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Low-carbon development of Russia: problems and prospects

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Abstract

This publication presents the results of research aiming to study the possibilities of promoting measures that could help reduce the impact on climate by replacing fossil fuels with alternative, carbon-free (renewable) energy sources, and implementing technological innovations. The study examines long-term scenarios for greenhouse gas emissions in Russia and their implications for the environment, public health and other spheres. Based on the results of the analysis, it offers recommendations on possible strategies to mitigate the impact on climate over the periods up to 2030 and 2050. These recommendations can serve the purpose of designing policies that will contribute to the implementation of the international climate agreement adopted in December 2015 at the 21st Conference of the Parties to the UNFCCC in Paris.

Keywords

low-carbon development, clean transport, greenhouse gases, climate policy, strategy, carbon-free (renewable) energy sources.

JEL: O11, O13, O14.

Introduction

Greenhouse gas emissions in Russia have been increasing since 1999. According to the national inventory, between 1999 and 2013, total GHG emissions increased to 71% of those in 1990. The increase in emissions by an average of 1% per year contrasted sharply with the rapid growth of gross domestic product (over 60% overall) and industrial output. During this period, there was a divergence in the growth trajectories of gross domestic product and greenhouse gas emissions, the so-called decoupling effect. The global financial and economic crisis of 2008 caused significant adjustments to the development of the country's economy, which affected greenhouse gas emissions: in 2009, total emissions in Russia decreased by 5.7% compared to the previous year. In 2010-2013, there was an increase in GHG emissions by 6.4%; in 2013 the level of greenhouse gas emissions was (excluding LULUCF) 71% of 1990, and, taking into account carbon sequestration (LULUCF), 57% of 1990. According to BP data, in 2014 the emissions from fuel combustion in Russia decreased by 1.5%, energy consumption decreased by 1.2% (8 million toe), coal consumption — by 5, 8%, gas — by 1.0%, oil — increased by 0.9% compared to the previous year (Ginzburg & Dokukin, 2021).

At present, the structure of greenhouse gas emissions in Russia is similar to the respective structure in most industrialized countries; in terms of CO2 equivalent it is as follows: carbon dioxide about 80%, methane — 16%, nitrous oxide — 1.8%, fluoride — 2.2%. About 98% of direct anthropogenic CO2 emissions are associated with the combustion of fossil fuels, the remaining 2% are emissions from various types of production, e.g. cement production. In the structure of CO2 emissions by fuel, natural gas accounts for 51%, oil — 24% and coal — 25%; these differ from the world indicators: 20%, 42% and 38%, respectively. The largest contribution to the total GHG emissions continues to be made by the energy sector — about 45%, metallurgy — 11%, transport — 10%, building materials and chemical industry — about 7% (Semenov, 2022), which can be explained by the predominance of energy-intensive industries and low level of renewal of fixed assets. Given the large share of industrial production in the Russian economy and its growth rates, it is becoming increasingly important to take these numbers into consideration when developing GHG emissions regulation.

Methodology

According to the national GHG inventory of Russia made in conformity with the prescribed classification of sources of GHG emissions and their removals, which is annually submitted to the UNFCCC secretariat, the most significant emission sources are the energy, land use and forestry sectors (LULUCF), with energy sector understood in a broad sense as including extraction, transportation, processing and consumption of fossil energy resources. The key factor that will determine the dynamics of GHG emissions in Russia in the coming decades is investment in modernizing production technologies and industrial capital; it is also crucial

to radically improve management and consistently encourage innovations in both production and consumption.

Energy consumption still generates massive emissions; the situation is changing very slowly although it has been proved that the use of energy-saving technologies in this sector can reduce Russia's total energy consumption by 40-48%. About a third of this saving potential is in the fuel and energy complex, another third is concentrated in construction and other industries, over a quarter — in housing and communal services, 6-7% — in transport, 3% — in agriculture (Ivanov et al., 2021). The dynamics of GHG emissions in Russia largely depends on the country's economic growth rate and its characteristics, structural reforms, taxation, innovation, investment policies, the pace of introduction of modern technologies, environmental regulation and a number of other factors.

