FIRST NATIONAL COMMUNICATION OF THE REPUBLIC OF ARMENIA

UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

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MINISTRY OF NATURE PROTECTION OF THE REPUBLIC OF ARMENIA
UNITED NATIONS DEVELOPMENT PROGRAM OFFICE IN ARMENIA
GLOBAL ENVIRONMENT FACILITY

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ABBREVIATIONS

ArmHydromet	Hydrometereological Department of the Republic of Armenia
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gases
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
NPP	Nuclear Power Plant
RA	Republic of Armenia
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Metereological Organization of UN

Chemical Symbols

CO	Carbon Monoxide
CO_2	Carbon Dioxide
CH_4	Methane
N_2O	Nitrous Oxide
NO_x	Nitrogen Oxides
NMVOC	Non Methane Volatile Organic Compounds

Measures

c.f.	conditional fuel
eqv.	equivalent
km	kilometer
km^2	square kilometer
km^3	cubic kilometer
g	grams
Gg	gigagram (10^9g)
ha	hectare
J	joule
PJ	petajoule
mm	millimeter
m	meter
m^3	cubic meter
thous.	thousand
mln.	million
ppm	parts per million
t	tone
kt	kilotone (10^3t)
Mt	megatone (10^6t)
MWt	megawatt
Wt.h.	watt - hour
KWt h.	kilowatt - hour
GWt h.	gigawatt - hour
$	dollars US

EXECUTIVE SUMMARY

The Republic of Armenia ratified the United Nations Framework Convention on Climate Change in May 1993.

In Armenia, a mountainous country with vulnerable ecosystems, distinguished by droughts and shortage of water, as well as liable to erosion, desertification and natural calamities, especially perceptible displays of unfavorable consequences of global climate change are to be expected.

Since 1996, in order to fulfill the basic provisions of the Convention, Armenia is implementing the project "Armenia - Country Study on Climate Change", which is funded by Global Environment Facility.

The principle obligations of Armenia, included according to the Convention into the group of developing countries, are:

- *inventorying of anthropogenic emissions and sinks of greenhouse gases according to the IPCC Guidelines on National greenhouse gas inventory;*
- *identification at national level of the regions, natural ecosystems and spheres of activity, which are the most vulnerable as a result of expected climatic changes and assessment of social and ecological consequences. Development of responding strategy on climate change, coordinated with the social and economic development;*
- *development of education, training of specialists, raising the awareness on climate change related issues, enhancement of public opinion to these problems;*
- *international cooperation and information exchange on issues with relevance to fulfillment of UN FCCC;*
- *submitting information on national measures for the fulfillment of the Convention and their results to the Conference of Parties;*
- *cooperation directed to reduction of anthropogenic emissions of greenhouse gases in all sectors of economy, especially in energy sector as well as in transport, industry, agriculture, forestry and waste removal.*

The results of activities carried out under the Convention are reflected in the First National Communication of the Republic of Armenia, principle provisions of which are presented in the given Executive Summary.

The peculiarities of development of economy and energy sector in Armenia in 1990-1995

Transition to market relations in Armenia as well as in other Republics of former USSR is accompanied by deep economic recession. The situation in Armenia was aggravated by catastrophic earthquake in 1988 and blockade of the main ways of communication because of conflict situation in Transcaucasus.

As a result of economic crisis in Armenia in 1995 in comparison with 1990 the following has taken place:

- *reduction of Gross Domestic Product (GDP) for 70 %;*
- *reduction of volume of the industrial production for 75 % and agricultural - for 30 %;*

- *reduction of the cargo flow and passenger flow accordingly in 16 and 5 times, including motor transport - in 70 and 4.5 times;*
- *sharp decrease of living standards of the population.*

Armenia has almost no fuel and energy resources of it own. The only traditional local source of energy are hydro-resources, half of which is already in use. The need for fuel is almost completely compensated due to import. At the same time Armenia has a certain capacity of solar, wind and geothermal energy and a prospective of their exploitation.

The general economic crisis, the 1989 decommissioning of the Armenian Nuclear Power Station after the earthquake, energy blockade of 1991-1994 and the immense increase of prices on energy resources have adversely influenced the whole energy sector of Armenia. Consequently, during 1990-1995 the following has taken place:

- *reduction of general energy consumption in 3.6 times;*
- *reduction of primary energy resource consumption in 2.5 times;*
- *reduction of the amount of used organic fuel in 5 times (including natural gas in 3 times, oil products in 7.5 times);*
- *reduction of electric power production almost in 2 times and thermal energy in 20 times;*
- *reduction of energy consumption efficiency - increase of the GDP energy capacity two-fold and of GDP electric capacity in 3.6 times;*
- *reduction of energy consumption per capita in 3.6 times.*

As a result of the mentioned factors the anthropogenic emissions of CO_2 in 1995 have reduced in almost five-fold compared to 1990.

Interrelation of principle social-economic and energy factors and emissions of greenhouse gases in Armenia in 1990-1995 as well as specific parameters of emissions are characterized by data, given in Table I

.

Table I *The determining factors and the greenhouse gas emissions in Armenia, 1990-1995*

Years	**Population**[1/]		**GDP**		**Power**		**GHG Emissions**[2/]		**GHG Emissions per capita**		**GHG Emissions per unit of GDP**	
	mln. people.	Rate % by 1990	In actual prices, mln. $	Rate % by 1990, in fixed prices	PJ	Rate % by 1990	kt CO_2 eqv.	Rate % by 1990	t CO_2 eqv / people	Rate % by 1990	t CO eqv / $ 1000	Rate % by 1990
1990	3.574	0	8770.0	0	350	0	25312	0	7.08	0	2.9	0
1991	3.645	1.9	8390.0	-19.8	336	-4.0	23165	-9	6.3	-10.4	3.3	11.4
1992	3.724	4.0	4312.0	-51.7	168	-52.0	11323	-55.2	3.0	-57.7	2.7	-7.3
1993	3.728	4.1	447.3	-74.4	142	-60.0	8255	-67.4	2.2	-69.0	3.7	12.7
1994	3.737	4.4	651.4	-73.0	82	-76.6	4779	-81.1	1.3	-82.0	2.0	-30.6
1995	3.765	5.1	1290.0	-70.0	96	-72.6	6193	-75.5	1.6	-77.0	2.4	-17.3

[1/] *Without taking into account the emigration of 677 thous. people in 1991-1994.*
[2/] *Excluding the emissions connected to the land use change and forestry*

From the given data it is evident, that during 1990-1995 the rates of GDP, energy consumption and greenhouse gas reductions are approximately identical and comprise 71-77%. In 1990 emission per capita in Armenia amounts 7.0t in CO_2 equivalent, and in 1995 it has decreased for 77 % and amounted 1.6t in CO_2 equivalent.

At the population of 0.06 % of the world population, Armenia's contribution in global greenhouse gas emission in 1990 was about 0.1 %, and in 1995 - 0.02 %.

National Greenhouse Gas Inventory

The National Greenhouse Gas Inventory was developed for the first time in Armenia according to the IPCC Guidelines. The National Greenhouse Gas Inventory of Armenia considers five of the six main modules of the IPCC Guidelines. These are "Energy", "Industrial Processes", "Agriculture", "Land Use Change and Forestry " and "Waste". The estimations have not been done for the "Solvent Use" module because of the absence of relevant methodology both in IPCC Guidelines and on the national level.

The greenhouse gas emissions have been estimated based on the volume of the relevant activities. In the calculations we have used both the IPCC default coefficients and the verified coefficients with regard to the specific conditions of Armenia. The volume of activities were determined according to the data provided by the state and institutional statistics.

According to the Resolution of the Second Session of the Conference of Parties to the Convention, 1990 was assigned as the basic year.

The main outputs of the Inventory, which can be made more precise in future, are given below.

Total emissions of gases with direct greenhouse effect - CO_2, CH_4 and N_2O and their values in CO_2 equivalent are given in Table II. Table III. provides data by categories of sources.

Table II *The anthropogenic greenhouse gas emissions in Armenia, Gg, 1990*

Greenhouse Gas	Absolute Emissions	Emissions in CO_2 equivalent[1]	Share in total emissions, %
CO_2	21396.08	21396.08	86.64
CH_4	152.76	3207.96	12.99
N_2O	0.2941	91.17	0.37
	Total	*24,695.21*	*100.00*

[1/] Global warming potential (GWP) accepted is 1 for CO_2, is 21 for CH_4 and 310 for N_2O (IPCC, 1995).

The given data illustrate that in 1990 the most significant greenhouse gas was CO_2 which made 86.6% for overall emissions. 93% of the overall national greenhouse gas emissions expressed in CO_2 equivalent are caused by the Energy sector. The emission of CO_2 from the Energy sector has the following distribution by sub-sectors: Energy and transformation industry - 53%, Transport - 17%, Residential and commercial / institutional sector - 18%, Industry - 10%, other - 2%.

In 1990 the CO_2 emissions in the Forestry sector made 80 Gg, removals made 697 Gg. The net removal counted for 617 Gg.

While preparing the inventory in the Energy sector besides the Reference Approach (Top-Down Method), the Method of Detailed Technology (Bottom Up Method) has been used. The results of both methods turned out to be correspondent, although the Method of Detailed Technology has many principal advantages, and the future development of activities directed to the Inventory preparation should be basically focused on the use of this method.

The Inventory also included the assessment of anthropogenic emissions of gases with indirect greenhouse effect, such as nitrogen oxides (NO_x), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOC).

At present in Armenia researches are being conducted in order to clarify the coefficients for methane emission for "Agriculture" and "Waste" sectors, as well as from water area of Lake

Sevan with regard to the on-going eftrophication as a result of the anthropogenic reduction of the lake level

Table III *Greenhouse gas emissions in Armenia according to source categories, Gg, 1990.*

Greenhouse Gas Source and Sink Categories	CO_2	CH_4	N_2O
Energy	***21382.78***	***80.25***	***0.1281***
A. Fuel Combustion	*21382.78*	*0.28*	*0.1262*
Energy and Transformation Industries	11332.87		0.0670
Industry	2138.28		0.0126
Transport	3635.07		0.0215
Residential and Commercial/Institutional sector	3848.90		0.0227
Other	427.66		0.0024
Biomass Burned for Energy		0.28	0.0019
B. Fugitive Emissions		*79.97*	
Oil and Natural Gas System		79.97	
Industrial Processes	***630.30***		
Agriculture		***47.01***	***0.1660***
Enteric Fermentation		44.07	
Manure Management		2.70	
Field Burning of Agricultural Residues		0.24	0.0060
Use of Nitric Fertilizers			0.1600
Land Use Change and Forestry	***-617.00***		
Changes in Forestry and other Woody Biomass Stock	-617.00		
Forests and Grassland Convention[1/]			
Abandonment of Managed Lands[1/]			
Waste		***25.50***	
Landfills		23.70	
Wastewater Treatment		1.80	
Waste Incineration[1/]			
Other [1/]			
Total Net Greenhouse Gas Emissions[2/]	***21396.08***	***152.76***	***0.2941***
Emissions from International Bunkers	404.80		0.0030

[1/]the activity types do not exist in Armenia
[2/]with consideration of the emission-removal balance in the Forestry sector

National strategy for limitation of greenhouse gas emissions

Armenia, as a developing country not included in the Annex I of the UN Framework Convention on Climate Change, has no obligations for greenhouse gas emission reduction. However, it could undertake voluntary obligations on their limitation with assistance from developed countries within the frames of corresponding mechanisms for implementation of the Convention. Respectfully, emission limitation strategy was developed based on the principle provisions of the Energy Master Plan of the Republic of Armenia for the period up to 2010.

The strategy is based on the optimal combination of the following factors:

- *ensure conditions for overcoming the economic crisis and subsequent sustainable social-economic development and, according to the feasible development scenario, attain 70 % of the economic level of 1990 by the year 2010;*
- *satisfy the energy requirements for the projected social economic development and increase the of energy consumption efficiency;*
- *implementation of necessary measures on perfection and structural transformations of energy-systems with cost effectiveness;*

- *maintain minimal level of greenhouse gas emissions and polluting substances.*

In case of the implementation of Energy Master Plan of the Republic of Armenia, the basic components for greenhouse gas emission limitation will be the following:

- *increase of resources and modernization of the existing generating capacities of the power stations and application of new highly efficient technologies (with a combined cycle) on thermal power stations. This will allow a considerable reduction of the specific consumption of fuel for the electric power production, and will result in annual saving in fuel after the year 2000 for 120-190 kt of conditional fuels (kt c.f.) and a corresponding reduction of CO_2 emissions;*
- *increase of the share of its own primary energy resources' production by increasing the share of hydro-power (from 18 % in 1990 up to 26.8 % in 2010), and the use of nuclear power; use of geothermal and wind energy, share of which in the electric power production will make 14.3 % in 2010. With the increase of the own primary power production from 10.9 % in 1990 up to 32-37 % in 2005-2010 a reduction of the share of thermal power stations in the power balance is projected from 82 % in 1990 up to 26.5 % in 2010;*
- *increase of the share of natural gas and reduction of the share of fuel oil in energy production. As compared to 1990 it is planned to reduce the share of fuel oil from 32% up to 9 % by 2000, and up to 6-7 % by 2005-2010, and increase of the share of natural gas up to 72 %;*
- *increase of the energy consumption efficiency and energy-saving. The main reserve for energy-saving is in electric-power industry and heat supply sector, as well as in industry and municipal and commercial sectors. The exploitation of these reserves will allow to save 318 kt c.f., and to reduce the CO_2 emissions for 609 Gg annually by 2010. A long term significant increase of the energy consumption efficiency can be achieved by the reduction of water losses in the irrigation systems and the application of gravitational irrigation. That will enable to increase the electric power generation in the hydro-power stations by 100 GWt h. annually. The energy consumption efficiency can also be achieved by the realization of a stimulating tax and tariff policy.*

Two basic scenarios are considered in the Energy Master Plan of the Republic of Armenia: one of them being the development without nuclear energy and the other - the development with nuclear energy. For both scenarios a computer modeling of the power system is carried out - considering the minimization of given expenses, energy-saving and emission of polluting substances to the atmosphere. The program has considered the scenario with a new nuclear power plant with higher safety level more preferable despite a minor excess in the given expenses. The nuclear plant has such advantages, as the diversification of fuel and reduction of dependence on its import, also lower levels of CO_2 emission.

The comparative estimation of scenarios has shown, that power system development under the scenario with a nuclear cycle will allow a CO_2 emission restriction for 1184 Gg/year in the period starting from 2005 to 2010, and for 869 Gg/year after 2010.

The forecast of the total energy demand of the national economy by different kinds of energy carriers is illustrated in Table IV. An appropriate forecast estimation of CO_2 emissions in the power sector is given in Table V. Forecast assessment of the equivalent emissions of greenhouse gases is presented in Table VI.

Table IV *The forecast of energy demand of the national economy of Armenia*

Energy Carriers	1990	1995	2000	2005	2010
Electric energy, GWt h. PJ	11290 155.2	5513 60	7420 81	8840 96	11000 151
Heat energy, mln. Gcal PJ	34 142.8	1.4 5.7	7.6 31.9	14.9 62,5	18.5 77.4
Engine oil, kt c.f. PJ	1975 58.0	593 20.3	893 26.2	7165 34.1	1444 42.3
Primary energy resources, kt c.f.. PJ	6362 186.4	2517 73.7	4149 121.5	5894 172.7	7387 216.4

*1Gcal =4.187 GJ. 1t c.f. = 29.308 GJ

Table V *The forecast of anthropogenic CO_2 emissions in the power sector of Armenia, Gg*

	1990	1995	2000	2005	2010
Energy and Transformation Industries	11333	2530	2515	2127	1929
Industry and Construction	2138	398	873	1877	1943
Residential & Commercial / Institutional sector	3849	1030	1760	2200	2750
Transport	3635	220	1577	3007	3678
Other	428	205	223	652	1177
Total:	21383	4383	6948	9863	11477

Table VI *The forecast of equivalent greenhouse gas emissions in Armenia*.*

	1990	1995	2000	2005	2010
Equivalent CO_2 emissions eqv., Gg	25312	6193	9161	12650	14726
Contribution to the total emissions, %					
CO_2	87.0	72.5	78.0	80.4	81.2
CH_4	12.6	26.8	21.4	19.0	18.3
N_2O	0.4	0.7	0.6	0.6	0.5
Emissions per capita, t CO_2 eqv./person	7.0	1.6	2.35	3.26	3.74
Armenia's share in global emissions, %	0.1	0.02			

* The values of global warming are accepted: for **CO_2** - 1, for **CH_4** - 21, for **N_2O** - 310 (IPCC, 1995)

The analysis of change for CO_2 emissions (energy sector and industry) in 1990-1995, and its forecast up to 2010 for the basic development scenario (preservation of the tendency) and for two scenarios of the development of energy sector shows, that by preserving the energy production and consumption tendencies at the level of 1990 (basic scenario) the total CO_2 emission in 2010 will make 77.3 % from the level of 1990 or 17026 Gg. The implementation of measures, stipulated by the strategy, will enable a CO_2 emission reduction by 2010 up to 54.3 % of the level of 1990, or up to 11960 Gg annually, that is 5066Gg lower than according to the basic scenario, and that will also reduce the emission indicator per unit of energy produced by 32 % (from 61.0 up to 42.2 Gg/PJ).

Possible consequences of climate change, vulnerability assessment and measures of adaptation

Global climate change and internal micro-climatic changes on the territory of Armenia might have the following consequences:

- *Change of the borders of natural climatic zones;*
- *Significant change of the biota;*
- *Change of the mode of the rivers' runoff, significant infringement of water balance of Lake Sevan and quantitative indicators of water resources;*
- *Change of amount of precipitation and soil moisture content;*

- *Change of Agriculture potential of the Republic;*
- *Change in indicators of the sick rate of the population.*

These consequences can essentially affect the climate-dependent branches of economy.

For the vulnerability estimation the IPCC scenario is accepted: increase of the air temperature in 2^0C and reduction of atmospheric precipitation for 10 %.

Natural ecosystems. *As a result of the analysis of the present condition of the mountain ecosystems of Armenia it has been established, that all of them have certain adaptation opportunities. The middle zones of each ecosystem on the height of 150-200m are pre-adapted to possible climate changes. Significant changes are not expected here.*

The modeling of the vulnerability of mountain ecosystems of Armenia with regard to the climate change for the next 100 years foresees a shift of the landscape-zone borders up the mountain for 100-150m.

The vulnerability assessment and measures of adaptation for ecosystems on the main landscape zones of Armenia according to the accepted climate change scenario is presented below.

It is expected that the desert - semi-desert zone area will expand by 33%, a new desert zone will form, and the semi-desert will move over to the bottom border of the forest in south-eastern part of the Republic. Due to the expansion of the desert - semi-desert zone and possible reduction of lake areas, and drying of salted swamps, a number of vegetation communities connected to the over-humidified habitats, as well as endemic and rare species are expected to disappear. The steppe belt will be the expanded by 4 % and shifted upwards by 150-200m, which will cause transformation of steppe vegetation communities. The present bottom belt of steppes will be replaced by semi-desert vegetation, the steppe will move over the sub-Alpine vegetation. At the same time the steppes will move over to the bottom border of the forest. The lower border of the forest belt will move upward by 100-200 m. Vulnerability of forests will increase as a result of increase of mass reproduction of leaf-cutting beetles, which will cause a 15% loss in the annual wood mass growth. The area of sub-Alpine belt will be reduced by 21%, and that of the Alpine belt - by 22% on the average, and its vegetation will occur in the most vulnerable situation. First of all the areas of Alpine meadows will be reduced, and the endemic and rare species will be endangered, because they will have no room to recede.

Increase of climate aridity and intensification of desertification processes can be expected under the projected increase of temperature and precipitation reduction.

The climate change and the shift of landscape zone borders will have a significant impact on the most vulnerable species of fauna of Armenia. The reduction of total biomass of the soil zoocomplexes by 14 %, reduction of habitats and the number of populations of some insects, reptiles and disappearance of certain rare and endemic species is expected. Forced migration and reduction of habitats will result in decrease of populations of some species of birds.

For the mitigation of adverse consequences of climate change of natural ecosystems of Armenia following measures on adaptation are necessary: creation of optimum landscape-zone structure for the country as a whole (increase of the forest share, including protective forest belts by 2050 up to 20.1% of the territory of the Republic); allocation of reserves and specially protected natural territories for the reduction of general anthropogenic pressure on the vulnerable ecosystems; introduction of endangered species into similar habitats, which will survive in case of climate change; preservation of the genofund of the most vulnerable and valuable species by keeping and cultivating in artificial conditions, preservation of gene material in seed banks, etc.; monitoring of vulnerable ecosystems.

Water resources. *In case of the accepted scenario of climate change, reduction of annual river flow by 15%, and increase of evaporation from the surface of Lake Sevan by 13-14% is expected. Adaptation measures include: increase of accumulation volumes of winter-spring river*

flow by 2,0 billion m^3; reconstruction irrigation systems in order to reduce the water loss and apply advanced water-saving methods of irrigation; increase of water stocks in Lake Sevan by transfer of free flows from full-flowing river-basins with simultaneous reduction of outlets from the Lake for energy and agriculture needs; economy and rational use of water in all branches of economy; and monitoring of water resources.

Agriculture. *In case of the forecasted climate change, depending on the vegetation period and the altitude of the district, a reduction of soil humidity by 10-30%, of natural humidity provision of various agricultural cultures by 7-13% and an increase of moisture deficit in soil by 25-50mm is expected. Under the projected change of climatic characteristics, the efficiency of plant-cultivation in Armenia can be reduced by 8-14%. The productivity of cereals will be reduced on average by 9-13%, vegetable cultures - by 7-14%, potato - by 8-10%, fruits - by 5-8%. The productivity of a more heat-resistant grapes can grow by 8-10%.*

The following consequences in pasture cattle-breeding are projected: reduction of the pasture area as a whole and the stocks of their production by 4-10%, including the areas of the most valuable and productive pastures of sub-Alpine and Alpine belts by 19-22%, and also a productivity decrease of mountain hayfields by 7-10%. In this respect a reduction of the number of cattle by 30% and production of cattle-breeding by 28-30% is expected.

