels drop in rivers and lakes, there will be an increased concentration of ^{137}Cs and ^{90}Sr radioisotopes in surface water sources of the Dnieper and Pripyat basins located in the Gomel and Mogilev Regions.

A forecast of climate change impact upon the groundwater level showed that if in the early 21st century the annual temperature rises approximately 0.2 °C on the average across Belarus, this may cause the groundwater level to drop by about 0.02 m versus the mark. If by 2025 temperatures rise 1.5 °C, this will lead to the groundwater level reduction of about 0.03 – 0.04 m versus the mark. At the same time, spring ranges of groundwater level will decrease similar to what was happening in the late 80s – early 90s during a five-year warming; levels of low-water periods will become even lower.

Territory inundation risk. Analysis of data about 1845 and 1931 floods shows that even more disastrous flooded conditions may develop in the territory of the country in the future. Such situation will be possible if anthropogenic pressures within the catchment area intensify resulting in considerable changes of run-off conditions.

Water energy risk. All active hydros of the Belarusian energy grid are categorized as “small”, for which guaranteed capacity is determined according to the December flow in a low-water year with estimated supply above 95%. Guaranteed capacity of the Polotsk Hydro, now under development, categorized as “medium-sized”, is established according to 80 - 85% flow supply conditions.

Waterworks facilities of small hydroelectric power plants comprise small daily-storage reservoirs that are largely susceptible to climate impacts. A rise of monthly mean temperatures of surfaces waters will lead to additional evaporation and corresponding losses of power generation. However, winter warming of the recent decades leads to the improvement of ice situation in water reservoirs and rivers.

Water transport risk. Under the influence of climate factors, the water-bearing capacity of rivers is subjected to considerable fluctuations both within the year and on a year-by-year basis. During the spring period, 42 - 62% of the annual flow is carried by rivers on the average. Each of 9 months of the summer and autumn-winter periods on the average roughly accounts for 4 - 6% of the annual flow.

In summer and winter months of low-water years the local flow may decrease to 2 -3% of annual flow, which affects water levels and operations of water transport which carries cargoes and passengers by the rivers of Pripyat, Dnieper, Berezina, Sozh and Dneprovsko-Bougsky Canal.

Adaptation of water economy and aquatic ecosystems should be aimed at mitigating negative consequences related to climate warming and promoting sustainable development of the Republic of Belarus.

Suggestions regarding most important adaptation measures.

The primary focus of adaptation measures in the field of water resources should be placed on the following:

- development of flood-control activities, first and foremost targeting the Polesie Area territory considering specific patterns of river run-off formation in Ukraine;
- establishment of reliable hydrometeorological monitoring, expanded use of radar and satellite data to evaluate snow cover characteristics and plan water management, agricultural and forest protection activities;
- regular forest amelioration within river basins as an effective way to combat erosive water streams;
- rationale for building underground water reservoirs in certain sections of the country which would allow regulating water regime in accordance with consumers’ needs, i.e. address the problem of water supply by increasing assured water content of a source.

Since it takes a great deal of time to implement water supply activities, large water management activities should be planned approximately 25 years in advance and their putting into service should be 10-15 years ahead of water needs.

Long-term water management planning should take into account vulnerability of surface waters and a somewhat limited nature of adaptation measures without relying on specific dates those changes should set in. Adaptation should in large measure include water saving, wide use of low-water technologies, a wider use of irrigation of agricultural land.

Climate warming might substantially deteriorate conditions for soil humidification, increase evaporation, decrease inflow of moisture onto fields, as well as prolong the vegetative period. All these events will create a need to develop irregular, mobile irrigation. On the ameliorated land, it will lead to a reduced average annual water-regulating effect of irrigation amelioration. It is also possible that sources used for forced supply of water onto the fields will lose some of their resources. Hence, in order to support irrigation and drainage facilities, measures will need to be taken to regulate surface and groundwater runoff, supply water from outside, and re-use drainage water.

4.4.1. Climate change impact on hydrological regime

Statistical and water-balance methods were used to assess changes of water resources under the impact of climate; biomanipulation methods - to explore aquatic ecosystems of the Naroch group of lakes; statistical methods - to study groundwater changes. A random component analysis of water discharge series was performed using the turning point and difference sign tests. Also Kendall and Spearman rank correlation coefficients were used.

Last-century precipitation analysis shows that early in the century the amount of precipitation was far more considerable, because it was the time when the western form of atmospheric motion dominated, according to G. Vangenheim. In the wintertime the run-off of Belarusian rivers increased [11, 20 - 22].

The warming of the 1920-30s, accompanied by precipitation reduction, especially in the east of the country, resulted in smaller run-off at that time and, consequently, negative run-off differences of Dnieper and Western Dvina in the periods of 1929-1945 and 1890-1902 [19,33].

River flows for periods with high-speed winds turned out to be somewhat smaller than for periods with low-speed winds due to evaporation decrease during the latter. Run-off difference comparisons for periods with high- and low-speed winds helped evaluate the contribution of this factor estimated on the average at about 10%.

Over a century of observations in different months, changes in extreme water discharges have been studied for Western Dvina and Pripyat. The most common abnormal years were: with maximum water discharge - 1931, 1932, 1933, 1958 and 1962, with minimum water discharge - 1921, 1939, 1954, 1969, 1976 and 1984. Run-off formation for rivers with small catchment is subjected to great fluctuations compared to large-catchment rivers.

