

# 4

## **Inventory of anthropogenic emissions by sources and removals by sinks of greenhouse gases**

### **4.1. Methodology**

In accordance with articles 4 and 12 of the UNFCCC, each Party to the Convention shall communicate to the Conference of the Parties "a national inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol to the extent its capacities permit, using comparable methodologies".

The main requirement in the preparation of the national GHG inventory is applying a methodology of calculations agreed and adopted in the COP UNFCCC, which allows international comparing of results.

Revised 1996 IPCC Guidelines for the National Greenhouse Gas Inventories, including software IPCC v 1.1 served as the basic documents and methodologies for all GHG emission calculations.

In accordance with IPCC, Tajikistan's inventory includes 5 categories of anthropogenic greenhouse gas emissions by sources and removals by sinks comprising of 9 gases with direct and indirect greenhouse effect during a 9 year period from 1990 to 1998.

Gases with direct greenhouse effect include: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), perfluorocarbons (CF<sub>4</sub>, C<sub>2</sub>F<sub>6</sub>). Gases with indirect greenhouse effect: carbon monoxide (CO), nitric oxide (NO<sub>x</sub>), non-methane volatile organic compounds (NMVOC). Sulphur dioxide (SO<sub>2</sub>) is considered as a gas advancing the formation of anthropogenic aerosols.

The state statistical data served as a basis for all calculations of greenhouse gas emissions. Additional data was obtained from: Ministry of energy, Ministry for nature protection, State forestry authority, State industrial committee, State committee on land resources and Ministry of agriculture.

GHG emissions related to production, storage, distribution and combustion of fossil fuels were studied under the category "Energy activities". Calculations of CO<sub>2</sub> emissions in this category are based on two approaches. The first considers statistical data on production, import, export, international bunker, and changes of fuel stocks in the country. The second approach, which was adopted as basic according to the IPCC recommendations, was based on statistical data on fuel consumption by various sectors of the national economy.

Gross calorific values recommended by IPCC are adopted in all calculations under the category "Energy activities", apart from the natural gas imported from Uzbekistan; therefore, local coefficients were applied for it. IPCC emission factors were adopted as default.

GHG emissions, which occur as a result of a physical-chemical processes, were calculated in the category "Industrial processes". Activities such as the manufacturing of ammonia, aluminum, steel, iron, cement, and lime were included in this category. The industrial activities related to refrigerant production were not considered in view of the absence of data. Emission factors in the category "Industrial processes" were adopted according to the IPCC recommendations.

GHG emissions related to animal husbandry, rice cultivation, combustion of agricultural residues, and agricultural soils were studied in the category "Agriculture". Emission factors in the category "Agriculture" were adopted in accordance with the IPCC recommendations.

In the category "Land use change and Forestry" calculations covered two types of activities recommended by IPCC, including "Changes in forest and other woody biomass" and "Emission and removal of CO<sub>2</sub> in soils". Coefficients and emission factors recommended by IPCC were applied in calculations taking into consideration proposals by national experts and scientists as well as consultations of UNFCCC.

Emissions of methane from solid wastes and wastewater purification are calculated in the category "Waste". Solid wastes in rural areas were not taken into account, in view of their dispersion over the territory. Coefficients and emission factors recommended by IPCC, along with proposals by nature protection institutions were used in these calculations.

The category "Solvents" was not considered in view of the absence of activity data and little contribution of this category to the total emissions.

Following the "IPCC Guidelines on uncertainties management" national experts have calculated and explained uncertainties in the national inventory caused by the lack of data and emission factors, and prepared recommendations.

Significant contribution to the preparation of the national inventory was ensured by regular consultations and close cooperation with the experts from the National Communication Support Program GEF-UNDP, UN FCCC Secretariat, Azerbaijan Climate Change Center, etc.

Electronic modules were prepared and submitted to the UNFCCC Secretariat.

## Anthropogenic impact on the climate system in Tajikistan



### Emissions from energy sector are $\text{CO}_2$ , $\text{CH}_4$ , $\text{N}_2\text{O}$ , $\text{CO}$ , NMVOC, $\text{NO}_x$ , $\text{SO}_2$

- Production of heat and electricity at heat power plants
- Fossil fuel combustion in manufacturing industry and construction
- Fossil fuel combustion in transport sector
- Fuel consumption in residential, agricultural and other sector



### Emissions from industrial processes are $\text{CO}_2$ , PFCs, HFCs, $\text{CO}$ , NMVOC, $\text{SO}_2$

- Production of aluminum and ferrous metals
- Production and maintenance of cooling equipment
- Production of ammonia
- Production of cement and lime
- Production of foodstuffs and beverages



### Emissions from agricultural sector are $\text{CH}_4$ , $\text{N}_2\text{O}$ , $\text{CO}$

- Enteric fermentation
- Manure management
- Cultivation of rice on flooded fields
- Agricultural soils
- Burning of agricultural residues



### Land use change and forestry are natural $\text{CO}_2$ absorbers

- Changes in forests and other woody biomass
- Absorption of  $\text{CO}_2$  by soils as a result of 20-year changes in land use
- $\text{CO}_2$  emissions as a result of illegal deforestation, biomass burning and soil dehumification



### Emissions from waste are $\text{CH}_4$ and $\text{N}_2\text{O}$

- Decay of organic substances in anaerobic conditions
- Communal wastewater purification
- Treatment of industrial wastewater

## 4.2. Tajikistan's contribution to global warming

Industrialization, urbanization, the increase of industrial and agricultural production, development of motor transport apart from social and economical benefits have resulted in the increase of greenhouse gas emissions and overall anthropogenic impact on the environment and climatic system.

According to expert assessments, contribution of Tajikistan to the global warming during 1970-2000 totalled 300 million tonnes of CO<sub>2</sub>, including emissions from fossil fuel combustion and cement production.

Until the 1990s, there had been a significant increase of carbon dioxide emissions, particularly emissions from solid fuel combustion rose by 22%, liquid fuels - 55%, gaseous fuels - 4 times.

In the 1990s, there was a decline in industrial production in Tajikistan, which resulted in the reduction of GHG emissions from fossil fuel combustion by 10 times, but cement production by 40 times.

## 4.3. Total greenhouse gas emissions

Five different gases with direct greenhouse effect considered in Tajikistan's GHG inventory. For comparison of their contribution into total emissions and assessment of their impact on the climate system, IPCC recommends submitting the results of the inventory in both absolute units and in CO<sub>2</sub>-equivalent. The latter depends on the global warming potentials (GWP), which consider the radiative influence of greenhouse gases during a certain period, as well as the lifetime of those gases in the atmosphere (tab. 4.1).

Table 4.1.

### Global warming potentials for main greenhouse gases for 100 year period

| Greenhouse gas    | Chemical formula              | GWP   |
|-------------------|-------------------------------|-------|
| Carbon dioxide    | CO <sub>2</sub>               | 1     |
| Methane           | CH <sub>4</sub>               | 21    |
| Nitrous oxide     | N <sub>2</sub> O              | 310   |
| Tetrafluorocarbon | CF <sub>4</sub>               | 6,500 |
| Hexafluorocarbon  | C <sub>2</sub> F <sub>6</sub> | 9,200 |

Source: IPCC

Some greenhouse gases in view of their physical and chemical properties possess an extremely high GWP. Among those are perfluorocarbons. In light of high GWP, even a small volume of their emissions accounts for a significant CO<sub>2</sub>-equivalent value.

The results of calculation show that the greatest greenhouse gas emissions in Tajikistan were observed in 1991; they resulted in 31 million tonnes of CO<sub>2</sub>-equivalent, and taking into account absorption in LUCF sector, they amounted in 30 million tonnes of CO<sub>2</sub>-equivalent. The lowest volume of GHG emissions was observed in 1998 and resulted in 6.3 million tonnes of CO<sub>2</sub>-equivalent. Taking into consideration absorption in LUCF sector, they amounted in 4.8 million tonnes (fig. 4.1)

During 1990-1998, carbon dioxide emissions dropped significantly when compared to methane, perfluorocarbons and nitrous oxide emissions.