For the mitigation of adverse consequences of climate change and the directed adaptation of the agrarian sector of economy of Armenia to the new condition of natural environment a wide range of adaptation measures should be implemented. Among those measures are first of all, the optimization of the land-use funds and the change of the structure of crops, the expanded introduction of humidity-preserving technologies, the revision of the zone distribution of irrigated lands, the application of advanced agro-technical measures, and the introduction of new frost-resistant and drought-resistant high-yielding varieties, the restoration and protection of pastures and the improvement of the breed-structure of herd.

Human health. *In the case of the expected climate change the weakening of adaptation mechanisms, as well as an increase of cardiovascular diseases, especially among the most vulnerable part of population is projected. There is a possibility of outbreak of plague epidemic situation as a result of partial covering of areals of plague microbe carriers. Expansion of the areals of carriers and increase of epidemic danger of malaria is expected. According to the forecast there could be an aggravation of epidemic situation for cholera. Increase of intestinal diseases as a result of the longer duration of the period with optimum temperatures for reproduction and development of causative agents in soil and water is predicted. The adaptation includes a complex of social, sanitary, preventive and administrative measures.*

Study of climatic system and systematic observation.

The climate change in Armenia is mainly stipulated by the global climate change of the Earth, and also on the internal microclimatic changes of anthropogenic origin.

The observed and expected changes of climatic characteristics in Armenia are assessed with the help of empirical-statistical methods on the basis of hydro-meteorological data of ArmHydromet, which include the observation of 56 meteostations during 1885-1996. The climatic anomalies are determined relative to standard period WMO (1961-1990).

Air temperature. *For the assessment of the observation data from 46 meteo-stations for the period of 1930-1990 were processed. Positive linear trend of the average annual air temperature in Armenia relative to standard period has made 0,3 ^oC.*

For the assessment of air temperature changes on the territory of Armenia the estimated values of global change of temperature were used depending on projected levels of global greenhouse gas emissions, attained by IPCC. The calculations showed that the average air temperature in Armenia will increase by 1,7^oC in 2100.

Atmospheric precipitation. *For the assessment of precipitation changes on the territory of Armenia observation data from 56 meteostations and sites for the period of 50-100 years were used. The values of the amount of total annual and seasonal precipitation have been studied and anomalies in relation to standard period were calculated. It is determined that the average annual amount of precipitation in the Republic for the studied period have decreased by 5,8%. In case this tendency is preserved, the precipitation on the territory of Armenia will decrease by about 10% in 2100.*

The received parameters of expected changes of the climatic characteristics on the territory of Armenia are well coincided with the IPCC estimations, received on general atmosphere circulation models for Southern Europe, where Armenia is located. In this respect the expert group has come to the preliminary conclusion on the choice of the climate change forecast scenario in Armenia in 2100 with the increase of air temperature by 2^oC and reduction of precipitation by 10%.

Scientific - technical programs.

In the Republic of Armenia the following technical programs, directly or indirectly connected to the reduction of anthropogenic greenhouse gas emissions and vulnerability of socio-ecosystems, are being implemented:

Energy Master Plan of the Republic of Armenia
Energy Conservation
Forest Sector Development
National Environmental Action Plan
Rehabilitation of Ecological Balance of Lake Sevan
National Strategy on a Biodiversity
Optimization of the irrigation system of Armenia.

In scientific and design organizations researches are being conducted on the development of renewable sources in industry, agriculture and the service sectors, as well as involvement of additional hydroresources in the energy balance by the construction of small hydropower stations.

Education, training of personnel and public awareness.

The Yerevan State University is training specialists on climatology.

Six Higher Educational Institutions of Armenia are training specialists in five fields of ecology, which can be requalified on the solution of climate change problems.

Training of personnel in Scientific-Applied Center of Hydrometeorology and Ecology at ArmHydromet is organized. In 1997-1998 specialists from Armenia have participated in training in France ("Meteo-France").

In the frame of the Program " Armenia - Country Study on Climate Change" an Information Center has been created and well equipped.

Raising the public awareness on the issues of climate change and its consequences is carried out in the following directions:

- *Conduction of seminars on various aspects of climate change;*
- *Publication and distribution of the brochures and information bulletins;*
- *Organization of radio - and TV programs and publication of articles in press;*
- *Conduction of thematic lectures in educational institutions of Armenia;*

Presentation and discussion of the results received for Armenia on the climate change problems in governmental and public organizations.

Chapter I. INTRODUCTION

At the end of XX century a number of global environmental changes, caused by the continuously expanding scales of human activities, have been observed. The increase of the greenhouse gas concentration in the atmosphere is one of these changes, which causes an intensification of the natural greenhouse effect, infringement of radiation balance between the surface of the Earth and atmosphere, and increase of their temperature. Global climate change can result in formation of new physical-geographical conditions on the Earth and can cause adverse consequences for natural ecosystems and mankind.

The basic contribution to the increase of greenhouse gas concentration in the atmosphere is done by the gases with direct greenhouse effect: carbon dioxide (CO_2), methane (CH_4) and nitric oxide (N_2O). The volume of CO_2 emissions is the greatest because of the continuous growth of global energy consumption and tremendous scales of fossil fuel combustion.

The increase of the main greenhouse gas concentration in the atmosphere for the industrial period of global development is presented in Tab. 1.1 (IPCC, 1995).

Table 1.1 *Concentrations of greenhouse gases in the atmosphere*

Gas	Preindustrial Period, ppm	1992, ppm	Growth %
CO_2	280.000	355.000	19.64
CH_4	0.700	1.714	144.86
N_2O	0.275	0.311	3.09

Simultaneous to the increase in global carbon dioxide emissions there is a large-scale woods removal, which brings to the reduction of CO_2 absorption from atmosphere.

In order to protect the climatic system from dangerous anthropogenic impact and prevent the adverse consequences of such impact, and acknowledging that climate change on the Earth and its adverse consequences are global concern, the UN member states have signed the UN Framework Convention on Climate Change in 1992, which was ratified by the Republic of Armenia in May 1993.

In Armenia, a mountainous country with vulnerable ecosystems, distinguished by droughts and shortage of water, as well as liable to erosion, desertification and natural calamities, especially perceptible displays of unfavorable consequences of global climate change are to be expected.

With population comprising 0.06 % of the world population, Armenia's input in the global emissions of greenhouse gases has made about 0.1 % in 1990, and 0.02 % - in 1995.

In 1990 in Armenia the anthropogenic emissions of greenhouse gases in CO_2 equivalents has made 25Mt (CO_2 - 87 %, CH_4 - 12.7 %, N_2O - 0.3 %). The emissions of the main greenhouse gas - CO_2 has made 6.2t per capita, and was about the same level with Sweden, Switzerland, Spain, France and was three times less than the emission level in the USA and twice less than in Japan (data of UNFCCC Secretariat), and the emission per unit of GDP: 2.5t CO_2/1000 US dollars.

In 1995 as a result of deep economic and power crisis the emission of greenhouse gases in Armenia was reduced to 77 % and made 5.8Mt CO_2 eqv.- including the emission of CO_2 - 4.5Mt, and the emission per capita and per unit of GDP - 1.2t CO_2 and 3.5t CO_2/1000 US dollars,

accordingly.

The basic commitments of the Republic of Armenia, which, according to the Convention, is in the group of the developing countries, are:

- Inventorying of anthropogenic emissions and sinks of greenhouse gases according to the Intergovernmental Panel on Climate Change Guidelines on national inventories of gases with greenhouse effect;
- Identification of regions, natural ecosystems and spheres of activity at the national level, which are most vulnerable for climatic changes, and estimation of social and ecological consequences. Development of strategy for responding to climate change, which will be coordinated with social-economic development;
- Development of education, training of personnel, raising public awareness on the climate change problems and attraction of public attention to these problems;
- Realization of international cooperation and information exchange on issues connected to fulfillment of the commitments to the UN Framework Convention on Climate Change;
- Provision of information about the national measures aimed at the fulfillment of the commitments to the UN Framework Convention on Climate Change and their results to Conference of the Parties;
- Cooperation aimed at the reduction of anthropogenic emission of greenhouse gases in all sectors of economy, especially in the power sector, as well as in the transport, industry, agriculture and forestry, and waste removal.

The First National Communication of Armenia on Climate Change prepared in the framework of the "Armenia - Country Study on Climate Change" project, which is funded by the Global Environmental Facility and with assistance of the UN Development Programme in Armenia. Representatives of many departments, organizations and scientific institutions of the Republic of Armenia participated in the development of the Communication.

Chapter 2. NATIONAL CIRCUMSTANCES

The Republic of Armenia is located in Southern Transcaucasus, on a joint of Caucasus with Forward Asia and occupies a small part of the extensive Armenian plateau. On the North and East Armenia borders with Georgia and Azerbaijan, on the West and South-East with Turkey and Iran accordingly. The Republic does not have access to sea.

The Republic of Armenia has an area of 29800 km^2, which is approximately equal to the territory of Belgium and Albania. The greatest extent from North-West to South-East is 360 km, and from West to East - 200km. The capital of the country is Yerevan.

2.1. Natural Characteristics

Armenia is a typical mountainous country. About 90% of its territory is over 1000m above sea level, including 40% - over 2000m. Average height of territory makes 1830m, the highest - 4090m, the lowest - 350m.

Geographical situation of Armenia, complex mountain relief and high-altitude zoning of territory have caused unique variety of natural conditions and natural resources.

The territory of Armenia is specific for strongly pronounced vertical alternation of six basic climate types - from dry subtropical up to severe Alpine, and temperature contrasts. In the low-lands the average air temperature in July and August reaches 24-26°C, and in the Alpine belt the temperature does not exceed 10°C. In January, depending on the height and peculiarities of the relief, the temperature varies within the bounds of 1-13°C. In Armenia the absolute maximum and minimum temperatures reach 41°C and -42°C.

In general, Armenia is distinguished by aridity - the average annual precipitation here reaches 570 mm. The significant part of the territory - over the 60% - receives less than 600 mm, 20 % - less 400mm, and on the bottom of the closed basins - only 200-300mm.

Armenia lays in the same geographic breadth as Spain, Italy and Greece, that is in a subtropical zone. Therefore one of the most characteristic features of its climate is intensity and abundance of solar radiation, which, accordingly, make 1.46 cal/cm^2 and 2500 hours per year.

Duration of the heating period is 120 days, and of the air conditioning - 90 days.

Due to the climate variety and large fluctuations of heights five basic landscape zones have been formatted in Armenia: semi-desert with fragments of desert, steppe, forest, Alpine and Nival.

The territory of Armenia includes 11 climatic zones, and agriculture is specialized according to those.

Armenia is also distinguished for extreme variety of land cover - about 15 types and 40 subtypes of land can be found here.

The flora and fauna of Armenia are marked by great variety of types. About 3500 plant species (almost half of the whole Caucasian flora) grow, and more than 500 species of vertebrate animals inhabit the territory of Armenia, including about 300 birds species, more than 50 species of reptiles, 8 amphibious species, more than 20 fish species and more than 80 mammal species. The world of insects includes 10-12 thousand species, other invertebrates - more than 1000.

The forests occupy only 11.2 % (334.1 thousand ha) of the territory of Armenia and are unevenly distributed: 62 % of forests is located on North-East, 36 % - on South-East, 2 % - in the Central regions. The forest area per capita is only 0.1ha. More than 200 tree species grow on the territory of Armenian, the main forest-formatting three species are: oak, beech and hornbeam. Main

assignments of forests in Armenia are protective, climate-regulating, anti-erosional, water-protective etc.

The water resources of Armenia are generally formed on its territory and on average make about 7.8km^3 annually, including surface -4.7, ground - 3.1. On territory of the RA there are more than 300 rivers over 10km long and about 9500 small drains up to 10km long. The density of the river network on the average is 0.4 km / km^2 and is extremely unevenly distributed. The rivers of Armenia are also marked for great non-uniformity of distribution of runoffs during the year and in the long-term, mainly due to mixed supply (snow, rain, subterranean waters).

There are over 100 mountain lakes in Armenia, and their majority, except for lake Sevan, are minor.

Lake Sevan is one of largest high-mountain fresh-water lakes of the world. Nowadays the level of the lake is 1896.7m, the surface area - 1241km^2, the volume - 33.4km^3. During the use of the lake water for electric power generation and irrigation the level went down on 19.3m, the surface area reduced on 175km^2, the volume of water on 25.4km^3.

The water resources of Armenia are used for hydropower, irrigation and water supply.

The distribution of the territory of Armenia and its land condition are given in Tables 2.1 and 2.2

The peculiarities of the natural complex of Armenia, such as high seismicity, intensity of slope processes, contributing to landslide occurrence, landslips and development of erosion, desertification, water scarcity and seasonal character of the river runoff, lahar exposure and aridity of territory and climate, rockiness and salination of lands, the high vulnerability of mountain ecosystems create large difficulties in the economic use of territory and require constant realization of complex protective measures. Additional concern is caused by the intensification of the mentioned phenomena connected to the possible global climate change.

Table 2.1 *Distribution of the territory of Armenia 1995, thousand ha*

Land Categories	Values
Total Area	2974.3
Agricultural Lands	1391.4
Including:	
arable lands	483.5
perennial plantations	74.7
fallow lands	0.8
grasslands	138.8
pastures	693.5
Forests	334.1
Swamps	0.4
Water Surface	164.0
Land occupied by buildings	50.0
Land occupied for roads and purlin	35.0
Other lands	979.2

Table 2.2 *Condition of Land Resources of Armenia, 1995*

Parameters	Values
Agricultural Cultivation of Lands, %	46.7
including the arable land	16.1
Total area of eroded lands and lands exposed to erosion, thous.ha	1225.0
including the agricultural lands	860.0
arable lands	120.0
The area of lands exposed to: thous.ha	
waterlogging,	0.4
salination,	15.0
underflooding,	43.0
Total area of rocky agricultural lands, thous. ha	610.0
including arable lands	140.0
Total area of irrigated agricultural lands. thous. ha	306.0
Including:	
arable lands	202.4
perennial plantations	84.6
grasslands	12.0
pastures	10.0
Area of lands occupied by Municipal Waste sites, thous. ha	30.0
Total area of transgressed lands, thous. ha	25.0
Protected territories, unit / thous. ha:	
reservoirs	4 / 63.0
natural national parks	1 / 145.0

2.2. Social Economic Characteristics

The population of Armenia is 3.76 mln (1995). The average density is - 120 person per km^2. The population is unevenly distributed on the territory of Armenia, caused by mountainous relief. More than half of population is concentrated in a high-altitude zone up to 1000m above sea level, occupying only 10% of territory of the RA - region of intensive agriculture and advanced industry. The population density here is 400 people per km^2. About 23 % of the population lives in the high-altitude zone 1000-1500m and about 25 % - on marks 1500-2000m. In mountain regions, located above 2500m, occupying 16.2 % of the territory, the constant population is absent.

Due to the acute decline of the socio-economic situation and high percentage of people of reproductive age in the emigrating part of the population an annual growth of the population of Armenia has reduced from the 1.9-2.1 % in 1965-1990 to 0.4-0.5% at present, and the natural growth of the population has decreased almost in 3 times as a result of the birth rate reduction on 42 %.

The emission baseline, strategy of limitation and forecast of greenhouse gas emissions are directly connected to specific peculiarities of the social economic development of Armenia during 1990-1995.

Change of the number of population of Armenia for the period of 1979-1996 is given in Table. 2.3.

Table 2.3 *Population of Armenia, thousand people*[1/]

Years	Total population	Including		In the total number of population, %	
		urban	rural	urban	rural
1979	3030.7	1992.5	1038.2	65.7	34.3
1989	3448.6	2363.5	1081.1	68.7	31.3
1990	3514.9	2427.6	1087.3	69.1	30.9
1991	3574.5	2484.7	1090.1	69.5	30.5
l992[2/]	3645.1	2515.2	1129.9	69.0	31.0
1993	3724.6	2581.1	1143.3	69.3	30.7
1994	3728.0	2572.2	1155.8	69.0	31.0
1995	3737.3	2578.7	1158.6	69.0	31.0
1996	3765.0	2606.0	1159.0	69.2	30.8

[1/]the data for 1979 and 1989 are given according to the sensus of population, and for 1990-1996 - according to the data of state statistics for the beginning of the year.

[2/]according to expert estimation the population of Armenia has decreased in 677 thous. people as a result of emigration during 1991-95 and its real number was: in 1991. - 3473, 1992. -3404.5, 1993. - 3243.4, 1994. - 3115.2, 1995. - 3060.7 thous. people.

Before the deep economic and power crisis, started in the beginning of the nineties, Armenia was a country with an advanced multi-branch industry, intensive agriculture and extended social infrastructure. According to the GDP production per capita Armenia was in the number of countries like Greece, Portugal, the former Socialistic countries of Eastern Europe.

In Armenia, as well as in other republics of former USSR, the transition to market relations has been accompanied by deep economic recession. The situation in Armenia is aggravated by a number of factors, connected to specific features of its economic structure. The main factors are:

- The low provision of own primary resources (by 18 %) provided that the basis of the industrial potential of the Republic is the processing industry, based on the imported raw materials. The local demand for fuel, black metals, wire and wood, and about 80 % of needs in raw materials for light industry were fully covered by import;
- The high integration degree of Armenia into the system of national economy of the former USSR and the weak home market. In fact, the complete destruction of economic relations, disintegration of the sale markets and the primary resource prices reaching the international level brought most of the industrial enterprises to the edge of bankruptcy.
- The low land provision and the sharp deficit of food resources, which was earlier covered by import of food products at the expense of export of industrial production.

The economic recession was aggravated by the catastrophic earthquake in 1988 and transport blockade because of the conflict situation in Transcaucasus.

As a result of the economic crisis compared to 1990 the following has taken place in Armenia by 1995:

- Reduction of GDP by 70 % (Table 2.4);
- Reduction of the volume of industrial production by 75%, and agricultural by 30 %;

- Reduction of cargo and passenger flow in 16 and 5 times, accordingly, including motor transport in 70 and 4.5 times;
- Reduction of the general power consumption in 3.6 times, that has resulted in CO_2 emission reduction in 5 times;
- Reduction of the living standard of the population. At present about 60% of the population lives below the poverty line with individual income lower than the cost of the minimal consumer basket, estimated in 21.4 US dollars (1998). According to the human development index, applied by UNDP, from the 48th Armenia went down to the 100th place in the world;

Table 2.4 *The Gross Domestic Product of Armenia.*

	1990	**1991**	**1992**	**1993**	**1994**	**1995**
GDP - in real prices, mln. $	8770.0	8390.0	4312.0	447.3	651.4	1290.0
Rate - in fixed prices, % (1990 -100%)	100.0	80.2	48.3	25.6	27.0	28.9
GDP per capita, $	2370.0	2300.0	1210.0	120.0	174.0	348.0
According to purchasing power parity (PPP)	4740.0	4610.0	2420.0	510.0	365.0	615.0

2.3. Energy Sector

Armenia has almost no fuel and energy reso+urces of it own. The only traditional local source of energy are hydro-resources, half of which is already in use. The demand for fuel is almost completely compensated due to import. At the same time Armenia has a certain capacity of solar, wind and geothermal energy and a prospective of their exploitation.

The complete estimated electrical capacity of the Armenian power system is 3593MWt, including heat power stations -1756MWt, hydro power stations - 1022MWt, nuclear power station - 815MWt. The general heat capacity of the electric power stations and the central heating boilers is about 3000Gcal/h. In the pre-crisis period Armenia was marked by a high level of centralized heat and gas supply to population.

The general economic crisis, the 1989 decommissioning of the Armenian Nuclear Power Plant after the earthquake, power crisis of 1992-1994 and the sharp increase of prices on energy resources have adversely influenced the whole energy sector of Armenia. Consequently, during 1990-1995 the following has taken place:

- reduction of general energy consumption in 3.6 times;
- reduction of primary energy resource consumption in 2.5 times;
- reduction of electric power production almost in 2 times and thermal energy in 20 times;
- reduction of energy consumption efficiency - increase of the GDP energy capacity two-fold and of GDP electric capacity in 3.6 times;
- reduction of energy consumption per capita in 3.6 times.

As a result of the mentioned factors the anthropogenic emissions of CO_2 in 1995 have reduced in almost five-fold compared to 1990. The same for the emissions per capita. The change in power consumption for 1990-1995 is given in Fig.2.1., and the correspondent changes in CO_2 emissions in the energy sector are given in Fig. 2.2.

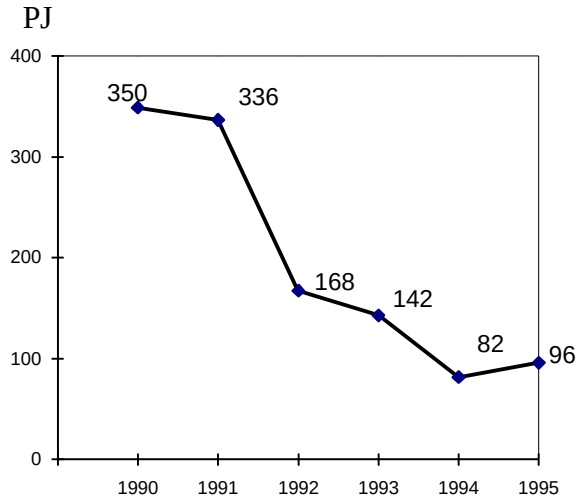


Fig. 2.1 Change in power consumption in Armenia, 1990 - 1995

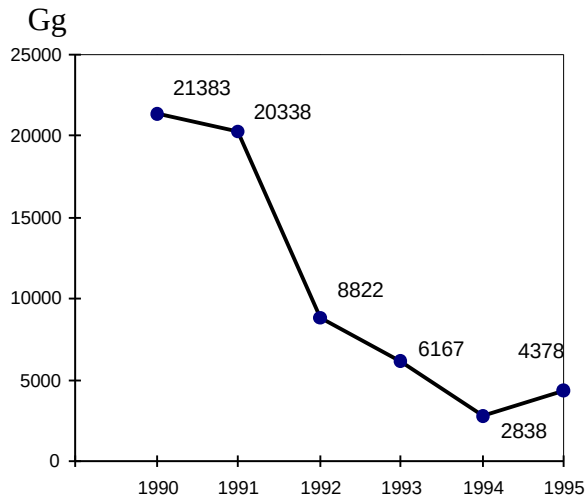


Fig. 2.2 Change in CO_2 emissions in the energy sector of Armenia, 1990-1995

The structure of the consumed energy according to energy carrier types is given in Fig. 2.3. In 1990 and 1995 the greatest share in general consumption belonged to natural gas, in 1995 the share of oil products reduced twice, and the share of hydro-power has increased in 3.8 times.

