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MECHANISMS AND PROJECTS FOR REDUCING GREENHOUSE GASES IN RUSSIA

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The article considers the problem of reduction of greenhouse gases emissions, one of the main anthropogenic causes of increasing carbon concentration in the atmosphere, and consequently the global climate change. In the second half of the XX century many schemes for involving market mechanism in solving these problems were proposed. These efforts increased in the last decade of XX century and finally the Kyoto Protocol supported many flexible mechanisms, as a solution for these problems. In spite of all these efforts, during the first period of its implementation (2008–2012) the emissions of carbon increased. This issue has been especially pronounced in Russia, one of the main global emitters. The paper explores the mechanisms and projects in Russia, and its importance for reducing the GHG emissions and fulfilling the commitments of Kyoto Protocol and other international documents.

Key Words: *greenhouse gases (GHG), the Kyoto Protocol, flexible mechanisms, Russian actions*

1. Introduction

The problem of air pollution with greenhouse gas (GHG) emissions and other substances does not look new. It has been addressed many times, both in terms of science and politics. On the anthropogenic side, this problem becomes especially manifest during and after the Industrial Revolution, through the such human activities, that lead to GHG emissions, e.g. fossil fuel combustion. It means that these GHGs come from sources other than nature, but as a result of human activity, and in quantities growing bigger and bigger over time. Since the beginning of the Industrial Revolution till the end of the XX century, around 300 gigatonnes (Gt) of carbon have been emitted to the air[1]. Such scale of carbon emissions is one of the key arguments to support the anthropogenic theory of climate change origins. Those theories has been proven as many times, as they have been challenged, so we will not spend much time on them in this work.

According to the source being quoted, and to other sources[2], if carbon concentration in the air settles at around 450 parts per million by volume (ppmv), which would result in 2°C air temperature rise with a 50% probability, it would bring carbon emission accumulated since the Industrial Revolution up to 670 gigatonnes (GtC). Based on these figures, a so-called “atmospheric margin” remaining to the humanity is around 370 GtC. People should “spread” it over time, allocate between states and industries, keeping in mind, among others, power generation and consumption. Other sources of carbon emissions should also be considered in addition to the greenhouse gases which cause the biggest trouble. In greenhouse gases emissions CO_2 accounts for 80–90% and its biggest share comes from power generation. In Russia 98.6% of the total CO_2 emissions comes from fossil fuel combustion. This picture is more or less similar for the rest of the world [3]. According to

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[1] Data of the Intergovernmental Panel on Climate Change (IPCC), quoted from [1].
[2] See e.g. [2].

the World Energy Council (WEC), by the time of the Kyoto Summit the global primary energy demand will grow by 2–3% per year. The energy demand is expected to increase by 50–70% to the year 2020. Given the current structure of the global energy balance and a three-fold CO_2 emission growth, the concentration of CO_2 may even double [3].

On the other hand, one should not underestimate the possibilities for recycling (absorption), no matter how little may they seem. It is possible to decrease CO_2 concentration in the air either by reducing emissions, or through CO_2 capturing and storing in subsoil, sea or river ecosystems. Plants and organic substances contained in soil are few examples of atmospheric carbon and greenhouse gases capturing. The capturing process occurs naturally during photosynthesis, when a portion of CO_2 is captured and sequestrated as soil carbon. A long-term cultivation of prairies and forests resulted in release of soil carbon all over the world. Nevertheless, there is a great potential for increase of carbon content in soils through reclamation of degraded areas and wide use of conservation techniques. According to many opinions, agriculture may become the biggest sink of CO_2 after implementation of corresponding techniques.

A carbon sink is a mean to capture (or "sequestrate") CO_2 from atmosphere, forests, soils, peat bogs, permafrost, ocean waters and ocean floor carbonate deposits. Most of those reservoirs are very large and slow-evolving systems with very limited anthropogenic influence. Forests are the most common carbon reservoirs. Plants and trees capture CO_2 from the atmosphere through photosynthesis, retain carbon to generate plant tissue and release oxygen back to the atmosphere. While agriculture is a source of greenhouse gas emissions, it offers, however, a huge potential of capturing and storing a big amount of carbon and other greenhouse gases in soil. Measures aiming at increase of carbon storage potential of soils include tree planting, change of traditional farming practices to conservation techniques, use of improved agricultural techniques, shift to permanent crops and reclamation of wetlands. Obviously, conservation farming and more efficient approach to plant remains management offer the highest potential of carbon sequestration in agricultural soils. This is particularly interesting for both scientific and political community.