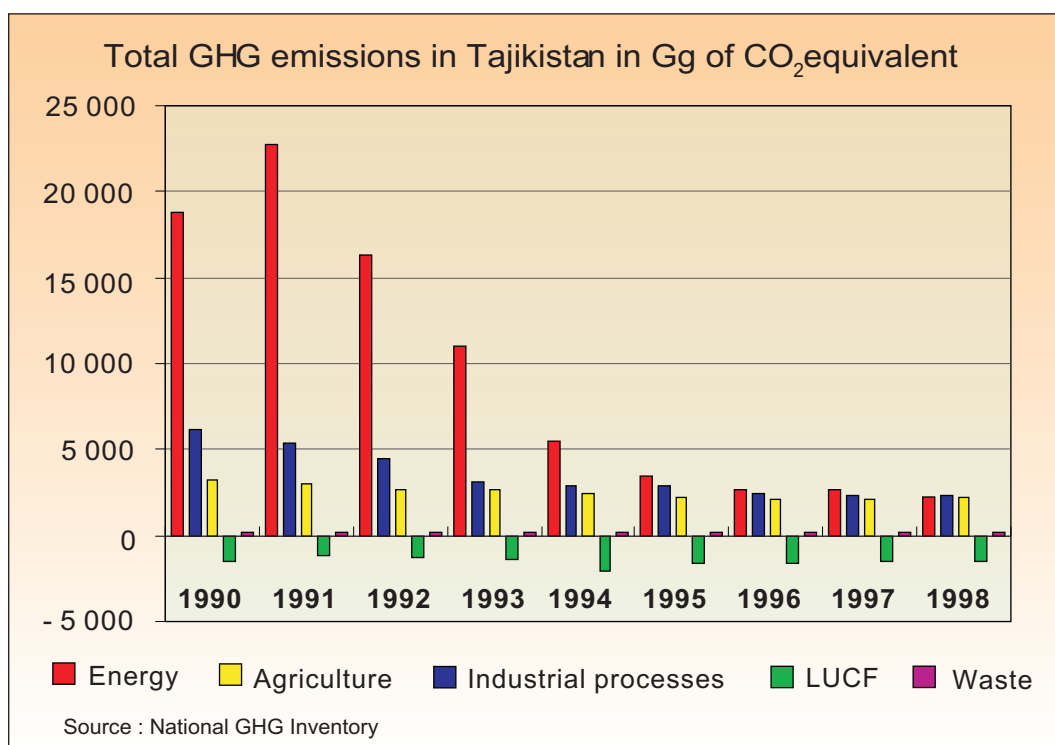


Fig. 4.1.

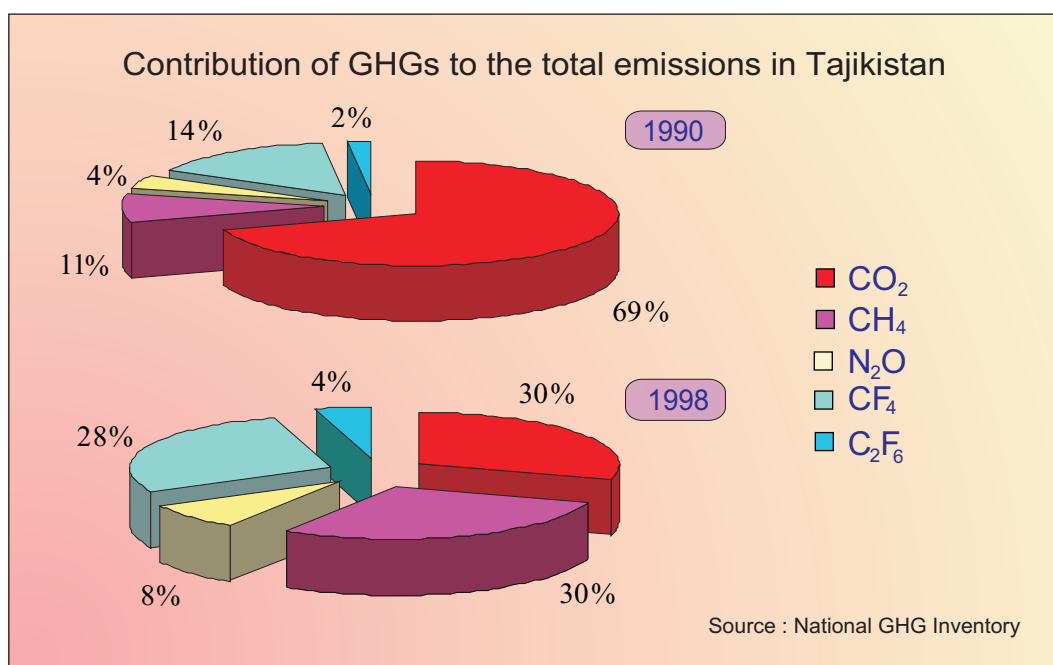


Fig. 4.2.

The decrease in greenhouse gas emissions is mainly related to the economic decline and deficiency in energy supply; the increase of their absorption is connected with land use changes in the late 1990s.

#### 4.4. Per capita greenhouse gas emissions

CO<sub>2</sub> emissions per capita have decreased from 3.8 tonnes to 0.5 tonnes; this index is the lowest in the Central Asian region. At a global level, Tajikistan has the 100th position in terms of specific CO<sub>2</sub> emissions (CDIAC). Given that combustion of fossil fuels is the major source of CO<sub>2</sub> emissions, it should be noted that essential hydropower potential explains the low level of CO<sub>2</sub> emissions for the time being (fig. 4.3).

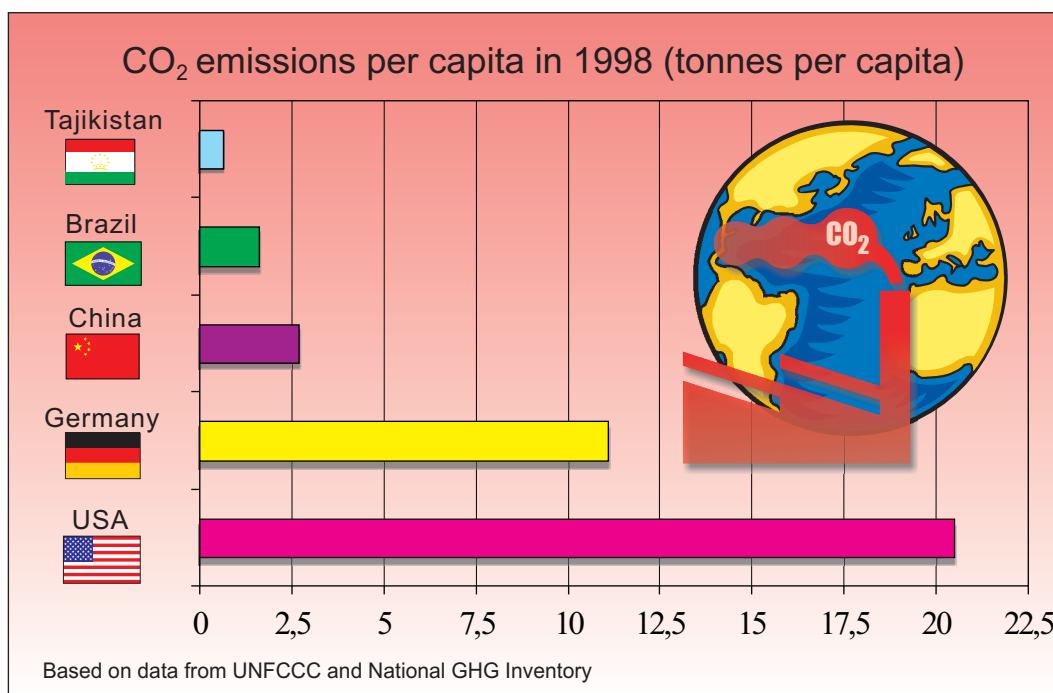


Fig. 4.3.

#### 4.5. Key sources of greenhouse gas emissions

Key source categories of the greenhouse gas emissions in Tajikistan, which aggregate 95% of all emissions during 1990-1998 varied from year to year (tab. 4.2)

Table 4.2.

