Global and Russian Budget of Carbon and the Kyoto Protocol: pro and contra

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ABSTRACT

According to the law of matter conservation it is possible to represent global budgets for atmospheric carbon and atmospheric oxygen as $M_1+M_2+M_3+M_4+M_5=0$ (carbon) and $a_1M_1+a_2M_2+a_3M_3+a_4M_4+M_5=0$ (oxygen). The budget terms here are the annual averaged mass change in the atmosphere (1), fossil fuels (2), terrestrial biota (3), dissolved organic (4) and dissolved inorganic carbon (5) of ocean pools, and (a) are stoichometric ratios ($O_2/CO_2$).

Using available empirical data it is possible to determine unknown $M_3$ and $M_4$ with relative uncertainties of all figures in equations do not exceed 10% (Gorshkov et al. 2000). Carbon budget of Russia including usage of fossil fuels was calculated according to these results: land use emission - 300 Mt/y and combusting fossil fuels emission - 400 Mt/y (total sum - 700 Mt/y); ocean carbon sink - 450 Mt/y and natural Russian ecosystem - 550 Mt (total sum ~ 1000 Mt/y). Therefore Russia is a region of the net sink of anthropogenic carbon and natural ecosystems of Russia sequestered 300 Mt/y of global carbon emission. Sequestering of the anthropogenic carbon by technical measures in the USA and some European countries costs from $.550 to 1100 It means that Russia provides $150 billion per year of ecological investment for the global community. Who will pay Russia for this? Is it necessary for Russia to ratify Kyoto Protocol before solving problems of the compensation? Policy-makers must change thinking on the developing of the future energy strategy.

Global energy policy and its outcome

Policy-makers have defined global energy strategy long time ago. This strategy means the growth and the efficiency. But this strategy is brought many ecological problems including global climate change. This means that now energy policy should move towards the answers of two questions. What does the humankind use the energy for, it is the first question. Is there any limit of growth of the energy usage, this is the second question. The answer to the first question is well known – for capacity building and economy growth, however the final result of energy use by humankind is a destruction of the environment, especially natural ecosystems, and a creation of production and consumption waste.

There is experimental data that validates the answer to the second question. The data of observations and analysis of the ice core demonstrated that there was no intensive increase of CO$_2$ in the atmosphere since 10 Kyr BP till the end of the 20th century. This means that there were no global changes then. During that time the humankind used power of the order of 1 TW. However in the end of 20th century the power of global economy exceeded 10 TW, the concentration of CO$_2$ in the atmosphere enhanced quickly and the temperature increased (Gorshkov, 1994; Houghton et al. 1995; Arsky et al., 1997; Makarieva et al., 2001).

There is also a theoretical answer to the second question. Natural ecosystems of the Earth are stable and they subsist for thousands of years. The analysis of such ecosystems demonstrates that the net primary biological production is distributed according to the size of the organisms: 90% of energy is consumed by the microorganisms up to 1 mm, about 9% by the organisms from 1 mm to 1 cm (insects mainly) and 1% remains for big organisms (including humans). Roughly this 1% of the net primary biological production is ~ 1 Gt of carbon or ~ 1 TW of power (Gorshkov, 1994). This is the limit of power, which humankind can use without destroying stability of ecosystems and disturbing of biochemical cycle of CO$_2$. Destroyed ecosystems (“land use”) became a sources of CO$_2$ emission. Thus, the existing strategy of the energy production growth led to the changes of gas concentration in the atmosphere and destruction of ecosystems on large territories (Hannah et al., 1994). In these conditions any sources of energy including the alternative ones are ecologically dangerous. The policy-makers need to change the global energy strategy. Their main strategy should be the reduction of the energy production and consumption,
more effective energy use, preservation of existing and restoration of destroyed natural ecosystems.

**Global budget of carbon**

The Kyoto Protocol is the result of the traditional energy strategy. It doesn’t take into account the sink of the anthropogenic carbon into natural ecosystems and the land use as a source of carbon emission, which is caused by the fact that there was no method to estimate these values. However we consider possible to estimate them on the basis of the Matter Conservation Law (MCL) in global scale.

The annual change rates of carbon in the atmosphere \( m_1 \), in fossil fuel \( m_2 \) and of non-organic carbon in the ocean \( m_3 \), which is absorbed from the atmosphere, were determined for 1991-1994, respectively, as \( 2.2 \pm 0.2 \), \( 5.9 \pm 0.3 \), \( 2.6 \pm 0.5 \) Gt per year (Keeling et al., 1996). The MCL can be written as:

\[
m_1 + m_2 + m_3 + m_4 + m_5 = 0, \quad (1)
\]

where the rate of carbon change in land biota \( m_4 \) and that of dissolved organic matter in the ocean \( m_5 \) are unknown. Sinks of carbon enter (1) as positive values, emission of carbon - as negative values.