2. Natural Resource Management

Environment management and protection systems have been developing under a combination of historical, cultural, political, economic and other drivers. This explains the variety of environment management and protection systems existing in different countries, and the use of various instruments and mechanisms. However, they can all be classified in three big categories of natural resource management methods:

- administrative regulation,
- economic mechanisms, and
- promotion of market relationship in environment management.

Administrative regulation is based on implementation of the relevant regulating standards and constraints. It includes also the exercise of direct control and licensing of environment management processes. All this is aimed at setting constraints that any manufacturer has to meet. Standards, restrictions, certificates and licenses are typical examples of this area.

The aim of economic mechanisms is to create conditions which make possible for manufacturers to take a rational approach to the environment management. On the other hand, they also include systems of payment for pollution, environment taxes, subsidies etc.

An environment management market could be promoted through mechanisms of allocation of emission quotas, use of set-off payments, emission quotas trade etc.

By all means, any of these approaches does not exclude the other. They are all applicable in the same time at different phases of production process. A setup of market relationship is based on creation of a trade platform for assigned amount units so that companies can buy, sell, trade or redistribute these allowances. An initial distribution of rights to pollute is required before the market

is set up. Such rights are distributed to those companies that should meet certain standards. They may either meet those standards by investing into waste treatment techniques, or buy allowances from those companies which managed to exceed their reduction commitments at the initial distribution.

Every country should take into account its national specifics when planning its environment protection system. However, some general characteristics are available. Figure 1 shows global sources of carbon emissions as of 2000. [4]

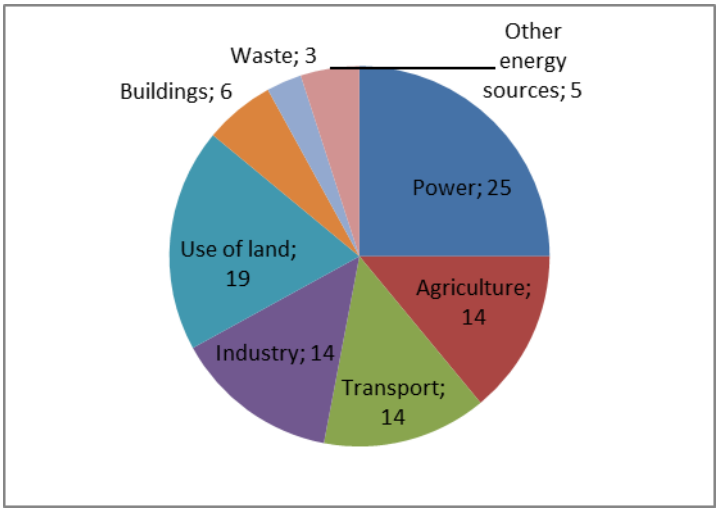

Figure 1. Sources of global carbon emissions (%) in 2000

Obviously, this structure will vary from country to country, depending on many factors like natural conditions, economy development level, in particular, of industry and energy sectors. However, overall potential effect of GHG should also be considered. If we take the potential effect of carbon dioxide as one, then, potential effects of other gases will be 21 for methane, 310 for nitrous oxide, 6,500 for perfluorocarbons, 11,700 for hydrofluorocarbons and 23,900 for sulfur fluorides, as it was established in the period of preparing the Kyoto Conference (see [5], [6]). We will not discuss these problems of commensurability of different greenhouse gases, although even the crucial figure in this scale, 11,700 for hydrofluorocarbons, i.e. HFC-23[3], many times was doubted.

3. Kyoto Protocol and Market Emission Regulating Mechanisms

There has been a long story of attempts to address air pollution problem at the highest international level. In 1992, the United Nations Conference on Environment and Development in Rio-de-Janeiro adopted the United Nations Framework Convention on Climate Change, or UNFCCC. The objective of the Convention set out in Art. 2, is “stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system”. The same Article further says that “such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner”. At the same time, a climate change is understood as change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (Art. 1, par. 2). In fact,

[3] HFC-23 is not standard chemical formula, it is a code, widely used for identifying haloalkane and this is how it is referred to in carbon market. Standard formula for threefluoromethane is CHF3.

this instrument extends and further develops the Montreal Protocol of 1987 (which entered into force on January 01, 1989) to the Vienna Convention for the Protection of the Ozone Layer.