**Key sources of GHG emissions for the period 1990-1998**

| IPCC category                                | Greenhouse gas                                  | Contribution |
|----------------------------------------------|-------------------------------------------------|--------------|
| ENERGY, Industry and construction            | CO <sub>2</sub>                                 | 8-27%        |
| ENERGY, Residential sector and other sectors | CO <sub>2</sub>                                 | 18-33%       |
| ENERGY, Transport                            | CO <sub>2</sub>                                 | 8-16%        |
| ENERGY, Oil-gas systems                      | CH <sub>4</sub>                                 | 5-10%        |
| INDUSTRIAL PROCESSES, Production of metals   | CF <sub>4</sub> , C <sub>2</sub> F <sub>6</sub> | 13-32%       |
| INDUSTRIAL PROCESSES, Production of metals   | CO <sub>2</sub>                                 | 2-3%         |
| AGRICULTURE, Enteric fermentation            | CH <sub>4</sub>                                 | 6-19%        |
| AGRICULTURE, Manure                          | CH <sub>4</sub>                                 | 1-2%         |
| AGRICULTURE, Agricultural soils              | N <sub>2</sub> O                                | 4-8%         |

Source: National GHG Inventory

#### 4.6. CO<sub>2</sub> emissions

In Tajikistan in the period of 1990-1998, the biggest CO<sub>2</sub> emissions were observed in 1991 (22,658 Gg), mainly because of the combustion of fossil fuels (fig. 4.5).

In total the volume of carbon dioxide emissions in the period under review has decreased more than 10 times, mainly because of the decline in energy-related activities.

The biggest share of CO<sub>2</sub> emissions are: combustion of fossil fuels, production of cement, aluminum, ammonia and ferrous metals. Insignificant CO<sub>2</sub> emissions occur as a result of soil dehumification.

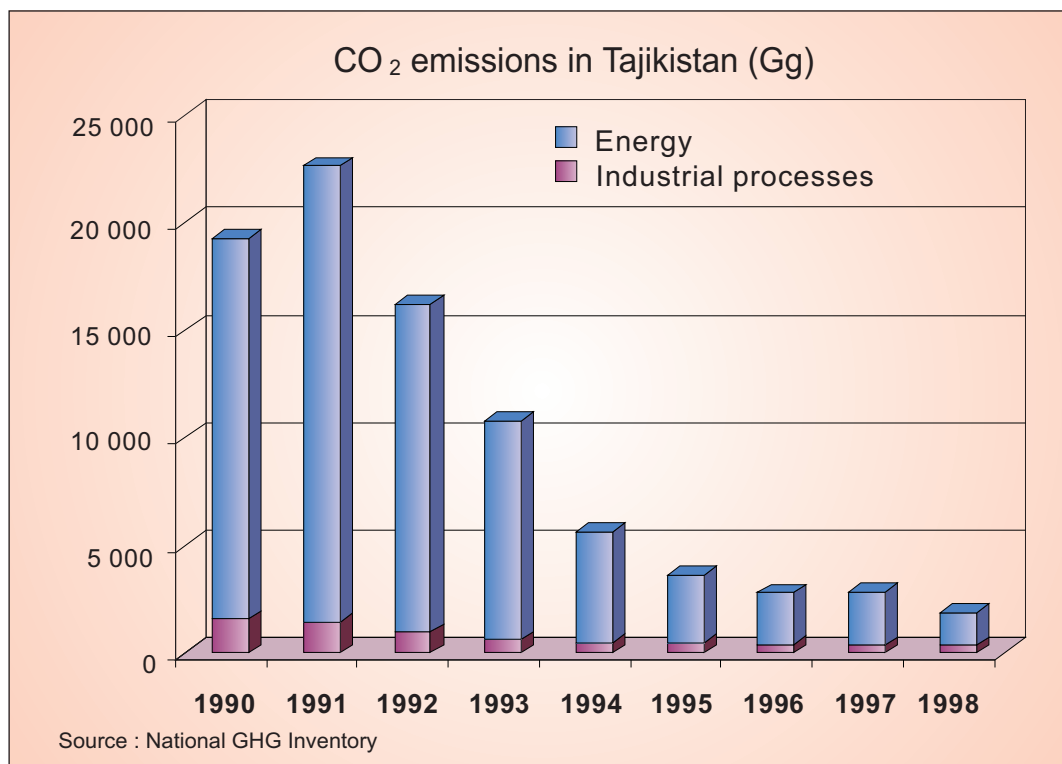


Fig. 4.4.

##### 4.6.1. CO<sub>2</sub> emissions in the category "Energy activities"

In Tajikistan the biggest CO<sub>2</sub> emissions were observed in 1991 at 21,235 Gg, the least in 1998 at 1,524 Gg. The residential sector is a major source of energy-related CO<sub>2</sub> emissions. From year to year, the share of this source amounted to 35-45% of total energy-related emissions. According to expert judgments, this source makes as much as 50% of CO<sub>2</sub> emissions considering unaccounted fuel consumption (wood, coal, etc.).

The second biggest source of energy-related CO<sub>2</sub> emissions is the manufacturing industry and construction. These sectors use fossil fuels (basically gaseous fuel) for its industrial needs. Fossil fuel is needed for the manufacturing of cement, aluminum, ammonia, etc. The most CO<sub>2</sub> emissions in manufacturing industry and construction were recorded in 1991 and amounted to 8,279 Gg. In 1998, the volume of CO<sub>2</sub> emissions was 193 Gg.

According to expert estimates, there is an uncertainty in data on fuel consumption, especially natural gas, for 1990 and other years. Tendency of fuel consumption does not coincide very much with GDP and other indicators dynamics.

There are about 250 thousand vehicles in the country, including 170 thousand individual motorcars. The number of vehicles per capita is 24 cars per 1000 people. The biggest number of individual motorcars per 1000 people is 31 cars in the capital city, Dushanbe.

CO<sub>2</sub> emissions in the transport sector in Tajikistan are quite high particularly from motor transport but still they are less than in residential and industrial sectors. In the period between 1990-1998, due to the economic crisis and lack of energy carriers, CO<sub>2</sub> emissions in transport sector have significantly decreased by 9 times, civil aviation by 10 times, railway transport by 5 times. The international bunker has not been considered in national GHG inventory.

The energy industry in Tajikistan is based on hydropower plants. This explains little contribution of energy industry into total CO<sub>2</sub> emissions. Use of natural gas in heat power plants reduces CO<sub>2</sub> emissions in comparison with coal plants. The share of the electric-power industry to the total CO<sub>2</sub> emissions in the "Energy" category for the period of 1990-1998 reduced from 0.3% to 0.1%. The national inventory does not consider consumption of natural gas in heat power engineering for the period of 1990-1992 due to the lack of data. CO<sub>2</sub> emissions from burning of biomass have decreased from 93 Gg in 1990 to 5 Gg in 1998.

#### **4.6.2. CO<sub>2</sub> emissions in the category "Industrial processes"**

The manufacturing industry makes a significant contribution to the national total of CO<sub>2</sub> emissions. From year to year the contribution of industrial processes range from 8% to 18%. The major sources of CO<sub>2</sub> emissions in this category are aluminum, cement and ammonia production.

The Tajik aluminum plant is the biggest producer of non ferrous metals in Tajikistan. The aluminum plant was built in the southwest of the country in 1985. Production of aluminum is based on a method of electrolysis on prebaked anodes. During processing aluminum, CO<sub>2</sub> (1.5 tonnes per 1 tonne of product) and other gases (CF<sub>4</sub>, C<sub>2</sub>F<sub>6</sub>) occur and affect the climate and environment. Contribution of aluminum production in CO<sub>2</sub> emissions in the category "Industrial processes" is the biggest and at various periods has amounted to 43-85%. CO<sub>2</sub> emissions in aluminum production during 1990-1998 dropped from 675 Gg to 293 Gg. Production of ferrous metals (cast iron and steel recycling) in Tajikistan is poorly developed, thus contribution of this source to the total CO<sub>2</sub> emissions is insignificant (from 4 Gg to 108 Gg in different years).

CO<sub>2</sub> emissions from cement and lime production are significant in the non-energy industrial sector. High temperatures in the process cement manufacturing turn raw materials into clinker. This process forms carbon dioxide (0.4985 tonnes of CO<sub>2</sub> per 1 tonne of cement). Before 1996, cement production was the second major source of CO<sub>2</sub> emissions (up to 34%). However, in the period 1996-1998, the contribution of mineral production to the total emissions decreased to 3-7%, and conceded emissions from ammonia production.

Production of lime involves several phases including extraction of raw materials, crushing, and screening, decarbonization, lime hydration to dioxide calcium and further transportation, storage and usage. Emission coefficient for lime production constitutes 0.79 tonnes CO<sub>2</sub> per 1 tonne of final product.