Use of primary power resources is presented in the Fig. 2.4. As it is evident from the data of 1990 the share of import was about 90%. In 1995 the import of primary power resources reduced in 3.3 times.

The fuel consumption in Armenia is presented in Fig. 2.5. Compared to 1990 the total fuel consumed reduced almost in 5 times, including natural gas in 3 times, fuel oil - in 23 times, petrol in 2.5 times, diesel fuel in 8 times. In 1995 the main fuel type was natural gas, the share of which in the general fuel use was about 70 %.

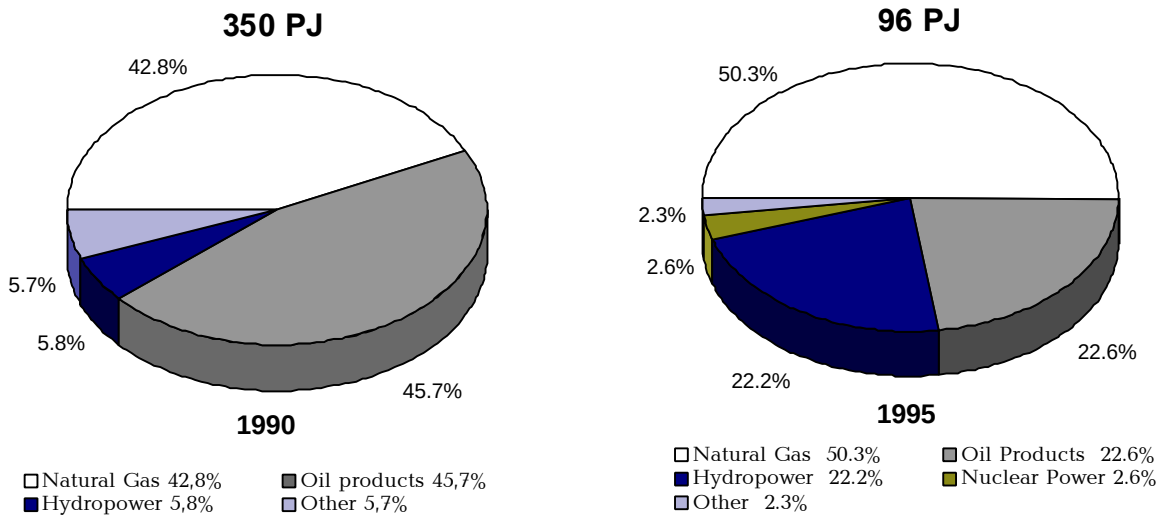
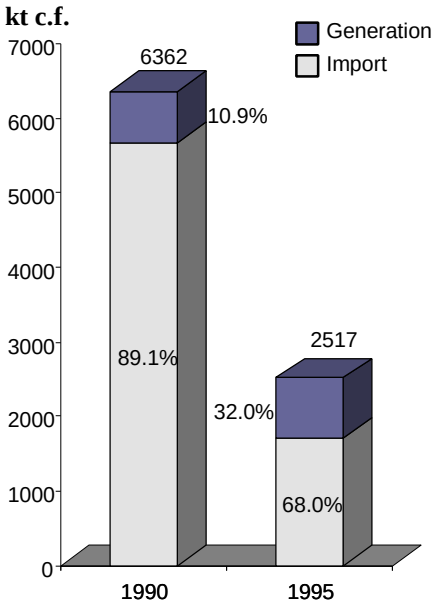


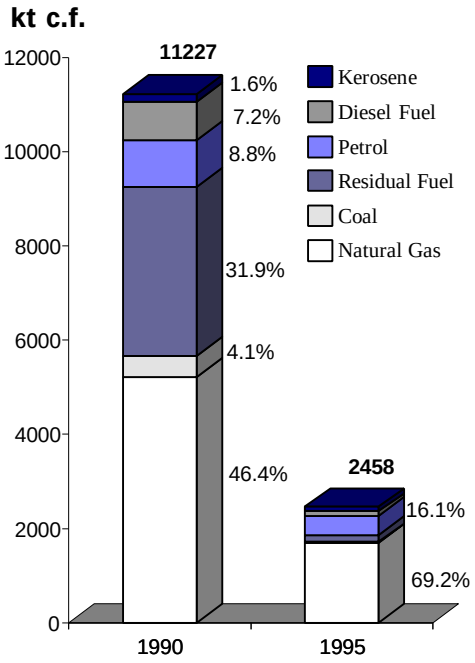
Fig. 2.3 Structure of consumed energy in Armenia, 1990, 1995



	1990	1995
Generation, kt c.f.	***692***	***806***
hydropower*	692	729
nuclear power*	-	77
Import: kt c.f.	5670	1711
natural gas	5212	1700
other	458	11
Consumption, kt c.f.	***6362***	***2517***

*1.0 GWt. hour=0.37 t c.f

Fig. 2.4 Use of primary energy resources in Armenia, 1990, 1995



	1990	1995
Primary fuel, kt, c.f..	***5670***	***1711***
natural gas	5212	1700
coal	458	11
Secondary fuel, kt, c. f.	***5557***	***747***
residual fuel	3582	157
petrol	990	395
diesel fuel	810	98
kerosene	175	100
The total amount of fuel	***11227***	***2458***

For conversion of the fuel amount from the natural units into conditional units the following multipliers are used: natural gas - 1.15; coal - 0.85; fuel oil - 1.37; petrol - 1.49; diesel fuel- 1.45; kerosene - 1.47.

Fig. 2.5 Fossil fuel consumption in Armenia, 1990, 1995

Under the general reduction of energy consumption in 3.6 times, the consumption of energy was reduced: in industry and construction - in 6.5 times, in agriculture - in 9.5 times, in transport - in 3.6 times, in municipal sector - in 2.7 times (Fig.2.6). The electric power generation in Armenia in 1987, 1990-95 is illustrated on Fig. 2.7. As a result of the Armenian Nuclear Power Station decommissioning and reduction of the charging load of thermal power stations on 60-75 % because of lack of fuel, the electric power generation in 1995 has decreased on 64% in comparison with 1987, and on 46 % - with 1990. At general reduction of electric power generation its structure has

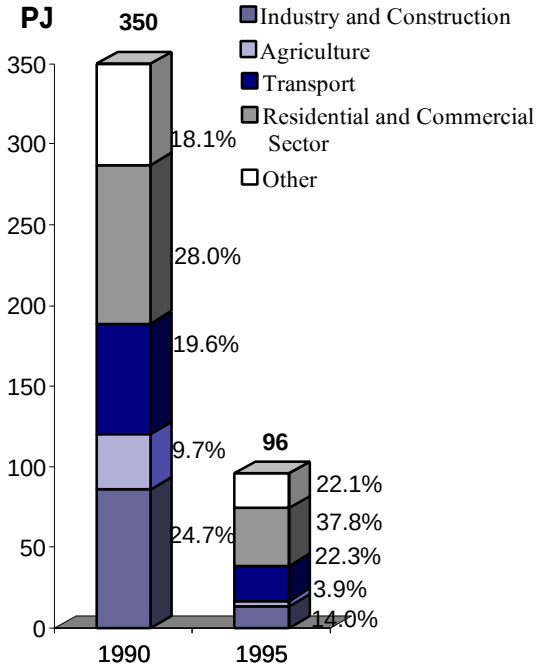
also changed and at the expense of sharp increase of share of hydro-power stations as a result of triple increase of generation by the Sevan-Hrazdan cascade and correspondent increase of the water outlets form lake Sevan for power purposes. In comparison with 1990 the current electric power consumption has reduced: in industry in 4.6 times, in an agriculture - in 7.8 times, in transport - in 2.3 times.

The distribution of the general power consumption by energy carrier types is presented in Table 2.5. In 1990 the share of electric power in general consumption was 44.3 %, heat power - 40.8 %, engine oil - 14.9 %, and in 1995 under the reduction of the general power consumption in 3.6 times: 69.7 %, 6.7 % and 23.6 %, accordingly.

Table 2.5 *Power consumption in Armenia by energy carrier types.*

Energy Carriers*	**1990**	**1995**
Electric Power, GWt.h. PJ	11290.0 155.2	5513.0 60.0
Heat Power, mln. Gcal. PJ	34.0 142.8	1.4 5.4
Engine Oil, kt c.f. PJ	1075.0 58.0	593.0 20.3
Primary Energy Resources, kt c.f. PJ	6362.0 186.4	2517.0 73.7

*1Gcal =4.187 GJ. 1t c.f. = 29.308 GJ



	1990	*1995*
Industry and Construction	86.3	13.4
Agriculture	34.0	3.7
Transport	68.5	21.4
Residential and Commercial Sector	98.0	36.3
Other*	63.2	21.2
Total Demand for Energy	***350.0***	***96.0***

* Own energy consumption, losses during energy transfer and other sectors of economy

Fig. 2.6 Power consumption by sectors of economy of Armenia, 1990, 1995

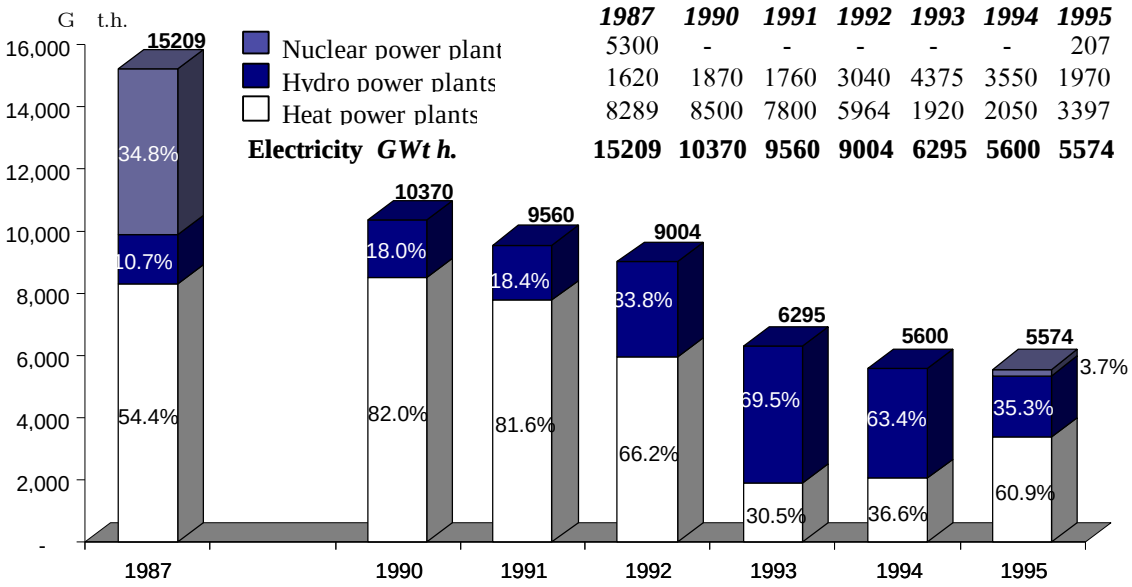


Fig. 2.7 Electric power generation in Armenia, 1987, 1990 - 1995

The economic and power crises have resulted in sharp decrease of efficiency parameters for energy use and energy provision of the population (Fig. 2.8).

Interrelation of principle social-economic and energy factors and GHG emissions in Armenia in 1990-1995 as well as the specific parameters of emissions are characterized by data, given in Table 2.6. The data illustrate that the GDP reduction, power consumption and the GHG emissions for the period of 1990-95 is almost similar and makes 71-77%. In 1990 the emissions per capita in Armenia was 7.0 t CO_2 eqv. In 1995 this value decreased on 77% as a result of deep economic crisis and has made 1.6t CO_2 eqv.

The conformity of changes in GHG emissions and GDP of Armenia is illustrated in Fig. 2.9. In 1995 the GHG emission has made 24.5% from the level of 1990.

Having population, comprising the 0.06% of the world population, the contribution of Armenia to the global GHG emissions in 1990 was about 0.1%, in 1995 - 0.02%.

Table 2.6 *The determining factors and the greenhouse gas emissions in Armenia, 1990-1995*

Years	**Population**[1/]		**GDP**		**Power**		**GHG Emissions**[2/]		**GHG Emissions per capita**		**GHG Emissions per unit of GDP**	
	mln. people.	Rate % by 1990	In actual prices, mln. $	Rate % by 1990, in fixed prices	PJ	Rate % by 1990	kt CO_2 eqv.	Rate % by 1990	t CO_2 eqv / people	Rate % by 1990	t CO eqv / $ 1000	Rate % by 1990
1990	3.574	0	8770.0	0	350	0	25312	0	7.08	0	2.9	0
1991	3.645	1.9	8390.0	-19.8	336	-4.0	23165	-9	6.3	-10.4	3.3	11.4
1992	3.724	4.0	4312.0	-51.7	168	-52.0	11323	-55.2	3.0	-57.7	2.7	-7.3
1993	3.728	4.1	447.3	-74.4	142	-60.0	8255	-67.4	2.2	-69.0	3.7	12.7
1994	3.737	4.4	651.4	-73.0	82	-76.6	4779	-81.1	1.3	-82.0	2.0	-30.6
1995	3.765	5.1	1290.0	-70.0	96	-72.6	6193	-75.5	1.6	-77.0	2.4	-17.3

[1/] *Without taking into account the emigration of 677 thous. people in 1991-1994.*
[2/] *Excluding the emissions connected to the land use change and forestry*

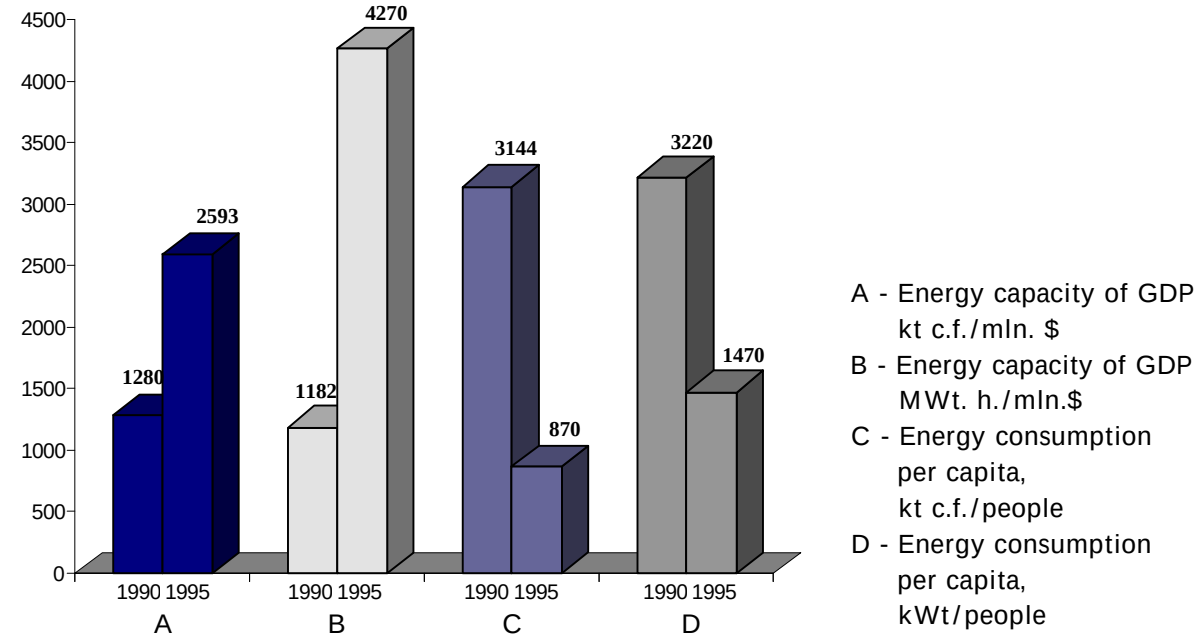


Fig. 2.8 Specific parameters of power consumption in Armenia, 1990, 1995

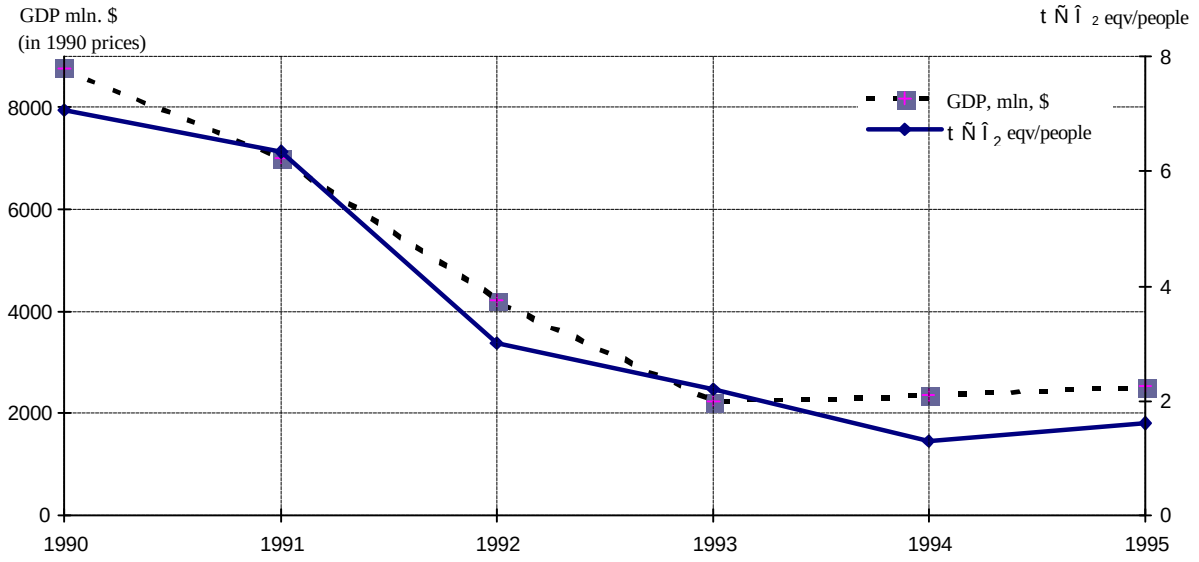


Fig. 2.9 GHG emissions per capita and GDP of Armenia, 1990-1995

Sources

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Chapter 3. NATIONAL GREENHOUSE GAS INVENTORY

3.1. Basic Principles

The National Greenhouse Gas Inventory was developed for the first time in Armenia according to the IPCC Guidelines. The National Greenhouse Gas Inventory of Armenia considers five of the six main modules of the IPCC Guidelines. These are "Energy", "Industrial Processes", "Agriculture", "Land Use Change and Forestry " and "Waste". The estimations have not been done for the "Solvent Use" module because of the absence of relevant methodology both in IPCC Guidelines and on the national level.

The greenhouse gas emissions have been estimated based on the volume of the relevant activities. In the calculations we have used both the IPCC default coefficients and the verified coefficients with regard to the specific conditions of Armenia. The volume of activities were determined according to the data provided by the state and institutional statistics.

According to the Resolution of the Second Session of the Conference of Parties to the Convention, 1990 was assigned as the basic year for the Inventory. Thus the Inventory data of GHG emissions for 1990 are given in more detail.

With the purpose of revealing the dynamics of greenhouse gas emissions the levels of GHG emissions other than the basic year have also been estimated for 1985, 1994-1996.

3.2. Greenhouse Gas Emissions in 1990

Total emissions of gases with direct greenhouse effect - CO_2, CH_4 and N_2O and their values in CO_2 equivalent (CO_2 eqv.) are given in Table 3.1. and the emission distribution according to source categories is given in Table 3.2. and Fig.3.1. provides data by categories of sources.

Table 3.1 *The anthropogenic greenhouse gas emissions in Armenia, Gg, 1990*

Greenhouse Gas	Absolute Emissions	Emissions in CO_2 equivalent[1/]	Share in total emissions, %
CO_2	21396.08	21396.08	86.64
CH_4	152.76	3207.96	12.99
N_2O	0.2941	91.17	0.37
	Total	*24,695.21*	*100.00*

[1/] Global warming potential (GWP) accepted is 1 for CO_2, is 21 for CH_4 and 310 for N_2O (IPCC, 1995).

The presented data illustrate that in 1990 CO_2 was the main greenhouse gas in Armenia, with the share of 86.64 % of the anthropogenic emissions. The share of CH_4 was 12.99 %, N_2O - 0.37 %.

Anthropogenic greenhouse gas emissions are presented according to source categories and sectors in Table 3.2.

Table 3.2 *Anthropogenic greenhouse gas emissions by source categories, Gg, 1990*

Source Category	CO_2	CH_4	N_2O	CO_2 eqv.
Energy	21382.78	80.25	0.1281	23107.74
Industrial Processes	630.30			630.30
Agriculture		47.01	0.1660	1038.67
Land Use Change and Forestry[1/]	-617.00			-617.00
Waste		25.50		535.50
Total:	***21396.08***	***152.76***	***0.2941***	***24695.21***

[1/]the balance of this category is negative, i.e. the CO_2 removal (697 Gg) exceeds the emissions (80 Gg).

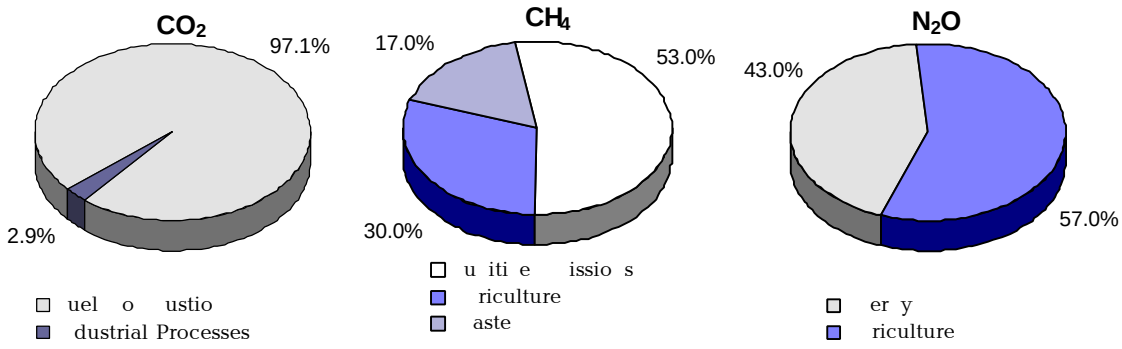

Fig. 3.1 Greenhouse gas emission distribution by source categories, 1990

Energy

The main part of greenhouse gas emissions are caused by Energy sector. The Energy sector has the 97 % of CO_2 emissions, 53 % of CH_4 emissions (as a result of fuel leakage) and 43 % of N_2O emissions. 93% of the overall national greenhouse gas emissions expressed in CO_2 equivalent are caused by the Energy sector.