Economic growth is one of the main causes of higher demand for energy resources. Rising GDP often leads to increases in demand for energy and, accordingly, in energy consumption followed by growing emissions. However, this dependence is not unambiguous. GDP growth can result from significant structural shifts in the economy, improved labor productivity or the use of new technologies that are often more energy efficient. Indeed, expanded services sector and greater share of high-tech and innovative products in output are not as a rule energy-intensive. International research into the correlation between greenhouse gas emissions from burning fossil fuels and GDP per capita shows that countries with higher per capita incomes have higher emissions, but, after reaching a certain level of income, the growth rate of emissions slows down. The carbon intensity index, calculated as the ratio of CO2 emissions to GDP, generally decreases as GDP is growing. This indicator, however, depends on many factors and is difficult to predict without certain specific data. For example, judging by the experience of France and Germany, an increase in the share of nuclear and/or renewable energy in a country will lead to a significant reduction in carbon intensity. Similarly, the use of new, more efficient technologies in production and consumption will also lead to a decrease in this indicator.

Strategies and long-term development goals

To estimate the amounts of GHG emissions in the long term, it is first of all necessary to construct realistic scenarios for the development of the economy that include structural changes, technological progress and many other aspects of economic existence of the country. In Russia, this task is performed both by public authorities, primarily the Ministry of Economic Development of the Russian Federation, and by research and expert groups. In today's international environment and economic conditions determined, among other things, by sanctions against Russian enterprises, falling energy prices and limited access to capital and technology, it is rather difficult to make forecasts for the economy as a whole or its individual industries. The slowdown in Russia's GDP growth, increasing inflationary expectations, sharp decreases in the rouble exchange rate and capital outflow — all these will certainly have a significant

impact on the development of the Russian economy in the short and probably in the medium term (Auzan et al., 2022).

In conditions of great uncertainty, in the near future it will be necessary to adjust the fundamental strategic documents outlining the development of the Russian economy and its key industries, e.g. the country's Energy Strategy. By the time of writing, however, no official documents that take into account the impact of new conditions on long-term economic development have been released and so the scenarios of economic development and the forecasts of greenhouse gas emissions in Russia are based on the previously adopted targets and indicators. Given the long-term nature of greenhouse gas (GHG) emission projections, the evolution of emissions up to 2030–2035 is likely to depend more on fundamental economic and technological factors than on the short-term effects of the imposed sanctions. An important factor of the dynamics of greenhouse gas emissions in Russia is the size of the population (Papenov, 2020) that determines domestic demand for energy-intensive products, consumption of energy resources (heat, electricity, fuel), household waste, livestock emissions, and other parameters. According to some estimates, the depopulation trend that began in 1990 will lead to a reduction in the population to 137 million people in 2030. The UN scenarios for 2030 make pessimistic forecasts: in the worst case, the population of the country could be reduced to 92.4 million people by 2050. In our calculations we use the conservative estimate of the Russian population of 120 million people by 2050.

Structure and dynamics of energy development

For the production of primary energy, Russia consumes about 700 million tons of oil equivalent of energy resources, about 90% of which are fossil fuels, i.e. oil, natural gas, coal. The remaining 10% come from low-carbon energy sources — nuclear, large hydropower and renewable energy (in 2012 its share was 0.1%). Long-term plans of development of Russia's energy sector are determined by the Energy Strategy designed by the Russian Ministry of Energy with the participation of state bodies, research institutions and business organisations; the Government of the Russian Federation's Decree dated November 13, 2009 No. 1715 officially approved the Energy Strategy of Russia for the period up to 2030. In the long-term forecasts of the Russian Ministry of Energy, the dominant role in energy supply is still assigned to fossil energy resources. With an increase in domestic energy consumption by 24% in 2035, the ministry expects gas consumption to rise by 24% and coal by 9%, while no changes are anticipated in consumption of oil.

It is also worth noting that the technological base of the economy is close to the "upper limit" of emissions typical of countries with a similar level of per capita income. This may be explained by the peculiarities of the Russian economy, which is dominated by energy-intensive industries, and by continued use of outdated equipment inherited from the USSR. According to the Federal State Statistics Service, more than 70 percent of the production equipment in the cost structure is older than 20 years, which means that it was most likely installed during the Soviet period. About half of the equipment

used by the large and medium-sized industrial enterprises is morally obsolete and physically worn out.