Analysis of climate impact on groundwater levels in the basins of largest rivers showed that annual changes of groundwater levels display a certain pattern related to climate. The spring groundwater level maximum normally occurs in April when levels rise from 0.4 to 2.3m. In the summertime the groundwater level depends on temperature and precipitation of one or two previous months. An inverse relationship was established with temperatures of the previous months – as the temperature rises, the groundwater level drops.

The analysis revealed the existence of an annual cycle, as well as cycles lasting for 3 - 4 and 6 - 7 years. 2-3, 4 - 6 and 10-12-year cycles have the highest degree of recurrence. It is impossible to establish longer cycles due to short observational series.

A rise of air temperature during the “warm” period (1988 - 1992) reduced the spring range of groundwater level throughout the country. The “cold” period (1964 - 1968) was accompanied by considerable spring ranges of the groundwater level.

Climate impact on river ecosystems. Major Belarusian rivers are asynchronous as far as fluctuations of main types of run-off are concerned (annual, maximum and minimum). A comparative evaluation of changes of the average annual run-off and quantiles of different supply, as well as maximum and minimum run-off since 1961 until 2000 shows that differences in annual run-off over the selected averaging periods are within calculating accuracy for both average and guaranteed magnitudes. The run-off of large rivers practically hasn’t changed. An increase of the Pripyat run-off that could be observed in 1965 – 1985 might be attributable to climate changes (years with varied water content).

Changes of the maximum run-off step outside the boundaries of accuracy of calculation, and it typically decreases for all rivers. These changes are most considerable for Berezina, Neman and Dnieper, smaller changes take place at Western Dvina and Pripyat.

Minimum run-off changes were different on different rivers: the minimum run-off increased substantially on the Pripyat, increased slightly on the Dnieper (Orsha), and remained the same on the rest of the rivers.

All changes in the hydrochemical background are within the hydrocarbonate-calcium type of waters both in the past and in the present.

Climate impact on lake ecosystems and water reservoirs. A spectral density analysis of temporal series of the lake level showed the presence of a long-period component – 20 - 30 years for most of the lakes in Belarus.

In dry years (1951, 1959, 1964) natural lacustrine reservoirs of Belarus are characterized by a single-humped curve of the annual level movement with the maximum falling on April - May. In wet years (1987, 1990, 1998) a typical pattern is a double-humped curve with the first maximum in March/April and the second maximum in autumn/early winter.

A warming of the recent thirteen years (1989 - 2001) affected the temperature and ice regime of rivers, lakes, and reservoirs.

Starting from 1989, the surface water temperature of reservoirs increased noticeably. The most considerable abnormalities can be seen in the springtime. In the summer months a deviation from mean long-term data decreases, and in the autumn months – increases.

The maximum water temperature over the entire period of observations was recorded in most of the lakes and reservoirs in 2001, constituting 28.8 ° C for the Lake Naroch, 29.4 °C for the Lake Neshcherdo, and 26.4 °C for the Lake Vygonoshchanskoe.

Studies of the Naroch Lake ecosystems produced the following conclusions:

- climate change indicators are easier to identify in lakes with a large 'lake area /basin area' ratio and using minimum average annual levels;

- moderate heating of water does not induce considerable changes in the dynamics of the system, there are only minor changes in the size of biomass and a shift of biomass peak occurrences. The effect of heating on algae is more appreciable in the spring and early summer seasons; in the zooplankton community, filter-feeding organisms can be seen to replace predators.

Between 1989 and 2001, water temperatures in Belarusian reservoirs crossed the 4 °C and 10 °C marks one week earlier than usual, and in autumn - 4 - 8 days later than usual. The same trend was true for crossing the 0.2 °C mark. Climate change resulted in a longer ice-free period. A rise of temperature in the surface layer enables algae to enter the active growth stage earlier and makes the duration of this stage longer (phytoplankton spring development).

Water amelioration impact on hydrological regime, groundwater level and climate. About 1.4 million ha have been ameliorated in the Polesie Area to date.

Drainage amelioration reduced the groundwater level, substantially decreased evaporation losses from their surface, reduced radiation balance and transpiration moisture demand. Drained mires heat faster than undrained ones, but have smaller heat conductivity. Drained peaty soils uncovered with vegetation heat up to 50 - 60°C and above, which is 11 - 20°C more compared to mineral soils. Drained peatlands are characterized by considerable daily ranges of soil surface temperature exceeding mineral soils in that respect by 7 - 8°C. Under the influence of grass cover these contrasts smooth away. During the vegetation period a plough-layer of drained peatlands is colder than in mineral soils. Totals of air temperature above 10°C in drained peatlands at 10cm depth over the vegetation period are 400 - 500°C less than for mineral soils, and a frost-free period becomes 30 - 60 days shorter. Peaty soils reclaimed by tile drainage turn out to be warmer that soils reclaimed by an open network of channels [9-11, 20].

Irrigation of drained mires causes the growth of radiation balance, the maximum temperature of their surface decreases 6 - 10°C.

Having changed the water-air regime of soils, the drainage reclamation dramatically affected the regime of many small and medium-sized rivers. The thickness of drainage network after the amelioration increased 2.5 – 4.9-fold, creating more favourable conditions for the discharge of flood waters.