All the countries, that had signed the UNFCCC, were split into three groups: 1) Annex I countries (OECD members and transition countries, including the EU members) that took special commitments on emissions reduction[4]; 2) Annex II countries (OECD members exclusively) assuming special financial obligations on aids to developing countries and countries in transition (including support of development and implementation of eco-friendly technologies), and 3) developing countries. The treaty came into effect on March 21, 1994 (Russia ratified the UNFCCC in November 1994). The parties agreed on a governing body, the Conference of the Parties, or COP, meeting on an annual basis to track the implementation of the UNFCCC provisions, to decide on further development of treaty rules and to discuss new commitments. [7]

The UNFCCC provisions were significantly extended on the COP-3 of December 1997 in Kyoto, Japan. COP-3 defined legally binding commitments on emissions reduction and adopted a Protocol setting out general rules, but without any specific details of their application. The next Conference of Buenos-Aires held in November 1998 (COP-4) failed to agree on implementation of measures to reduce GHG emissions, with resistance of the USA as the major cause. After the next unsuccessful summit which took place in the Hague in 2000 (COP-6), the objective of the Kyoto Protocol concerning 8% reduction of GHG emissions by 2010 compared to 1990 level, became questionable.

The Kyoto Protocol is an international agreement that binds the member countries to reduce GHG emissions (carbon dioxide CO_2 methane CH_4, nitrous oxide N_2O, hydrofluorocarbons or HFCs, perfluorocarbons or PFCs, and sulfur hexafluoride SF_6)[5] by 5.2% compared to the 1990 level. The Protocol was open for signature from March 16, 1998 till March 15, 1999. It was signed and ratified by almost all countries of the world. 192 countries ratified the Kyoto Protocol as of November 25, 2009. The Protocol has not been signed by Afghanistan, Andorra, Vatican and San-Marino. In 2012 Canada withdrew from the Protocol, while the USA has not ratified the treaty. As of the date above, the countries that ratified the Kyoto Protocol accounted 63.7% of global GHG emissions. On February 16, 2005 the Kyoto Protocol came into force (to make it happen, the Protocol should have been ratified by countries accounting at least 55% of GHG emissions worldwide). The first implementation period ran from January 01, 2008 till December 31, 2012. This is the first global agreement on environment protection based on a market regulating mechanism which is the international trade of quotas on GHG emissions.

The Kyoto Protocol, which is a supplement to the UNFCCC, provides for three so-called "flexible mechanisms" as a mean for international community to reduce GHG emissions. These flexible mechanisms were developed by COP-7, which took place late 2001 in Marrakesh (Morocco) and adopted on the first Meeting of the Parties to the Protocol (MOP-1) late 2005.

These flexible mechanisms are the following:

- **International Emissions Trading**, making possible for countries, or particular businesses located in those countries, to sell or to buy GHG emission allowances at domestic, regional or global markets;
- **Joint Implementation mechanism** (JI) which includes projects of GHG emission reduction implemented in one of the countries included in Annex I to the UNFCCC by means of investments, in total or in part, from another country included in Annex I;

[4] Countries included in Annex I to the UNFCCC: Australia, Austria, Belarus[a], Belgium, Bulgaria[a], Canada, Croatia[a*], Czech Republic[a*], Denmark, European Economic Community, Estonia[a] , Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia[a], Liechtenstein*, Lithuania[a], Luxembourg, Monaco*, Netherlands, New Zealand, Norway, Poland[a], Portugal, Romania[a], Russian Federation, Slovakia[a*], Slovenia[a*], Spain, Sweden, Switzerland, Turkey, Ukraine[a], United Kingdom of Great Britain and Northern Ireland, United States of America, (a - Countries that are undergoing the process of transition to a market economy.; * - Countries added to Annex I by an amendment that entered into force on 13 August 1998).

[5] Annex A to the Kyoto Protocol [8].

- **Clean Development Mechanism** (CDM), comprising GHG emission reduction projects carried out in a UNFCCC country (generally – a developing country), which is not included in Annex I, by means of investments, in total or in part, from another country included in Annex I.

