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REDUCTION OF GREENHOUSE GAS EMISSIONS IN RUSSIA: STATE OF THE PROBLEM AND COMPENSATORY MEASURES FOR REFORESTATION AS A NET CO_2 ABSORBERS

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The article presents an overview and estimation of the present-day developments in reducing greenhouse gas (GHG) emissions in Russia. It contains a consideration of measures developed at country level and individual GHG-issuing corporations to combat climate change. Special attention is paid to the ways of carbon dioxide (CO_2) compensation, taking into account the absorption capacity of forests. The article describes the experience of the largest Russian oil company "Tatneft" in implementing a project to develop and scale a triploid aspen with increased absorption capacity for planting seedlings in forests in order to reduce and compensate for the carbon footprint.

Keywords: climate regulation, greenhouse gas emissions, carbon footprint, CO_2 compensation, the absorption capacity of forests, the forest ranges.

Within the existing circumstances, one of the crucial global environmental problems that require a joint solution by the entire international community is the increase in greenhouse gas (GHG) emissions into the atmosphere which is provoked by both natural causes (for instance, large volcanic eruptions or large-scale burning of forests) and anthropogenic, i.e. caused directly by human activity, and above all, the use of fossil fuels in the energy sector, deforestation and land use changes. Under the influence of all above-mentioned factors, the concentration of carbon dioxide (CO_2) and other greenhouse gases increases in the atmosphere. That, in turn, enhances the natural greenhouse effect and leads to an increase in temperature at the Earth's surface [Terentyev, 1996]. According to the observations of climatologists, only over the last century the average temperature on the planet has increased by 0.74°. But even such a seemingly insignificant increase has already led to irreversible climate change.

Recognizing the need for a unified and coordinated response to global climate change, the world community has been taking concrete steps for two decades to coordinate actions aimed at solving this problem These measures are enshrined in three international agreements: the UN Framework Convention on Climate Change (UNFCCC, 1992), the Kyoto Protocol to the UNFCCC (1997) and the Paris Agreement (2015).

Within the Paris Agreement accepted following the results of the 21st UNFCCC Conference, the participating countries agreed to prevent an increase in the average temperature on the planet by 2100 by more than two degrees Celsius compared to the pre-industrial era. The agreement assumes voluntary commitments of countries to reduce GHG emissions. As of February 2020, 189 countries, the EU [Mitrova et al., 2020] and Russia, which ratified this agreement in September 2019 [Analytical Center, 2021], are parties to the Paris Agreement.

According to research analysts, it warms 2.5 times in Russia due to its geographical location and in the Arctic zone — 4–6 times faster than the average in the world [Mitrova et al., 2020]. Russian weather forecasters have calculated that if gas emissions remain at the same level, then the climate of Siberia will significantly warm up by 2080. Winter temperatures will increase by 9° on average, and summer temperatures by 5.7°. At the same time, the precipitation level will also increase on average by 140 mm per year. The permafrost area will be reduced by a fourth part [Mitrova et al., 2020].

In the north of Russia, the trends towards an increase in the temperature of permafrost rocks already occur. The sea ice are the most significant indicator of climate change in the marine part of the Arctic. According to Russian Federal State Statistics Service, the average area occupied by sea ice has decreased to 300 thousand km^2 over the past 15 years — this is 4–5 times less than in the 1980s. A decrease in the duration of snow cover is being registered in most of the country (in winter 2018–

2019 on average in Russia it was 12.7 days shorter than normal — an unprecedented short period since 1967). The minimum soil temperature has increased for 1976–2019 (<0.4°C/10 years at depths up to 320 cm), the linear trend of annual precipitation growth was 2.2% of the norm. The most paramount negative feature of the summer precipitation change is its decrease in the main grain-producing areas of the European part of Russia: about 4%/10 years in the Central and Volga Federal Districts, in the Southern Federal District this value reaches almost 5%/10 years [Abramova et al., 2020].