One of the most practical ways to reduce greenhouse gas emissions in Russia is to promote energy efficiency and energy saving. The International Energy Agency estimates that energy efficiency measures will reduce global GHG emissions by 40% by 2050: 24% in the end-use fuel sector, 12% in electricity consumption, 7% in electricity generation and by switching to cleaner fuels. Russia's potential for energy efficiency has been assessed by various organizations and expert groups. One of the latest studies by the World Bank and CEEF claims that Russia can "save" up to 45% of primary energy consumption if it implements a set of related measures. A study by the Energy Balance Forecasting Agency (APBE) shows that the energy saving potential that can be realized by 2020 reaches 250-275 million tons of standard fuel per year, or about 63% of Russia's total potential. It estimates the total energy saving potential at 420 million, with 70% of this amount to be found in the five largest sectors, i.e. residential sector, electric power, industry, transport and heat supply. The size of the economic potential exceeds the amount of electricity and heat produced in the country minus generation losses, and accounts for more than a third of all fossil fuel consumption in Russia (excluding large hydropower). This means that replacing fossil fuels with alternative energy sources is feasible: the use of its impressive economic potential may increase the share of renewable energy sources in the country's energy balance up to 25-30% releasing additional amounts of natural gas and oil for export (Nikonorov & Huseynova, 2023). These estimates do not take into account the territorial location of energy sources and demand for energy or the problem of timing between energy supply and consumption. The potential of renewable energy sources becomes especially significant given the minimal greenhouse gas emissions from their use in comparison with fossil fuels. Not only can Russia replace traditional fuels (gas, oil, coal) with alternative ones; in the future it can take a leading position in the field of renewable energy, in the market for renewable energy technologies, and ultimately become a major exporter of carbon-free types of energy resources (Nikonorov et al., 2020).

The global development of low-carbon technologies is one of the most effective ways of reducing the impact on climate system. An important source of information on current and future technologies is the International Energy Agency (IEA), which publishes special reports on this topic. IEA materials have been used to model GHG emissions in many studies. They show that the numbers of new trucks and cars using hybrid or electric engines, fuel cells (hydrogen), and liquefied gas are going to be really impressive, with the scale of implementation of up to 350 million units by 2050.

The decrease in the costs of using decarbonization technologies in the electric power industry is another significant indicator. For some of these technologies, cost reductions could reach 77% (solar) by 2050: the cost of hydrogen fuel cell vehicles is expected to fall by 79% and that of electric vehicles by 58%. In power generation, however, there are additional obstacles: for example, a coal-fired thermal power plant on average has a service life of about 40 years or more. Commissioning, construction

and exploitation of such power facilities create a strong inertia in the whole energy system, which makes switching to other types of energy resources practically impossible even if the necessity arises as no technical preparations were made in advance. In this respect, the benchmark to follow is the experience of the People's Republic of China (Nikonorov et al., 2023).

The low-carbon transition scenario assumes the existence of a strategy and action plan to stimulate low-carbon development and their effective implementation in the key sectors of the economy, i.e. energy, transport, construction, communal services and manufacturing. Model calculations proceed from the assumption that the Russian economy and its key industries will grow at a high rate, the welfare of the population will increase, and effective measures will be taken to introduce low-carbon and carbon-free technologies (Tarkhov, 2019).

Significant reduction in GHG emissions after 2030-2035 can be achieved through the use of carbon capture and utilization (CCS) technology, which is believed to be currently available in Russia for commercial use. Also of great importance for the decarbonization of the economy is the large-scale use of renewable energy sources (RES) and other carbon-free energy sources. Upon reaching the Paris climate agreement goal of two degrees Celsius (2015), the structure of energy sources should undergo radical changes: coal combustion is to be reduced to almost zero, about 90% of gas should be used in universal gas mixtures (UGS), up to 22% of energy can come from nuclear generation, 28% from large hydroelectric power plants; the share of the wind energy is to be 12%, and solar energy 7% (Bokuchava & Semenov, 2022). Redistribution between energy sources can be achieved through changes in the cost of technologies used and in availability of necessary resources. For example, nuclear power generation can be replaced by renewables and biomass from waste; Russia has vast resources for this. The possibilities of increasing generation at large hydroelectric power plants are rather limited due to physical and technological, environmental, socio-economic conditions, so it is possible to replace the "falling" amounts of energy generation in this segment with other carbon-free sources.