International Emissions Trading belongs to "cap and trade" mechanisms. It involves a government (or other authority) setting a "cap", i.e. maximum allowable aggregate total quantity of (greenhouse) gas emissions, and selling or giving the corresponding number of allowances to emitters. Other two Kyoto mechanisms, JI and CDM, are project-based schemes. More important of these two is CDM. The mechanism is as follows. The "additional" project is established, that will reduce emissions. A developing world entity, or industrialized-world government, corporation, bank or hedge fund earns the difference between emissions with and without the project. This earn comes in the form of CER (Certified Emission Reduction), a kind of credit, not a permit or allowance. CERs can be then traded, for example credit earned in one underdeveloped country can be transformed into a permit to emit in Europe. Such example is possible through the EU ETS (European Union Emission Trading Scheme). EU ETS started in 2005, and became the largest greenhouse-gas market.

In 2011, the COP-17 in Durban, South Africa, agreed to extend the validity of the Kyoto Protocol till 2020.

The emission trading, as set out by the Kyoto Protocol, followed by international activities appeared to be a dramatically new idea for many opinions. However, those ideas are not completely new. One can find their traces, though not so manifest, starting from the famous work of A.Pigou [9] followed by R.Coase, with later formulated the well-known and influential Coase theorem [10].[6] Main theoretical incentive to establish emissions market came from Canadian economist J. H. Dales (see [12], [13]) and American economist Th. Crocker (see [14]). On the other hand, the practice itself of emission trading is not new either. The start of SO_2 and NO_x trading in the USA dates back to 1990s, and, despite certain skepticism in the begging, today it is generally seen as a success [1]. However some opinions disagree with that. Larry Lohmann stresses that the first proposals of such trading came back in 1960, while the following two decades were required to prepare its implementation, with a number of unsuccessful trials in the 90s. Finally, this practice became successful after the Kyoto Protocol. An outstanding role in this field was taken by Al Gore, who became a notorious player at this emerging market [15].

In the first decade of the XXI century, the EU picked up the initiative by creating the European Union Emissions Trading Scheme (EU ETS), the biggest carbon emission market in the world. It concerns exclusively trading of industrial carbon dioxide emissions. By the end of the first decade, the turnover at carbon emission market has exceeded 100 bln US dollars. Some forecasts say that by the end of the second decade it may become a rival to the market of financial derivatives, which is, so far, the biggest in terms of turnover. It should be noted, however, that despite of how big this new market is, its contribution to the main objective, which is carbon emission reduction, is disproportionally low, as it was noticed in the early years of the EU ETS. Hepburn says [1], with reference to his early work [16] and other sources [17] that in 2005 the contribution of EU ETS to GHG emission reduction was between 50 to 200 megatonnes (Mt) of carbon dioxide ($MtCO_2$), which corresponds to a global reduction around 0.1 to 0.4%. The annual contribution was expected at 200 $MtCO_2$ over the period between 2008 and 2012.

4. Kyoto Protocol and Russia's Actions

The Russian Federation ranks among the countries with the highest GHG emissions in the world. Emissions of CO_2 (carbon dioxide, accounting for 90% of the total national GHG emissions included into the Kyoto Protocol) were recorded at 2.388 billion tons in 1990. This corresponds to 17.4% of the total CO_2 emissions by the countries included in Annex I to the UNFCCC, where the 1990

[6] For more details on development of these ideas and of environmental economy in general, see [1], and in particular [11].

level was set as the baseline. In early 90s Russia saw a drastic economy decrease, especially in industry, which drew a significant reduction of total GHG emissions. According to the data presented by Russian Federation in its Second National Communication to the UNFCCC, CO_2 emissions in 1994 were at around 70% to the 1990 level.[7]

Russia ratified the UNFCCC on November 04, 2004 by enactment of the Federal Law 34-FZ, committing to "exercise measures called to mitigate effects of climate change through limitation of GHG emissions, and protection and improvement of sinks and reservoirs". The Federal Law "On Ratification of the Kyoto Protocol to the United Nations Framework Convention on Climate Change" was passed in the RF State Duma on October 22, 2004, followed by adoption by the RF Federation Council on October 27, 2004. President Putin signed the Law on November 04, 2004 (reference No.128-FA). The Kyoto Protocol came into effect on February 16, 2005, i.e. 90 days after Russia had submitted the ratification document to the secretariat of the UNFCCC on November 18, 2004.