Vakhsh fertilizer plant located in the south of the republic nearby Kurgan-Tube is the main producer of ammonia in Tajikistan. During 1990-1998, production of ammonia has significantly decreased - from 109.5 to 21.3 thousand tonnes. Ammonia is being produced from natural gas. About 1.5 tonnes of CO<sub>2</sub> is formed per 1 tonne of ammonia. The contribution of ammonia production to the total CO<sub>2</sub> emissions in industrial processes during 1990-1998 made 8-10%.

The most CO<sub>2</sub> emissions in the category "Industrial processes" were observed in 1990 and amounted to 1,565 Gg, including: metal production - 784 Gg, mineral production - 617 Gg and the production of chemicals - 164 Gg. In 1998, due to economic decline, lack of energy resources and decreased production volume, CO<sub>2</sub> emissions in the industrial sector decreased by 4.6 times. The least significant decrease (2.3 times) was in aluminum production, and the most significant was in mineral production (60 times).

#### **4.7. State of the natural sinks of carbon and CO<sub>2</sub> dynamics in the category "Land use change and forestry"**

Forests and soils are the biggest absorbers of CO<sub>2</sub>. Change of organic substances in soils takes place over a long time period (20 years), while in forests it occurs annually.

Distinctive feature of land resources in Tajikistan are:

Domination of non-agricultural lands (68%) among which are glaciers, snowfields, mountains, pebbles, rocky cones, mountain deserts and other unusable lands;

Small areas of forests and bushes (3%);

Most agricultural lands are pastures;

The most valuable parts of available lands are arable, which are being intensively used.

Until the 1940s, major cultivated areas were located in the foothills. Valleys were mainly used as winter pastures or for crops cultivation.

Significant increase of irrigated lands particularly under cotton happened in the second half of the 20th century.

In the period of 1997-1990s irrigated areas of the Republic of Tajikistan increased to 178.4 thousand hectares as a result of land reclamation (Urtaboz, Tashrabad, Garauly, etc.), which increased arable lands to 150.6 thousand hectares, perennial plantations to 17.5 thousand hectares (tab. 4.3). Land reclamation took place due to fallow lands (53.9 thousand hectares), hayfields (10.2 thousand hectares), pastures (52 thousand hectares) and other lands (110 thousand hectares).

At present, out of 14.2545 million hectares of land in Tajikistan 4.5461 million hectares are being used for agriculture, which corresponds to 31.9% of the total area of Tajikistan. Arable lands occupy 734.2 thousand hectares.

Uncontrolled cattle grazing, substitution of forestlands by ploughed lands, inadequate agro techniques in mountain conditions lead to erosion and soil degradation.

Due to deforestation, the occurrence of landslides and mudflows become more frequent. Fertile topsoil gets washed away.

Soils with a high degree of erosion comprise 58.8% of all soils, including those with the highest extent of erosion at 23.9%. Almost all mountain and high mountain soils are prone to water erosion (more than 60-70%). Besides, some 23.5% of soils are prone to wind erosion, and a possible maximum share of light gray soil at 62%.

Figure 4.3.

**Dynamics of area of agricultural lands for the period 1970-1998 (10<sup>3</sup> hectares)**

| Year | Total land area |        | All agricultural lands |        | Including:   |        |                       |              |            |          |        |
|------|-----------------|--------|------------------------|--------|--------------|--------|-----------------------|--------------|------------|----------|--------|
|      |                 |        |                        |        | Arable lands |        | Perennial plantations | Fallow lands | Hay-fields | Pastures |        |
|      | Total           | Irrig. | Total                  | Irrig. | Total        | Irrig. | Total                 | Total        | Total      | Total    | Irrig. |
| 1970 | 14,254.9        | 530.7  | 4,330.5                | 493.5  | 772.7        | 414.4  | 62.7                  | 73.2         | 37.3       | 3,384.6  | 9.4    |
| 1971 | 14,254.5        | 539.1  | 4,328.3                | 500.5  | 763.1        | 422    | 63.9                  | 73.2         | 39.2       | 3,388.9  | 9.6    |
| 1972 | 14,254.5        | 547.6  | 4,369.2                | 507.8  | 765.7        | 428.8  | 65.6                  | 68.3         | 38.2       | 3,431.4  | 9.7    |
| 1973 | 14,254.5        | 555.6  | 4,362                  | 514.2  | 758.9        | 432.7  | 68.3                  | 55.7         | 37.7       | 3,441.4  | 13.9   |
| 1974 | 14,254.5        | 564.8  | 4,363.9                | 523.2  | 759          | 439    | 69.3                  | 49.1         | 38.8       | 3,447.7  | 16.1   |
| 1975 | 14,254.5        | 578.7  | 4,373.7                | 537    | 755          | 452.6  | 71.4                  | 47.3         | 38.2       | 3,461.8  | 15.5   |
| 1976 | 14,259.4        | 593.3  | 4,384.8                | 550.8  | 761.5        | 467.1  | 73.3                  | 42.2         | 38.7       | 3,469.1  | 15.4   |
| 1977 | 14,254.5        | 603.3  | 4,385.5                | 560.4  | 766.8        | 477    | 74.3                  | 37.4         | 37.7       | 3,469.3  | 15.2   |
| 1978 | 14,254.5        | 612.1  | 4,385.4                | 568.5  | 773.1        | 485.7  | 76                    | 36.4         | 37.2       | 3,462.7  | 14.1   |
| 1979 | 14,254.5        | 620.6  | 4,387.3                | 576.4  | 777.7        | 494.9  | 77.8                  | 35.2         | 36.4       | 3,460.2  | 12.5   |
| 1980 | 14,254.5        | 627.6  | 4,394.5                | 583    | 783.4        | 502.3  | 78.2                  | 35.8         | 35         | 3,462.1  | 12.4   |
| 1981 | 14,254.5        | 637.1  | 4,388.4                | 591.5  | 787.1        | 510.5  | 78.3                  | 34.1         | 34.8       | 3,454.1  | 12.8   |
| 1982 | 14,254.5        | 644.4  | 4,383.4                | 598.9  | 793          | 518.7  | 78.6                  | 33.1         | 34.5       | 3,444.2  | 12.5   |
| 1984 | 14,254.5        | 658.1  | 4,336.4                | 610.4  | 797.6        | 530.7  | 81                    | 28.2         | 31.5       | 3,398.1  | 11.4   |
| 1985 | 14,254.5        | 665    | 4,374.3                | 615.5  | 803.6        | 536.7  | 83.4                  | 24.5         | 31.5       | 3,431.3  | 10.3   |
| 1986 | 14,254.5        | 679.7  | 4,392.8                | 628    | 813.2        | 550.1  | 83.6                  | 23.9         | 31.5       | 3,439.8  | 10.0   |
| 1987 | 14,254.5        | 692.7  | 4,385.1                | 639.6  | 822.9        | 563.5  | 85.4                  | 21.9         | 30.4       | 3,424.5  | 7.6    |
| 1988 | 14,254.5        | 696.1  | 4,417.1                | 564.2  | 822.5        | 564.3  | 89.5                  | 23.3         | 30.3       | 3,451.6  | 7.2    |
| 1989 | 14,254.5        | 705.4  | 4,415.3                | 647    | 819.3        | 566.3  | 94.5                  | 22.8         | 30.1       | 3,448.6  | 4.9    |
| 1990 | 14,254.5        | 709.1  | 4,431.2                | 647.4  | 815          | 565    | 99                    | 19.3         | 27.1       | 3,470.8  | 4.2    |
| 1991 | 14,254.5        | 717.8  | 4,434.1                | 653.3  | 811.2        | 567.9  | 103.4                 | 19.7         | 26.4       | 3,473.4  | 4.3    |
| 1992 | 14,254.5        | 713.3  | 4,438.8                | 646.9  | 808.6        | 560.2  | 106.3                 | 19.4         | 26.3       | 3,478.2  | 4.3    |
| 1993 | 14,254.5        | 714.7  | 4,480.0                | 646.8  | 806.8        | 558.3  | 108.6                 | 19.7         | 26.1       | 3,518.8  | 4.0    |
| 1994 | 14,254.5        | 719.9  | 4,617.2                | 647.1  | 806.2        | 557.4  | 111.4                 | 19.2         | 23.7       | 3,656.7  | 2.9    |
| 1995 | 14,254.5        | 715.1  | 4,578.5                | 642.7  | 801.2        | 553.3  | 111.2                 | 19.3         | 23.7       | 3,623.1  | 2.9    |
| 1996 | 14,254.5        | 718.3  | 4,585.5                | 618.4  | 764.6        | 525.7  | 108.0                 | 23.0         | 23.6       | 3,666.3  | 2.9    |
| 1997 | 14,254.5        | 718.4  | 4,564.9                | 616.4  | 764.4        | 525.9  | 105.6                 | 22.9         | 23.6       | 3,648.4  | 2.8    |
| 1998 | 14,254.5        | 713.6  | 4,546.1                | 600.2  | 734.2        | 508.7  | 102.7                 | 26.1         | 23.6       | 3,659.5  | 2.8    |

Source : Tajik State Committee on Land Use (2001)

According to IPCC methodology, for CO<sub>2</sub> removal calculations, soils were conditionally divided into intensively and non-intensively used.