After the drainage amelioration annual run-off increased within 26 out of 50 surveyed catchment areas. The effect of drainage was particularly appreciable within small catchments with an area of under 2,000 – 3,000 km^2 in the first years (due to reduction of total evaporation and groundwater supply). In the first years annual run-off rose by 20 - 30 %, and run-off during a low-water period – by 50 - 70 % and more. No major changes have taken place within other catchment areas.

In forecasting impact of climate change on surface waters, the following options have been given consideration to:

option 1 – the average annual air temperature rises 2°C versus the current level while the amount of precipitation remains unchanged;

option 2 — the amount of annual precipitation drops 10% while the air temperature remains unchanged;

option 3 - the amount of annual precipitation drops 10%, while the average annual air temperature rises 2 °C;

option 4 – the presence of mires (drainage-induced) and forest (logging-induced) in the catchment area decreases, while the density of river network (through creation of drainage canals) and the area of ploughed land (through intensive utilization of new agricultural lands) increase 5, 10, 20 and 30% of the current levels with climate conditions remaining unchanged.

Calculations lead to believe that option three is the most unfavourable variant of run-off variation forecast for rivers of the Belarusian Polesie, with run-off reduction reaching 45.2%. Should this be overlaid with 10% anthropogenic pressure, the average annual run-off may decrease 50%.

Projected climate warming will cause next negative reaction on the part of both aquatic ecosystems on the whole and their separate elements in particular, especially this will be felt by river floodplains – most sensitive landscapes.

4.5. Socio-economic systems

Both now and always climate has been and will be one of the major factors upon which the life on Earth in all of its manifestations depends.

One of the key consequences is a change of natural ecosystems. According to some estimates, certain ecosystems will be unable to make adaptations to newly emerging climate conditions and may be lost forever [12].

Climate change entails a higher frequency of extreme climate events (floods, droughts, severe and warm winters).

Socio-ecologically, most important are agroclimatic consequences of global warming that will be of great importance for addressing the food problem in the future.

Experts believe that agricultural impact of global warming caused by adverse meteorological conditions even in countries with a relatively stable climate may develop into ecological damage making up the lion's share in sums lost in all sectors of economy taken together. A comprehensive assessment of geoecological situation of urbanized territories shows minimum geoecological stability of urban communities in most of the regions of the country, especially in its centre. It has been established that cities develop a special microclimate that greatly differs from a climate existing in adjacent territories [12]. Therefore global climate changes will affect primarily natural and ecological potential of cities' geosystems and to a lesser degree – the condition of their natural and anthropogenic systems. One of the crucial socio-economic implications of climate warming is energy and fuel savings for heating needs.

According to climate change forecast-driven calculations, the heating period in most of Eurasia will shrink by one month, in Central Russia – by approximately two weeks [21].

Other sources suggest that by the beginning of the 21st century the heating season will decrease by 30 – 60 days in the north and 10 – 15 days in central and southern parts of the former Soviet Union territory. If projected climate warming turns out to be true, by the middle of the 21st century the heating period will shorten even greater – by 2 – 4 months in the north and by 1 –1.5 months in the rest of former Soviet Union.

For Belarus, an important positive factor of warming will be a milder severity of climatic conditions, which currently predetermine the cost of supporting the economy. For our region, fuel and energy savings resulting from shorter duration and lessened severity of the cold season and, as a result, reduced heating costs for buildings may become one of the important socio-economic consequences of the expected anthropogenic climate warming.

Keeping indoor temperatures at a comfort level in residential and industrial facilities throughout the year is very costly. It is possible to quantify such warming impact by calculating changes in the duration of heating period, as well as heat shortage and accumulated temperatures exceeding the pre-determined comfort level.

In Belarus, district heating systems are very common, for which standards and norms have been developed. According to these norms, heating period begins when the average daily air temperature drops to 8 ^{0}C, and the system should maintain indoor temperatures at around 18 ^{0}C [18].

According to the ECHAM-1A forecast, air temperatures in high latitudes will vary between 0.5 and 2.5 –3.0 ^{0}C by the middle of this century [21].

Changes in heating season patterns are of special account in analyzing climate change impact on the energy sector.

Below is a calculation of climate impact on the reduction of heating period and related fuel savings. According to our calculations and analysis, heating period got 6 - 9 days shorter mainly because of its earlier end. The average temperature of heating period rose 1 – 1.5 ^{0}C (in the north more). All of this lessened degree days by 9 – 11 %. Heating costs should mirror this accordingly.

The ongoing change of climate characteristics will create a need to adjust parameters of the construction climatology and “Construction Norms of Belarus”.

We also analyzed changes in the average monthly and annual temperatures in Belarus between 1964 and 2005 and, based on that and taking into account certain studies [12,15,18,21], determined the projected average monthly temperature for the country.

A temperature change analysis showed that the temperature does not rise as significantly in summer as it does in winter which dovetails into studies in other countries. The air temperature rises more significantly during the first half of the year, while it even somewhat goes down in November and December.

The basic duration of heating season totalled 6.5 months. If average annual temperatures rise from 0.5 ^{0}C to 3 ^{0}C, heating period shrinks by 6 and 36 days, respectively. Our calculations regarding a change of heating period agree well with data contained in [21]. Air temperature is projected to rise predominantly during the first half of the year.