In 2013, about ten years after Russia had ratified the Kyoto Protocol, President Putin issued the Decree "On reduction of greenhouse gas emissions", as a further development of the international treaty. This Decree provides for reduction of GHG emissions before 2020 by 25% compared to 1990 level. In order to put this ambition into life, the RF Government, together with expert community, is using all its best efforts to develop a so-called system of regulations on greenhouse gas emissions. Basically, the Government is talking about a carbon market at the national scale, like those existing and successfully expanding in the leading global economies.

During the years since Russia has accepted its binding targets of the Kyoto Protocol, annual GHG emissions have notably grown, from 1.66 billion tons of CO_2 in 1994, or 2.11 billion tons in 2004 up to 2.32 billion tons in 2011, sequestration omitted, see figure 2 [19]. The structure of GHG emissions in Russia 1990–2012 is shown on figure 3 [20], and the structure of sources of GHG emissions for the same period on figure 4 [20].

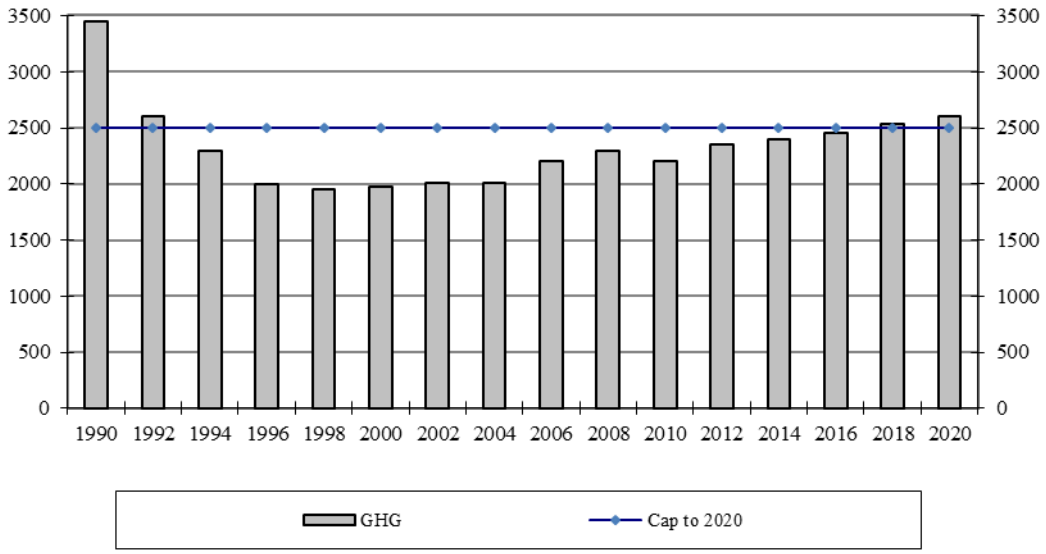

Figure 2. GHG Emissions in Russian Federation, 1990-2012, and forecast till 2020

[7] Quoted per [18].