The probability of emergency fields remains high, taking into account the nature of the prevailing hazards at economic, agricultural and infrastructure facilities when they are exposed to various natural phenomena, for instance, wildfires, avalanches and earthquakes. According to the Ministry of Emergency Situations and the Ministry of Agriculture of Russia, the reference apparatus (RA), there was a sharp increase in officially registered damage from emergencies in agriculture in the second decade of the XXI century. In 2000–2009 the damage to farmers estimated by direct costs for the cultivation of dead fields amounted to 27.4 billion rubles. In contrast, in 2010–2019 the cultivation costs went up and were more than 103 billion. According to the RA, these losses correspond to the damage of farmers from the loss of products at a level of at least 270 billion rubles over 20 years [Abramova et al., 2020].

Every year there are from 5 to 7 units of large fires, the area of their point of origin is 25 hectares or more for ground protection of forests and more than 200 hectares for aviation protection of forests. As shown on Fig. 1, in 2019 their part in the structure of natural emergencies amounted to 12,2% [Sechin, 2021]. Remote data from the Federal Forestry Agency system (fig. 2) show that previously catastrophic fires with an area of more than 10 million hectares occurred approximately once every five years, however, from 2018 the area of forest fires does not fall below 15 million hectares [Provin et al., 2021].

During the second decade of XXI century, a negative impact of prolonged periods of extremely high temperatures on the level of morbidity and mortality of the population has been registered in many cities and regions of Russia. The effect of the blocking anticyclone in the summer of 2010 was particularly pronounced. In recent years, the frequency and severity of heat waves have increased: abnormal heat was observed in 2015, 2018, 2020–2021. In 2021, an abnormal heat wave covered almost the entire European part of Russia, Yakutia, the Amur Region and Primorye.

All this confirms the fact of the ongoing climate changes in Russia which in the long term poses a threat to human life and health, a danger to the infrastructure of the economy and the risks of reducing food security, and, consequently, climate regulation should become a priority of the country's state policy. Unfortunately, 4.5% of the total emissions in the world are descended from Russia, the country is one of the five largest global emitters of GHGs after China (28.8%), the USA (14.5%), the European Union (9.7%) and India (7.3%) [Abramova et al., 2020].

Figure 3 represents the dynamics of anthropogenic GHG emissions in Russia for 1990–2019 [Mitrova et al., 2020]. As shown on the Figure, the value of the total CO_2 emissions is eq. in Russia (excluding the sector «Land Use, land use change and forestry (LULUCF)») had an unstable trend during the entire analyzed period: it decreased (in the periods: 1990–1998, 2009, 2013–2014) than a growth occured (in the periods: 2000–2008, 2010–2012 and after 2014). The reduction of GHG emissions observed in different years was mainly influenced by changes in the sectoral structure of the economy and structure of the country's fuel balance, as well as due to the absorption capacity of the forestry sector. To a certain extent, this was the result of the implementation of a whole range of operational and long-term measures to adapt to climate change undertaken by the state in accordance with the Comprehensive Plan for the Implementation of the Climate Doctrine of the Russian Federation for the period up to 2020. According to research conducted by the Energy Center of the Moscow School of Governance "Skolkovo" together with the member companies of the Oil Advisory Forum, the problem of climate change had a low priority both

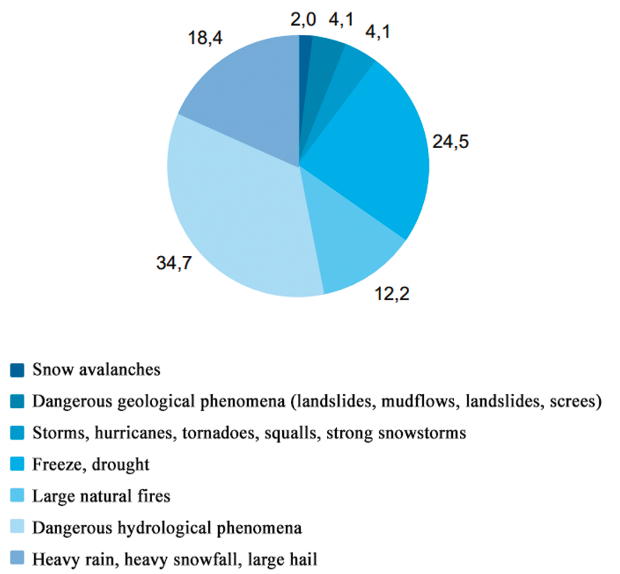

Fig. 1. Structure of natural emergencies by nature and type of sources of occurrence in 2019 (as a percentage of the total)