The main part of CO_2 emissions is caused by fuel combustion. The distribution of CO_2 emissions by fuel types is illustrated in Table 3.4 and in Fig. 3.2, and the emission distribution by sectors is presented in Fig. 3.3.

The large part of CO_2 emissions from the fuel combustion is caused by the Energy and Transformation Industry (53 %) and Transport (17 %).

Industrial Processes

In Armenia the basic technology of this category, connected to CO_2 emissions, is cement production. In 1990 CO_2 emissions from cement production made for 630.3Gg or about 3 % of total CO_2 emissions.

Agriculture

In this category CH_4 emissions was 47.01 Gg, N_2O - 0.17 Gg or, 30 % and 57% of total greenhouse gas emissions, accordingly. Sources of CH_4 emissions are mainly agricultural animals and manure management, N_2O emissions are mainly produced from the application of nitric fertilizers. The emissions of CH_4 and N_2O as a result of burning of agricultural residues are insignificant (0.24

Gg and 0.01 Gg, accordingly). On Fig. 3.4 the distribution of methane emissions by animal types is illustrated.

Table 3.3 *Greenhouse gas emissions in Armenia by source categories, Gg, 1990.*

Greenhouse Gas Source and Sink Categories	CO_2	CH_4	N_2O
Energy	***21382.78***	***80.25***	***0.1281***
A. Fuel Combustion	*21382.78*	*0.28*	*0.1262*
Energy and Transformation Industries	11332.87		0.0670
Industry	2138.28		0.0126
Transport	3635.07		0.0215
Residential and Commercial/Institutional sector	3848.90		0.0227
Other	427.66		0.0024
Biomass Burned for Energy		0.28	0.0019
B. Fugitive Emissions		*79.97*	
Oil and Natural Gas System		79.97	
Industrial Processes	***630.30***		
Agriculture		***47.01***	***0.1660***
Enteric Fermentation		44.07	
Manure Management		2.70	
Field Burning of Agricultural Residues		0.24	0.0060
Use of Nitric Fertilizers			0.1600
Land Use Change and Forestry	***-617.00***		
Changes in Forestry and other Woody Biomass Stock	-617.00		
Forests and Grassland Convention[1/]			
Abandonment of Managed Lands[1/]			
Waste		***25.50***	
Landfills		23.70	
Wastewater Treatment		1.80	
Waste Incineration[1/]			
Other [1/]			
Total Net Greenhouse Gas Emissions[2/]	***21396.08***	***152.76***	***0.2941***
Emissions from International Bunkers	404.80		0.0030

[1/]the activity types do not exist in Armenia
[2/]with consideration of the emission-removal balance in the Forestry sector

Table 3.4 *Anthropogenic CO_2 emissions from fuel combustion in Armenia, Gg, 1990*

Fuel Types	Emission	Share, %
Solid	757.89	4
Liquid	12162.62	57
Gaseous	8462.27	39
Total:	**21,382.78**	**100**

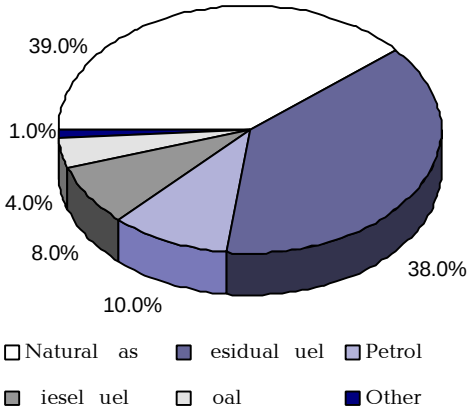

Fig. 3.2 Distribution of CO_2 emissions by fuel types, 1990

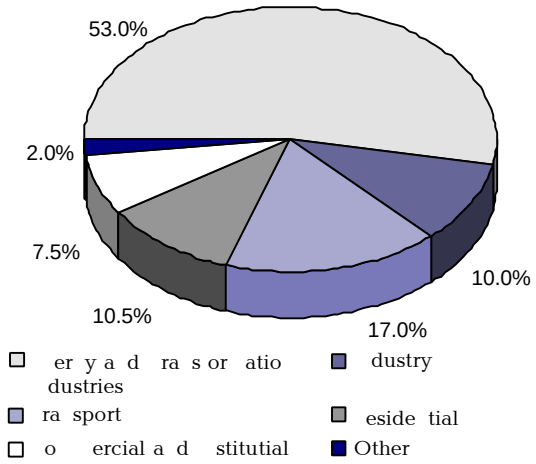

Fig. 3.3 Distribution of CO_2 emissions by Energy sub-sectors, 1990

Land Use Change and Forestry

In the given category the CO_2 emission and absorption is estimated to be caused only by forestry sector. The emission and absorption connected to land use change in Armenia are not taken into consideration, as the activity on forest and grassland conversion is not realized, and the abandoned managed lands are located on abrupt slopes, thus are exposed to constant degradion and do not accumulate carbon.

In the forestry sector all amount of accumulated carbon as a result of change in forest and other woody biomass stocks from the sphere of economic activity is estimated.

The tree species and forestry peculiarities in Armenia are considered in the calculation of carbon emissions and absorption in the forestry sector, thus own specified coefficients were applied, in particular, the values of carbon fraction of dry matter and annual biomass growth.

In 1990 CO_2 emissions form forestry sector were 80Gg, absorption - 697Gg, the net absorption - 617Gg.

Waste

The methane emission in this category was 25.5 Gg or 17 % of total CH_4 emissions. And, more than 90 % of these emissions in the given category is caused by waste sites. Distribution of CH_4 emissions by waste categories is illustrated in Fig.3.5.

The formed methane is not utilized and is completely emitted into the atmosphere. According to corresponding statistics, the amount of waste and wastewater removed from the populated areas is registered. The estimation of emissions was carried out both on the basis of the above-mentioned registration and the local values of appropriate coefficients, and applying methodology and coefficients recommended by IPCC. A discrepancy in the results, received by these two methods, is about 13 %.

The aforementioned value of methane emissions is calculated by application of data of national statistics and coefficients.

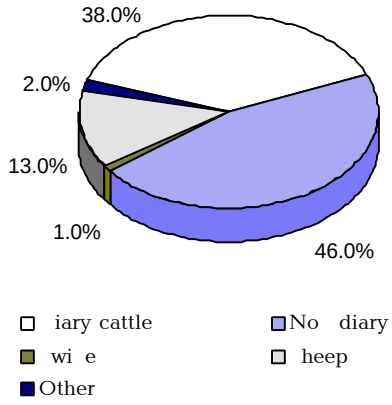

Fig. 3.4 Distribution of CH_4 emissions by types of agricultural animals, 1990

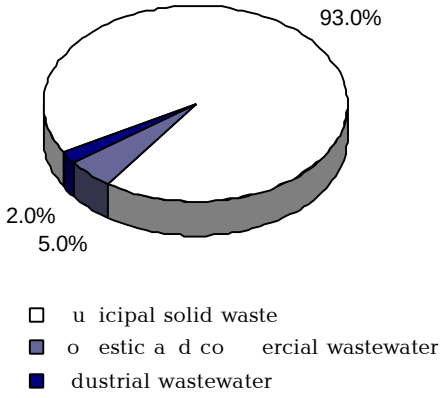

Fig. 3.5 Distribution CH_4 emissions from the "Waste" module, 1990

International Bunkers

In 1990 CO_2 emissions from bunker fuel, used for international transportation was 405.8Gg. The calculations have included the use of bunker fuel only for realization of international air transportation, since Armenia does not have access to sea and marine. According to IPCC Guidelines emissions from bunker fuel are not included in the balance of the Inventory.

3.3. Greenhouse Gas Emissions in 1994-1996

In order to identify the dynamics in anthropogenic greenhouse gas emissions and their change in comparison to 1990 the emissions for 1994-1996 are also calculated.

The greenhouse gas emissions in Armenia for the mentioned years, expressed in CO_2 equivalents, distributed by source categories are presented in Table 3.5 and in Fig. 3.6.

Table 3.5 *Anthropogenic greenhouse gas emissions by source categories, 1990, 1994-1996 (Gg CO_2 eqv.)*

Source Categories	***1990***	***1994***	***1995***	***1996***
Energy	23107.74	3277.59	3777.59	3682.53
Industrial Processes	630.30	53.00	114.00	130.00
Agriculture	1038.67	824.45	805.38	761.23
Land Use Change and Forestry	-617.00	-26.00	-387.00	-438.00
Waste	535.50	474.60	411.60	401.10
Total:	**24695.21**	**4603.64**	**4721.57**	**4536.86**

As it is obvious from the data given above, the anthropogenic GHG emissions in Armenia in 1995 have decreased by 80% compared to 1990, including the energy sector - on 84%, in cement production - on 82%, in agriculture - on 27%, from waste sector - on 23%. In 1994 the CO_2 removal in the forest sector reduced on 85% because of mass forest cuttings for heating needs.

The mentioned sharp change in greenhouse gas emissions is a consequence of deep economic and energy crisis in Armenia in 90's.

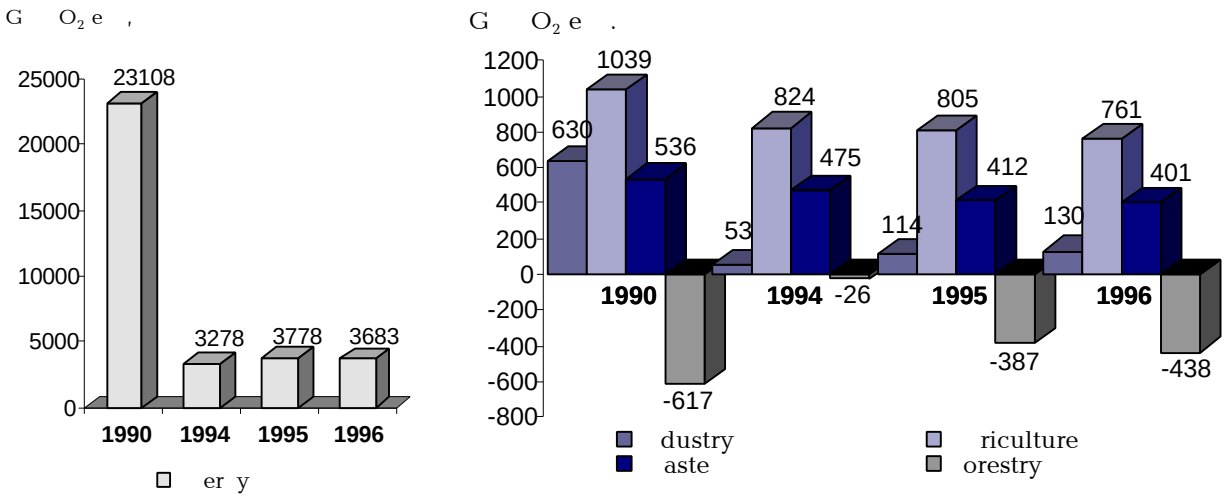

Fig. 3.6 Dynamics of greenhouse gas emissions changes in Armenia, 1990 - 1996

3.4. Annex

According to IPCC methodology and recommendations two methods were used for the calculation of GHG emissions in the Energy module: reference approach ("Top Down" method) and detailed technology based calculation (method "Bottom Up").

Using the Reference Approach and the statistical data on fuel-energy balance of the Republic of Armenia for a number of years allowed to determine the summarized values of emissions of gases with direct greenhouse effect (CO_2, CH_4 and N_2O). The coefficients recommended by IPCC (default coefficients) for certain types of fossil fuel were widely used.

The application of Detailed Technology Based Calculation method allowed to clarify the values of the main greenhouse gas emissions based on more detailed information on the applied technology of fossil fuel combustion.

The importance and perspectiveof inventorying the greenhouse gas emissions the "Bottom Up" is clear, as it enables

- to have detailed information on particular emission sources and technologies, to develop and introduce particular measures on emission reduction;
- having a wide scale of detailed information, to develop a more detailed program and greenhouse gas emission limitation strategy using the computer models and programs recommended by IPCC (e.g. LEAP, ENPEP and other);
- conduct international cooperation more efficiently to meet the objectives of the Climate Change Convention, including cooperation within the framework of existing implementation mechanisms;
- to organize effective management in the sphere of greenhouse gas emission limitation at national level;
- reduce errors and eliminate omissions and uncertainties in inventorying the GHG emissions on a continuous basis.

Comparison of results, received by the above-mentioned methods testify to their rather high degree of comparability.

In fact, application of the reference approach has enabled to estimate rather fully and precisely the values of both emissions of CO_2 and CH_4 and the total values of the emissions of gases with direct greenhouse effect (expressed in CO_2 equivalents). The relative difference in values of considered parameters by specified two methods makes no more than 3%.

Whereas, the relative difference for estimations of N_2O emissions, received by these two methods is a little bit higher, which is a consequence of the consideration of peculiarities of the technologies of fuel combustion at determination of greenhouse gas emissions with the application of method of detailed technologies.

Alongside with the above-mentioned, during the inventory preparation anthropogenic emissions of gases with indirect greenhouse effect were considered: nitrogen oxides (NO_x), carbon acid (CO) and non-methane of volatile organic compounds (NMVOC).

In Table 3.6 the values of anthropogenic emissions of greenhouse gases and their precursors in the Energy sector of Armenia elaborated by the method of detailed technologies are given, and in Fig. 3.7 their structure is presented.

Table 3.6. *Anthropogenic greenhouse gas emissions and their precursors in energy sector of Armenia Detailed technology based calculation, 1990.*

Source Categories	Energy Consumption	Emissions, Gg					
	PJ	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
All Energy	***319.386***	***21152.80***	***78.4620***	***0.6491***	***72.9015***	***282.2302***	***47.2740***
A. Fuel Combustion	**319.386**	**21152.80**	**1.3195**	**0.6491**	**72.9015**	**282.2302**	**47.2740**
Energy and Transformation Industries	***167.972***	***11337.95***	***0.1792***	***0.0642***	***29.5496***	***2.8393***	***0.3656***
Heat and Electricity Generation	167.972	11337.95	0.1792	0.0642	29.5496	2.8393	0.3656
Electricity Generation	84.632	5990.54	0.0454	0.0389	18.6258	1.3864	0.1416
Combined Generation	18.291	1232.21	0.0079	0.0069	4.2125	0.3069	0.0358
Heat Generation	65.050	4115.21	0.1258	0.0184	6.7113	1.1460	0.1883
Industry	***33.179***	***2053.30***	***0.0751***	***0.0084***	***3.2599***	***0.9836***	***2.1596***
Transport	***53.308***	***3778.87***	***0.8561***	***0.0649***	***33.3438***	***242.5397***	***37.8400***
Civil Aviation	0.566	40.49	0.0011	0.0003	0.1642	0.0680	0.0102
Road Transport	50.442	3569.99	0.8432	0.0601	30.1197	241.0520	37.5211
Railways	1.603	117.52	0.0096	0.0032	2.8858	0.9780	0.2084
Internal Navigation	0.045	3.30	0.0002	0.0001	0.0717	0.0224	0.0049
Other Transport	0.651	47.57	0.0020	0.0012	0.1024	0.4194	0.0954
Small Combustion	***59.937***	***3,666.59***	***0.1775***	***0.5012***	***4.9002***	***30.7840***	***5.6269***
Commercial/ Institutional	29.592	1,844.45	0.0699	0.4129	2.4942	1.0063	2.6633
Public/Residential	28.121	1,659.99	0.0902	0.0088	1.9205	28.4598	2.5309
Rural/Forestry/Fishing	2.223	162.15	0.0174	0.0795	0.4855	1.3180	0.4327
Other	***4.990***	***316.09***	***0.0315***	***0.0103***	***1.8480***	***5.0837***	***1.2819***
B. Fugitive Emissions			**77.1425**				
Oil, Natural Gas			***77.1425***				

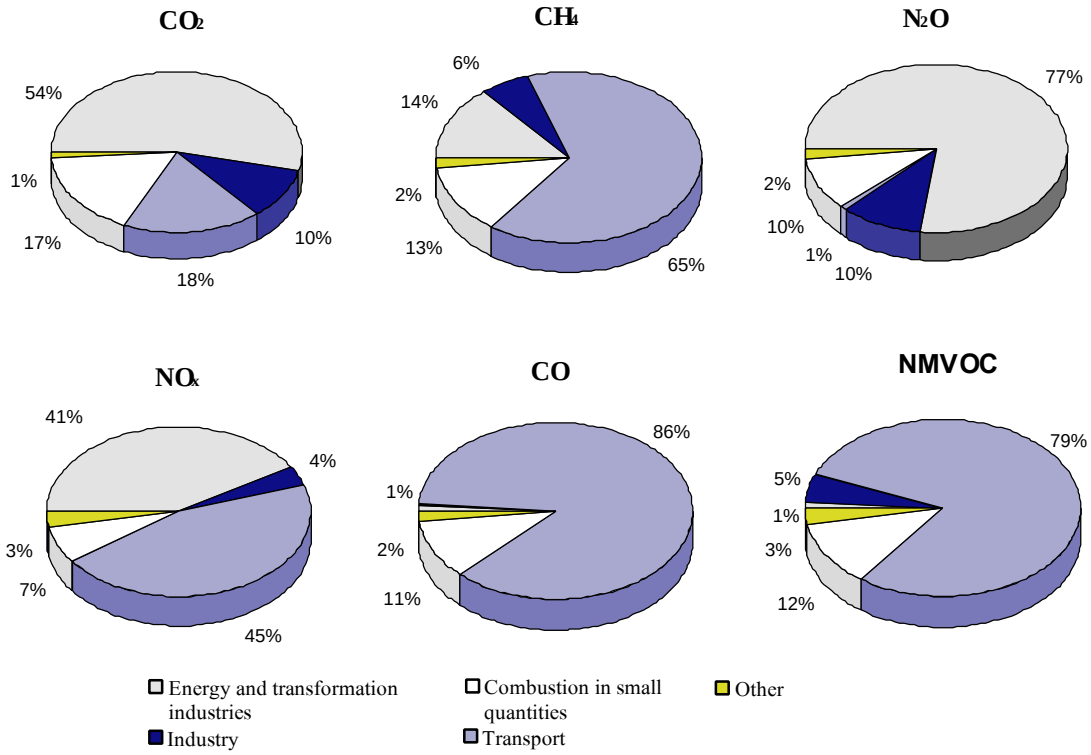

Fig. 3.7 The Structure of greenhouse gas emissions and their precursors in Energy sector of Armenia

With the purpose of thorough introduction of a method of detailed technologies in Armenia from a beginning of 1998 the CO_2, CH_4 and N_2O greenhouse gases have also been included in the list of emissions of hazardous substances into the atmosphere, subject to the state statistical registration, alongside with air polluting substances.

The tab. 3.7 illustrates precursors of greenhouse gas emissions from all sectors. These data will be in future supplemented and revised.

Table 3.7 *Precursors of greenhouse gas emissions, Gg, 1990*

Main Modules	NO_x	CO	NMVOC
1. Energy	72.9015	282.230	47.274
2. Industrial Processes			
3. Agriculture	0.2214	5.745	
4. Land Use Change and Forestry			
5. Waste			
Total:	**73.1229**	**287.975**	**47.274**

In order to reduce the uncertainty factors (Report of the Second Session of the Conference of Parties to the Convention) in the frames of "Armenia - Country Study on Climate Change" Project special field studies have been undertaken and conducted on specification of emission factors for methane from the following emission source categories for specific conditions of Armenia:

- "Agriculture " ("Enteric Fermentation" and "Manure Management" submodules);
- "Waste".

Besides researches are conducted on determination of the methane emission from lake Sevan basin connected to the intensive euthrophication processes as a consequence of anthropogenic decrease of the lake level.

The received results will be used in the preparation of the Greenhouse Gas Inventory of Armenia in future.

Sources

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Chapter 4. NATIONAL STRATEGY FOR LIMITATION OF GREENHOUSE GAS EMISSIONS

Armenia, as a developing country not included in the Annex I of the UN Framework Convention on Climate Change, has no commitments for greenhouse gas emission reduction. However, it could undertake voluntary obligations on their limitation with the assistance of the developed countries within the frames of the corresponding mechanisms for implementation of the Convention. Therefore, emissions limitation strategy was developed based on the principle provisions of the Energy Master Plan of the Republic of Armenia for the period up to 2010.

4.1. Scenario of Social-Economic Development of Armenia for the Period till 2010

The forecast of the greenhouse gas emissions and measures for their limitation are directly connected to the long-term development of a social-economic situation in Armenia and the corresponding energy demand.

Armenia's economy faces a difficult problem of overcoming the deep economic crisis of the first half of 90's and subsequent maintenance of sustainable social-economic development.

Table 4.1. presents the experts' macroeconomic estimation for three possible scenarios (optimistic, probable and pessimistic) of the development of Armenia's economy, elaborated within the frames of "Armenia - Country Study on Climate Change" project. Later those estimations for the probable scenario have coincided with macroeconomic forecast of the Governmental Program of Social-Economic Development of Armenia up to the year 2005.

Table 4.1 *The development scenarios of the economy of Armenia.*

	1990	**1995**	**2000**	**2005**	**2010**
	Optimistic				
GDP - in fixed prices, %	100	29	40	62	100
Consumption funds, %	100	15	50	70	100
	Probable				
GDP - in fixed prices, %	100	29	37	50	70
Consumption funds, %	100	15	30	45	65
	Pessimistic				
GDP - in fixed prices, %	100	29	33	40	55
Consumption funds, %	100	15	24	35	50

The optimistic scenario supposes to ensure 7 % annual rates of economic growth in 1998-2000, and 9-10 % - in 2001-2010. The rates of growth for industry for the given periods are 3 % and 7 % accordingly, agriculture - 4 % and 5-6 %, sphere of services 7 % and 9-10 %. According to that scenario the economic capacity and living standards of the population of 1990 will be restored by 2010.