Intensively used soils are: gray-brown, gray, mountain brown, and carbonate soils, which are intensively used under rain-fed crop plantations, gardens, and vineyards. Also this category includes juniper forest soils, partly soils of lowland and mountain pastures.

Non-intensively used soils are saline lands, soils rich in stones, mountain deserts, mud-deserts, gray-brown, light-brown, steppe, and meadow soils.

As a result of land use change, soils annually absorb about 600-1600 Gg CO<sub>2</sub>.

The total stock of carbon in intensively used soils in comparison to initial soil conditions sharply decreases. This is observed in valley and foothill soils under monoculture agricultural crops or lack of alfalfa sowings.

The most significant decrease of humus (dehumification) is observed in heavy saline soils and to a lesser extent this process occurs in gray-brown and gray soils. In mountain brown soils that are ploughed the decrease of humus is insignificant.

Since 1992, due to the economic crisis, the population has been intensively developing hillside lands that formerly used to be pastures. In 1994-1997, steep slopes (up to 35°) were ploughed for cereal crops cultivation. Intensive land reclamation is accompanied by heavy erosion and loss of humus, which in turn leads to carbon loss and increased desertification.

In terms of CO<sub>2</sub> absorption, forests in Tajikistan take second place after land resources. They are good accumulators of moisture preventing soils from erosion and serving as valuable food, medical and industrial materials.

The total area of forests is 410 thousand hectares, which are mainly managed by the State Forest Authority. Arboreal species diversity includes 268 trees and bushes.

The most common national forests are junipers that spread in semi-arid mountain regions at an altitude from 1,500 to 3,200 masl and comprise one third of the total area of forestlands.

Juniper forests are good regulators of surface runoff preserving soils from the erosion process in mountains and valleys, as well as CO<sub>2</sub> sinks.

Juniper forests occupy an essential part of national forests. They are predominant in Northern Tajikistan on the slopes of Gissar, Zeravshan and Turkestan ranges and consist of 3 dominant species: *Juniperus seravshanica*, *Juniperus turkestanica* and *Juniperus semiglobosa*. The area of junipers with a plenitude of 0.3 and more is 150 thousand hectares (tab. 4.4). Average juniper timber stock makes 21.2 cub.m a hectare.

Pistachio forests are well adapted to the arid hot climate and occupy 78 thousand hectares. As a rule, pistachios (*Pistacia vera*) comprise clean tree plantations or with portions of almond trees (*Amygdalus bucharica*). The pistachios are predominant in southern Tajikistan at an altitude from 600 to 1,400 masl. Pistachios, together with walnut plantations (*Juglans regia*) and almonds are valuable sorts of nuceferous trees.

Walnut forests occupy a territory of 8 thousand hectares and differ by their demand in terms of soil and climatic conditions. Walnut forests grow in Central Tajikistan at an altitude between 1,000 and 2,000 masl, where annual precipitation is no less than 800-900 mm a year and annual mean temperature reaches 8-13°C.

Table 4.4.

## Forestlands and timber stock

| Type                       | Total                          |                             | Including state forest fund    |                             |
|----------------------------|--------------------------------|-----------------------------|--------------------------------|-----------------------------|
|                            | Area<br>(thousand<br>hectares) | Timber stock<br>(mln.cub.m) | Area<br>(thousand<br>hectares) | Timber stock<br>(mln.cub.m) |
| Juniper                    | 150                            | 3.2                         | 122                            | 2.7                         |
| Pistachio                  | 78                             | 0.4                         | 74                             | 0.38                        |
| Almond                     | 12                             | 0.03                        | 10                             | 0.02                        |
| Walnut                     | 8                              | 0.4                         | 3                              | 0.1                         |
| Birch                      | 2                              | 0.05                        | 0,4                            | 0.02                        |
| Poplar                     | 6                              | 0.2                         | 3                              | 0.1                         |
| Willow                     | 4.4                            | 0.06                        | 0.7                            | 0.02                        |
| Maple                      | 44                             | 0.6                         | 35                             | 0.5                         |
| Elm                        | 1                              | 0.03                        | 0.1                            | -                           |
| Saxaul                     | 8                              | 0.02                        | -                              | -                           |
| Cherry-plum                | 2.6                            | 0.03                        | 0.3                            | -                           |
| Bushes                     | 58.4                           | 0.43                        | 7                              | 0.3                         |
| Other woody<br>plantations | 35.6                           | 0.2                         | 4                              | 0.03                        |
| TOTAL                      | 410                            | 5.62                        | 289.5                          | 4.17                        |

S o u r c e: Tajik State Forest Authority (2001)

Maples (*Acer turkestanicum*) occupy 44 thousand hectares of the national forests. Poplars, willows, birches, sea-buckthorns and other types of groves are spread fragmentarily. Saxaul plantations are spread in sand-deserts of the southern regions.

Sanitary forest cuttings are practiced in Tajikistan for improving ecological conditions. In the past, the felling volume totaled 15 thousand cub.m, while at present it has decreased to 7 thousand cub.m a year.

One of the main forest's state indicators in Tajikistan is tree density, because this value defines erosion and preventive properties of tree plantations. The area of plantations with a tree density of 0.6 and higher is only 20%. Plantations with a tree density of 0.3-0.4 and fragmentarily wood-shrubby plantings are most common.

The calculation of the total amount of carbon in the annual growth of forests and tree plantations is based on the IPCC methodology and coefficients. Data is obtained from Tajik State Forest Authority and FAO. When considering the changes in woody biomass some types of human activities such as illegal deforestation and forest cuttings were taken into account.

For tree plantations out of forests (parks, squares, plantations), the growth of evergreen and deciduous trees was estimated as 8 tonnes of dry mass per hectare a year.

Recently, forest rehabilitation has diminished. At the same time, uncontrolled deforestation has significantly increased, since the provision of coal, wood, electricity and other types of energy for the rural population has ceased.

Woodlands near to human settlements, forest shelterbelts along the roads, which are not protected at a national level, have been dramatically affected. For the period of 1990-1998, the number of trees outside the forests has decreased by 1.7 times.

Table 4.5.

**Forested area and annual biomass growth**

| Forest types | Area (thousand hectares) | Annual biomass growth<br>(tonnes of dry mass per hectare) |
|--------------|--------------------------|-----------------------------------------------------------|
| Evergreen    | 150                      | 30.0                                                      |
| Deciduous    | 158                      | 63.2                                                      |
| Others       | 102                      | 20.4                                                      |

Source : National GHG Inventory

Table 4.6.

**Reforestation in Tajikistan (thousand hectares)**

| Type of activity                   | 1990 | 1994 | 1998 |
|------------------------------------|------|------|------|
| Forest sowing and planting         | 4.3  | 1.9  | 2.3  |
| Promotion to natural reforestation | 0.1  | 1.2  | 0.8  |

Source : Tajik State Forest Authority (2001)

Overgrazing that takes place on state forest territories has a long lasting impact. This causes soil degradation and the impoverishment of forests and herbal cover in forested areas. Uncontrolled deforestation and forest clearing with the purpose of agricultural crop cultivation have led to low density tree cover and vanishing forests over large territories. Because of deforestation, CO<sub>2</sub> absorption by forests and trees outside forests has been steadily decreasing since the 1990s. Given that in 1990 this was recorded at 588 Gg, by 1998 forests accumulated only 410 Gg. In the period of 1990-1998, absorption of CO<sub>2</sub> by forests has decreased by 35%.

In the result of land use changes and reclamation of new lands, absorption of CO<sub>2</sub> by soils has increased from 932 Gg in 1990 to 1 436 Gg in 1998. Emission of CO<sub>2</sub> from intensively used soils has increased from 19 Gg in 1992 to 84 Gg in 1998.