Synthesis and decomposition of organic carbon are accompanied by the change in the mass of oxygen. Stochiometric ratios \( (a) \) \( \text{O}_2/\text{CO}_2 \) for all these processes are well known. Change of oxygen concentration in the atmosphere is measured by highly-sensitive technique (Keeling et al., 1996), and stochiometric ratios \( (a_1, a_2, a_3, a_4, a_5) \) in the other pools are defined by empirical data (Gorshkov et al., 2000). The stochiometric ratios for the sink of carbon by the physical-chemical system of the ocean \( a_3 = 0 \), because the process is not accompanied with any change in the concentration of oxygen. From the MCL one can find a budget of oxygen in four pools:

\[
a_1 m_1 + a_2 m_2 + a_4 m_4 + a_5 m_5 = 0. \quad (2)
\]

From equations (1) and (2) the unknown rate of change of dissolved organic carbon in the ocean \( m_5 \), the net land use emission \( m_4 \), the full land use emission, and the sink of carbon in preserved natural land ecosystems for the period 1991-1994 were calculated (Table 1). Relative uncertainties of all data of the table 1 do not exceed 10% (Gorshkov et al., 2000).

<table>
<thead>
<tr>
<th>SOURCES</th>
<th>SINKS</th>
</tr>
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<tbody>
<tr>
<td><strong>COMBUSTING OF FOSSIL FUEL</strong></td>
<td><strong>ECOSYSTEMS OF LAND</strong></td>
</tr>
<tr>
<td>5.9</td>
<td>2.9</td>
</tr>
<tr>
<td><strong>LAND USE</strong></td>
<td><strong>“BIOLOGICAL OCEAN PUMP”</strong></td>
</tr>
<tr>
<td>6.7</td>
<td>4.9</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
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</tbody>
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The important result is that the anthropogenic carbon emission at the account of the land use exceeds the industrial emission. The fact is that the Kyoto Protocol ignores the land use carbon emission and the its sink to the preserved ecosystems; it creates favorable conditions for some countries and unfavorable for some other countries, for example for Russia, Canada in the Northern Hemisphere.

**Budget of the anthropogenic carbon in Russia**

For estimation of industrial carbon emission in Russia the data about consumption of energy for 1999 was used. It is \( 6 \text{ t} \) of equivalent fuel per capita (Shelepov, 2000). Taken into account the fact that 10% of energy consumption are provided by hydro- and nuclear stations, the consumption of fossil fuel per capita was \( 5.4 \text{ t} \). The structure of fossil fuel consumption is 19%
for coal, 23% for oil, 58% for natural gas (Shelepov, 2000). Using the modified method of Marland-Rotty (Klimenko et al., 1997) the emission of carbon in Russia was calculated. In 1999 it was 400 Mt. This value is close to that we have calculated by using other methods of estimation (Losev, Ananicheva, 2000).

The global industrial carbon emission as 6200 Mt in 1998 (Global Environment..., 2002), the data about the land area with disturbed ecosystems in the world (Hannah et al., 1994), in Russia (Danilov-Danilleryan, Losev, 2000) and the data of Table 1 were used for calculating of carbon budget in Russia. These values are conservative, so the results may be generalized to 1999 or 2000.

The land area, where the natural ecosystems are disturbed, is 85 Mkm² or 60%, if the total land area is 135 Mkm² taken without areas covered with glaciers and with the bare rock surface. The area of disturbed territories in Russia is 6 Mkm² or 4.5% of the total area of the land use, the latter provides 6700 Gt per year of carbon emission (Table 1). It means that Russia’s share is, roughly, 6700 Gt/year x 0.045=300 Mt/year. Therefore the total anthropogenic carbon emission in Russia is 700 Mt per year.

The physical and chemical system and the “biological pump” of the World Ocean absorb 7500 Mt of carbon per year (Table 1). The share of Russian carbon emission from the global emission (12600 Mt per year) is 6% (Table 2). It means that the value of Russian carbon emission, which is absorbed by the ocean, is 7500 Mt/year x 0.06=450 Mt/year.

Territories with unperturbed and weakly perturbed ecosystems in Russia are 11 mln km² (Danilov-Danilleryan, Losev, 2000) or 22% of the global territory. Carbon that sinks to this pool may be calculated as 2900 Mt/year x 0.22=600 Mt/year (Table 1). Therefore the total sink of Russian carbon to the ocean and to ecosystems of Russia is more than 1000 Mt per year. This value exceeds full emission from the Russian territory by 300 Mt per year. Therefore Russia is the area of the net sink of global anthropogenic carbon.