The probable scenario is characterized by 5.5% annual rates of economic growth in 1998-2000, and 6-6.5% - in 2001-2010. The rates of growth for industry for the given periods are 2 % and 5-6 % accordingly, agriculture - 3 % and 4-5%, services 6 % and 8-9 % by 2010. Two thirds of

economic capacity of the country and living standards of the population of 1990 will be restored by the year 2010.

The pessimistic scenario is based on lower rates of economic growth: 3-4% annually for the period of 1998-2000, 4-5% - in 2001-2010. The rates of growth for industry for the given periods are 1% and 3-4% accordingly, agriculture - 2% and 3-4%, sphere of services - 5% and 7-8% by the year 2010. By 2010 only half of the economic capacity of the country and living standards of the population of 1990 will be restored.

All three scenarios are characterized by outstripping growth of the sphere of services in comparison with the production of material goods. The expected changes in the GDP structure are illustrated in Table 4.2.

Table 4.2 *Structure of gross domestic product of Armenia, %.*

	1990	1995	2000	2005	2010
Total GDP, %	100	100	100	100	100
industry	44	29	22	20	20
agriculture	13	40	32	30	30
construction	18	4	10	9	9
services	25	24	30	34	34
net indirect taxes	-	3	6	7	7

See the forecast of changes in the number of population of Armenia in Table 4.3. As a result of acute decline of social-economic situation and large share of people in reproductive age among the emigrating part of population, the annual 1.9-2.1 % increase of population registered in 1965-90 at present has decreased to the level of 0.4-0.5 %.

Table 4.3 *The forecast of the number of population of Armenia, by the end of year, thousand people.**

Number of population	1990	1995	2000	2005	2010
without the account of emigration	3575	3765	3882	3880	3940
with the account of emigration	3575	3061	3107	3154	3200

* Official estimation of the number of population without the account of emigration in 1991 - 1995 at an annual 0.3-0.4 % increase of population and the estimation of the number of population with the account of emigration in terms of stabilization of emigration flows after 1995 are presented.

4.2. Power Policy of Armenia

The economic crisis and power blockade of 1991-1994 have caused negative changes in the fuel and energy complex and in the whole Energy sector of Armenia.

The need for the implementation of new energy policy has been caused by the overcoming of energy crisis, and the formation of market relations. That policy has found its reflection in the state Energy Master Plan of Armeniafor the period up to 2010.

According to the Plan the main objectives of energy strategy of Armenia are the following:

- Provision of energy safety by reducing the dependence from unforeseen disruption of

import of fuel and, thereby increasing the use of local power resources and diversification;

- Identification of directions and creation of conditions for the most efficient use of energy resources and production capacities of the energy system, provision of reliability of power supply for the restoration of economic capacity of the country and living standards of the population.

Major factors, which determine the development of the energy system of Armenia, are the following:

- Reconstruction, increase of resources and modernization of existing generating capacities in order to raise the efficiency of the energy system as a whole and reduce the fuel consumption;
- Development of nuclear power from the positions of diversification and provision of nuclear safety;
- Energy saving policy;
- Increase of the share of natural gas in the internal consumption;
- Intensification of the local hydro-resource development;
- Use of alternative renewable energy resources (geothermal and wind energy);
- Environment protection;
- Creation of strategic reserves of fuel;
- Institutional reorganization in the field of energy production, transmission and distribution of electrical and thermal energy - respective to the transition to market relations;
- Implementation of measures on expedient price and tax policy, which will ensure energy saving and economically efficient use of energy carriers in the new economic conditions;
- Minimization of expenses on the planned development of the energy system and cost price of energy.

The vulnerability factor of water resources, connected to expected climate change, has not been included in the Energy Master Plan, as by that time this factor was not studied. However, taking into consideration that it can play an essential role in the long-term prospective, it is necessary to consider the expected vulnerability of hydropower resources in the energy sector development strategy. At the same time the accomplishment of the above mentioned priorities of energy policy will promote the reduction of CO_2 emissions in the energy sector of the country.

Two basic scenarios are considered in the Energy Master Plan of the Republic of Armenia: one of them being the development without nuclear energy (scenario A) and the other - the development with nuclear energy (Scenario B, with the nuclear cycle).

Scenario A supposes to cover the demand for energy mainly through new capacities of heat power stations by commissioning three Steam-Gas Power Device, which work on a combined cycle, and temporary closing-down the operating power-generating unit of the Nuclear power plant (NPP). Scenario B supposes to continue the operation of power-generating unit of the NPP (or to replace it with a new safer NPP) and putting into operation one Steam-Gas Power Device instead of three, mentioned in Scenario A.

Both scenarios suppose rehabilitation, increase of a technical resource and modernization of existing capacities of hydropower stations and heat power stations, start-up of a new power-generating unit (Hrazdan-5), partial closing-down and liquidation of outdated units on heat power stations, introduction of new capacities, and also the use of geothermal and wind energy.

The Energy Master Plan includes the following key positions.

Till 2005:

- Introduction of geothermal power station with a capacity 10MWt;
- Introduction of four wind- power stations with a total capacity 1.2MWt;
- Introduction of small private hydro-power stations with a total capacity of 35.5MWt;
- Introduction of two Steam-Gas Power Devices with total capacity of 337MWt and closing down the operating unit of the NPP.

Till 2010:

- Introduction of new three geothermal power stations with a total capacity of 165MWt;
- Introduction of four new wind- power stations with a total capacity of 13.2MWt;
- Introduction of new small private hydro-power stations with a total capacity of 35.5 MWt and hydro-power stations with average capacity of 164MWt;
- Introduction of a new Steam-Gas Power Device with a total capacity of 167MWt - in addition to two, introduced earlier, (scenario A without new NPP), or introduction of a new NPP with a 500MWt capacity and leaving one of the earlier introduced Steam-Gas Power Device with a total capacity of 167 MWt (scenario B with a nuclear cycle).

For both scenarios a computer modeling of the power system is carried out - considering the minimization of given expenses, energy-saving and emission of polluting substances to the atmosphere. The program has considered the scenario B - with a new nuclear power plant with higher safety level - more preferable despite a minor excess in the given expenses. The nuclear plant has such advantages, as the diversification of fuel and reduction of dependence on its import, also lower levels of CO_2 emission.

The comparative estimation of the scenarios is presented in Table 4.4. The calculations of CO_2 emissions show, that the development of energy system under the scenario B will allow to limit the CO_2 emissions by 1184Gg/year in the period from 2005 to 2010, and by 869Gg/year after 2010.

Table 4.4 *Comparative evaluation of the scenarios of the energy system development in Armenia*

	2000		2005		2010	
	A	**B**	**A**	**B**	**A**	**B**
Fuel consumption,* kt c.f. fuel.	1486	1486	2126	1250	1675	1145
Including:						
residual fuel	146	146	152	110	93	95
natural gas	1340	1340	1974	1150	1582	1050
CO_2 emissions, Gg	2512	2512	3568	2127	2798	1929
Expenses, mln. $	302	474	635	1047	507	390

* With the account of heat production at heat power stations

4.3. Forecast of Energy Consumption

The forecast of energy consumption is focused on the provision of social-economic development Armenia under the probable scenario.

Electric Power

The forecast of electricity generation in Armenia under the scenario with a nuclear cycle in the layout of power station types is presented in Fig. 4.1.

In the long-term view, the increase of the share of hydro-power stations in the energy production (from 18 % in 1990 up to 26.8 % in 2010), the decrease of the share of heat power stations (from 82 % in 1990 -up to 26.5 % in 2010) are expected. According to the above-mentioned program a certain part (14.3 %) of the electric power production will belong to geothermal and wind-power stations by 2010. The perspective structure of electric power production will enhance the lowering of dependence from fuel import, reduction of its use in the electric power production, and consequently, the reduction of CO_2 emissions.

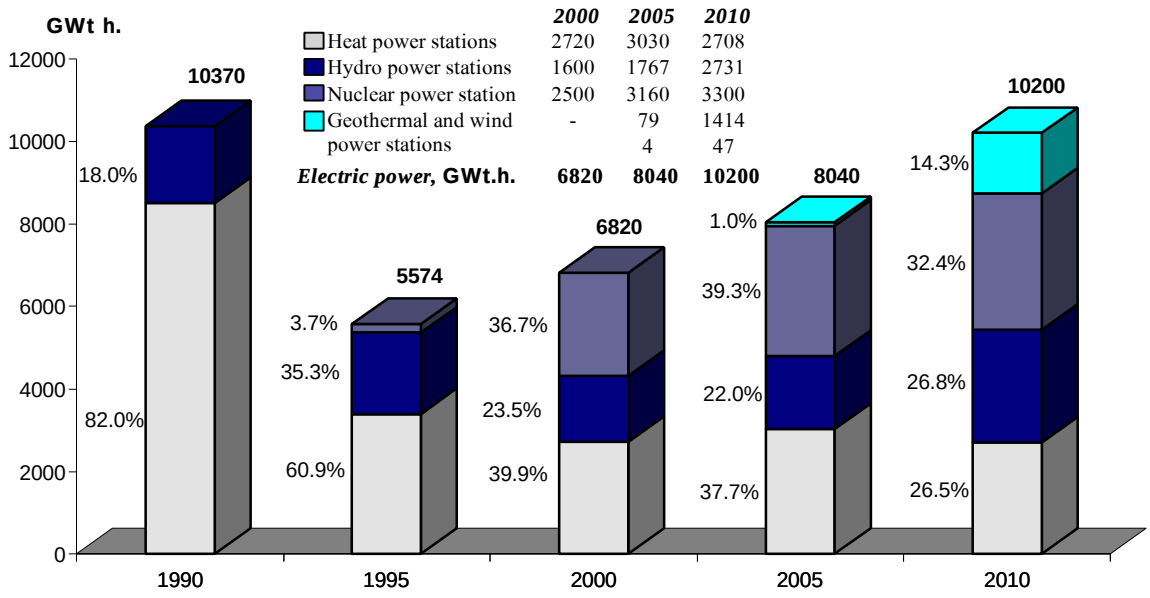


Fig. 4.1 Forecast of electric power generation in Armenia until 2010

Primary Energy Resources

The forecast of production and consumption of primary energy resources is presented on Fig. 4.2. The given forecast parameters reflect one of the basic strategic purposes of development of the Armenian energy sector - reduction of dependence on fuel import. In 1990 the share its of own primary fuel and energy resources in the power consumption made 10.9 %, and will make 32-37 % in 2005-2010.

Fuel

The forecast of demand for fuel in the national economy of Armenia is presented in Fig. 4.3. It is expected that in the long term view the share of residual oil in total fuel, used in the energy production will decrease from 32 % in 1990 to 6-6.8 % in 2005-2010, and the share of natural gas will increase from 46.4 % up to 70-72 %. That kind of change of the ratio in the use of gas and residual oil fuel in the long term will at the same time enhance the limitation of CO_2 emissions.

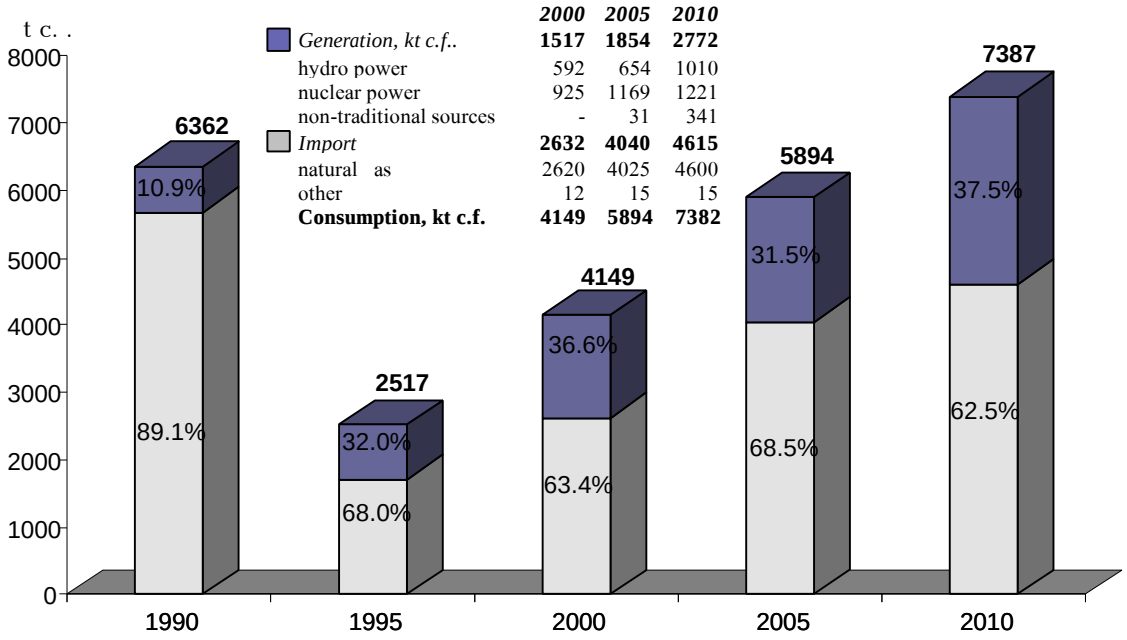


Fig. 4.2 The forecast of generation and consumption of primary power resources in Armenia

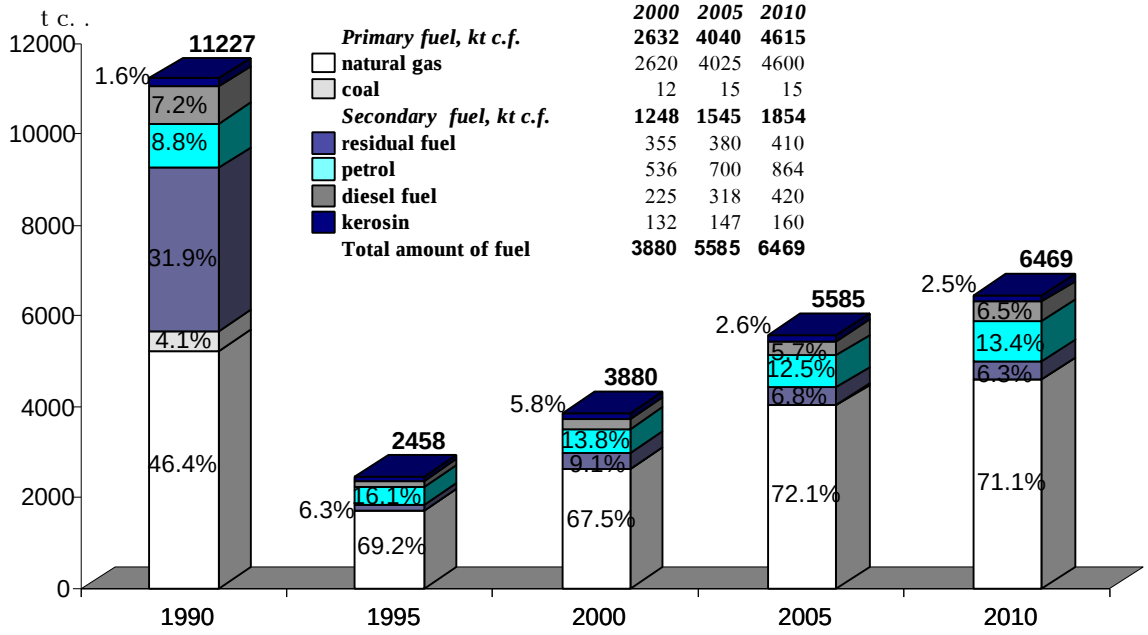


Fig. 4.3 Forecast of the fuel demand in Armenia

General Energy Consumption

The forecast of energy demand of the national economy of Armenia according to the kinds of energy carriers is presented in Table 4.5, and the forecast of demand for energy in according to different sectors of economy is presented in Fig. 4.4.

The specific parameters of energy consumption, which characterize the energy provision and the efficiency of the fuel and energy resources use, are presented in Fig. 4.5.

Table 4.5 *The forecast of energy demand of the national economy of Armenia*

Energy Carriers	1990	1995	2000	2005	2010
Electric energy, GWt h. PJ	11290 155.2	5513 60	7420 81	8840 96	11000 151
Heat energy, mln. Gcal PJ	34 142.8	1.4 5.7	7.6 31.9	14.9 62,5	18.5 77.4
Engine oil, kt c.f. PJ	1975 58.0	593 20.3	893 26.2	7165 34.1	1444 42.3
Primary energy resources, kt c.f.. PJ	6362 186.4	2517 73.7	4149 121.5	5894 172.7	7387 216.4

*1Gcal =4.187 GJ. 1t c.f. = 29.308 GJ

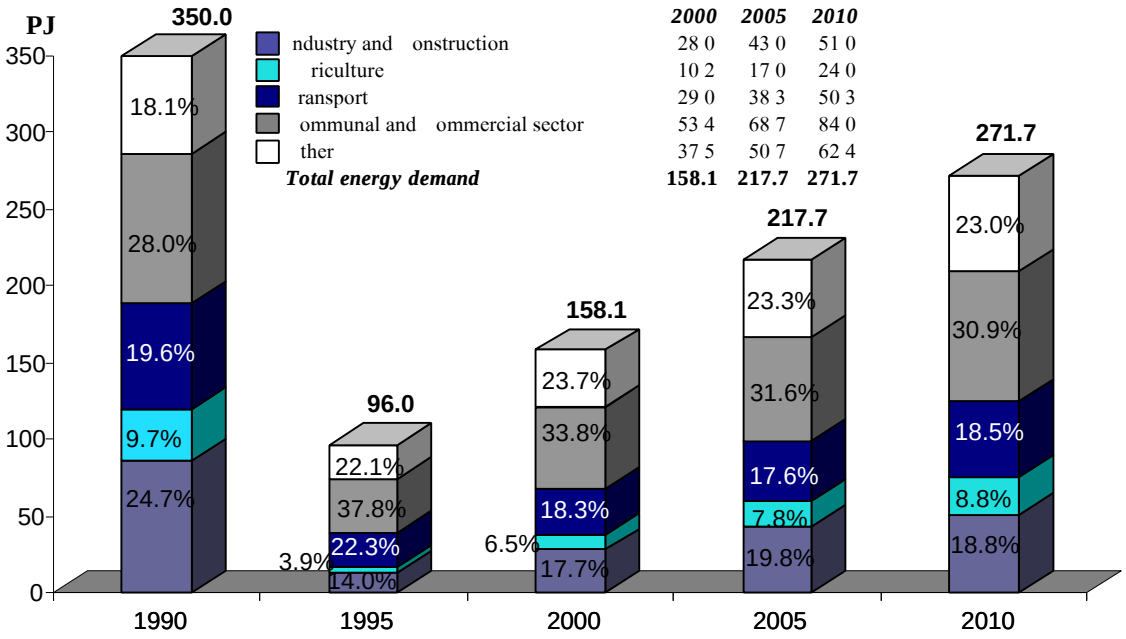


Fig. 4.4 The forecast of energy demand according to different sectors of economy

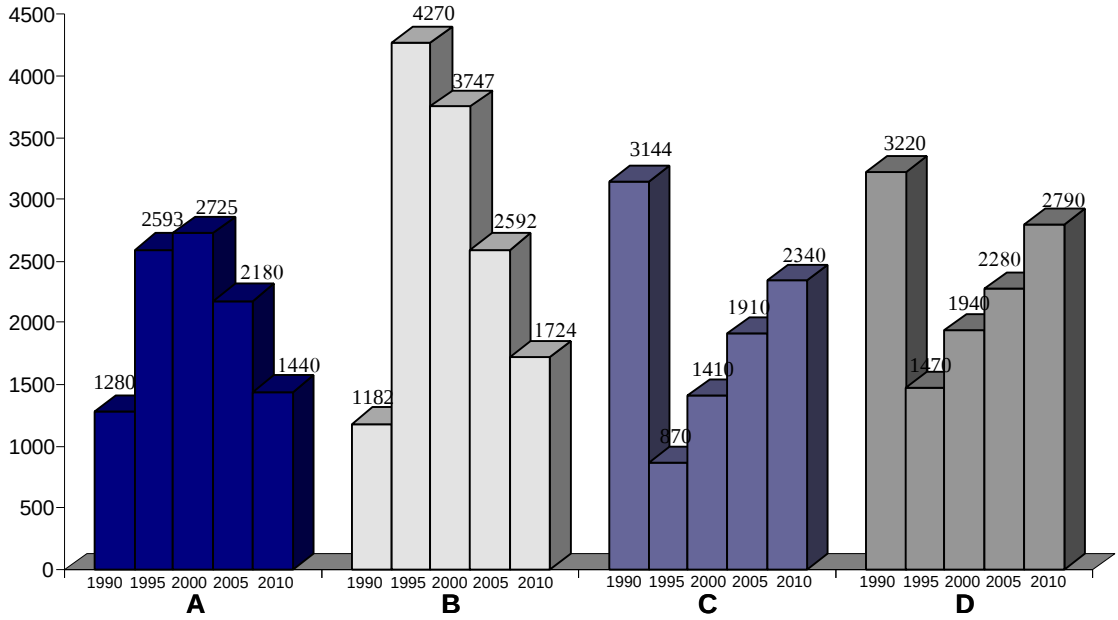
4.4. Strategy of Greenhouse Gas Emissions Limitation

The strategy is based on the optimal combination of the following factors:

- Provision of conditions for overcoming the economic crisis and further sustainable social-economic development with the achievement of 70 % of the economic level of 1990 in

2010, according to the probable scenario of development;

- Supply the energy demand of the projected social-economic development;
- Implementation of necessary measures for the improvement and structural reorganizations of energy system with the least amount of expenses;
- Maintenance of the minimal level of greenhouse gas emissions and polluting substances.