Apart from heating period impact, increasing temperatures will also affect heat losses of buildings during the cold season.

Reduction of heat losses, hence savings of fuel to be used to heat buildings, will reach 3.5 % as temperatures rise 0.5 ^{0}C, and 15.3 % as temperatures rise 3 ^{0}C.

Thus, total fuel savings will amount to 6.6 % for a 0.5 ^{0}C temperature increase and 33.8 % for a 3 ^{0}C increase. The results obtained tie up quite well with those obtained for Western Europe and Russia's European part [21].

4.5.1. Health impact of climate change

Human health is the cardinal aspect of climate change implications. In global terms, changes in natural ecosystems may trigger growth of ecological refugees, in whom probability of debilitated health, diseases and consequently death rate is likely to be higher. Global warming is expected to create an environment conducive to certain pests and diseases, which will affect human health in an adverse manner [21].

Comfort level of work, recreation and living conditions considerably influence human health. Ensuring comfort as the climate changes will help iron out negative socio-economic implications of the process.

Impact of weather and climate depends on the value (and sign) of deviation of actually observed values of climate factors from their certain combination considered to create a "comfort level".

The direct effect of these factors may be "instant", i.e. provoked by dominant weather, or may be contingent upon a chain of events, i.e. upon synoptic situation. Effects can be cumulative and emerge as a result of lasting exposure to varying conditions.

Impact of temperature changes on human body. For most of the healthy people at rest, air temperature from 15 to 25°C indicates heat sensations that create the comfort zone [8,18]. Delayed heat losses occurring during high temperatures may help suppress important functions of the organism, reduce its viability and predispose to infectious diseases. A considerable drop in air temperature also disrupts heat regulation in limbs and mucosae of respiratory tract accompanied by cold. Mortality rate caused by cardiovascular diseases in moderate and high latitudes is invariably the highest during the cold season, January and February, and the lowest in warm months – July and August. Apparently, this is because heat factors affect elasticity and peripheral resistance of blood vessels, activity of sympathetic nervous system and physiochemical condition of blood (viscosity, coagulation time).

Extreme heat or cold, i.e. excessive thermal stress, are undoubtedly harmful: a moderately hot climate increases susceptibility to intestinal diseases, moderately cold climate – to respiratory diseases. The following conditions belong to the moderate heat-and-stress type: asthma, bronchitis, allergic rhinitis (hay fever), rheumatic conditions (in particular, rheumatoid arthritis), heart diseases (in particular, cardiac infarction and chest pains), apoplexy, certain eye diseases (e.g. acute glaucoma, acute conjunctivitis) and vascular disorders.

Sharp fluctuations of temperature noticeably affect incidence and death rates. It has been found that an inter-day temperature change of 6 °C and more causes negative sensations in people.

Great values of the inter-day temperature variability are connected with circulation processes and air mass changes above the territory of Belarus. The inter-day temperature variability is at its minimum in July – August (1.4 – 1.8 °C). In the wintertime, as circulation processes intensify, it grows reaching its maximum point in January – February (2.5 – 3.0 °C). Unfavourable inter-day temperature variability (over 6 °C) is mainly observed in winter – about 6% in the southwest and 10 – 11% in the northeast dropping considerably only in summer (3 – 5%).

Thus, the warm season (2nd – 3rd decade of May – 1st decade of September) is characterized by optimum values of air temperature, when meteopathic reactions occur least of all. However even at lower temperatures under certain circumstances it is expedient to condition the body and harden oneself.

Impact of humidity changes on human body. The influence of air humidity on human organism is primarily associated with water metabolism regulation. Sharp increases of air humidity are known to cause renal diseases and pulmonary haemorrhage [18]. However if the air is too dry, it is also unhealthy because it can cause irritation of respiratory tract, coughing, short breath, general excitement, headache and insomnia. The comfort level is attained when humidity is average (50 %) and does not vary sharply.

Belarus is characterized by increased humidity throughout the year. During cold periods from October through March, average monthly relative humidity ranges from 80 – 90%, humidity variations across the territory are not traceable. Air humidity peaks in November-December (87 – 90%).

In spring when the temperature rises, relative humidity decreases from 77 – 83% in March to 65 – 70% in May reaching its lowest point in the annual cycle.

Daily cycle of relative humidity in winter is practically not pronounced. In summer the difference between its limit values during the day is 15 – 25% (in the southeast above 30%). The highest humidity is observed before the sunrise, when the temperature reaches its lowest point. The lowest relative humidity is observed in postmeridian hours, when the temperature reaches its highest point.

Dry days with humidity less than 30% are rare in Belarus – mainly in April-May – about 5% in the south and even less than that in the north.

So, the most favourable conditions for people in terms of relative humidity are observed during the spring and summer period (May – August).

Impact of atmospheric pressure changes on human body. In medical terms, it is not the absolute value, but rather sharp changes of this value that matter the most [21].

Reduction of atmospheric pressure by mere 5 – 6 mb entails impaired breathing, reduced pulmonary and tissue gaseous metabolism, oxygen impoverishment of blood and tissue which increases the risk of cardio-vascular diseases.