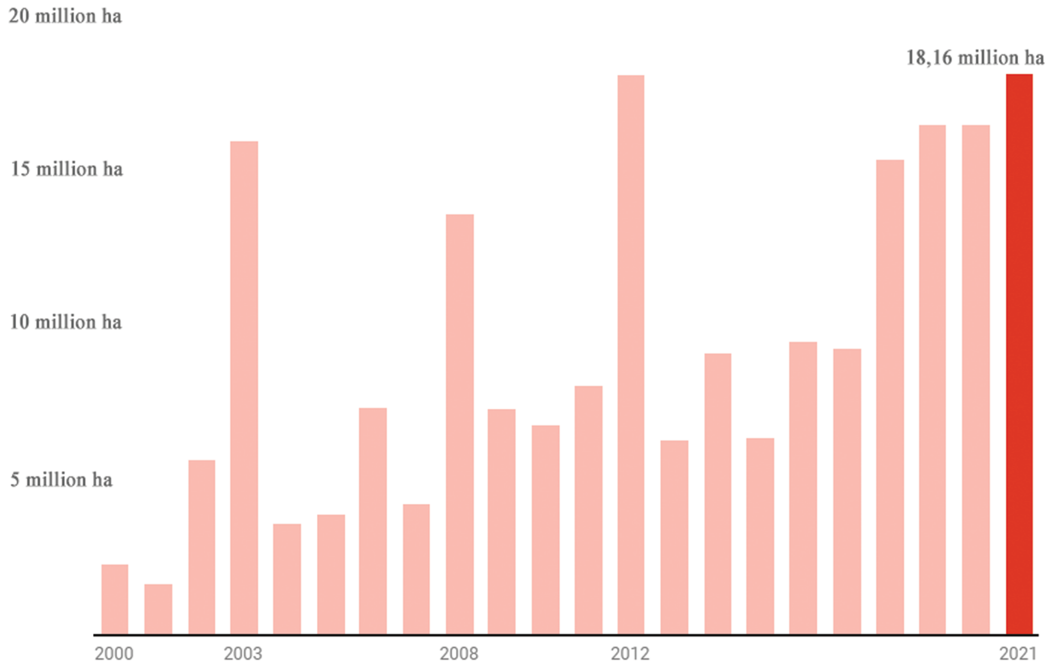

Fig. 2. Area of forest fires for the year from 2000 to 2021 Data for 2021 are indicated as of September 20