It is possible that Russia and other countries will attain the goal set in the Paris Climate Agreement and the global temperature will not exceed 20C by 2050. Taking into account the growth of the world's population, one can expect that at this level the increases in the concentration of greenhouse gases (GHGs) in the atmosphere will be contained and climate change moderated — on condition that the country modernizes the main sectors: energy (electricity and heat generation), transport, metallurgy, construction, energy consumption in buildings and structures; these account for about 80% of CO2 emissions in the country. Model calculations have shown that keeping the global temperature below 20C may be attainable under various scenario assumptions: there is a fairly wide range of options for solving the problem of decarbonization of the Russian economy, and the choice of one or another option depends on the country's strategy and political decisions. It is necessary to point out that such a significant reduction in greenhouse gas (GHG) emissions should not mean a deterioration in the population welfare or drop in Russia's energy consumption (Snakin, 2022).

According to some scenarios, GDP per capita is expected to grow approximately 3.3 times between 2010 and 2050: the demographic situation, according to Russian researchers, will improve by 2050 and there will be an increase in final energy consumption by at least 25%. At the same time, the costs of transforming the economy towards decarbonization, according to our data, are not much higher than the costs associated with maintaining the current economic model and energy infrastructure. It should not be surprising because the need to ensure extraction, transportation and use of fossil fuels involves ever-increasing costs. According to the CEEF projections for the future until 2050, at the current rates of production and export of oil and gas Russia will not be able to ensure economic growth and self-sufficiency with only these energy sources; it will therefore be vital to change the energy generation model in Russia if the country is to maintain its potential for economic growth.

An important effect of the development of a low-carbon economy is the creation of new jobs. According to the International Institute for Systems Analysis, the growth in electricity generation using renewable energy sources leads to an increase in "direct" employment in construction, production of materials and components, management — up to 614 jobs per 100 MW, as well as an increase in "indirect" employment to 4666 jobs per 100 MW. Taking into account the results obtained in our study, by 2035 there will be an increase in energy production using renewable energy sources (RES) up to 95.7 TWh per year, and we can estimate additional "direct" employment in the field of RES, which will be more than 1.2 million jobs, and "indirect" employment — 6 — 8 million jobs (Bobylev & Porfiriev, 2018).

In the course of extensive research, assessments were made of the effects of implementing measures to reduce greenhouse gas emissions in the energy sector, primarily from thermal power plants and boiler houses in large settlements. It has been shown that decreases in chemical air pollution will lower the risks to public health. Scenarios with GHG emissions reduced to the level of 20C are associated with deep decarbonization of energy generation and economy as a whole. Its large-scale side effects include decreases in environmental pollution, morbidity and mortality from the dangerous impact of technologies used for extraction, transportation and consumption of fossil fuels (primarily coal) and many others. The development and implementation of green technologies will not make Russia less competitive. On the contrary, it will strengthen the competitive positions of domestic business in the emerging international low-carbon economy, help it find and capture new markets and ensure the implementation of the UNFCCC and the UN Global Development Goals.

One of the promising green technologies is hybrid systems that can use both renewable and conventional energy sources, including uninterruptible power supplies that store energy when it is available and release it from batteries when needed. In the Republic of Altai, small-scale power generation is widely used in hard-to-reach and sparsely populated areas. Hybrid autonomous power systems using renewable energy sources are used in many settlements of Altai (Suronash, Yailyu, Balykcha, and others), where it is difficult to provide centralized power supply. One of

the most notable examples of the use of autonomous power supply is the case of the city of Barnaul, where in 2007 a new house owner faced a dilemma: to connect it to a centralized power supply and pay a fairly high price (about 2 million roubles) or, following the advice of a friendly engineer, install an autonomous power supply, save more than 20% of the amount asked for the centralized one and be independent from electricity suppliers. The house owner chose the second, innovative option. He had the building improved — the walls made thicker, special window openings added — and the energy efficiency of the building significantly increased, which is especially important at winter temperatures below 400C. Solar panels were installed, with reasonable precautions against snow and pollution, a wind generator as an additional source of energy and a diesel generator as a backup. The main problem, as shown by operating experience, consists in energy storage. None of the batteries of domestic or foreign manufacturers retained the power declared in the technical passport for more than 1 year. The purchase of new and additional disks became one of the main items of the house-owner's expenses.