In Belarus atmospheric pressure mostly changes smoothly from day to day: in 30 – 50% of cases by less than 2 mb a day. Unfavourable pressure drops of over 10 mb a day are recorded in 25 – 35% of cases in winter; 60% in spring; 10 – 30% in autumn. During the period of intense cyclonic activity in the cold season, day-to-day changes of atmospheric pressure reach their highest values – up to 30 mb, during summer – up to 12 – 16 mb.

Impact of wind changes on human body. The dependence of the condition of human organism on the direction of wind is determined by physical and chemical characteristics of the moving air. Wind strength has great importance. The stronger the wind is, the more it impedes the correct breathing causing short of breath; it tires, irritates the nervous system causing anxiety, headache and insomnia [18]. The wind regulates the filling of skin vessels with blood directly affecting skin receptors, enhances metabolism in a reflex manner, influences gaseous metabolism. When temperatures are low, it sharply increases heat emission of the body, which may lead to overcooling of the body. This increases cold risk. A complete lack of wind in the warm season produces a relaxing effect, pampers the body and, conversely, small wind increases skin vaporization, stimulates and tones up the organism. The wind speed within the range of 2 m/s is considered very good during climate treatment [18,21].

Parameters of near-surface wind speed that are relevant for spa treatment depend first of all on the nature of earth surface both in terms of macroclimate and microclimate (terrain features, vegetation, availability of water bodies, constructions, etc.).

Impact of cloudiness on human body. Cloudiness influences the light regime: clouds block the passage of solar radiation to the ground thus sharply limiting its salutary effect; it also causes precipitation that sharply disrupts daily temperature and air humidity. These two factors, if clearly pronounced, may affect the body in an adverse manner during the overcast weather [18].

Medical climatology views cloudiness as one of the key factors determining the length of helioprocedures, because it directly influences the passage and intensity of solar radiation, and duration of sunshine.

In conclusion it should be mentioned that all the above factors of the environment act upon human body collectively, not in isolation. The impact will depend on the combination of factors.

According to modern beliefs, the intensity of weather variability has an important role to play in the integrated impact of climate on human body. Emerging meteorological reactions aggravate the course of a disease causing unwanted changes in man's health and mood.

Among many elements that contribute to the physical condition of the near-surface layer of the atmosphere, there are factors that affect the organism directly – air temperature and humidity, atmospheric pressure and wind. There is no doubt as to their effect on human body. Both periodic and aperiodic changes of these elements are important for the rhythm of physiological functions and exchange processes (during the year). In case of pathology it is the aperiodic processes that affect human body to a greater extent. Research data indicates that up to 80% of patients afflicted with different diseases react to unsteady weather by the enhancement of their condition.

All of the above enables us to regard the weather impact on human body as a multiple, varying-range action of periodic and aperiodic physical elements of the atmosphere's near-surface layer, where general elements play the key role. Changes of these elements correspond to the periodicity of physiological functions and exchange processes, biological reactions, which characterize activities of the human organism, and their influence on the emergence of meteotropic reactions, incidence and death rates is conditioned by how much the human organism lacks adaptive mechanisms and capacity.

If one bears in mind that protective mechanisms of human organism play a decisive role in addressing all sorts of harmful impact (infection, regenerative processes, toxicoses, oxygen starvation, etc.), the relevance and enormous practical meaning of using spa factors for health purposes become understandable.

Let's examine changes of the temperature pathogenicity index, humidity, wind speed, inter-day pressure differences, and the annual cycle of the complex pathogenicity index over the last 30-40 years.

The pathogenicity index (PI) method allowing an analysis of meteorological parameters in their entirety was used to make bioclimatic assessment of weather conditions (according to V. Bokshe). During the course of the PI analysis human cardio-vascular diseases were found to be most of all linked to day-to-day pressure variation. Air humidity produces the greatest effect on the incidence rate of respiratory tract diseases together with the air temperature PI and wind speed PI, because low temperature and wind speed coupled with high humidity cause the body to become too cool, increase heat emission leading to more cold-related diseases.

According to the analysis results, the annual PI curve has the highest values during the cold season (acute weather) and lowest values in summer. In spring and autumn PI tends to increase gradually towards winter months (irritating weather). This is confirmed by an annual picture of disease incidence rates, which hit their maximum in winter and their minimum in summer.

The weather's average annual complex pathogenicity index (CPI) generally tends to decrease on the territory under study.

As far as the annual cycle is concerned, CPI shows a declining trend in the cold season as a result of a temperature-humidity regime change.

A change of the general atmospheric circulation led to changes of particular pathogenicity indices. Over the past 30-40 years of observation, average annual indices of air temperature pathogenicity (ATPI) and wind speed pathogenicity (WSPI) have tended to gradually decline across the country.

The highest ATPI reduction occurs in the northern part of Belarus (sanatorium "Letzy", Vitebsk Region). The WSPI decrease is least pronounced only in the south-west of the country (sanatorium "Boug", Brest Region). The reduction of the air humidity pathogenicity index (AHPI) is also at its maximum in the north where it decreased more than 1.5 units over the period of observation (sanatorium "Letzy"). In the central and south-western parts this reduction is not so noticeable. On the contrary, there is a clear upward trend in the AHPI dynamics for the south-east of the country as far as annual average parameters are concerned (Gomel). Also the interday atmospheric pressure variability pathogenicity index (IAPVPI) tends to grow steadily throughout the country.