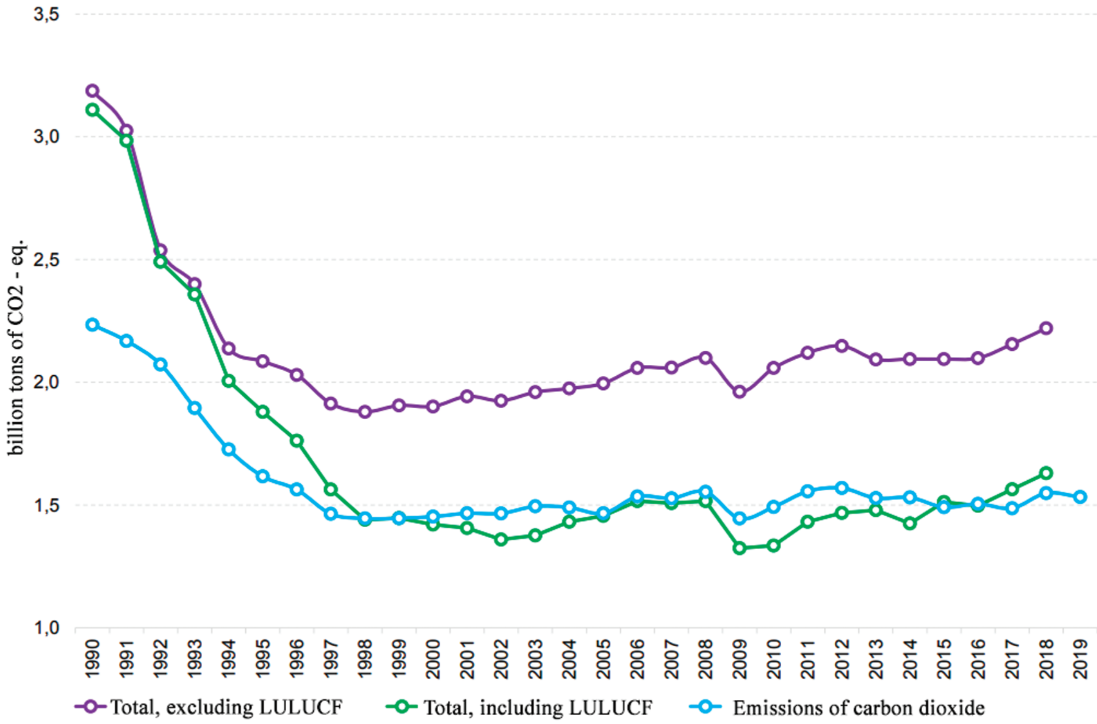

Fig. 2. Total anthropogenic GHG emissions in Russia, billion tons of CO_2 — eq., 1990–2019

for the population and business in Russia, unlike many other countries of the world [Mitrova et al., 2021].

After the ratification of the Paris Agreement on September 21 in 2019, the organization of the process for the development of specific measures for adaptation to climate change at the level of individual regions, industries and corporations was launched. Russia has set a goal for itself — to reduce GHG emissions by 2030 to the level of 70–75% relative to indicators in 1990, provided that the absorption capacity of forests is taken into account as much as possible [Mitrova et al., 2020].

Currently, in accordance with the Decree of the President of the Russian Federation No. 666 dated 04.11.2020, the Government of the Russian

Federation is developing a Strategy for the long-term development of Russia with low GHG emissions until 2050 with two main scenarios of low-carbon development: basic and intensive. The basic scenario accepted as a basis provides for a large-scale increase in the energy efficiency of the Russian economy, full provision of the balance of forest reproduction, expansion of area of their protection and a significant reduction in continuous logging. Development under this scenario will reduce the carbon intensity of Russian GDP by 9% by 2030 and by 48% by 2050 (relative to the current level) [Strategy, 2021].

According to research analysts [Grigoriev et al., 2020] Russia has opportunities to reduce CO_2 emissions and a huge potential to improve the energy efficiency of the Russian economy. In particular, the share of coal remains high in the country's energy balance (about 18%) which means that there is an opportunity to abandon this "dirty" energy source. In addition, there is a whole set of carbon-free sources of generation — nuclear power plants, hydroelectric power plants, renewable energy sources (for example, solar, wind energy), which together give about 40% of the output [Bakhteev et al., 2018]. However, it is not enough to compensate for the high carbon intensity of domestic products only by fulfilling state tasks to reduce emissions, since monitoring and reporting on GHG emissions, according to Federal Law No. 296-FZ dated 02.07.2021 "On Limiting Greenhouse Gas Emissions", become mandatory for legal entities and individual entrepreneurs whose activities are accompanied by GHG emissions, the mass of which is equivalent to 150 or more thousand tons of carbon dioxide per year for the period up to January 1, 2024 or 50 or more thousand tons of carbon dioxide per year for the period from January 1, 2024, [Federal Law, 2021]. The tasks of the business now include not only the preparation of reports but also calculation of the carbon intensity of manufactured products, comparing this indicator with European competitors in order to assess the potential of reducing the carbon footprint based on this analysis, including from the point of view of possible energy saving projects, working with the quality of raw materials used in technological processes.

Industrial corporations operating in such sectors of the economy as energy, agriculture and industrial production have a special role to play in reducing GHG emissions since they are the main source of GHG emissions. Even for today, many Russian companies including "Gazprom", "Rosneft", "Rusal", "Norilsk Nickel" voluntarily carry out an inventory of GHG emissions and implement climate projects. Some companies have started calculating the carbon footprint of their products and assessing climate risks in the absence of Russian requirements but in accordance with international standards. Among the external factors pushing large Russian businesses to reduce their carbon footprint are regulatory risks, the requirements of foreign exchanges, investors and partners, as an increasing number of them refuse to cooperate with companies with poor carbon characteristics.