Table 4.7.

**Summary of GHG inventory in the category "LUCF" (Gg)**

| CO <sub>2</sub> sources and sinks         | 1990  | 1991  | 1992  | 1993  | 1994  | 1995  | 1996  | 1997  | 1998  |
|-------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Change of carbon stock in mineral soils   | 940   | 635   | 713   | 923   | 1,658 | 1,295 | 1,323 | 1,210 | 1,161 |
| Intensively used organic soils (emission) | -     | -     | - 19  | - 38  | - 57  | - 66  | - 76  | - 80  | - 84  |
| Net land-use                              | 940   | 635   | 694   | 885   | 1,601 | 1,229 | 1,247 | 1,130 | 1,077 |
| Forests                                   | 588   | 582   | 546   | 491   | 447   | 428   | 425   | 414   | 410   |
| TOTAL                                     | 1,528 | 1,217 | 1,239 | 1,376 | 2,048 | 1,657 | 1,671 | 1,544 | 1,487 |

Source : National GHG Inventory

**4.8. CH<sub>4</sub> emissions**

The biggest CH<sub>4</sub> emissions for the period of 1990-1998 in Tajikistan were in 1991 (176 Gg), mainly because of enteric fermentation, manure management and fugitive emissions in oil-gas systems.

In the period under review, the volume of methane emissions has decreased more than 25%, as a consequence of structural changes in the agricultural sector and decrease in fossil fuel production and consumption (fig. 4.5).

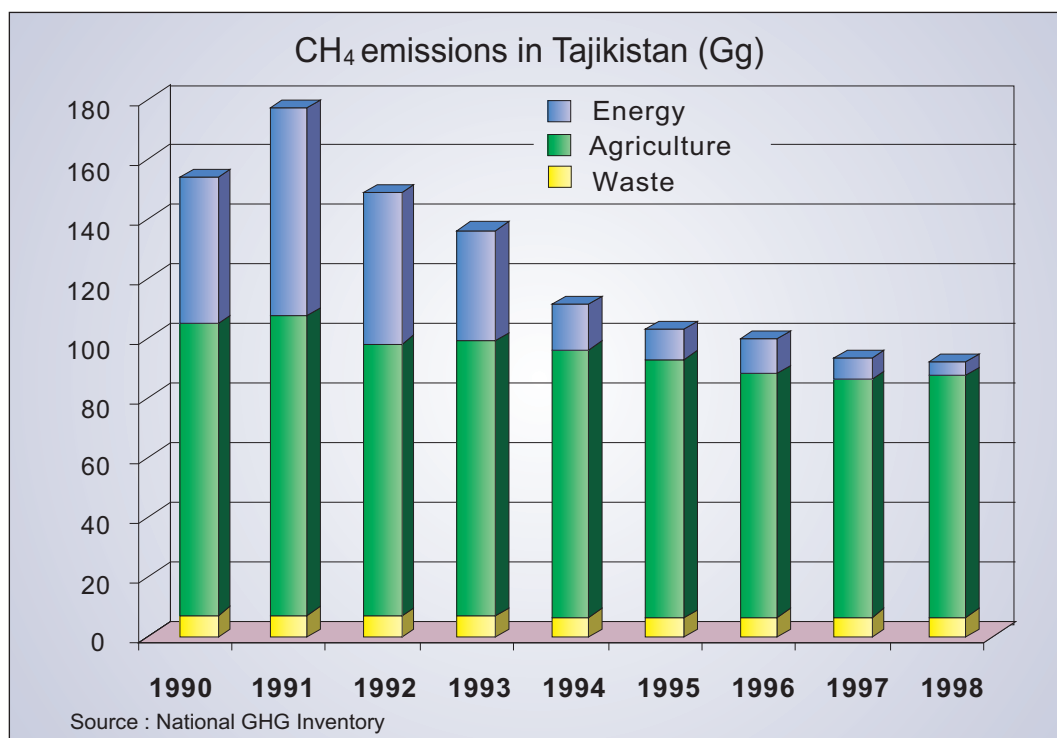


Fig. 4.5.

#### 4.8.1. CH<sub>4</sub> emissions in the category "Agriculture"

The greatest volume of methane emissions (80-86%) occurs due to enteric fermentation, and, to a lesser extent, manure management (10-11%). The rest of emissions occur due to rice cultivation and the burning of agricultural residues (3-8%).

In 1990-1998, CH<sub>4</sub> emission decreased by 22% which generally corresponds to the number of livestock.

Methane is formed in the process of herbivorous animals' enteric fermentation. The amount of emitted methane depends on the number of animals, breed, age, feeding type, quality and quantity of food, climatic conditions within cattle breeding zones and grazing technologies. It should be mentioned that ruminants produce 97-98% of the total CH<sub>4</sub> emissions from enteric fermentation. Methane emissions from this source have decreased in the period of 1990-1998 from 83 Gg to 65 Gg.

CH<sub>4</sub> emissions from manure depend on the number of livestock, the method of storage and utilization of manure. If manure is managed as a liquid substance it decays in aerobic conditions and forms methane. If manure is managed as a solid substance, or is used on the fields as a fertilizer, methane does not occur. In the period of 1990-1998, methane emissions from this source have decreased from 10 Gg to 9 Gg of these 90% are due to dairy cattle.

The flooding of rice fields leads to the decay of organic substances, which results in the formation of methane during vegetation. Rice crops constitute an area of 18-22 thousand hectares annually. Major zones of rice cultivation are Sogd region, flood plains of the Vakhsh river and Gissar valley. In comparison with 1992, rice fields have increased by 1.5 times.

Variations of methane emissions from rice fields depend on the type and structure of soil, organic and mineral fertilizers, irrigation mode and other factors. During the period of 1990-1998, CH<sub>4</sub> emissions from this source have increased from 4 Gg to 6 Gg.

Some agricultural residues remain on the fields and they are usually burned. This leads to GHG emissions in small amounts. CH<sub>4</sub> emissions in this sector are insignificant.

#### **4.8.2 CH<sub>4</sub> emissions in the "Energy" category**

Methane emissions related to mining, processing and consumption of fossil fuels, occur in coal mining and oil-gas systems in Tajikistan. The contribution of this category in total CH<sub>4</sub> emissions varies from year to year between 5% and 35%.

Coal mining is developed mainly in the north of the country (Shurab and Fan-Yagnob coal deposits). The Shurab mine has been operating for more than 100 years. Since the 1950s, the annual volume of coal production amounted to 500 thousand tonnes, and in certain years, it reached 1 million tonnes. However, in the 1990s, due to structural changes in the economy, the annual volume of coal production decreased from 475 thousand tonnes in 1990 to 18.5 thousand tonnes in 1998.

Coal in Tajikistan is mainly being mined by an underground method, with only few coal deposits being operated aboveground. According to expert estimates, 1 tonne of coal mined underground in local conditions brings 15 cub.m of methane emissions, and coal mined on the surface produces 1.2 cub.m of CH<sub>4</sub>. In 1990-1998, CH<sub>4</sub> emissions in coal mining decreased from 4.8 Gg to 0.2 Gg.

The volumes of oil and gas production in Tajikistan are low (25 thousand tonnes of oil and 35 million cub.m of gas). These volumes of production do not satisfy the growing demands of the country. Methane emissions in the oil-gas systems occur in the process of mining, transportation, storage and consumption of fuel, as well as due to obsolete equipment, leakages, accidents, etc. CH<sub>4</sub> emissions from oil-gas systems were the biggest in 1991 at 60 Gg, and by 1998 they had decreased to 2.3 Gg.

#### **4.8.3 CH<sub>4</sub> emissions in the "Waste" category**

Main sources of CH<sub>4</sub> emissions in this sector are solid waste disposal sites and wastewater treatment facilities. Methane is formed from the decay of organic substances in anaerobic conditions.

There are no waste recycling and waste incineration plants in the country. Solid wastes are transported to specialized waste disposal sites with a depth of five meters and less. Methane, which is formed from solid waste is not utilized and directly emitted into the atmosphere.

To assess methane emissions from solid waste disposal sites many types of activity data were considered, taking into account the volume of formation of communal wastes at 0.5 kg/person/day, including wastes formed in gardens, yards and commercial sites. Communal wastes, which are formed in rural areas, were not taken into account in view of their dispersion over the territory.