Results

The development of renewable energy sources has a wide range of positive social effects that include:

1) healthier population: as a result of switching from coal and other fossil fuels to renewable energy sources, there will be a substantial reduction of atmospheric air pollution by harmful, often cancerogenic substances, such as mercury, arsenic, heavy metals and fine particles, among which PM2.5 and PM10 are especially dangerous as they penetrate into the blood through the alveoli of the lungs; this will lower the risks to human health (premature mortality, morbidity, especially in children and the elderly);

2) improved quality of life of the population owing to equipping houses with electrical and other household appliances;

3) more reliable power supply, enabling food processing and storage, especially in remote areas;

4) improved remote access to information (Internet, means of communication), which is especially important for providing the necessary medical care and consultations, making appointments for examinations and medical services;

5) obtaining additional income related to the use of energy (tourism, animal husbandry, agriculture and others);

6) job creation in the distribution and installation of renewable energy sources: young people are more willing to return to their native places, to their shepherd parents, to remote settlements where renewable energy sources are now used.

According to local residents, with the advent of small-scale power generation the quality of life in remote areas has been radically improving. The use of renewable energy sources is also important from gender perspective.

The results of research and discussions in academic and expert communities indicate that there is an urgent need for business and public organizations, regional governments and the Government of the Russian Federation to implement the necessary measures aimed at designing a strategy for low-carbon development of the Russian economy. The strategy should serve to reduce emissions and speed up the removal of greenhouse gases. It is absolutely vital that measures are taken to increase the competitiveness of the country's economy through improving the welfare of the population, provide better employment opportunities and reduce adverse effects of economic activity on human health. When designing these measures, the policymakers need to safeguard the interests of various groups of the population including the gender aspects of development, in other words, encourage inclusive growth.

The country also needs a strategy for low-carbon development over the period up to 2050, with synchronized target indicators for individual industries and sectors of the economy. Its ultimate goal is to reduce greenhouse gas emissions in accordance with the global target of preventing the temperature rise by more than 20C. In this regard, the most urgent needs are, first, to develop a roadmap to achieve the national objective of ensuring that the level of 2030 GHG emissions does not exceed 70% those in 1990 and, second, to create an appropriate mechanism that will be checked for accordance with the Paris Agreement on Climate every five years. Based on the analysis of the opportunities for decarbonization of the economy in the long term, it is possible to determine priority goals and objectives for the development of low-carbon technologies, which include creating new materials, promoting activities in agriculture and forestry to reduce emissions and increase the removal of greenhouse gases, and improving waste management.

It is extremely important to develop a set of measures to monitor technological development and implement breakthrough low-carbon technologies, products and materials that can help reformat the global economy in general and the Russian economy in particular. It is necessary to identify threats, risks and opportunities for the Russian businesses involved and ensure participation of domestic enterprises that will need to obtain expertise in manufacturing, technology and business activity connected with the "fallout" of new low-carbon development trends. The most serious attention should be paid to the technologies that ensure low-carbon development, i.e. renewable energy sources including solar, wind, geothermal, tidal, biofuels and others. The potential of renewable energy sources in Russia is enormous: it is many times greater than the annual production of primary energy in the country.

The cost of many types of renewable energy technologies is declining as the scale of their introduction in the world increases. It is expected that between 2020 and 2050, the costs of renewable energy technologies will fall by 77% or more. In Russia, the level of expertise in energy saving and energy efficiency technologies is extremely low, while the potential for reducing fuel consumption when implementing energy efficiency measures reaches 420 tons of reference fuel. The current policy, however, does

not provide for the opportunities for practical realization of this potential. Moreover, certain retreat has been observed (the termination of federal funding for the energy efficiency program).