A - GDP energy capacity, kt c.f./ mln.$
B - GDP electricity capacity, MWt h./mln.$
C - power consumption per capita, kt c.f. /people
D - electricity consumption per capita, kWt /people

Fig. 4.5 Forecast of the specific parameters of energy consumption in Armenia

In case of the implementation of the Energy Master Plan of Armenia basic components for limiting the greenhouse gas emissions will be the following:

- Increase the resources and modernization of the existing generating capacities of power stations and application of new highly efficient units (with combined cycle) at heat power stations, that will enable a considerable reduction in the specific charge of fuel for energy production and will result in annual economy of fuel 120-190 kt. c. f. after 2000 and respective reduction of CO_2 emissions;
- Increase of the share of its own primary energy resource production by increasing the share of hydro-power (from 18 % in 1990 up to 26.8 % in 2010), and by using the nuclear energy and geothermal and wind energy. Their share in the energy production will make 14.3 % in 2010. Along with the increase of the share of its own primary energy production from 10.9 % in 1990 to 32-37 % in 2005-2010 a reduction of the share of heat power stations in the energy balance from 82 % in 1990 to 26.5 % in 2010 is projected;
- Increase of the share of natural gas and decrease of the share of residual oil in the energy production. If compared to 1990 a decrease in the share of residual oil from 32 % to 9 % by 2000 and to 6-7 % in 2005-2010, and increase of the share of natural gas up to 72 % are projected;

- Increase of the energy efficiency and energy saving. The main potential of energy saving is in electricity and heat supply, as well as in the industry, communal and commercial sectors, the use of which will enable the saving of 318 kt. c.f. and the C_2O emission reduction to annual 609 Gg by 2010. It is possible to attain a significant increase in energy efficiency by decreasing the loss of water in the irrigation systems in future, that will enable the increase of power generation on the Sevan-Hrazdan cascade of the hydro-power station by 1000GWt.h. annually, the application of gravitational irrigation, as well as the stimulation of tax and tariff policy implementation.

The projected parameters of energy saving and corresponding reduction of C_2O emissions are presented in Table 4.6.

Table 4.6 *Projected energy saving.*

	2000	2005	2010
Saving in energy resources, kt c.f.	57.0	216.0	318.0
Including:			
energy generation	-	121.0	189.0
industry	51.0	68.5	79.0
lighting	6.0	26.5	50.0
Prevented emissions, Gg CO_2 / annually	106.0	414.0	609.0

4.5. Forecast of Anthropogenic Greenhouse Gas Emissions

The estimation of greenhouse gas emissions which affect the climate change, is done according to the IPCC guidelines. The forecast emissions is designed based on the expected volumes of corresponding activity and demand for energy by the ultimate users by five years of the estimated period for the most probable macroeconomic development scenario and corresponding energy consumption, which were considered in the previous chapters. The emission sources are classified by four basic modules mentioned in the IPCC guidelines: power, industry, agriculture, wastes.

The estimation of forecasted emission levels of the main greenhouse gas - C_2O is based on the future fuel and energy balance of Armenia for each interval of the projected period and for the data on the expected production of cement - the basic technology in a category "Industry" which is connected to the CO_2 emission. The coefficients of specific emissions which were generalized by kinds of fuel and recommended by IPCC were taken into consideration for the estimations.

The expected CO_2 emission as a result of different fuel type combustion is presented in Table 4.7. The reduction of the share of CO_2 emissions from combustion of oil and the increase of CO_2 emissions from natural gas burning is expected in the long term.

Table 4.7 *Expected anthropogenic CO_2 emission in Armenia from fuel combustion, Gg.*

Fuel	1990	1995	2000	2005	2010
Coal	1070	29	33	44	44
%	5.0	0.8	0.5	0.1	0.4
Natural gas	8339	2794	4301	6600	7553
%	39.0	63.8	61.9	67.1	65.8
Liquid secondary fuel	11974	1555	2614	3219	3850
%	56.0	35.4	37.6	32.8	33.8
Total	21383	4378	6948	9863	11447
Emissions as to 1990, %	100.0	20.4	32.4	46.1	53.5

The forecast of the distribution of CO_2 emission as a result of fuel combustion to the main

components of power sector of Armenia is presented in Fig. 4.6. The output data show, that the share of CO_2 emissions from heat power stations and industry will be reduced in the long term. As for the communal and commercial sectors, the emissions will increase and the change in emissions from transport will be insignificant. The received patterns correspond to the outline of the energy policy, to the trends of the accepted scenario of economic development and expected changes of the GDP structure.

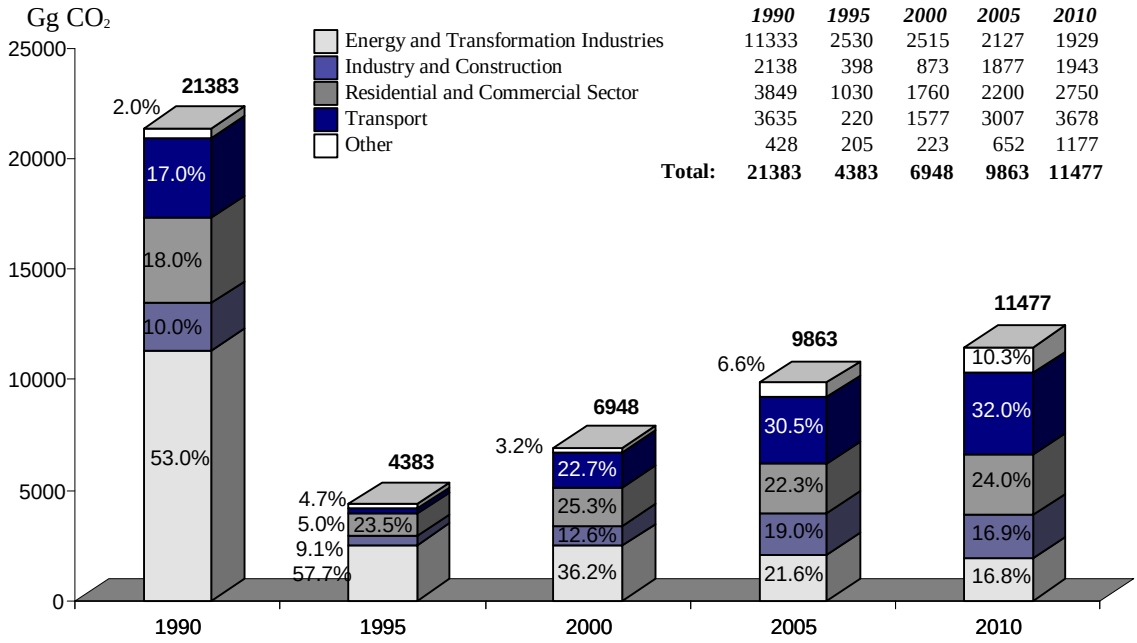


Fig. 4.6 Anthropogenic CO_2 emissions in Energy sector of Armenia in 1990-1995 and forecast up to 2010

The analysis of the received estimation parameters of the envisaged CO_2 emissions in the Energy sector shows, that despite the increase in 1995-2010, if compared to 1990, its level will make 32.4 % in 2000, 46.1 % - in 2005, 53.5 % - in 2010. Such limitation of CO_2 emissions will be ensured by changing the structure of a fuel and energy complex, modernization of generating capacities of heat power stations, raise of energy efficiency and energy saving, which have been incorporated in the Energy Master Plan of Armenia.

The forecast of CO_2 emission from cement production is presented in Table 4.8.

Table 4.8 *Forecast of anthropogenic CO_2 emissions from cement production in Armenia.*

	1990	**1995**	**2000**	**2005**	**2010**
Cement production, kt	1486	228.1	411	650	1050
Emissions, Gg	630	114	202	319	513

The anticipated estimation of total national CO_2 emission is presented in Table 4.9. As it is obvious from the given data, 96-97 % of national CO_2 emission is caused by power generation.

See the forecast of anthropogenic CH_4 emissions in Table 4.10.

Table 4.9 *Forecast of total anthropogenic CO_2 emissions* in Armenia.*

Source	1990	1995	2000	2005	2010
Power Generation	21383	4378	6948	9863	11447
%	97.1	97.4	97.5	96.8	95.7
Cement Production	630	114	202	319	513
%	2.9	2.6	2.5	3.2	4.3
Total	22013	4492	7150	10182	11960

* Without the account of emissions, connected to changes in land-use and forestry activities.

Table 4.10 *The forecast of anthropogenic CH_4 emissions, Gg.*

Source	1990	1995	2000	2005	2010
Fugitive emissions	80	23	35	54	62
Agricultural livestock & manure management	46	36.4	37.6	39.6	42.7
Municipal solid waste (waste landfills)	23.7	18.7	19.6	19.8	22.3
Wastewater treatment	1.8	1.0	1.2	1.3	1.4
Total	151.5	79.1	93.4	114.7	128.5

Table 4.11 is illustrating the forecast of total greenhouse gas emissions expressed in CO_2 equivalents according to the global warming potential (GWP)s. The data show that the main greenhouse gas in Armenia is CO_2 with 87 % share in the greenhouse gas emissions in 1990 and 78-81 % are envisaged. The contribution of Energy sector to equivalent emissions of 1990 was 84.5 %, in 1995 - 71 %, and 76-78 % are envisaged in the long term.

The change of CO_2 emissions (energy generation and industrial processes) in 1990-1995 and the forecast by 2010 for the basic scenario of development (the preservation of the trends) and two scenarios of energy development is illustrated in Fig. 4.7. If the production and energy consumption trends are preserved of 1990 level (basic scenario), in 2010 the total CO_2 emission will make 77.3 % from the level of 1990 or 17026 Gg. The implementation of measures, envisaged by the strategy, in 2010 will enable the CO_2 emission reduction up to 54.3 % of the 1990 level or up to 11960 Gg annually, which is by 5066Gg less than according to the basic scenario, and also to minimize the parameter of emissions per unit of generated energy by 32 % (from 61.0 to 42.2Gg/PJ).

Table 4.11 *The forecast of equivalent greenhouse gas emissions in Armenia*.*

	1990	1995	2000	2005	2010
Equivalent CO_2 emissions eqv., Gg	25312	6193	9161	12650	14726
Contribution to the total emissions, %					
CO_2	87.0	72.5	78.0	80.4	81.2
CH_4	12.6	26.8	21.4	19.0	18.3
N_2O	0.4	0.7	0.6	0.6	0.5
Emissions per capita, t CO_2 eqv./person	7.0	1.6	2.35	3.26	3.74
Armenia's share in global emissions, %	0.1	0.02			

* The values of global warming are accepted: for **CO_2** - 1, for **CH_4** - 21, for **N_2O** - 310 (IPCC, 1995)

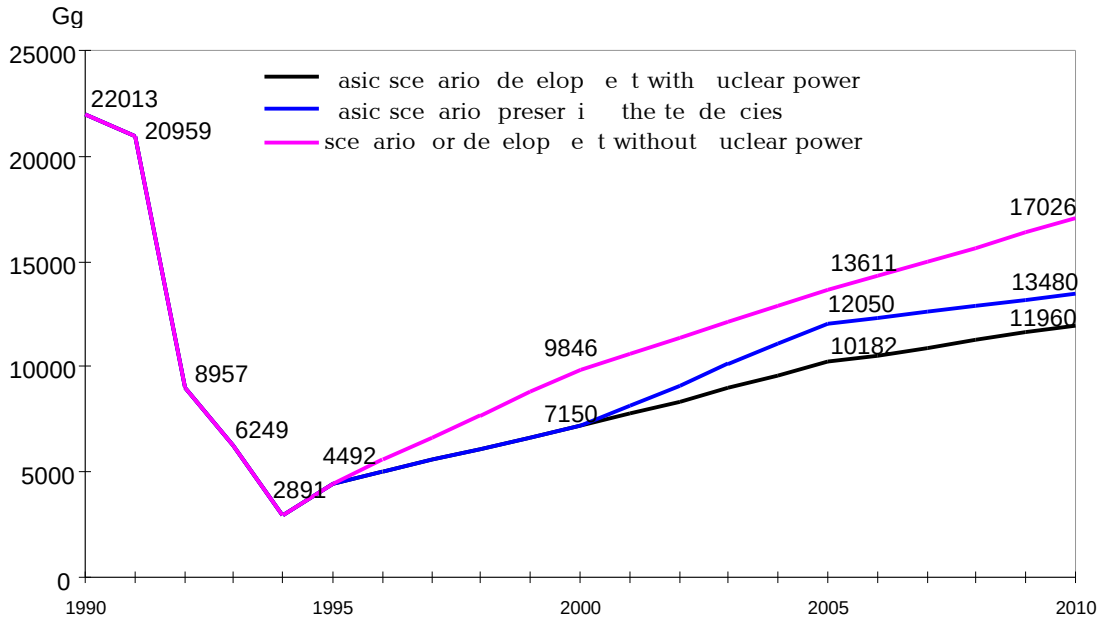


Fig. 4.7 Change of anthropogenic CO_2 emissions in Armenia in 1990 - 1995 and forecast up to 2010

4.6. Development of Sinks

In the national strategy of mitigation of the adverse impact of greenhouse gases the development of absorbers has an important meaning. It is well known, forest vegetation is considered the best natural carbon absorber. For the development of complex measures in forestry sector of Armenia, which will be directed to the increase of carbon absorption and mitigation of the adverse impact of climate change, the COMAP computer model recommended by IPCC has been used.

The output data are presented in Table 4.12.

Table 4.12 *Envisaged parameters of the forestry sector development and carbon absorption.*

Parameters	Measures			
	Afforestation	Reforestation	Forest protection	Woodland creation
Area, thous. ha	255.0	40.0	14.5	11.0
Period, years	50	20	40	11
Total stock of accumulated carbon, mln. T	16.0	3.0	3.0	1.3
Income from 1t of accumulated carbon, $	0.01	0.76	0.04	13.85
Income from the measured implemented on 1 ha, $	2.0	57.0	9.0	1640.0
Income from absorption of 1t of carbon from the atmosphere annually, $	0.0001	0.0060	0.0030	0.1040
Preliminary expenses for 1t of accumulated carbon, $	3.30	0.30	0.09	9.00
Preliminary expenses for the measures on 1ha, $	510.0	19.0	20.0	1062.0
Expenses on 1t of accumulated carbon by the current prices, $	4.95	0.14	1.30	10.00
Expenses on measures implemented on 1ha by the current prices, $	775.0	11.0	273.0	1183.0

Envisaged Researches

- Estimation of technical and economic efficiency of measures on CO_2 emission reduction in the Energy sector of Armenia.
- Estimation of vulnerability and economic consequences of climate change for climate-dependent branches of economy of Armenia.
- Elaboration of the concept responding strategy for the economy of Armenia in the conditions of adaptation to expected climate changes.

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Chapter 5. POSSIBLE CONSEQUENCES OF CLIMATE CHANGE, VULNERABILITY ASSESSMENT AND ADAPTATION MEASURES

Global climate change and internal micro-climatic changes on the territory of Armenia might result in vulnerability of natural ecosystems and have the following consequences:

- Change of the borders of natural climatic zones;
- Significant change of the biota;
- Change of the mode of the rivers' runoff, and quantitative indicators of water resources;
- Change of amount of precipitation and soil moisture content.

These consequences can essentially affect the climate-dependent branches of economy (e.g. agriculture, forestry, energy, etc.) and the sick rate of the population.

For the vulnerability estimation the IPCC scenario was accepted: increase of the air temperature in 2^{0}C and reduction of atmospheric precipitation for 10 % (*see* Chapter 6) for the republic as a whole.

The forecast indicators of vulnerability of natural ecosystems, agriculture and public health in Armenia are received with the help of specially developed computer models.

5.1. Natural Ecosystems

The mountain ecosystems are vulnerable to global climate change and are the bio-indicators of these changes. The sum-up of historical, archeological, paleobotanic, paleopalinologic data certify that significant changes in the ecosystems of Armenia have taken place in the last three millenniums, and were connected to global warming and climate aridation. During that period the forest areas have significantly reduced, the semi-desert and steppe vegetation belts have expanded, and the Alpine vegetation belt has reduced, etc.

As a result of the analysis of the present condition of the mountain ecosystems of Armenia it has been established, that all of them have certain adaptation opportunities. The middle zones of each ecosystem on the height of 150-200m are pre-adapted to possible climate change. Significant changes are not expected here.

The modeling of the vulnerability of mountain ecosystems of Armenia with regard to the climate change for the next 100 years foresees a shift of the landscape-zone borders up the mountain for 100 - 150 m (Fig. 5.1).

Desert - Semi-Desert Belt

At the moment desert - semi-desert belt in Armenia is located on the range of 400 to 1250m above the sea level and occupies the area of 4550 km^2 (Fig. 5.1). Within the boundaries of the belt

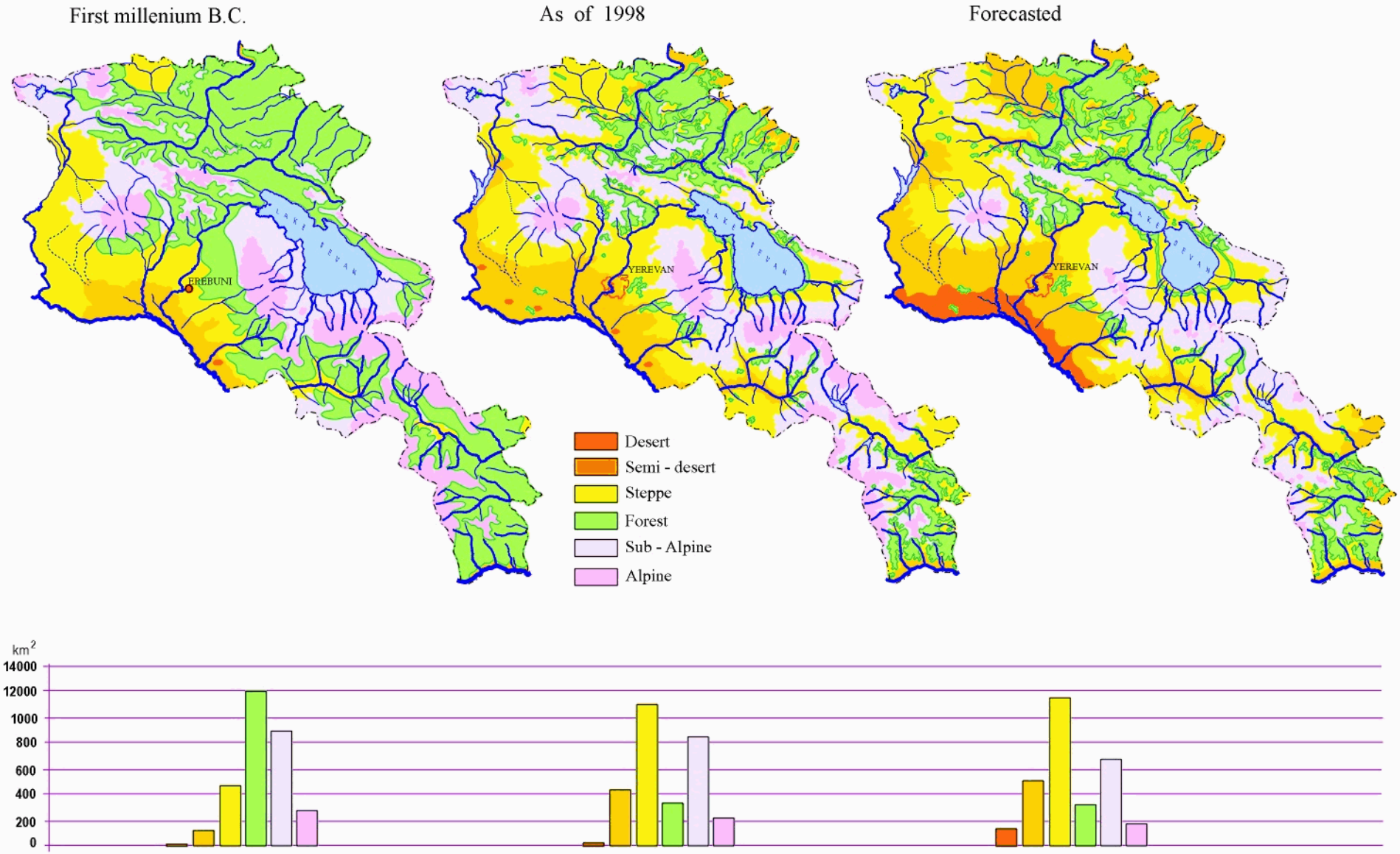

Fig. 5.1 Redistribution of vegetation zones in Armenia

the vegetation is presented by xerophyte[1/] communities, which apply to the desert and semi-desert vegetation, and by intrazonal[2/] groups. The deserts are presented by psammophyte[3/] and halophyte[4/] communities, and could be found in little isles among semi-desert vegetation on Ararat plain, and occupy around 200 km^2 area.

According to paleobotanic and paleopalinologic[5/] data in the first millennium B.C. the area of desert - semi-desert belt was significantly smaller. At the considered climate change scenario the area of desert - semi-desert belt will expand up to 6800km^2 on average, thus on Ararat valley the desert zone area will be about 1600km^2. In the forest covered regions (especially in the south-east region) the semi-desert is expected to approach the bottom border of forests.

In case of the expansion of the desert - semi-desert belt a number of vegetative communities, related to the overmoistened habitats, are expected to disappear. Probably the areas of lakes on Ararat plain will reduce, together with the areas of coastal vegetation (reed, reed mace, rush communities, etc.). The salted bogs are exposed to the danger of complete disappearance and, probably, will turn in salt-marshes. Consequently, a whole number of endemic and rare plant species, like Barseghyan's flax, Ararat sonchus,*Thesium compressum* and others will disappear. Moreover, the irrational use of irrigation water will bring to the expansion of salted lands areas.

Steppe Belt

At the occurrence of the considered climate change scenario the steppe belt in Armenia will expand from 11000 to 11440km^2 (Fig. 5.1), thus there will be its displacement upwards on 150-200m. The contemporary bottom strip of steppes will be replaced by semi-desert vegetation, and the sub-Alpine vegetation will move to the top border of the steppe. It is also obvious, that there will be the approach of steppes to the forest, first of all due to penetration of steppe plants through the bottom border, and also in the contact places of steppes and forests on the western and eastern slopes of mountains.

The move of the steppe zone upwards will cause a transformation of steppe vegetative communities. An expansion of the areas of tipchak and tragakant[6/] steppes by the reduction of the feather-grass steppe areas should be expected. The feather-grass steppe with narrow-leaved feather-grass will reduce most of all, and that is connected with their arrangement on the most flat slopes with chernozem (black earth) and low-rocky soils, and in the majority of the regions of Armenia with the increase of height of district steepness and rockiness of slopes grow.

Significant damage to the steppe vegetation will be rendered by insect-pests (Agrotinae noctuid moths, chrysomelid-beetles, etc.).

[1/] xerophyte communities - communities of arid areals

[2/] intrazonal communities - communities consisting of only one plant species, and which do not form a complete belt, but could be found only in small strips among other plant species in appropriate areals

[3/] psammophyte communities - communities, which are attached to sandy soils.