There are three basic types of waste disposal sites in Tajikistan:

- 1) Specialized solid waste disposal sites (Dushanbe, Tursun-Zade, Khujand, Penjikent, settlement Somoniyon). Composting and mechanical pressing is used for the management of such sites.
- 2) Waste disposal sites with a depth greater than 5 meters. These type of sites are found in 12 different cities within the country;
- 3) Waste disposal sites with a depth less than 5 meters. Such sites exist within 53 different towns of the country.

CH<sub>4</sub> emission from solid wastes in Tajikistan for the period of 1990-1998 has not changed significantly from 6.1 to 6.8 Gg, which is conditioned by the dynamics of the urban population, types of dump and morphologic structure of solid communal wastes.

Methane in wastewaters is being formed in aerobic conditions. The amount of organic substances influence methane emission intensity.

Over 70% of wastewater is thrown into natural reservoirs and filtration fields without purification and constitutes 4.7 cub.km a year. CH<sub>4</sub> emission from wastewater purification was calculated for 30 settlements with sewage disposal facilities. The volume of CH<sub>4</sub> emissions from wastewaters in the period of 1990-1998 is insignificant and varies from 0.23 Gg to 0.25 Gg.

Methane emission also occurs in industrial wastewaters. The national inventory shows that wastewater from the food processing industry produces 62.9%-76.2% of the total CH<sub>4</sub> emissions from this source. The least is contributed from the textile industry 0.28%-1%. The volume of CH<sub>4</sub> emissions from industrial wastewaters is insignificant.

Total CH<sub>4</sub> emissions in the period of 1990-1998 in the "Waste" category have decreased from 7.4 Gg to 6.6 Gg, due to the reduction in wastewater and solid waste disposal volumes.

#### 4.9. N<sub>2</sub>O emissions

The biggest volume of N<sub>2</sub>O emissions in the period of 1990-1998 in Tajikistan was indicated in 1990 (about 3.8 Gg); the lowest emission was indicated during 1995-1998 (about 2 Gg), mainly caused by the application of mineral fertilizers; this source account for between 95% and 99% of all N<sub>2</sub>O emissions. N<sub>2</sub>O emissions from other sources in the category "Agriculture" (manure management, waste) are insignificant (fig. 4.6).

The volume of nitrous oxide emissions in the period under review has decreased by 50% as a result of reduced application of mineral fertilizers and the reduction in fossil fuel consumption.

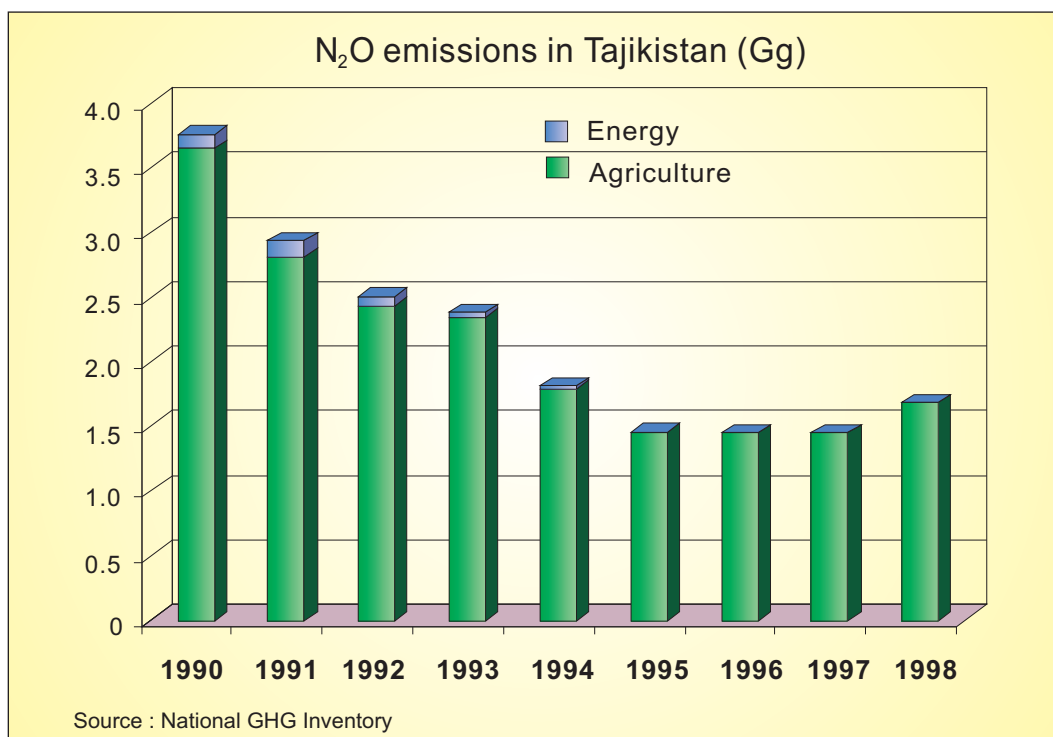


Fig. 4.6.

N<sub>2</sub>O emissions from agricultural soils depend on: the types of soil, contents of humus, activities of microorganisms, liming, cattle pasturing, fertilizing, and other factors.

While calculating N<sub>2</sub>O emissions from agricultural soils, the experts used data on the application of mineral fertilizers, which enriches the soil with nitrogen and reinforces the processes of mineralization, changing the biological activity.

In Tajikistan the application of mineral fertilizers has been decreasing since 1991, due to the reduction in imports and the low capacity of domestic production.

Another source of N<sub>2</sub>O emissions is the high-temperature combustion of fuel, when nitrogen consisting of atmospheric air reacts with oxygen. Given that heat power plants and transport in Tajikistan are few, the volume of N<sub>2</sub>O emissions is insignificant and for the period of 1990-1998 comprised less than 0.2 Gg.

#### 4.10 Emissions of perfluorocarbons

The only source of perfluorocarbon emissions in Tajikistan is the aluminum smelting, which forms up to 100% of these emissions. CF<sub>4</sub> comprises the biggest part of emissions (91%); the smallest part is comprised by C<sub>2</sub>F<sub>6</sub> (9%).

The Tajik aluminum plant is located 53 km west from Dushanbe. The plant capacity is more than 500 thousand tonnes of primary aluminum a year. The plant also produces various aluminum alloys and construction profiles. The plant is a giant of national metallurgy, and it consumes a lot of electricity and natural gas.

The global average coefficient of PFC emissions (1.4 kg of CF<sub>4</sub> per 1 tonne of produced aluminum) was adopted in the national GHG inventory. Given that the production of aluminum in the period of 1990-1998 has decreased from 450.3 thousand tonnes to 195.6 thousand tonnes, PFC emissions decreased respectively by 57%. The biggest volume of PFC emissions was recorded in 1990 at 0.69 Gg, which correspond to 4,647 Gg of CO<sub>2</sub>-equivalent. The least PFC emissions were recorded in 1997 at 0.29 Gg.

In the process of aluminum production different hazardous pollutants are emitted into the atmosphere, including nitric oxide, carbon oxide, sulphur dioxide and fluorides that negatively impact the environment. Thus, emission control and the purification of hazardous pollutants should be priorities.

Table 4.8.

**PFC emissions in aluminum industry (Gg)**

| Greenhouse gas                | 1990  | 1991  | 1992  | 1993  | 1994  | 1995  | 1996  | 1997  | 1998  |
|-------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| CF <sub>4</sub>               | 0.63  | 0.53  | 0.48  | 0.35  | 0.33  | 0.33  | 0.28  | 0.26  | 0.27  |
| C <sub>2</sub> F <sub>6</sub> | 0.06  | 0.05  | 0.04  | 0.03  | 0.03  | 0.03  | 0.03  | 0.03  | 0.03  |
| CO <sub>2</sub> -equivalent   | 4,647 | 3,905 | 3,488 | 2,551 | 2,421 | 2,421 | 2,096 | 1,966 | 2,031 |

Source: National GHG Inventory

### 4.11. Emissions of GHG precursors and SO<sub>2</sub>

Anthropogenic activities, along with GHG emissions lead to the emissions of CO, NO<sub>x</sub>, non-methane volatile organic compounds (NMVOC) and SO<sub>2</sub>, which affect both the climate system and environment (fig. 4.7).