The annual course of individual pathogenicity indices also undergoes certain changes. For example, in all of the target territory ATPI tends to decrease in the winter and spring time from December to April when it is at its maximum. During summer months ATPI is the lowest and has practically remained unchanged over the period under investigation. However especially in the north and north-west of the country (sanatorium “Naroch”) these parameters somewhat decrease in August. In the autumn time, on the contrary, ATPI tends to increase, which when combined with growing WSPI makes the autumn period already from the third decade of September virtually unsuitable for climate therapy. The highest ATPI increase in autumn occurs in November; it is getting close to winter months according to absolute pathogenicity parameters, and during some years it is the most unfavourable month of the year. This is particularly salient for the north of Belarus.

In the northern part of Belarus WSPI also tends to decline, especially in the spring and summertime. WSPI variability smoothes away towards the centre of the country, does not express itself at all and even somewhat tends to grow in the south (Gomel).

As for the AHPI dynamics, it decreases in the north mainly in spring and summer, however a declining trend can be traced in autumn too, in the north-east (sanatorium “Letzy”). This creates conditions for the improvement of climate’s healing powers (in terms of heat and humidity), since the AHPI reduction makes it easier to tolerate high temperatures during the warm season, which is very important for respiratory patients; and to better conditions for winter rest and health improvement. The AHPI reduction in the south and south-west (sanatorium “Boug”) enables spa treatment here for most of the year and it is the most favourable region for climate therapy in terms of the temperature and humidity interplay.

IAPVPI tends to grow in the northern (sanatoriums “Letzy”, “Naroch”) and central (Minsk) regions of the country, which substantially worsens conditions for health improvement here for people with cardio-vascular pathologies. Only in the south (Brest, Gomel) the IAPVPI parameter values remain practically unchanged, with a slight increase only in spring.

The information about the ongoing weather impact on human organism helps distinguish the deterioration of health caused by meteorological factors as opposed to other factors.

The projected temperature rise, wind speed reduction, atmospheric pressure variability increase and air humidity growth will lead to varied Pathogenicity Index trend changes.

An increasing number of high-temperature days and periods puts extra pressure on organism, especially for heart patients, and reduces capacity for work. Protective measures should be provided, in particular indoors (air conditioners, ventilators, possible architectural solutions).

In the course of the recent warming, so far chiefly attributable to rising winter temperatures, thaw characteristics have changed considerably. The number of thaw days and uninterrupted thaw periods increased. All of this also creates additional load on the body, because it requires certain changes as a thaw begins followed by a cold period. The incidence of cold-related diseases increases as a result.

Apart from direct influence of weather factors, there is indirect climate impact, since climatic conditions largely determine the nature of food, sanitary methods, design of residential houses, offices and industrial enterprises, affect the makeup of the society and family, as well as viability of insects and animals – carriers of pathogenic microorganisms within their habitats.

Diseases that are not typical of Belarus are a matter of particular concern. These are infections that started to be diagnosed during the last 40 years.

In 1998, studies of bloodsucking mosquitoes in Belarus resulted in the detection of an antigen of a Western Nile fever virus. Mosquitoes were collected in all landscape-climate zones (LCZ) of the country. The virus infectiousness in mosquitoes was 7.1% generally across the country. The highest infection rate (12.0%) was recorded in the southern LCZ; in the middle LCZ the rate was 11.8% and in the north - only 2.8%. If we break it down by regions, the highest infection rate was in the Gomel Region (15.0%) and Minsk Region (11.8%); the lowest – in the Vitebsk Region – 2.8%. No Western Nile virus antigen was detected in mosquitoes in the Grodno Region.

The so-called "pasture tick" (Dermocentor pictus) is common in Belarus. It may be a carrier of two pathogens – tick-borne encephalitis and tick borreliosis (Lyme disease). Every year several dozen cases are diagnosed in Belarus. However the actual incidence rate is much higher. The following districts are most unfavourable in this respect: Belovezhskaya Pushcha, Berezinsky Reserve, Borisov and Dokshitsy Districts, certain areas of the Mogilev and Gomel Regions. Besides tick penetration into the ecosystems of city parks and squares is very dangerous, because it greatly increases the risk of tick-borne infections.

Remembering the Siberian version of encephalitis and the fact that "more powerful" strains that are more difficult to treat may gradually displace the European type with a milder clinical picture, it is safe to say that encephalitis is a very important problem that needs to be investigated further.

So, substantial changes in human health will take place if climate change forecasts are accurate.

4.5.2. Adaptation of socio-economic systems to climate change

By now there are only a few works on the socio-economic consequences of the predicted climate change, therefore suggested conclusions are largely based on expert estimates that require further refining.

The potential damage of adverse weather and climate conditions in the moderate zone countries is the greatest in agriculture (circa 70%). If protective measures are taken, it can be lowered by 35 – 40%. A share of likely damage for aviation, construction, power production, heating, manufacturing, transport and other sectors varies between 0.1 and 2% of gross national income, while avoidable losses range from 20 to 40% of total losses.

It has been established that the wind speed dropped by 15 – 20% over the last 20 – 25 years, which reduces the wind energy potential. Water consumption is an issue of considerable importance for development of the country in the climate warming context. Fresh water is constantly growing in demand against the backdrop of projected reduction in the quantity and quality of fresh waters.