As part of resistance to climate change, experiments are being held and several projects implemented in different parts of the world. So far, the results have not been satisfactory because of high costs and inadequate technologies: for many countries, the implementation of the climate goal of the Paris Cooperation will not possible without CCS technologies. Russia has experience and specialists who can search for technologies replicated within the framework of international projects related to low-carbon and carbon-free transport, such as road and freight, air transportation and pipeline transport, where there have been radical changes in terms of environmental safety and carbon regulation. Many countries have successfully stimulated demand for electric and hybrid vehicles and the gasified modes of transport, at the same time promoting research on hydrogen transport that uses fuel cells despite the increased risk involved, which will require electric charging stations, "smart roads" systems and other infrastructure to use special protection technologies. (Kudryavtseva & Baraboshkina, 2021). The scale of development of the market for low-carbon transport was tens of millions of units of new cars annually by 2020, and in 2030-2050 it will amount to hundreds of millions of units (Kudryavtseva et al., 2021; Semchenkov, 2020; Semchenkov, 2021).

At present, many countries, including Russia, lack expertise in energy storage devices. Inexpensive energy storage is therefore to become a priority of global low-carbon development. The introduction of such technologies on a global scale will need a change in the entire energy value. This is a direct way to abandon, and not only in agricultural or remote areas, the centralized energy supply in favour of decentralized and highly autonomous one both for the population and enterprises, which will in turn stimulate the introduction of renewable energy technologies for consumers' own needs and their transition from centralized energy systems.

Aready now, ecological farms use a mixed system, where energy sources are combined with electric transport and completely consume autonomous energy supply. In Russia, there are research laboratories involved in developing energy storage technologies, but so far this area has not received the attention it deserves. This contrasts sharply with the 52 active measures taken by the world's leading companies (including Tesla and others). The Energy Strategy of Russia needs adjustments to take into account the tasks of low-carbon development and decarbonization of the energy and economy for the period up to 2050, as well as the goals and commitments adopted in the Paris Climate Agreement. It is vitally important to give priority to low-carbon energy in Russia so that business community, innovative companies, inventors, developers of low-carbon technologies, financial and investment institutions could actively work in this direction. The country needs clear, firm and ambitious goals to increase the absolute volume of energy production from carbon-free sources including renewable energy sources, to build low-carbon transport infrastructure and autonomous energy supply systems (Akimova, 2020).

It is extremely dangerous to fall into the so called carbon trap when the industries using fossil energy resources will secure the use of the current carbon-intensive production processes for decades to come, e.g. continue to build coal-fired power plants that normally pay off in about 30-40 years. There is also the problem of excess capacity in the electric power industry. With a total installed capacity of about 250 GW, only about 60% (at peak load) is currently used, according to the Russian Energy Agency. At the same time, more than 90% of fixed assets in the electric power industry were introduced decades ago in Soviet times, and obsolete electrical and heat networks account for more than 70%, according to the Federal State Statistics Service.

Measures to support alternative uses of coal

In a low-carbon economy, the role of coal will obviously be drastically reduced through various regulations, including a ban on its combustion without CCS technologies. Russia's coal reserves are enormous: at the current rate of production and consumption they will last for hundreds of years; its coal industry employs a huge number of enterprises, financial and investment companies and research institutes. This is a very socially intensive industry and the issues of industry survival in the new low-carbon economy are very sensitive. It is necessary to abandon the position of "not noticing" the challenges facing the coal industry in the transition to a new model of low-carbon development. There is a large arsenal of tools that include coal-chemical technologies, coal gasification, extraction of mine methane and methane from coal seams, integrated use of coal (isolation and utilization of all useful chemical elements), and others. At the same time, it is necessary to ensure the fulfillment of social and environmental requirements for the projects in the development of the coal industry in the new conditions. The alternative use of coal will help overcome the problem of divestment (withdrawal of investments) in the coal industry, which many countries have in common.