These calculations give the lower limit of the amount of carbon sink in Russian ecosystem because of the wild (natural) forests are not taken into account. Natural forests have the biggest potential of sink. Table 2 Contribution of Russia in the global industrial emission in 2000

<table>
<thead>
<tr>
<th>Regions and countries</th>
<th>Industrial emission</th>
<th>% from global emission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe (without Russia)</td>
<td>1400</td>
<td>20</td>
</tr>
<tr>
<td>China, Japan and Korean peninsula states</td>
<td>1400</td>
<td>20</td>
</tr>
<tr>
<td>USA</td>
<td>1625</td>
<td>24</td>
</tr>
<tr>
<td>Russia</td>
<td>420</td>
<td>6</td>
</tr>
<tr>
<td>World</td>
<td>6850</td>
<td>100</td>
</tr>
</tbody>
</table>

According to the estimation of the World Resources Institute (Bryant et al., 1997), the share of Russian natural forests is 26% of global area of the whole part of such forests. According to (Hannah et al., 1994) and inventory of Russian forests in 1998, the area of natural and nearly natural forests (100 years old and more) in Russia take 1/3 from the world forest territory (Losev, 2000). And last, but not the least fact: the well-known specialists agree that the main pool of carbon sink on landsurface are boreal forests and wetlands of the Northern Hemisphere (Timofeev-Resovskiy, 1968; Gershkov, 1994; Global Environment..., 2000; Houghton, 1997). Russian boreal forests constitute 60% of the world boreal forests. That is why the calculation of the net anthropogenic carbon sink in Russian ecosystem presented above gives the low limit of the estimation.

There is experimental confirmation of theoretical calculations of anthropogenic carbon sink in Russia ecosystems. We mean a paper of the international team of scientists, which was published in 2001 (Myneni et al., 2001). On the basis of the normalized difference vegetation index (NDVI) analysis (40 thousand of space images) the authors estimated the biomass
increment in temperate and boreal forests in the Northern Hemisphere on the area about 1420 Mkm$^2$ for July 1981- December 1999. Russia anthropogenic carbon sink was estimated as 284 Mt/year only for 642 Mha forest area, because of the limited resolution of space images. Therefore about 400 Mha of forests, wetlands and other ecosystems (forest-tundra and tundra), which are entirely about 40% of all ecosystems, have not been taken into account for Russia. This empirical data agrees well with theoretical results, based on the Matter Conservation Law and stoichiometric ratios.

The complexity of Kyoto process

Now the global warming and Kyoto Protocol became not only a subject for debates, but also the issue of political conflicts, particularly when the president of USA George Bush refused to ratify the Kyoto Protocol. Some scientists doubted about a number of the global warming problem aspects, but they pay the most attention to climate problems (network of the observations, processing the data about temperature increase rate, climate models, reconstruction of paleotemperature by ice cores records, etc. with revealing of uncertainties and mistakes) and estimation of economical and social consequences of global temperature rise. The last one depends upon the authenticity and reliability of climate models, thus they are even more uncertain than the discussed climate problems.

Detailed review and analysis of stated complicated problems is given in book, prepared by the international team of authors (Kondratiev et al., 2001). The main conclusion of it is the fact that International Convention on the Climate and Kyoto Protocol are not adequate with the total data on global warming. In polemics on the global warming problems the biota role, which regulate and stabilize the environment (Timofeev-Resovsky, 1968; Gorshkov, 1994), and unstable equilibrium, typical for the Earth climate, are not taken into account (Gorshkov et al., 2000).

The modern anthropogenic changes of the environment including climate change occur with higher speed than natural processes. It means that the environment, and climate in particular, are unstable. However the fact of stable existence of life on Earth during 4 billion years in a very narrow range of physical conditions oscillation (particularly the temperature of the atmosphere boundary layer) demonstrates that the climate was always acceptable for the proper forms of life. It affirms that the Earth has it’s own mechanism of stabilization of the environment and climate which is distinctive from the physical one. This mechanism is the biota of the Earth which does not only stabilize but also forms the environment and climate (Timofeev-Resovsky, 1968; Gorshkov, 1994; Global Environment…, 2002; Steffen, Tyson, 2001). Ignoring the fact of antropogenic emission and sequestering of carbon by biota simultaneously, demonstrates futility of quotes that reduce only industrial carbon emission. This particular approach is incorrect: not quotas for the emission from fossil fuel combusting are important, but quotas for natural ecosystems reconstruction, especially forests, which provide the sink of carbon and other biogens. We don’t mean plantation forests. During the growth and development of planted forests there is no full compensation of carbon emission, which occurred during the previous cutting of natural forest. The history of forest clear-cut in Europe demonstrated: the biomass of the planted coniferous forests, which substitute old natural beech and oak woods, is twice as smaller as the former forests had. Only preservation and restoration of natural forests, but not silvaculture, create a real mechanism of anthropogenic carbon sink from the atmosphere. As the estimations show (Gorshkov et al., 2000), to stop the growth of carbon concentration in atmosphere without reconstructing the energy system seems to cost 30-40% reduction forest exploitation. Thus, humankind has to reduce the territories where forest is under use now by about 30 - 40% and allow natural forest ecosystem to recover in this areas (Fig.1).