It is well known that a range of the largest GHG issuers in Russia is traditionally headed by companies in the energy sector (extraction of fuel or raw materials for its manufacture, transportation, storage and distribution of energy carriers, production of thermal and electric energy). They account for approximately 79% of the total GHG emissions and in the GHG structure itself more than 70% is CO_2 generated during fuel combustion. Probably for this reason, the largest energy companies, such as "Rosneft", "Gazprom", "Lukoil", "Tatneft", integrated into the global economy, have identified the fight against climate change and the reduction of GHG emissions as their development priorities. They assess their carbon footprint and take steps towards reducing emissions, taking into account the Paris Agreement and the European "Green Deal".

"Rosneft" is ahead of many oil and gas companies in the world in terms of emissions today. According to experts, in terms of specific GHG emissions, the Russian giant already has a 1.5–2 times lower indicator than Chevron, Exxon Mobil, Sinopec and ConocoPhillips. "Rosneft" is also overtaking such energy giants of the industry as Eni, Shell, Total and BP [Mitrova et al., 2021]. At the end of 2020, Rosneft became the first company in our country to develop and adopt a comprehensive carbon management plan until 2035 with clear targets for reducing GHG emissions. This plan contains a set of measures for energy conservation, the development of its own wind energy and the purchase of energy from renewable sources, investments in the gas program, utilization of associated petroleum gas as well as the use of "blue" hydrogen.

Taking into account the fact that the sector "Land Use, land use change and forestry" in Russia was a net GHG absorber, the company considers the development of natural forest absorbing systems and the emergence of carbon quota turnover systems as an important source of further carbon footprint reduction. "Rosneft" intends to contribute to the disclosure of Russia's natural potential for CO_2 uptake by forests. In the period of 2020, the company planted 1.5 million trees and in the last three years — 3.5 million trees. This allows us to count on the absorption of 10-20 million tons of CO_2 equivalent annually [Sechin, 2021]. By 2035, "Rosneft" has set itself a larger goal — to unlock the potential of the absorbing capacity of forests in Russia and develop a large-scale program for

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afforestation and maintenance of forest ecosystems to compensate for emissions.

Another major energy corporation named "Tatneft" has been accounting for GHG emissions since 2016, and as of 2019 has achieved a 5% reduction in them. Annually, the company prevents emissions into the atmosphere in the amount of 3 million tons of CO_2-eq. greenhouse gas due to the high level of useful use of APG (96.4%). In the total mass of all GHG emissions including carbon dioxide, methane and nitrous oxide CO_2 accounts for 99.79%. To reduce the carbon footprint, "Tatneft" has set a goal to reduce CO_2 emissions by 10% by 2025, by 2030 — by 20%, and by 2050 — to become carbon neutral [Gaifullina et al., 2018], i.e. to reduce CO_2 emissions to zero and its analogues in the course of production activities or compensate for them through projects with net negative emissions. This can be achieved in various ways, for example, by reducing direct emissions and switching to renewable energy sources (RES); apply technologies for direct capture of CO_2 from the atmosphere or use BECCS technologies, and, furthermore, to capture CO_2 during the combustion of biomass (plants and crops). Also the investing in projects that reduce CO_2 emissions can be useful. "Tatneft" is considering the possibility of using all options.

Currently, the company applies innovations in the entire chain of business processes in oil production, refining, petrochemicals and electric power; expands the range of products with a low carbon footprint; controls emissions reduction throughout the supply chain. The Company uses the best available technologies and technological solutions that have proven their effectiveness in order to reduce the negative impact on the environment and climate and increase the sustainability of ecosystems. For instance, installations for capturing light fractions of hydrocarbons from reservoirs or gas have been introduced which can significantly reduce harmful emissions into the atmosphere and improve the environmental situation. At the same time, innovative methods are being sought in such promising areas as the development of production using renewable energy (clean energy generation with low carbon content) and biofuels; the introduction of technologies for CO_2 capture and storage (Carbon Capture and Storage, CCS). In particular, the company has already identified two sites where wind turbines can be installed in the future while having its own thermal power plants and engineering centers. A project has been launched to purchase electricity from private owners of renewable energy sources. The project is still only at the initial stage but it has huge potential both from an economic and environmental point of view.