[4/] halophyte communities - communities, which are attached to salinated soils.

[5/] paleopalinological data - data on the pollen and spores of extinct plants.

[6/] tragakant steppes - steppes, which have a vegetation of mostly thorny, pillow-like bushes

Forest

The present forest area of Armenia is 459.9 thous. ha, from which 334.1 thous. ha, or 11.2 % of the territory is covered by forests. This makes only 0.1 ha of forest-covered area per capita. 62 % of forests is located on north-east of the republic, 36 % - on south-east. Only 2 % of forests are in the central regions. There are more than 200 species of trees and bushes growing in the forests of Armenia, and the main forest-forming species are oak, beech and hornbeam. The historical, archeological, paleobotanic, and other data testify that the forest covered area of the republic used to three times larger in the past, and in the first millennium B.C. comprised about 35 % of the present territory of Armenia. The map of forests of Armenia as of the first millennium B.C. is designed by analysis and integration of these data (Fig. 5.1).

On north-east of Armenia the top borders of forests will be in favorable conditions: only some upward move should be expected (150-200m). Due to high adaptation abilities of forests at heights from 1600-1750m above the sea level essential changes will not take place. The bottom border of the forest on the southern slopes, arid rare-woods in particular, probably, will start moving upward, or the share of semi-desert plant species in these vegetative communities will start to increased.

In the central forest region on the top border of forest the forecasted climate change will also be favorable, and only some upward move of the border should be expected. The southern slopes along the bottom border of the forest (1450-1550m above the sea level) will be the most vulnerable, and that's where the approach of the mountain-steppe vegetation and replacement of verdure oak-groves should be expected.

The bottom border of the forest in the south-east forest region will be the most vulnerable. The following changes are expected to take place: deterioration of conditions for seminal forest renewal, intensification of semi-desert plant species penetration, expansion of hornbeam and oak dry type forests areas, and also some (for 100-150m) upward move of the bottom border of forest. On the height of 1600-1700m above the sea level essential changes will not take place. The conditions for the top border of the forest will become favorable and an upward move should be expected.

The forest strip which is close to the bottom border, with the area of about 3-5 % forest area of the republic is, on the whole, the most vulnerable in Armenia.

It should be noted, that the change of the forest bottom border can take place in the nearest 50-100 years, and for the change of the top border, where the conditions will become favorable, a few centuries should be considered for the slow natural afforestation.

The vulnerability of forests of all three forest regions from phyllophagous insects should be especially emphasized. The area of mass reproduction of phyllophagous pests will engage 69500ha on average, the loss in the annual wood mass growth will be 63200m^{3}or 15% of the total annual gain, i.e. the loss will increase in 6.9 times. At present the areas of forests, annually damaged by insects, make on 14500ha average, losses of the annual gain of forest - 12252m^{3}or 2.8 % of the total annual gain.

Sub-Alpine Belt

At present the sub-Alpine belt in Armenia has 8523 km^{2}area. In case of accepted climate change scenario the area of this belt will reduce for about 21 % (Fig. 5.1). The steppe vegetation and, with lower speed, forest vegetation will approach the sub-Alpine vegetation along the bottom border. However, in the majority of cases the sub-Alpine meadows, due to intensive turf-formation,

can resist to penetration of forest plants for a long time, especially in the northeast region, where the change of climatic parameters will not be extremal for sub-Alpine vegetation. On the top border the sub-Alpine the vegetation will move over the Alpine. As a whole significant reduction of sub-Alpine meadow and high-grass areas in Armenia should be expected, because during the displacement sub-Alpine belt upwards in the majority of cases relatively large areas are occupied by stone screes and placer, on which petrophilous[7/] variants of sub-Alpine vegetation will develop.

Alpine Belt

At present the Alpine vegetation occupies an area of about 2200km^{2}within the boundaries of 2800-4095m above the sea level. In case of the considered climate change scenario a reduction of the Alpine belt areas should be expected by 22 % on average (Fig. 5.1). The vegetation of Alpine belt will be found in the most vulnerable condition - especially the areas of Alpine meadows and carpets will be reduced. On the majority of mountain ridges, where suitable climatic conditions (temperature and humidity) will be preserved due to relatively high altitude, the soil conditions (mainly the mechanical structure) will not enhance the preservation of Alpine meadows and carpets. The communities of Alpine vegetation will be well preserved on strongly rocky areas, stone screes and placers on the highest mountain ridges and tops of Armenia. In this respect, endemic and rare plant species, which grow on lower mountain ridges, (Komarov's caraway, Pallace's immortelle, Caucasian rodadendron,*Physoptichis caspica,* etc.) are more exposed to extinction.

Soil Invertebrates

Soil invertebrates are essentially ensuring the formation and functioning of soil, therefore the research of soil zoocomplexes (pedofauna) is a necessary stage in the evaluation of ecosystem conditions and changes occurring in them under external influence.

Preliminary comparative analysis of the dynamics of pedofauna and climate parameters has shown, that the most representative parameter of pedofauna is the total biomass, and decisive for pedofauna is the moisture provision, which is characterized by the amount of precipitation. Their decrease by 10 % leads to the reduction of total biomass by 14 %.

The total amount of precipitation is proved to be decisive for the total number and structure of herpetobium[8/]. The decrease of the amount of precipitation entails the reduction of the number of herpetobiums, the reduction of the share in gatherings of more higrophilous species[9/], and the increase of the share of more mesophillous.

Insects

Insects - are the integral component of almost all the ecosystem of land, ensuring their functioning and biological diversity. The evaluation of the possible climate change influence on them is a necessary element of general forecast of vulnerability and adaptation capabilities of ecosystems. In Armenia there are mostly numerous beetles (more than 4000 species) and butterflies (more than

[7/] petrophilous communities - communities characteristic of extremely rocky areas

[8/] herpetobium -invertebrates, inhabiting mostly on the soil surface

[9/] higrophilous species - species demanding a lot of moisture

2000 species).

It is obvious, that for the majority of wide polyphagous[10/], and also for species, connected with azonal vegetation, the main limiting factor, stipulating the top limit of dispersal, is temperature; as a rule, this limit for fodder plants is significantly higher and the trophic factor is not limiting. An upward displacement of the top border of areals by 250-500m can be forecasted, and a respective expansion of the areals by 40-50 % (appendix, Fig. A1).

For mono-[11/] and olygophagous[12/], which are more closely connected to certain vegetative communities, the possible changes will be directly connected to the displacements of these communities; the expansion of the areas of deserts and semi-deserts will cause expansion of insect areals connected with this type of vegetation. On the other hand, it is assumed that the reduction of areas in the desert-semi-desert belt, and in some places, even the disappearance of driving cenoses, that will cause the oppression of their entomocomplexes and extinction of some species, including the endemic and subendemic ones. Change in areas, occupied by forest and steppe vegetation, will be insignificant, and the conditions in some insect habitats can become even more favorable.

The conditions of Alpine (sub-Alpine and Alpine) ecosystems are the most endangered, for their majority, especially on midheight mountains (up to 2500-3000m) there will be almost nowhere to recede. A reduction of areals and fragmentation of available populations of species with subsequent extinction of separate fragments and whole small populations should be expected.

Reptiles

Mainly the most well-studied species, timed to certain landscape zones with relatively narrow areals, were examined during the vulnerability analysis of reptiles. The given approach is supported by the fact that such species have less ecological plasticity (stenobionts), and, hence, are more sensitive to global climate changes. These peculiarities can be applied as bioindicators of climate change.

Among the most well-studied species of snakes are Darevski viper, mountain viper, Armenian viper.

Darevski viper is of special interest: its areal is rather limited and covers south-eastern part of Javakheti mountain ridge at heights 2600-2800m above the sea level. The fact of the increase of this species' areal bottom border on 100m for the last 40 years is noteworthy. In 1954-1960 this species was found also at height of 2500m above the sea level (appendix, Fig. A2). Estimating biotic and abiotic factors of the microbiotop, it is possible to assume, that the areal displacement of the species has taken place as a result of some climate warming in the region. The specified fact testifies to the opportunity of bioindication of global climate change through the change of areals of this unique species. It should be noted though, that at the considered climate change scenario the given species will be exposed to extinction, because at heights of more than 2800m there are no satisfactory ecological conditions necessary for development and hibernation (stone placers, among which this

[10/] polyphagous - species which feed on different plants which belong to various botanical families

[11/] monophagous - species feeding on plant species which belong to single botanical species, and very rarely - on different close species .

[12/] olygophagous - species, feeding on the representatives of single botanical genus, and sometimes on several close general genuses

species spends most of its life time). The adaptability of Darevski vipers is low, and in the forecasted temperature mode part of the population (about 50%) will die away.

Adaptability of the other examined species - mountain vipers - is much wider, which explains the distribution of a species at heights from 1200 up to 3000m above sea level. The consequences of probable climate change for this species will be ambiguous. The vulnerability of separate population will be low in the view of existence of a favorable landscape at vertical moving.

Similar order is observed for the Armenian vipers' population, inhabiting at heights from 1300 up to 2800m above sea level.

Some rare lizard species of, inhabiting in Alpine landscape will become vulnerable: Chernov's lidless skink, Smallasian lizard, Transcaucasian poly-colored lizard.

Birds

There have been more than 350 species of birds registered on the territory of Armenia, which are categorized in 18 orders.

About 35 % of the ornithofauna representatives in the republic are settled species, 45 % build their nests on the territory of the republic, which on winter season leave its boundaries, 10 % birds of passage, 7 % of species come for hibernation from the north, 3 % are birds of casual passage. At the analysis of vulnerability of ornithofauna of the republic, species dated to various landscape zones (desert - semi-desert, steppe, forest, sub-Alpine and Alpine) were investigated.

The population of species as gray partridge and chukar, separate representatives of passerine order, eurasian skylark, common rosefinch, eurasian tree sparrow, jay have wide adaptation opportunities.

In connection with the expansion of desert - semi-desert zone, the areals of bellied sand-grouse, eurasian nightjar, and other birds in the desert - semi-desert ecosystems will be extended.

The displacement of landscape belt borders will result in changes in all zone habitats. Small reservoirs and swamps in the valley of Araks river, in particular. will be exposed to drying out. It will adversely affect the populations of the representatives of Stegonopodes, Gressores and Anseriformes orders, which inhabit there. Many representatives of these orders are included in the Red Book of the republic, in particular, the great and little cormorants, great white egrette, eurasia spoo ill.

The vulnerability of separate species is possible to forecast precisely. For example, it is possible to expect some reduction in the number of Caucasian grouse populations (appendix, Fig. A3), as a result of the reduction of the areas of Alpine meadows, which are the habitats of this species, and some displacement of the top border Caspian Snowcock areals (appendix, Fig. A4). The population of some predatory birds (Golden eagle, lammergeir vulture) will also be vulnerable, because the attachment to the places where they nestle hamper their migration. The latter will become inevitable in case of the displacement of birds populations, which make their forage reserve. The forced migrations will cause recession of the number, which will endanger their existence at the general low density of these species.

Apparently, separate representatives of passerine orders, which inhabit in the forest belt at heights of 1600-1800m above the sea level (and also the synanthrop species) will be the most adapted.

Desertification

According to the conducted researches, in the last 3 thousand years significant climate aridisation has already occurred in Armenia - forest areas were significantly reduced, sub-Alpine and Alpine meadows and areas of semi-deserts and dry steppes (Fig. 5.1) extended.

The forecasted increase of average temperature and decrease of the amount of precipitation will significantly increase the climate aridity, and which in itself will result in intensification of desertification processes. As shown above, these processes will result in significant expansion of semi-deserts belt and formation of the belt with desert conditions. There will be a significant reduction of belts with mesophillous (communities, adapted to the average mode of humidification) conditions (sub-Alpine and Alpine).

In the forecasted conditions of climate change, processes of further soil degradation will probably occur. If in 1990 in Armenia there already were 1225 thousands ha of land, eroded to different degrees, in the future their areas will expand progressively, especially taking into consideration, that in case of realization of some forecasts of climate change the greatest part of precipitation will have downpour character, and will significantly enhance the soil wash off. Moreover, the irrational use of water resources for irrigation results in intensive soil salination, and in case of rise of temperature and amplification of evaporation these processes will also be intensified. The not standardized pasturage of cattle on pastures of steppe and sub-Alpine belts also results in the degradation of pastures, which is characteristic of desertification.

Adaptation Measures and Mitigation of Negative Consequences

As shown above, the forecasted climate change will cause significant negative consequences for the nature of Armenia. Thus, the application of measures and approaches, directed to the maximum reduction of these consequences and cease of the environmental degradation processes should become the important component of the strategy in responding to climate change.

Basic adaptation measures for the natural ecosystems of Armenia are the following:

- creation of optimal landscape-zone structure for the republic as a whole (increase of the forest share given the preservation of landscape diversity);
- gradual increase of forest cover area for 266500 ha by the year 2050, i.e. from present 11.2 % of territory up to 20.1 % through annual forest planting, including the area of protective woodland belt for 5300ha; making of a large-scale timber industry plantations of accelerated rotation; application of integrated system of forest protection from pests, illnesses, weeds, cuttings, cattle pasture, fires, etc. (appendix, Fig. A5);
- allocation of reserves and specially protected natural territories for the mitigation of general anthropogenic pressure on vulnerable ecosystems, including intrazonal coastal cenoses of desert and semi-desert zones, and also the Alpine communities for the realization of their own adaptability at forecasted climate change;
- introduction of endangered species, which are in proper (similar) biocenoses, which will be preserved in case of the probable climate change;
- preservation of genetic fund of the most vulnerable and valuable species by their maintenance and cultivation in artificial conditions, preservation of genetic material in seed banks, etc..
- realization of measures, directed to the mitigation of the climate change impact on the

vulnerable components *in statu* or creation of conditions for the existence of separate species in case of displacement of their areals;

- monitoring of endangered ecosystems, mapping of areals of Alpine species and species of coastal cenoses for revealing the "island" populations and species, which have "nowhere to recede";
- the adaptation of the legislative base in the field of environment protection to the expected climate change.

For stopping the desertification process the following measures are necessary.

- Expansion of the forest covered areas (*see* measures on forest adaptation);
- Creation of a protective woodland belt in all regions, where the desertification processes proceed most actively;
- Creation of protective plantations and engineering structures for combating mud-torrents;
- Active retention of snow on fields;
- Strict standardization of loads on pastures;
- If necessary, the desalination of salinated soils;
- Organization of monitoring of the desertification processes.

5.2. Water Resources

Water resources of Armenia are used as sources for hydro power, irrigation and water supply, therefore the estimation of their vulnerability at possible climate change and realization of necessary adaptation measures are of extreme importance.

River Flow

For the rivers of Armenia the big irregularity in the distribution of flow during the year and in the long-term view, is caused mainly by the mixed (snow-rain-subsoil) feeding.

On many water-collectors of republic the flow is very sensitive even to insignificant changes and fluctuations of climate. Empirico-statistical methods have shown, that the annual and seasonal flow displays great sensitivity to the changes in precipitation, than to changes in air temperature. However for pools, where the snow melting makes the basic part of water reserves, the flow distribution in months is more sensitive to air temperature, than to precipitation.

For the mountain countries, like Armenia, precipitation in the form of snow plays a special role in the river flow formation. The feeding of the majority of rivers in Armenia is done mainly through little snow waters. On the territory of Armenia the height of the snow cover depends on the orographic conditions and varies from 10-15cm at height of 900-1200m to 2.5m at height of more than 3000m.

In case of climate warming a reduction of the distribution area of snow cover and the terms of its preservation are expected to take place. In the process of the study of dynamics of the formation and melting of a steady snow cover for the period of 1961-1990 time shifts were observed.

The snow cover formation has moved to later terms, and its duration has decreased for a week in comparison with the norm. The water reserves in the snow on territory of the country as a whole have decreased for 5-10% for the considered period.

The quantitative evaluation of the changes in the characteristics (vulnerability) of the river flow in case of the expected climate change, applied with reference to particular water-collectors, which are located in various physio-geographical conditions, and cover almost all large rivers of Armenia, has presented, that in case of air temperature rise for 1.5^{0}C and reduction of atmospheric precipitation for 10-15%, the total annual flow will decrease for 15-20%. Taking into account, that the total annual flow of the studied rivers makes 75% of the whole river flow, the received results can be applied to the whole river flow of Armenia.

However, it should be noted, that for some river basins there is a certain discrepancy between the data on precipitation amount, snow cover characteristics and observable changes of river flow. In order to get more correct forecasts of vulnerability of water resources additional research is required.

Lake Sevan

Lake Sevan has a unique role in the natural complex of Armenia. Moreover, it is considered the only long term source of drinking water for a wide region. The use of lake waters for irrigation and power purposes has played an important role in the economic development of Armenia, however, at the same time has resulted in gross infringement of its ecological balance.

The most vulnerable element of the water balance of the lake is the evaporation from its surface. It has been proven, that in case of rise of air temperature for ^{0}C the average annual evaporation in comparison with its basic (years 1961-1987) Figure, will increase for about 13-14%.

Taking into account the known degree of uncertainty in the evaluation of the forecast of temperature and, especially, of precipitation, (related, first of all, to the error of initial data), an evaluation of the change of the lake water balance for several scenarios of climate change (Table 5.1) was made.

Table 5.1 *Change of Lake Sevan water balance for the climate change scenarios*

Scenario of climate change		**Change in water balance of the lake, mln. m^3/year**
Change of temperature, ^{0}C	**Change of precipitation, %**	
+2	0	-150
+2	-10	-250
+3	-15	-360

For the scenario considered in the present communication (rise of temperature for ^{0}C and reduction of precipitation for 10%) reduction of volume of water in the lake water balance will make about 250 mln. m^3.

In case of the implementation of such scenario and by keeping the present rate of the use of lake water resources, the equilibrated water balance will be established at the sinking of the water-level for another 20 meters with essential intensification of erosion processes in the lake basin (appendix, Fig. A6).

The expected changes of elements of water balance of Armenia for the specified scenario of

climate change are presented in Fig. 5.2.

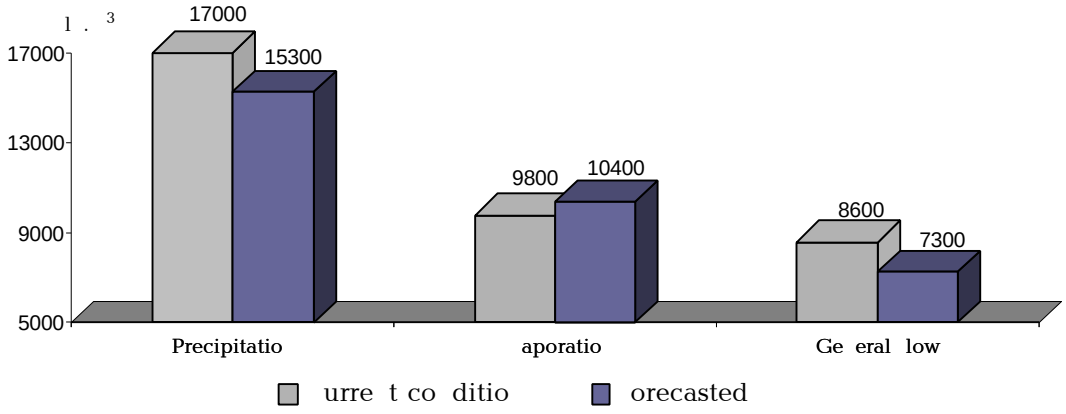

Fig. 5.2 Elements of water balance of Armenia

The presented data should be considered as the first approach, which reflects the direction of the process and order of expected changes of the characteristics of water balance of Armenia. Taking into account the extreme importance of the problem in water-supply of Armenia in future, and for more precise and detailed forecasts, additional researches should be carried out, which will be directed to development of strategy for responding to the vulnerability of water resources in energy, agriculture, municipal sector, etc.

Adaptation Measures

For the mitigation of climate change impact on the water resources of Armenia and adaptation of economy to the new natural conditions, the following measures should be carried out:

- Increase of volumes of accumulation of winter-spring flow of the rivers by the construction of new reservoirs with a total volume of 2.0 billion m^3;
- Revision of territorial distribution of water resources and transfer of part of the flow from the basins with sufficient water-supply to those with poor supply;
- Reconstruction of irrigation system in order to reduce losses of water, application of advanced water-saving methods of irrigation;
- Enlarging the water reserves of Lake Sevan by transferring the free flow from full-water river basins into the lake, reduction of the water outlet from the lake for irrigation purposes and prevention of water use for power generation in the non-irrigation period;
- Saving and rational use of the water in all branches of economy;
- Improvement of the monitoring of water resources;
- Development of a national program of the use of water resources - considering the long-term demand of the national economy and possible climate change.

5.3. Agriculture

In case of realization of the climate change scenario (rise of air temperature for 2^0C and reduction of precipitation for 10%) significant fall of efficiency of the agriculture of Armenia is possible. The adverse impact will be aggravated, if the processes of the climate warming and aridisation coincide with amplifying degradation of soils.

Plant-growing

At forecasted climate change the humidity of soil will decrease for 10-30%, - depending on the vegetation period and height of the district and the natural moisture provision of various agricultural crops - for 7-13 %, and the moisture deficit in soil will increase for 25-50mm (see section 6.2).

Analysis of overall response of main crops' yield to climatic conditions has shown, that at expected change of the climatic characteristics, the efficiency of plant-growing in Armenia can be reduced for 8-14 %. Thus, the reaction of various crops to changes will not be similar: the productivity of crops, cultivated in the bottom hot and drought zones, will be reduced for 10-14%, and cultivated in moderate zones - for 7-10%.

The productivity of cereals will be reduced on the average for 9-13%, vegetable crops - for 7-14%, potato - for 8-10%, horticultures - for 5-8%. The productivity of more heat-tolerant grapes can rise for 8-10%.

Wide complex of adaptation measures should be implemented for the mitigation of adverse consequences of climate change and for the targeted adaptation of agrarian sector of economy of Armenia to the new condition of natural environment. These are, first of all, the optimization of use of land reserve and change of crops structure, the wide introduction of moisture saving technologies, the revision of zone distribution of irrigated lands, the application of advanced agrotechnical measures, and the introduction of new high-yielding frost- and drought-tolerant crops, the improvement of the breed structure of herd.