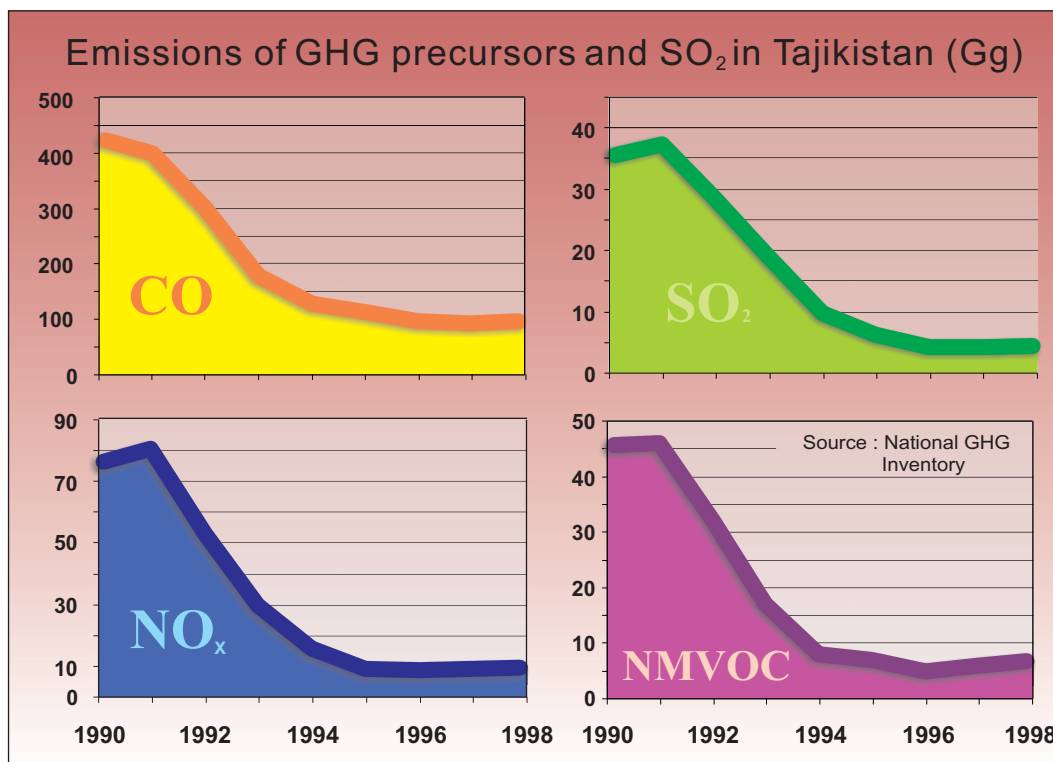


Fig. 4.7.

Nature protection institutions maintain records of these gas emissions. The data on emissions of GHG precursors is published on a regular basis in National environmental reports. However, in view of differences in methodologies and insufficient reflection of all emission sources in this data, new calculations in the national inventory were based on the IPCC methodology.

CO emissions in Tajikistan occur from incomplete fuel combustion and some industrial processes. The biggest share of CO emissions belong to the transport sector and aluminum industry. Generally, the volume of CO emissions is significant and in the year 1990 it amounted to 430 Gg, at that most emissions resulting from fuel combustion (247 Gg). Recently, CO emissions amount to 96 Gg.

According to scientific research, carbon oxide (CO) emissions are the reason for the methane atmospheric concentration increase, thus inventory and control of CO emissions are now a priority.

There are indications in state statistical reporting that CO emissions in Tajikistan are less than that indicated in the national GHG inventory. This can be explained by more detailed calculations used in the national GHG inventory, which is based on IPCC methodology.

Emissions of NO<sub>x</sub> (NO and NO<sub>2</sub>) occur due to high-temperature fuel combustion and other processes. In Tajikistan, NO<sub>x</sub> emissions are insignificant since the volume of fossil fuel consumption is not large. The major source of NO<sub>x</sub> emission is the transport

sector. The biggest volume of NO<sub>x</sub> emissions in the country was indicated in 1991 and amounted to 83 Gg. By 1998, NO<sub>x</sub> emissions decreased to 9 Gg. National statistics maintain the records of NO<sub>x</sub> emissions. However, as it was mentioned earlier, the volume of NO<sub>x</sub> emissions according to statistics is lower than that in national GHG inventory.

Non-methane volatile organic compounds (NMVOC) are emitted as a result of incomplete fuel combustion, high-temperature industrial processes, such as glass manufacturing, paving of roads, etc. NMVOC emissions in Tajikistan are not large. In the period under review, in 1990 they did not exceed 45.5 Gg. By 1998, they decreased to 7 Gg.

Sulphur dioxide is one of the most harmful components of anthropogenic emissions. SO<sub>2</sub> emissions in Tajikistan decreased from 35 Gg in 1990 to 3 Gg in 1998. The biggest share of SO<sub>2</sub> emissions belongs to the transport sector.

#### 4.12. Uncertainty assessment

The assessment of anthropogenic emissions by sources and removals by sinks of greenhouse gases is based on the application of various activity data, coefficients, conversion factors and methods of calculations. Existing uncertainties are due to data gaps, quality and quantity of activity data, status of scientific knowledge, national circumstances, and skills of GHG inventory experts.

Table 4.9.

**Uncertainty assessment of GHG emissions and removals**

| IPCC source categories                                    | Greenhouse gas   | Uncertainty   |
|-----------------------------------------------------------|------------------|---------------|
| ENERGY, Industry and construction                         | CO <sub>2</sub>  | Middle        |
| ENERGY, Residential sector etc.                           | CO <sub>2</sub>  | Low           |
| ENERGY, Transport                                         | CO <sub>2</sub>  | Low           |
| INDUSTRIAL PROCESSES, Production of metals                | PFCs             | Not estimated |
| AGRICULTURE, Enteric fermentation                         | CH <sub>4</sub>  | Middle        |
| ENERGY, Oil-gas systems                                   | CH <sub>4</sub>  | Not estimated |
| AGRICULTURE, Agricultural soils                           | N <sub>2</sub> O | High          |
| INDUSTRIAL PROCESSES, Production of metals                | CO <sub>2</sub>  | Low           |
| AGRICULTURE, Manure management                            | CH <sub>4</sub>  | Middle        |
| INDUSTRIAL PROCESSES, Chemical industry                   | CO <sub>2</sub>  | Low           |
| LUCF, Forestry                                            | CO <sub>2</sub>  | Middle        |
| LUCF, Emission and absorption of CO <sub>2</sub> by soils | CO <sub>2</sub>  | Middle        |
| WASTES, Solid waste disposal                              | CH <sub>4</sub>  | High          |
| ENERGY, Residential sector                                | CH <sub>4</sub>  | Not estimated |
| AGRICULTURE, Rice cultivation                             | CH <sub>4</sub>  | High          |
| ENERGY, Solid fuels                                       | CH <sub>4</sub>  | Middle        |
| ENERGY, Electro energetic industry                        | CO <sub>2</sub>  | Low           |
| ENERGY, Transport                                         | N <sub>2</sub> O | Not estimated |
| WASTES, Wastewaters                                       | CH <sub>4</sub>  | High          |

Source: National GHG Inventory

To assess uncertainties, national experts applied IPCC Good Practice Guidance on Uncertainty Management. It was decided to identify an uncertainty percentage for each sector and subdivide the uncertainties into three basic groups:

- the low uncertainty group (10-33%),
- the middle uncertainty group (33-66%), and
- the high uncertainty group (66-100%).

The low level of uncertainty is observed in the category "Energy" (tab. 4.9.). There is a problem of coincidence in energy balance, particularly with natural gas, which causes uncertainty for a few emission sources to the middle level of reliability.

A low uncertainty is observed in the category "Industrial processes". An exception is PFC emissions from aluminum production as they possess exceptionally high GWP, and instrumental monitoring is needed to define exact volumes of PFC emissions.

A middle uncertainty is observed in the category "Agriculture". Uncertainties in methane emissions from enteric fermentation and manure management are estimated in some years to be low or middle because of the lack of statistical data and possible inaccuracy in emission factors in local conditions. The high level of uncertainty is estimated in N<sub>2</sub>O emissions from agricultural soils (tab. 4.9.).

A high uncertainty is stated in methane emissions from waste disposal on lands and domestic wastewater because of the absence of statistical data and the possible inaccuracy in emission factors. A middle uncertainty is estimated in the category "Land-use change and forestry". It occurs because emission factors for different types of soils are not sufficiently researched. Besides, there are some gaps in the data on the potential of national forests to absorb CO<sub>2</sub>.