Highly urbanized areas are expected to suffer the greatest impact of climate change. These consequences might include difficulties with water supply, increased heat loads, emergence of favourable conditions for a variety of infections [17,55].

The ongoing changes in climate characteristics will require adjusting parameters of construction climatology and "Construction Standards of Belarus".

Assessments of pathogenicity indices of temperature, humidity, wind speed, inter-day pressure differences, and the annual cycle of the complex pathogenicity index over the last 40 years have shown that these indices tend to develop in different directions. Pathogenicity indices of air humidity, inter-day pressure variability grow negatively affecting human health. At the same time, wind speed drops and temperature rises ensuring a positive behaviour of the pathogenicity index of these elements.

Climate warming will increase the time people spend in recreational zones (forest, banks of rivers, lakes, water reservoirs), therefore increased anthropogenic pressure can be expected on these ecosystems and, as a result, inadequate water quality and exacerbation of epidemiological situation.

So, considerable changes in the condition of human health will occur if projected climate changes are accurate.

In conclusion, let it be stressed that ecosystems (water, forest and agricultural) cannot be viewed in isolation, for all things are intermeshed in the nature. Human health is largely determined by the status of environment, therefore it will be relevant to carry out integrated assessments of ecosystems, economy and health impact of climate change in the future. It will contribute to identifying the most "winning" adaptation measures not only at a national level, but also at an interstate (regional) level.

PART V. EDUCATION AND PUBLIC AWARENESS RAISING

5.1. General data

In accordance with Article 6 of the Convention, the Parties, including the Republic of Belarus, shall "promote and facilitate": the development and implementation of public awareness programmes on climate change and its effects; public access to information on climate change and its effects; public participation in addressing climate change and its effects and developing adequate responses; training of scientific, technical and managerial personnel.

Belarus developed and put in place systems of environmental education, personnel training and re-training, and informing public on matters related to the environment. Cooperation with ecological non-governmental organizations is in progress. So, there is potential to support the country commitments under the UNFCCC. The key documents that give substance and guidance to ecological education are the Ecological Education Concept and the National Programme of Ecological Education Improvement, both approved by Resolution No 12/362 of the Education Ministry dated 21 April, 1999, and Resolution No 31 of the Ministry of Natural Resources and Environmental Protection dated 19 March, 1999.

5.2. Analysis of the National Programme of Ecological Education Improvement

For a variety of reasons, the review and final approval of the programmes have been put on hold for a long time. After the review and approval by the Ministry of Environment and Ministry of Education the programme has not been approved by the Council of Ministers of Belarus to this point. It is to be stated that the main provisions of the programme concerning the acquisition of specific environmental knowledge and skills were not used in developing standards of higher education for all specialties, which was completed during 2000-2001. Also they were not used in the elaboration of the Higher Education Development Concept – 21st Century. The said concept mentions environmental protection only in the context of international cooperation.

The activity plan to support the implementation of the National Programme of Ecological Education Improvement lists 45 items.

In general, it can be stated that the activity plan underpinning the National Programme of Ecological Education Improvement is being implemented for the key positions. Some items can be removed from the Programme altogether, since they no longer capture the relevance of the matter. It is advisable to consider adjusting terms of implementation with regard to items that lag behind.

In conformity with the Programme, coordination of activities in the field of environmental education in Belarus and Programme enforcement should be carried out by a Coordinating Council, which should comprise representatives of the Ministry of Education, Ministry of Natural Resources and Environmental Protection, research institutions under the said ministries dealing with environmental education, basic educational institutions of all levels. However up until today the Coordinating Council has not been created, which makes it more difficult to conduct consistent and concerted work through all the stages of the education system, and synthesize the available environmental education experience. The following scientific and methodological councils were created in Belarus in 1998: "Environmental Protection" (as part of the educational and methodological consolidation of universities for education in the field of nature use and forestry), "Ecology" (as part of the educational and methodological consolidation of universities for natural science education). These scientific and methodological councils could well be used as a starting point for the establishment of the environmental education coordinating council.

The use of information technologies has appreciably expanded since the time the Programme has been developed, including in education. Therefore it is expedient to reflect activities based on the use of new information technologies in ecological education in the Programme (online conferences, electronic textbooks, remote learning, etc.).

Since currently an educational reform is underway in the country (a switch to a two-level higher education system, etc.), there is a need to promptly introduce respective changes to the current Programme or develop a new one.

As attested by the practical experience of the Programme and its results, it fails to pay proper attention to:

- public education;
- mass media participation in education relating to the environment and sustainable development;
- training of journalists working in thematic areas of the environmental conventions;
- participation of NGOs in public education and awareness raising;
- training of specialists in specific ecological areas;
- training of staff of superior competence in areas related to meeting commitments under the three global conservation conventions.

The said deficiencies should be addressed during the elaboration of a new programme. Suggestions on how to improve work in these areas and a more detailed problem analysis are given below.

5.3. Specialized education

In Belarus, universities produce specialists under a number of core ecological specialties and specialities oriented to professional solution finding in areas connected to the environment to one extent or another. Such specialties include 'heat supply, ventilation and air protection', 'water supply, abstraction, wise use and protection of water resources', 'ecology', 'radioecology', 'environmental protection and wise use of natural resources', 'radiobiology and radiation medicine', a number of agricultural and forestry specialities.