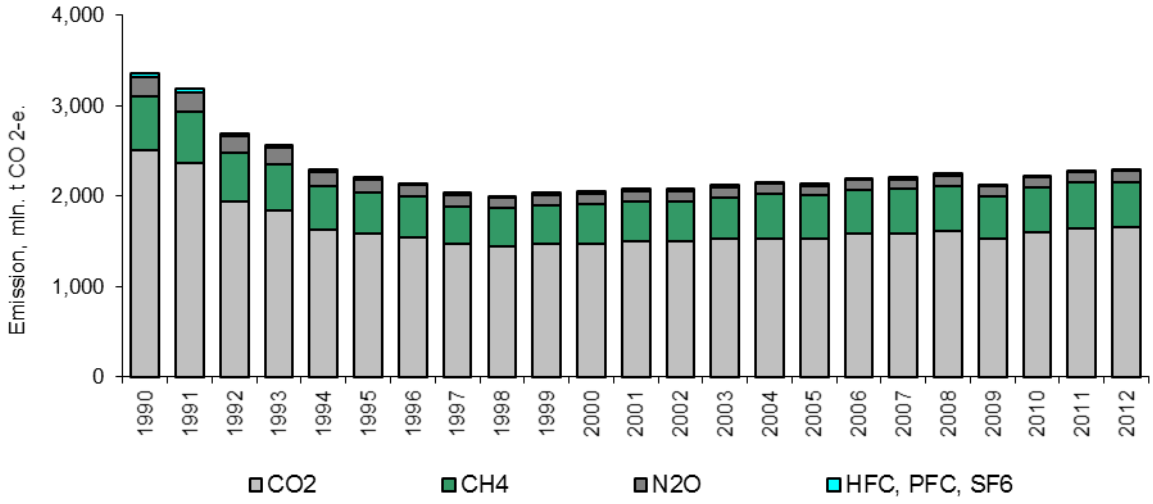

Figure 3. The structure of GHG emissions in Russian Federation 1990–2012

However, mechanisms of the Kyoto Protocol did not start operate in the RF did during the first year of its application. Creation of the domestic trade market for GHG emission allowances was, in fact, suspended for undefined period. There were no joint projects either to replace old equipment at Russian factories with more efficient and "green". The reason behind was a lack of documents required to establish the GHG emissions register.

In March 2006 the RF Government addressed the issue of implementation of the provisions set out in the Kyoto Protocol. The Ministry of Economic Development and other government agencies were given the task to build in two months a concept of proposal for a legislative act that would regulate the implementation of the Kyoto Protocol in Russia. Also one month was given to prepare a document to regulate the application of the Article 6 of the Kyoto Protocol which would allow Russia to invite investments in joint implementation projects.

Figure 4. The structure of sources of GHG emissions in Russian Federation 1990–2012

According to the RF Government Decree No. 332, adopted in May 2007, the Ministry of Economic Development has become the pole to coordinate and to approve applications filed for joint implementation projects.

By early 2008, the official web-site of the UNFCCC posted around 50 joint implementation projects originated from Russia. Russia is a place of work for a number of international companies like CAMCO, Global-Carbon, SGS, body for independent assessment (determination) of emissions reduction projects, and Tricorona Ab, Sweden, which is one of the biggest buyers of allowances.

By 2009 the Ministry of Economic Development have received around 125 applications from Russian companies. Their carbon potential totaled to 240 million tons of CO_2 equivalent, what means approximately 3.5 to 4.0 billion euros. However neither of those applications was approved.

The next RF Government Decree, No. 843, pertaining to this field, was adopted in October 2009. This Decree vested the RF Sberbank with authority to participate in all activity in connection with obtaining, transfer or acquisition of GHG allowances. Sberbank became responsible for bidding and further assessment of applications, while the Ministry of Economic Development decided on approval of applications after those assessments. As a next step, the filed project underwent an independent and accredited monitoring to confirm the amount of emissions being reduced for the given period. All these steps passed, the company should receive money from carbon unit buyer via Sberbank under an ERPA (Emission Reductions Purchase Agreement). However, the fact of vesting Sberbank with functions of carbon units operator was criticized.

Late June 2010 the Ministry of Economic Development approved the first 15 joint implementation projects. The projected emission reduction was expected at 30 million tons of CO_2 equivalent. In November 2010 Sberbank completed assessment of 58 applications filed in the second bid campaign and totaling to 75.6 million tons.

The first deal on carbon allowances by a Russian company took place in December 2010. Mitsubishi and Nippon Oil, Japanese partners of Russian Gazprom Neft at Yety-Purovskoye field development in Yamalo-Nenets Autonomous Okrug, obtained their allowances. Those allowances had become available after laying of field pipelines by Gazprom Neft to transport wellhead gas to SIBUR processing facilities instead of burning it. As compensation, Gazprom Neft got access to know-hows and equipment.

This positive example has been further developed. According to research team [21], over 250 important Russian companies have been involved in “carbon” projects over recent years. Those companies represent various industries of Russian economy, including fuel and energy, forestry and timber processing, chemicals, steel-making and non-ferrous metallurgy, housing and utility services.

In April 2014 the RF Government approved an action plan to implement President Decree No. 752 of 30.09.2013 “On GHG Emission reduction” aimed at bringing the emission level by 2020 to not more than 75% of emission level of 1990. The plan developed by the RF Ministry of Economic Development provides for set-up of monitoring and reporting on GHG emissions, along with measures to reduce GHG emission and progressive shift to financial regulation. The latter should include introduction of a “carbon tax” and domestic trading of carbon allowances.