"Tatneft" pays great attention to compensating measures for CO_2 emissions, taking into account the absorbing capacity of forests. As well-known, forests are able to affect the amount of CO_2 in the atmosphere by absorbing it during the growth period. The role of CO_2 as a growth stimulator is rooted in the details of photosynthesis, in which an increase in the concentration of carbon dioxide intensifies this process. In order for a tree to start absorbing CO_2, it must take 15–20 years before it grows from a seedling into an adult tree. Young and middle-aged trees have the greatest absorption capacity: for example, at the age of up to 20 years, plants absorb 0.934 t/ha of CO_2 per year, at the age of 20 to 40 years — 1.611 t/ha of CO_2, and the highest values of CO_2 absorption in most woody plants are observed at the age of 40–60 years [Krasutsky, 2018]. Subsequently, with an increase in age, the assimilation properties of plants fall sharply and in over-standing plantings turn out to be close to zero. Therefore, it is possible to increase the intensity of CO_2 absorption by replacing mature forests with young trees due to reforestation and afforestation.

In addition, trees of different breeds have different degrees of CO_2 absorption. For example, deciduous plantations are generally characterized by higher biological productivity and the highest assimilation parameters, accumulating up to 62.8 t/ha of carbon-containing organic substances during the year, while coniferous — only 44.2 t/ha.12 [Krasutsky, 2018]. There is an objective need for large areas for planting as well as monitoring and accounting for the development of forest plantations. This is especially important because not every tree planting is a guaranteed way to reduce the carbon footprint or neutralize it, and there are certain risks associated with illegal logging, insect pests, forest fires. Unfortunately, the number and area of forest fires in Russia is growing, as evidenced by statistics for the period from 2000 to 2021, and long periods of heat and drought are happening more often. Therefore, the active participation of large industrial companies in unlocking the potential of the absorbing capacity of forests in Russia by planting green spaces is a response to new challenges to solve the problem of GHG emissions compensation.

In order to create a favorable environment and increase the absorption of greenhouse gases, "Tatneft" is implementing a Targeted program to replenish forests. The company's "forest" programs have been counting down since 2000, and since 2013 the project "Forest from gas stations" has been working, according to which a certain part of the proceeds from the sale of fuel at the company's gas stations is spent on planting green spaces. Not only coniferous (pine, spruce) and deciduous trees (oak, poplar, fruit trees) are planted, but

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also shrubs. For the period from 2013 to 2019. The retail and sales of "Tatneft" enterprises have planted about 8 million seedlings, 2 million trees in 2020, and in 2021 it is expected to increase this number to a record 5 million trees. By 2030, "Tatneft" plans to compensate for GHG emissions by 25% of the 2020 level by planting forests [Gaifullina et al., 2018].

Tatneft actively cooperates with various structural divisions of the forestry of the Republic of Tatarstan (RT) and private business supporting startups aimed at conducting scientific and experimental research on the selection, cloning and breeding of seedlings of promising tree forms most adapted to local conditions. As wiedly known, for the conditions of the Middle Volga region and, accordingly, for the Republic of Tatarstan, one of the fastest growing and precocious tree species is aspen as a result of which these plantings prevail over all forest-forming species of the Republic. However, the main disadvantage of aspen is the high degree of damage to the trunks by rot. Therefore, with the support of "Tatneft", we together with the staff of the laboratory of microclonal vegetative reproduction of the GBU RT "Educational and Experimental Sabinsky Forestry" are implementing a project for the selection, cloning and mass reproduction of triploid aspen in laboratory and greenhouse conditions, followed by the use of the obtained high-quality planting material to create aspen plantations.