The fact that the Kyoto Protocol ignores the anthropogenic emission and sink into the ecosystems provides profits for developed countries, which destroyed their ecosystems long time ago, and for some of the developing countries, which replaced their natural ecosystems with
agrosystems. Therefore the countries, which preserved their natural forests, loose their advantage.

Development of economy aimed at increasing level of life and comfort, lead to the destruction of natural ecosystems. The price of it is the loss of ecological resource. Natural ecosystems should be taken as a resource altogether with mineral resources, land and bioresources in the frame of market economy. If one government runs out of its ecological resource, it’s obvious that it increases the ecological problems and solves them at the expense of countries where this resource is preserved. The only exceptional ecological resource is the World Ocean, which is the common property. It works as an absorber of the part of the world’s anthropogenic carbon sink. Each country owns a part of this sink, which is proportional to the country’s share to the global emission. The anthropogenic carbon sink into the land natural ecosystems should be considered in this country’s carbon budget. If ecosystems of the country absorb the part of the world’s carbon emission, additionally to its own emission, it is necessary to coordinate international values for every ton of absorbed carbon sink.

**The price of anthropogenic carbon sink to Russian natural ecosystems.**

According to the expert’s estimations the expenses for reduction of the carbon emission for the USA and some European countries are $150-$300 and for Japan is more then $300 per 1 t of CO₂ or from $550 to more then $1100 per 1 t of carbon (Bedritzky, 2000). Therefore the minimum cost of the global part of carbon that Russian ecosystems absorb every year is from $160 to 325 billion. This sum is the net investment of Russia to global stability of world environment.

For the lowering the carbon emission the Worldwatch Institute proposed to introduce a “carbon tax” - about $50 per 1 t of carbon in order to stimulate improving the combustion technology (Kondratiev et al., 2001). In this case the minimum cost of global part of the carbon sink in Russia would be $15 billion per year. According to the Worldwatch Institute information this tax can increase the cost of 1 l of gas by 4.5 cents, and price of 1 kW of energy by 2 cents.

The other way is to go to the alternative sources of energy. There are estimations of concurrent sun and hydrogen technologies (Kondratiev et al., 2001). For developing them it is necessary to introduce the tax on the use of the fossil fuels from $70 till $660 per 1 t carbon. Therefore the minimum value of the global part carbon sink in the Russian ecosystems would be from $21 to 177 billion per year.

In the USA there were made the estimations of sequestration of the half of the carbon emission (Bates, 1990) through the substitution of fossil fuel energy by nuclear energy. They show that it requires $50 trillion and constructing one nuclear reactor every 2.5 days during 38 years. Taking into account the fact that the half of the carbon emission in the USA for was about 700 Mt (in 1990) the minimum value of the global part carbon sink by preserved Russian ecosystems is more than $.20 trillion.

The price of all types of mineral resources of Russia is not less than $ 28 trillion, and estimation of their profitable part is $ 1.5 trillion (Putin, 2000). Comparison of the mineral resources price with the price of global part carbon sink in natural ecosystems demonstrates that now it is more profitable to preserve these ecosystems in Russia. Their price and value are going to grow. Does Russia need to ratify the Kyoto Protocol? Isn’t it better to revise its contents taking into account full data on sources and sinks of anthropogenic carbon?

**References**


**Figures**
- Fig.1 Schematic representation of the boreal forest state under various regimes of anthropogenic load (Gorshkov, Makarieva, 2000)
- 1. Natural state of forest ecosystems: succession is around 150 years, biomass is about 200 t/ha, sustainable for thousands years
- 2a Modern Siberian forests: the sharp drops of the biomass are primarily related to forest fires
- 2b Modern European Russian forests: the sharp drops of the biomass are due to final harvesting (clear-cut) and fires
- 3. Intensive silviculture (Finland): Biomass storage does not reach sustainable level and slowly go down
- 4. Agrosystems: Biomass storage is very low and drops further over time