5. Conclusion

The seeking of efficient mechanisms to mitigate GHG emissions and carbon concentration in the atmosphere is very important. New IPCC data [22] show increase of those emissions at the global level, especially emissions from fossil fuel combustion and cement production, wich contribute with about 68% in anthropogenic emissions: anthropogenic CO_2 emissions to the atmosphere were 555 ± 85 PgC (1 PgC = 10^{15} gC) between 1750 and 2011 and of this amount, fossil fuel combustion and cement production contributed 375 ± 30 PgC and land use change (including deforestation, afforestation and reforestation) contributed 180 ± 80 PgC. Atmospheric CO_2 concentration increased at an average rate of 2.0 ± 0.1 ppm per year during between 2002 and 2011. This decadal rate of increase is higher than during any previous decade since direct atmospheric concentration measurements began in 1958.

This problem and efforts are very important for the Russian Federation, too. The high quality inventory is an important step to greenhouse gas emission mitigation. As a Party to the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol, since 2006 the Russian Federation regularly prepares and submitts its national greenhouse gas inventories,

beginning from the first prepared and submitted in 2007 [23]. This makes the improvement of greenhouse gas inventory possible, see e.g. [24].

Today there are few scenarios to be considered in the field of GHG emissions in Russia:

- *"There is no straight road to the future"*. This scenario implies uncertainty and widespread forecasts of GHG emission, especially in energy sector;

- *"Sisyphus Road"* translated in curves with high peaks of GHG emissions, expected at 5 000 million tons of CO_2 equivalent by 2050;

- *"Baseline Zone"*, leading to emission growth by 33–55% to 1990 level in energy sector;

- *"Carbon Plato"*, meaning that up to 2060 there would be no increase of GHG emissions to 1990 level;

- *"Low-Carbon Russia"*, characterized by a slowdown of GHG emission growth till 2030 and keeping them lower than 1990 level till 2040;

- *"Low-Carbon Russia – Aggressive",* assuming rather stringent commitments taken by Russia on GHG emission reduction for the future, and implementation of wide array of special measures to meet these commitments [25].

There are 108 GHG emission reduction projects approved by the RF Ministry of Economic Development, with total carbon potential of 311.6 million tons of CO_2 equivalent. In addition 156 projects have been initiated for a total emission reduction exceeding 386 million tons of CO_2 equivalent over 2008–2012. It means that Russia is taking the leading position at the global carbon market, placed second after China, with a project portfolio for 700 million tons of CO_2 equivalent, far ahead its competitors (India, Ukraine etc.) [21].

The priority should be given to the last two development scenarios. It looks possible provided that the old capitalization on achievements of the USSR era is changed to new investments in know-hows offering better performance in terms of energy efficiency and carbon intensity, and are in line with the third millennium targets. The way to reach this goal is a full-scale implementation of Environment Management Systems.

An Environment Management System, as part of the overall corporate management, features a well-structured organization. Its main target is to implement provisions set out in the environment policy through deployment of environment protection programs. Being a cycle, an environment management system is oriented at continual improvement of environmental and economic performance of a company, including GHG emission parameters. Russia already knows positive experience of GHG emission reduction (see example of Gazprom Neft above) through application of the Environment Management System. The adherence of the Russian Federation to the WTO implies specific commitments on implementation of ISO 14000 and ISO 19011 standards, along with a comprehensive deployment of environment management systems. This brings some optimism regarding decrease of GHG emissions.

References

[1] Hepburn, C. Carbon Trading: A Review of the Kyoto Mechanisms, *Annual Review of Environment and Resources*, *32*, (2007), pp. 375–393. DOI: 10.1146/annurev.energy.32.053006.141203

[2] Stern, N.H.; S. Peters, V. Bakhshi et al. *Stern Review: The Economics of Climate Change*, Cambridge University Press, Cambridge, UK, 2006.

[3] Pliaskina, N.I. Building of Market Relationship in the Field of Environment Management and Development Trends of Energy Policies in the Context of the Kyoto Protocol, *Bulletin of Novosibirsk State University. Series on social sciences and economy, 5*, (2005), 1, pp. 24–40 (in Russian).

[4] Putti, V. R. *Kyoto Protocol and Carbon Market Drivers*, World Bank, Washington, USA, 2007.

[5] Lashof, D. A. and D. R. Ahuja. Relative contributions of greenhouse gas emissions to global warming, *Nature, 344*, (1990), 6266, pp. 529–531.