The climate warming and aridisation will result in the expansion of zones of plant-growing for 200-300m, which will be enhanced under the forecasted water deficit, which, in its turn, will bring up the need for changing the structure of the sowing areas. The sowing areas of potato, cabbage and spring barley can be successfully moved to height of 2600m, and crops of early-maturing sorts of these crops will be probably displaced from plain to the zone of 1400-1500m and higher. The early-maturing sorts of fruits - pear, apple, plum, etc., which can be cultivated in zones at height 1400-2200m will also be moved from plain to foothills. Thus, in the Ararat plain plantations of grapes, peach, apricot, and also the sowing areas of heat-loving vegetable crops (tomato, pepper, eggplants, etc.) can be extended, and the borders of their cultivation can be successfully extended in the internal arid regions up to height of 1600m, and in the northeast - up to 1200m. The top border of winter wheat cultivation will reach 2000m in the northeast, and in the internal regions - 2300m. In both regions in the zone at height of 400-900m subtropical crops - pomegranate, Fig, Japanese persimmon, nuts can be successfully cultivated, and the area of such valuable technical culture, as geranium can also be extended. Tobacco, various fruit and vegetable crops will be cultivated in medium and high zones.

Grazing Industry

Pastures are the basic fodder base of animal husbandry in Armenia. Animal husbandry was one of the major branches of agriculture during many centuries. Pastures in Armenia are located on all high-altitude belts. The most productive pastures are situated in the sub-Alpine, steppe and Alpine belts.

The forecasted climate change will cause the following consequences for the grazing industry:

- Reduction of pasture areas as a whole and of their productivity for 4-10%;
- Expansion of the areas of low-yield pastures of the semi-desert belt for17%;
- Reduction of the areas of the most valuable and high-yield pastures of the sub-Alpine belt for 19% and Alpine belt - for 22% and the productivity of mountain grasslands for 7-10%;
- Increase of the share of poisonous, prickly and weed plants in structure of vegetation pastures, fall of their productivity and reduction of forage quality of the grass;
- Reduction of the head of the livestock for 30% and the dairy cattle production for 28-33%.

Adaptation Measures

The reduction of water resources, connected to climate change, will have an adverse impact on the irrigated agriculture. Therefore, measures on the improvement of the irrigation system and the reduction of losses of irrigation waters and the preservation of moisture reserves of the soil are especially important. The estimations have shown, that through the introduction of technically intact irrigation system, it is possible to save 20-25% of irrigation water only in Ararat valley. The application of the drop method of irrigation of vineyards and fruit gardens will enable the reduction of the water irrigation outlay in 4-6 times - if compared to the used method.

The preservation of soil humidity will be contributed by the application of evening and night watering, which increase the humidity for 8-10%, by the conduction of cereal and vegetable crops watering with high frequency and by small portions, by mulching the soil with volcanic rocks (Dacit tuffs, perlits, slags), which will enable the reduction of evaporation from soil in 3-4 times, and also by use of manure.

The implementation of appropriate agrotechnical measures is necessary for the expansion of adaptability of plant growing. In case of rise of temperature for $2^{0}C$ the plan vegetation period will increase for 20-25 days on average, therefore, the planting of winter crops in autumn has to be done 10-12 days later, and planting of spring crops in spring and the transplantation of plant seedlings - 10-12 days earlier.

The lowering of vulnerability of crops at large depends also on optimal terms of implementation of measures, like soil cultivation, fertilizer application, combating pests and diseases, harvest and shelter of grapes, etc..

For organizing vineyards and horticultures on less-frost-inclined forms of relief it is necessary to create terraces with special irrigation system on the slopes, and also, to regulate the photo- and micro-climate using the method of improvement of overground part of the vineyards and fruit gardens. This method contributes to the increase of the soil shading and receipt of light by the foliage surface, and lowering of soil temperature and evaporation from its surface.

The creation and the introduction of new high-yielding frost- and drought-tolerant sorts of

agricultural crops is important during the change of climatic conditions.

For the mitigation of the adverse impact of climate change on grazing industry the following adaptation measures are required: giving the pastures a long-term rest and, whenever possible, irrigation of certain sites 1-2 times a year; maintenance of the optimal ratio of the livestock and pasture areas; introduction of new inventory for pastures, estimation of norms and terms of pasture and load distribution in view of the contemporary unfavorable situation, ecological factors and forecast of climate change; increase of biodiversity of pastures and mountain grassland through introduction of more valuable species of grass; restoration of large cattle-breeding complexes, improvement of the breed structure of herd, observance of norms and terms of feeding, etc..

5.4. Human Health

Diseases of Cardio-Vascular System

Analysis of the sickness rate of cardio-vascular system diseases, and also the forecast of their change has presented the probability of vulnerability of adaptation mechanisms and increase of the number of cardio-vascular diseases, especially among the risk group (sick, old people).

The expected climate change will, at the same time, have a favorable influence: the decrease of the sickness rate of chronic rheumatic heart diseases, especially in childhood.

Transmissible Infectious Diseases

The partial areal overcovering of two various strains of plague microbe vectors (Microtus arvalis and Meriones vinogradovi) is expected to cause the aggravation of epidemic conditions of plague with an opportunity of passing of strains on the newly-formed joint areals, which are currently isolated form each other (natural plague centers), with unpredictable epidemic consequences (appendix, Fig. A7, Fig. A8).

The expansion of areals of the vectors and the aggravation of epidemic situation of malaria can be expected because of the optimization of a temperature mode in the foothill - upland zone and the increase of quantity of anofelegenic reservoirs as a result of the aridity increase. At the same time, the possibility of alleviation of malaria danger in the semi-desert zone related to the expected parching of swamps and reservoirs of this belt is observed (appendix, Fig. A9, Fig. A10).

Non-transmissible and Parasitic Diseases

The possibility of aggravation of epidemic situation of cholera is connected to the expected expansion of circulation areals of El-Tor vibrio and creation of favorable conditions for the increase of its enzymatic activity in reservoirs, which are seeded by the pathogen, has been detected.

The increase of the sickness rate of intestinal infections is predicted in connection with the prolonging of the period with optimal temperatures for reproduction and development of activators in water and soil, and also with the expected deterioration of sanitary-hygienic conditions as a consequence of the vulnerability of water resources in the republic.

At the same time the climate change impact on the activators of parasitic diseases and

helminthes is not so simple. If in the foot-hill zone the rise of temperature is favorable for the development of parasites and helminth eggs, then in the semi-desert zone the withering of the top layer of the soil and extreme temperatures can result in their extinction with the corresponding alleviation of epidemic exposure in these regions.

Adaptation Measures

- Increase of social-economic living standards of the population;
- Increase of the sanitary-hygienic awareness level and household culture of the population of the republic;
- Use of house construction technologies, which enhance the creation of optimal temperature mode;
- Creation of zones with a sparing microclimate (parks, green zones, fountains, etc.) in the populated areas;
- Monitoring the risk group population vulnerable to thermal load;
- The preliminary notification of the population and organization of preventive measures to facilitate emergency responses to extreme heat;
- The strict quarantine surveillance on borders, at the airports for prevention of infectious agents transmission;
- Monitoring of exposed territories for especially dangerous infections in order to take timely measures for revealing and treatment of the sick and parasite-vectors for the prevention of further spreading of the infection;
- Combating of infections agents and vectors;
- Monitoring and control of sanitary-hygienic condition of water-collecting and water-supply network, maintenance of water-pipes by modern installations and means for water purification and disinfection;
- Vaccination and chemical prevention measures for the population (in case of epidemic complications);
- Use of individual protection means.

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Chapter 6. RESEARCH OF CLIMATE SYSTEM OF ARMENIA AND SYSTEMATIC OBSERVATIONS

6.1. General Information

The hydrometeorological observations in Armenia have been carried out for more than hundred years - since 1885. At present the network of observation includes 45 meteorological stations (from which 19 are included in the world meteorological system), 3 climatic stations, 70 meteorological, 105 river and 7 lake observation sites.

Since 1992 Armenia is a member of the World Meteorological Organization (WMO) and Interstate Council of CIS on Hydrometeorology, and is committed to cooperate with the world and regional centers and national hydrometeorological services in the field of information exchange. The part of the given observations is presented for publication in WMO and world centers of information on climate (Germany, Japan) for using in the atmospheric general circulation models.

The hydrometeorological observations and their analysis, and also the climate change monitoring in Armenia are carried out by the National Hydrometeorological Service - Armhydromet. Based on the Armhydromet data "The Directory on Climate of Armenia and the Climate of Large Cities of the Republic" was published. The materials on the service are widely used in planning and in various branches of national economy of Armenia.

In the situation of economic crisis of transition period and absence of required funding the observation network has faced an extremely difficult conditions. The observations are conducted irregularly and not in their complete volume, the system of collection, processing and transfer of the given observations is morally and physically out of date. Scientific researches on hydrometeorology and climatology, which, in particular, are connected to the implementation of the UNFCCC by Armenia, were sharply reduced.

National hydrometeorological service gets significant support within the framework of cooperation with the WMO and bilateral cooperation. Under the WMO program of cooperation "Meteo-France" has provided Armenia with the RETIM-AEROMET system, which enables receiving meteorological data and maps through the geostationary statistics, and also with CLICOM system of climatic data reception and service, which is used to reach the objectives of the "Armenia - Country Study on Climate Change" Project. The Armenian experts have passed a training course in "Meteo-France" on climate change related aspects.

At present activities are implemeted on creating a hydrometeorological data-base in compliance with the WMO standards in Armhydromet.

The hydrometeorological and climatological studies are conducted in Armenia in the following scientific organizations:

- In Scientific-Applied Center on Hydrometeorology and Ecology of Armhydromet;
- In the Department of Climatology of Armhydromet;
- In the Institute of Geological Sciences of National Academy of Sciences of the RA;
- At the Geographical Faculty of the Yerevan State University.

6.2. Observable and Expected Climate Change in Armenia

The climate change on the territory of Armenia is caused mainly by the impact of global climate change of the Earth, and also by the internal microclimatic changes of anthropogenic origin.

The observed and expected changes of the climatic characteristics of Armenia are estimated with the use of empirical-statistical methods, recommended by IPCC and Armhydromet hydrometeorological data-base, including the observations of 56 meteostations for the period of 1885-1996. Climatic anomalies, i.e. the deviations of mean monthly, seasonal average meteorological parameters from their norms (mean values for 30-year period) are determined relative to WMO standard period of 1961-1990.

Air Temperature

The observation data of 46 meteostations for 1935-1990 were processed for the estimation of change of temperature of the atmosphere layer close to the earth surface. The seasonal and average annual temperature values are received of for the series of various length and rectilinear trends are constructed. The latter determines the anomalies in temperature for the examined period (Fig. 6.1). Warming and fall of temperature on the territory of the republic do not have a unidirectional tendency. For the period of 1935-1990 the anomalies of air temperature changed within the range of $\pm 1^0$C. The map of anomalies of air temperature on territory the of Armenia was designedby obtained data (appendix, Fig. A11). These temperature anomalies practically coincided with similar data for Georgia along the border between republics.

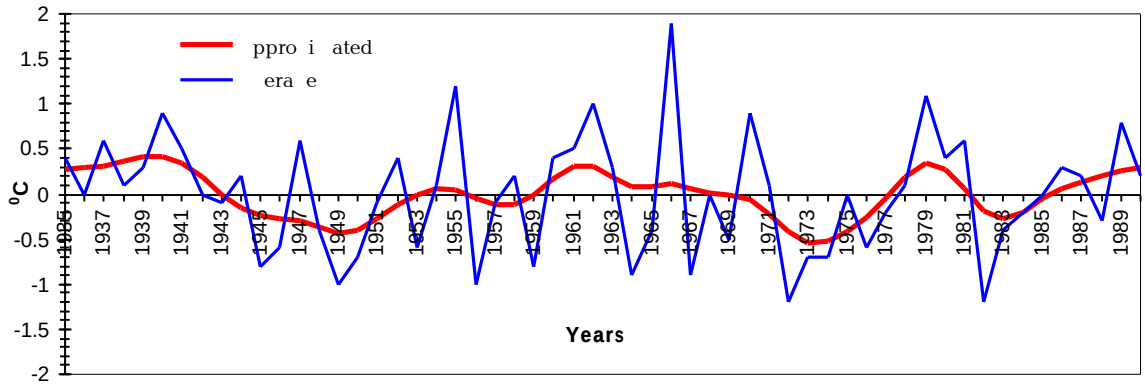

Fig. 6.1 Average annual air temperature anomalies on the territory of Armenia for the period of 1935-1990

In the studied period according to seasonal distribution the greatest increase of air temperature on the territory of the republic is observed in winter (0.8^0C); in autumn a 0.1^0C downturn is observed.

The IPCC calculated values of global change of temperature relative to the forecasted levels of global greenhouse gas emissions, were used for the evaluation of the expected changes of air temperature on the territory of Armenia. Preliminary estimations have shown, that average air temperature in Armenia will increase for $1,7^0$C in 2100.

Atmospheric Precipitation

The data of observations from 56 meteostations and sites in 50-100 year range were used for the estimation of the change of precipitation on the territory of republic. Total annual precipitation, and also seasonal precipitation for warm and cold periods are studied. The precipitation anomalies of separate regions relative to the standard period are calculated, and the map of anomalies in annual precipitation on the territory of Armenia is designed (appendix, Fig. A.12). The results of integration of the obtained data for the territory of the republic as a whole are presented in Fig. 6.2. The observable precipitation by 1995 and the expected annual precipitation on the territory of Armenia are presented in Table 6.1.

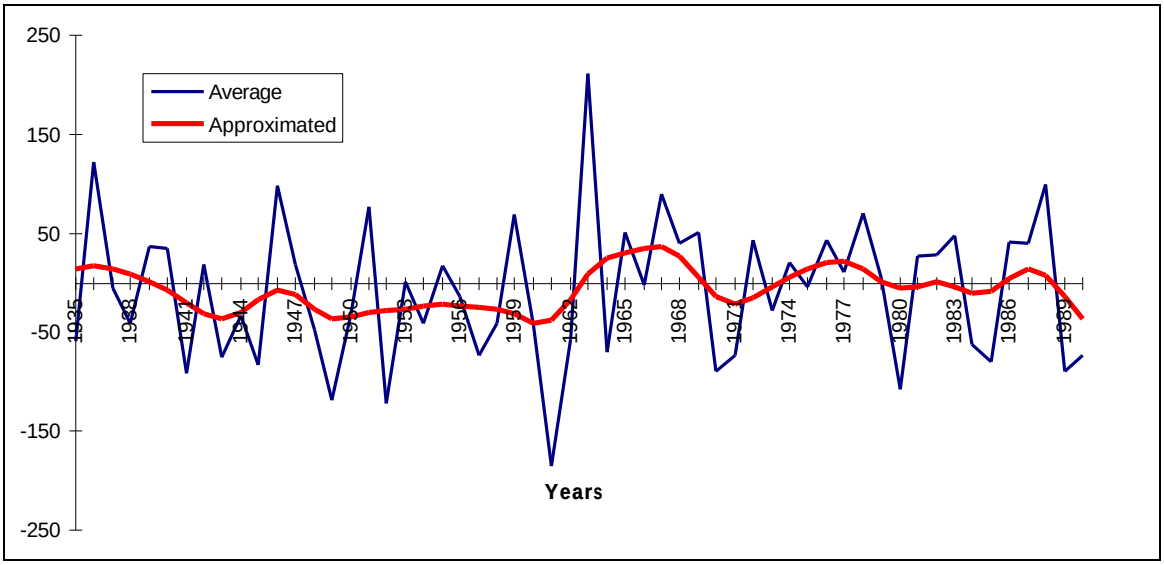

Fig. 6.2 Average annual atmospheric precipitation anomalies for the period of 1935-1990

The research has proved, that the average annual precipitation has decreased for 5.8 % on the territory of Armenia. If the tendency of change will be preserved in 2100, the precipitation on the territory of the republic will as a whole decreased for about 10 % (59mm).

Table 6.1 *Observed and expected changes of atmospheric precipitation on the territory of Armenia.*

	Observed changes					Expected changes					
	Norm of precipitation	Length of series	Change according to the trend in the period		Gradient of change	**2025**		**2050**		**2100**	
	mm	**years**	**mm**	**%**	**mm/y.**	**mm**	**%**	**mm**	**%**	**mm**	**%**
Territories with precipitation reduction	583	56	-89	-15.2	-1.6	-47.0	-8.2	87.0	14.9	-166.0	-28.4
Territories with precipitation increase	556	64	56	10.0	0.9	26.0	4.7	48.0	8.6	91.0	16.3
Average annual on the whole territory	569	60	-33	-5.8	-0.6	-17.0	-2.9	-31.0	-5.4	-59.0	-10.3

Evaporation and Evaporation Capacities

The empirical-statistical method has been used for calculation of the changes of evaporation and evaporation capacities at forecasted changes of air temperature and precipitation. It is determined, that in case of increase of air temperature for 1-2^{0}C, the total evaporation is expected to increase for 3-5 %, and evaporation - for 40-80mm per year. Additional deficit in irrigation water will appear in case of increase of evaporation and reduction of precipitation for 10 %. The deficit will make 8-15 % from accepted irrigation norms for various regions of the republic.

Soil Humidity

Soil humidity is very sensitive to precipitation and air temperature. Multifactor linear connection between soil humidity, temperature and precipitation have been revealed on the basis of long-term observation of soil humidity, and the expected change of soil humidity in case of air temperature increase for 2^{0}C and reduction of precipitation for 10 % have been calculated. Calculations have shown, that in different vegetation periods, the stocks of productive soil humidity decrease for around 10-30 %, thus the reduction will sharply vary in various climatic belts of the republic. Significant changes will take place also in the natural moisture-provision of plants and agricultural crops, which will decrease on the average for 7-13 %, and in the deficit of moistening, which will increase in humid areas for 25-33mm, in dry - for 35-50mm.

Hazardous Hydrometeorological Phenomena

In various regions the weather conditions might also change in connection with global climate change, and, consequently, the frequency of the most dangerous hydrometeorological phenomena as well, which will impair the population and economy. The recurrence study of perilous hydrometeorological phenomena characteristic for Armenia for the period of 1935-1990 has shown, that, in comparison with the average values, the frequency of strong winds (more than 25m/s) has increased for 18%, frosts (lower than 0^{0}C in the vegetation period) and hot dry winds has not changed. The frequency of abundant precipitation (more than 20mm per 12 hours), has decreased for 12% hailstones (with diameter of more than 20mm) - for 17%, mud-torrents - for 4%. The reason of noted changes in connection with climate change were not examined.

On the basis of atmosphere general circulation model of with the use of selected long-term series of meteodata at some meteostations of Armenia, a method has been developed in the Institute of Physics of Atmosphere of the Russian Academy of Sciences. This method allowed to increase the reliability of climate change forecast in addition to the above-stated studies.

Direct and indirect long-term data on the snow cover, mode of water resources, moisture-exchange dynamics of mud-torrents phenomena, long-term statistics of perilous hydrometeorological phenomena, astro-climatic data (long-term dynamics of the cloudiness change of the night sky according to the data of Byurakan astrophysical observatory), and also the information of historical, petrographical and geographical materials on climate change in halocene were used during the analysis of reliability of the results received by different methods.

The studies have shown the comparability of received results for the territory of Armenia as a whole. However, the detailed elaboration of the estimations for territory has shown some discrepancy, and sometimes, an incompatibility of the forecast results, especially on precipitation, river flow, snow cover and other (*see* the paragraph of vulnerability of water resources).

The received parameters of expected changes of climatic characteristics on the territory of Armenia well concide with the IPCC results, which were received on the atmosphere general circulation models for the region of Southern Europe where Armenia is included. In this connection, the expert group has come to the preliminary conclusion about the choice of the forecast scenario of climate change in Armenia in 2100 with the increase of air temperature for ^{0}C and with the reduction of precipitation for 10 % as a base scenario.

6.3. Scientific - Technical Programs

The following technological programs, directly connected to the reduction of anthropogenic greenhouse gas emissions and vulnerability of socioecosystems are implemented in the Republic of Armenia:

- The Energy Master Plan of Armenia.
- The program "Energy Conservation".
- Forest sector development.
- The national Environmental Action Plan.
- Rehabilitation of ecological balance of lake Sevan.
- National strategy on biodiversity.
- Optimization of the irrigation system of Armenia.

Research on the development of renewable energy sources in the industry, agriculture and in the service sector, and also on the involvement of additional hydroresources by constructing small power station in the power balance are being carried out in scientific and design organizations.

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Chapter 7. EDUCATION, TRAINING OF PERSONNEL AND PUBLIC AWARENESS

The preparation of experts on climatology is conducted at the Yerevan State University.

The training of personnel and specialties, related to environment protection, who can be requalified on the of climate change problem solution, is conducted in the following higher educational institutions of Armenia:

- Yerevan State University - chemical ecology and ecobiology;
- State Medical University - medical ecology;
- Institute of National Economy - economy of nature use;
- Armenian Pedagogical Institute - teachers of ecology;
- Armenian National Branch of International Ecological-politological University - ecology and nature use, economy of nature use, hydrometeorology and climatology;
- Yerevan University of Ecology and Law - ecology and ecological right;
- State Engineering University of Armenia - engineering ecology.

Preparation of young experts in the Scientific-Applied Center of Hydrometeorology and Ecology of Armhydromet is organized. In 1997-1998 the experts from Armenia participated in a training in France ("Meteo-France").

An Information Center, with modern computer equipment, is created within the framework of the Program "Armenia - Country Study on Climate Change". Sources of information are: funds of large libraries of Armenia, Papasian library at the American University of Armenia, library of the UN Development Program in Armenia, the IPCC, WMO materials, Conference of Parties to the UNFCCC, National Communications on Climate Change of various countries, etc. The Internet is used for obtaining materials. The information is classified and is stored in the center in the electronic form. The received materials were used by the experts, participating in the Program, for preparation of the First National Communications on Climate Change.

Raising public awareness on the climate change problems and its consequences will be conducted in the following directions:

- Conduction of seminars on various aspects of climate change;
- The publication and dissemination of brochures and information bulletins;
- Press publications and organization of radio- and TV programs.
- Conduction of thematic lectures in educational institutions of Armenia;
- Presentation and discussion of the results received for Armenia during the research on the climate change problems in governmental and public organizations.

APPENDIX