The process of training specialists in these fields to one degree or another involves issues connected with ecological problems, including anthropogenic pressure on climate. Studying for a number of agricultural and forestry specialities that are directly related to processes that influence both GHG emissions and sinks implies the consideration of topics and issues related to anthropogenic pressure on climate.

Since 1998 they have started to train specialists in the field of "energy efficient technologies and energy management" in Belarus. Energy saving departments have appeared at Belarusian National Technical University and Belarusian State Technological University. Considering the fact that the energy sector is the main GHG emitter, this specialty can be considered as the basic one for preparing specialists dealing with GHG inventory and control and capable of implementing practical limitation measures. Therefore curricula for this specialty should be, to the extent possible, oriented towards problems related to GHG control and emission limitation.

The organization of training under ecological specialties is initiative-based. What is more, the state interest is not always taken into consideration. Taking into account the need in specific specialists (of very narrow scope) to support activities under the conservation conventions, it is necessary to:

- define directions and forms of training specialists according to the UNFCCC profile, chiefly through post-graduate courses, post-diploma education system, traineeship;
- address the problem of training personnel of superior scientific competence for the thematic areas covered by the UNFCCC.

Keeping public informed

In order to build public opinion, consistent efforts are needed to inform the general public about the environment and a range of problems linked to climate change through governmental and non-governmental organizations, mass media. The Republic of Belarus put in place a system to inform the public about the environment status and conservation measures. A number of magazines, newspapers are published, radio programmes are aired. The production of ecological radio and television programmes is small.

Monthly ecological material is published in the newspapers “Narodnaya Gazeta”, “Belorusskaya Niva”, “Culture”, “Vecherny Minsk”, “Minsk Courier” and many local newspapers. For several years now “Zvyazda” has been systematically publishing ecologically-themed materials. But this is clearly not enough. The level of publications fails to meet the up-to-date requirements. The problem is not only lack of ecological information, but the inability to present it in the right way as well.

Among radio programmes the “Ecological Monitoring” with a 60-minute running time is worth mentioning, where sometimes a certain amount of time is assigned for UNFCCC-related information.

None of four national television channels of Belarus (ONT, LAD, BT, STV) have a special programme dedicated to ecological problems. There are practically no programmes based on national material, which is also true for Russian channels (ORT, RTR, NTV) that broadcast in the territory of our country.

The Belarusian viewing audience finds out about UNFCCC-related problems from short features about energy saving and conversion to local fuels (biofuel, peat). UNFCCC and KP problems on the Russian channels are presented inasmuch as they relate to the accession to the Kyoto Protocol. References of climate-change problems (greenhouse effect) and UNFCCC dramatically increase in frequency in summer during high-temperature periods, and in the coverage of extreme meteorological events (drought, hurricane, etc.).

Public ad clips (over 25) running on all channels commissioned by the Ministry of Environment and dedicated to the Belarusian nature and ecological problems are of great educational and didactic value. However a clip about the exceptional role of mires for the biosphere and their conservation importance sometimes can be followed a story, unaccompanied by any commentary, about a planned considerable increase of peat production.

Within the framework of the EU Project “Technical Assistance to Ukraine and Belarus with Respect to their Global Climate Change Commitments” a regularly updatable website has been created at www.climate-by.com. The site offers extensive information in the field of global climate change and global response to it, there is a large section of resources offering the latest methodological developments in JI projects, GHG inventories. There is a possibility to hold a forum at the site.

5.4. Existing problems

Problems of building public awareness about UNFCCC via mass media are first of all connected with lack of reliable and accessible information on all the issues related to climate change, including Belarus-specific information. In the light of the publication of the First National Communication awareness-raising activities will be galvanized. A web-site on UNFCCC created under the project will make its contribution to keeping the public and specialists informed. Better use should be made of specific materials concerning the challenges Belarus faces in the light of climate change, and every citizen should feel they have a part to do in addressing these challenges. This will enhance the level of motivation to protect environment at a practical level.

Secondly, journalists are not sufficiently aware about the UNFCCC subject-matter. Special attention should be paid to the training of newspaper, radio and television journalists doing environment for competent coverage of problems relating to climate change, biodiversity, land degradation. To this end, it is possible to use the already available informational materials, including from the Internet, educational seminars, booklets, popular books, thematic creative competitions, etc.

5.5. Proposed measures

Non-governmental organizations can contribute sizably to better public awareness on climate change, although their capacity in the UNFCCC area of responsibility is somewhat poorer than under other conventions. Therefore it is important to ensure that raising awareness about climate change matters is closely linked to information and communication policies under the related conventions.

To develop mass media capacity, it is recommended to:

- run a competition for the best series of publications, best TV and Radio programme (with cash bonus) on the subject of ecology, including connected with the UNFCCC theme;
- arrange training (skills advancement) of journalists covering ecology with the involvement of leading scientists and NGO experts of Belarus;
- find a way to publish an ecological magazine designed for the general readership and bring the best expertise available to write materials for it.

The improvement of the education, personnel training and climate-change awareness raising system is related to the development of a new National Education Improvement Programme, which should build on extensive experience of the previous similar programmes taking into account modern requirements regarding the organization, content, means and techniques of education. If the results of the analysis presented within this chapter are taken into proper consideration, it will help substantially improve the content of the Programme and set its focus on specific problems related to meeting commitments under the three global environmental conventions.

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