[6] Houghton, J. T.; L.G. Meira Filho, B. A. Callander, N. Harris, A. Kattenberg, K. Maskell (eds.) *Climate change, 1995: The scince of climate change*, Cambridge University Press, Cambridge, 1996.
[7] ***. *United Nations Framework Convention on Climate Change*, New York, USA, 1992.
[8] ***. *Kyoto Protocol to the United Nations Framework Convention on Climate Change*, New York, USA, 1998.
[9] Pigou, A. C. *The Economics of Welfare*, Macmillan, London, UK, 1920.
[10] Coase, R. H. The problem of social cost, *Journal of Law and Economics*, *3*, (1960), 1, pp. 1–44.
[11] Pearce, D. An Intelectual History of Environmental Economics, *Annual Review of Energy and the Environment*, *27*, (2002), pp. 57–81. DOI: 10.1146/annurev.energy.27.122001.083429
[12] Dales, J. H. Land, water, and ownership, *Canadian Journal of Economics, 1*, (1968), 4, 791–804. DOI: 10.2307/133706
[13] Dales, J. H. *Pollution, property and prices: An essay in policy-making and economics*, University of Toronto Press, Toronto, Canada, 1968.
[14] Crocker, Th. D. "The Structure of Atmospheric Pollution Control Systems." In: *The Economics of Air Pollution*, edited by H. Wolozin, pp. 61–86. W. W. Norton and Co., New York, 1966.
[15] Lohmann, L. Neoliberalism and the Calculable World: the Rise of Carbon Trading, in: Birch, Kean & Vlad Mykhnenko (eds.) *The Rise and Fall of Neoliberalism*, Zed Books, London and New York, UK & USA, 2010, pp. 77–93.
[16] Hepburn, C. Regulating by prices, quantities or both: an update and an overview, *Oxford Review of Economic Policy*, *22*, (2006), 2, pp. 226–247. DOI: 10.1093/oxrep/grj014
[17] Ellerman, A. D. & B. K. Buchner. Over-allocation or abatement? A preliminary analysis of the EU Emissions Trading Scheme based on the 2005-06 emissions data, Regulatory Policy Program Working Paper RPP-2007-03. Cambridge, MA: Mossavar-Rahmani Center for Business and Government, John F. Kennedy School of Government, Harvard University, 2007.
[18] Safonov, G.V. Outlook on Russian Participation in GHG Emission Allowances Trade, *The HSE Economic Journal*, *4*, (2000), 3, pp. 349–368 (in Russian).
[19] ***, System of GHG emission regulations as a basis of the green economy of Russia. Conference papers, MGIMO, Moscow, May 14, 2014. https://russiancarbon.org/conference-mgimo/
[20] ***, Natsionalniy doklad o kadastre antropogennykh vybrosov iz istochnikov i absorbtsii poglotitelyami parnikovykh gazov ne reguliruemykh Monrealskim Protokolom 1990–2012. (The National Report on the Inventory of Emissions by Sources and Removals by Sinks of the Greenhouse Gases of the Russian Federation). Federalnaya sluzhba po gidrometeorologii i monitoringu okruzhayuschey sredy, FGBU IGKE Rosgidrometa i RAN, Moskva, 2014. (in Russian)
[21] Averchenkov, A.A.; A.Y. Galenovich, G.V. Safonov, Y.N. Fedorov. *Greenhouse Gas Emission Regulation as a Driver to Increase the Competitiveness of Russia*, NOPPU, Moscow, Russia, 2013 (in Russian).
[22] ***, Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2013.
[23] ***, Natsionalniy doklad o kadastre antropogennykh vybrosov iz istochnikov i absorbtsii poglotitelyami parnikovykh gazov ne reguliruemykh Monrealskim Protokolom 1990–2006. (The National Report on the Inventory of Emissions by Sources and Removals by Sinks of the Greenhouse Gases of the Russian Federation). Federalnaya sluzhba po gidrometeorologii i monitoringu okruzhayuschey sredy, FGBU IGKE Rosgidrometa i RAN, Moskva, 2007. (in Russian)
[24] Uvarova N.E., Kuzovkin V.V., Paramonov S.G., Gytarsky M.L. The improvement of greenhouse gas inventory as a tool for reduction emission uncertainties for operations with oil in the

Russian Federation, *Climatic Change*, *124*, (2014), 3, pp. 535–544. DOI: 10.1007/s10584-014-1063-x

[25] Bashmakov I.A. and A.D. Myshak. *Determining Factors of GHG Emissions in Russian Energy Sector: 1990-2050*, Center for Energy Efficiency (CENEf), Moscow, Russia, 2013. (in Russian).