Since the formation of forest plantations from any monoculture impoverishes the forest biocenosis and reduces the resistance of trees to the effects of various external factors, causing diseases and premature death, forests from mixed plantations are traditionally considered environmentally friendly. At the same time, a specific forest biocenosis always has a geographical reference and is characterized by features peculiar to a certain area. In relation to our project, the choice of triploid aspen as a breeding stock of clones is quite justified and is explained by the following circumstances. Firstly, this type of aspen differs from the usual one in that it has three complete sets of chromosomes, copies of which were found in the forests of Tatarstan. Due to this, triploid aspen has such properties as high rot resistance, a high degree of CO_2 absorption and oxygen production. Secondly, planting is carried out plantation, that is, 400 pieces of trees per 1 hectare of land, and, thirdly, a small fir planting strip runs between them (fig. 4). Since anthropogenic CO_2 emissions in Russia are mainly associated with the activities of energy sector enterprises, the planting of triploid aspen as a good CO_2 absorber is the most preferable for "Tatneft".

Fig. 4. Triploid aspen plantation with a fir planting strip

Research on the development of technologies for clonal micro-propagation of fast-growing hardwoods, including triploid forms of aspen and several types of birch, as well as the mass production of elite planting material was carried out at the branch of the Institute of Bioorganic Chemistry of the Russian Academy of Sciences named after M.M. Shemyakin and Yu.A. Ovchinnikov in Pushchino within the Federal Target Program "Research and Development in priority areas of the scientific and technological complex of Russia for 2014–2020". In addition, in the reforestation laboratory of the St. Petersburg Scientific Research Institute of Forestry, planting material of fast-growing aspen forms was obtained using the in vitro method with subsequent planting of plantations. The results of these studies formed the basis for the implementation of a project supported by "Tatneft" on the selection, cloning and mass reproduction of triploid aspen. The selection was carried out in the forests of Aznakaevsky and Nurlatsky districts of the Republic of Tatarstan. The best clones were introduced into the culture of micro-shoots and are maintained in the collection under in vitro conditions in the biotechnology laboratory of the Sabinsky Forestry Breeding Center. The project is carried out in two stages; the deadline is two years. At the first stage, which has already been completed, in the conditions of the greenhouse complex, the selection, cloning and cultivation of seedlings were carried out using appropriate substrates to achieve double CO_2 absorption by clones. This allowed the breeding center of Sabinsky Forestry to supply 1 million seedlings of this aspen breed for "Tatneft" within one year (from 2020 to 2021) for the purpose of subsequent planting them in the territories secured by "forest" programs.

At this stage, monthly monitoring is carried out in order to collect data on all dynamic indicators of the formation and growth of seedlings (accumulation of biomass; formation of the leaf surface for subsequent calculation of the use of photosynthetic potential, development of the assimilation surface of leaves; change in the structure of agrophytocenosis and its optical-biological characteristics with an assessment of the efficiency of the use of radiant energy; CO_2 absorption, etc.). Thanks to the investment support from "Tatneft", it is planned to implement this project on schedule which, in turn, will contribute to achieving the targets of its "forest" programs. If this experience is scaled up and commercialized, it will be possible to achieve certain results in solving the general problem of reducing CO_2 emissions not only in a particular region, but also on the scale of our entire country.

Thus, summarizing the above, we can draw the following conclusions:

1. Russia has opportunities to reduce CO_2 emissions and a huge potential to improve the energy efficiency of the Russian economy. However, for the time being, our country remains among the top five global GHG emitters and is at the stage of formation of climate regulation.

2. After the ratification of the Paris Agreement in 2019 and in response to international challenges, the climate agenda for reducing GHG emissions and CO_2 compensation takes priority positions in the country's public policy, and also becomes the topic of climate responsibility of business and, above all, the largest energy and industrial companies as the main emitters of CO_2.

3. As part of the fight against climate change, the experience of the leading oil companies "Rosneft" and "Tatneft" is indicative, which were among the first in Russia to start implementing carbon management plans with clear targets for reducing GHG emissions through the implementation of afforestation programs with their subsequent scaling.

4. The implementation of the project on the selection, cloning and cultivation of triploid aspen in laboratory and greenhouse conditions of the GBU of the Republic of Tatarstan "Educational and Experimental Sabinsky Forestry" with the investment support of "Tatneft", as well as the subsequent use of the obtained high-quality planting material to create aspen plantations in the Republic of Tatarstan as the best net CO_2 absorbers is a real answer to new challenges to solve this problem in relation to a specific territory.

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