Not only international organizations (the World Bank, the EBRD, etc.) refuse to support coal projects, but also the largest institutional investors — pension funds, insurance companies and others — that manage long-term investment resources in the amount of several trillion US dollars. There is an urgent need to explore the application of carbon capture and utilization (CCS) technologies in Russia. These technologies are not yet well understood, although the oil industry has long used the method of injecting the gas mixture of carbon dioxide, methane and some other substances into oil wells to pressurize and produce oil. Depending on local conditions, geological structures or deep reservoirs for gas injection and many other factors, oil producing companies use various CCS technologies. Russia should take into account global and domestic experience (for example, in the oil and gas sector), prospects and plans for the use of CCS in Australia, USA, Canada, EU and other countries. We need to look into the possibility of implementing pilot projects and participating in joint international initiatives on CCS. Without the use of CCS technologies, it may not be possible to achieve the goal of limiting global temperature rise to no more than 20C.

The analysis of the results of the study of deep decarbonization of the economies of 16 largest countries allowed the author to assess the potential of and develop a set of measures for the implementation of export-oriented projects in the field of carbon-free energy. In a low-carbon economy, priority will be given to energy resources, materials, products and services produced with a minimal carbon footprint. Already now it is necessary to determine promising areas for the participation of Russian enterprises. The country has huge resources for producing green energy: tidal power plants and other renewable energy sources can produce carbon-free electricity that can be exported via modern (superconducting) power lines or as hydrogen, liquid biofuels or next generation fuels for cars and aviation. Development of energy storage technologies, production of nanotubes used in basic materials (plastic, cement, rubber, aluminum) is to radically improve their strength and other properties, such as increasing batteries service life without changing power.

Highly science-intensive energy products can become alternative to the export of traditional energy resources and energy-intensive products, such as metals or chemical products. It is advisable to enter into international agreements to promote such projects and products in key partner countries, including China, India, Brazil and facilitate the introduction of new standards for the carbon intensity of products and production processes among the Russian enterprises. Along with the planned activities to develop a system for monitoring and reporting on GHG emissions and carbon regulation measures, this will contribute to the involvement of businesses in the reduction of GHG emissions, optimization of carbon performance indicators, and reduction of risks arising from tightening regulatory mechanisms at the international level, e.g. related to products delivery to the EU or USA.

Conclusion

In the near future, Russia will need to develop and adopt a long-term strategy for the development of forestry (until 2050 and beyond), taking into account the tasks of adapting to climate change and increasing the carbon sequestration function of Russian forests. Current measures to combat the effects of climate change in forestry are ineffective. This is due both to the organizational and legal system of management in the industry, and to the lack of incentives to preserve the ecological and climatic function of forests. Without large-scale measures to conserve forests until 2040, the problem of a sharp decrease in the carbon sequestration potential of forests will arise, caused by deterioration of the age structure and species composition of forests, increase in the frequency and scale of forest fires due to a drier climate, the spread of forest diseases and pests (Canada experienced this in the late 1990s), deforestation without proper reforestation and other factors.

The loss of the climate-regulating function of the boreal forests of Russia as a major source of carbon sequestration will have global consequences, spurring an increase in the concentration of CO2 in the atmosphere and the processes of climate change

(global and local). BCG experts called the ability of Russian forests to absorb carbon three times underestimated. According to them, it could reach 1.8-2.2 billion tons of carbon equivalent per year, although this figure is now considered to be 0.6 billion tons […]. The value of such a takeover could range from $9 trillion to $57 trillion (now estimated at $4-17 trillion). All this, experts believe, can allow Russia to take a leading position in combating climate change. But this will require a change in approaches to the strategy of accounting, protection and management of Russian forests. When implementing strategies, programs and plans for low-carbon development at all levels (federal, regional, municipal, corporate and individual projects), it is necessary to take into account economic, technological, environmental, social consequences, including the impact on environmental pollution, public health, gender aspects of implemented policies and measures. It is necessary to conduct special studies to assess the impact of low-carbon development on employment, the quality of new jobs created, the risks of job losses in certain industries, such as coal mining, and regions. According to available international studies, a large number of jobs for highly qualified specialists are created in the renewable energy (RES) sector, and even more jobs are created in related sectors.

At the same time, employment is often local in nature, that is, jobs are provided to local residents, including in remote areas. At present, there are very few studies in Russia on the gender aspects of economic development and the negative effects of climate change. Meanwhile, the world is paying more and more attention to this problem. It is widely believed that women are the most vulnerable and more affected by climatic factors than men. Caring for children, elderly family members mainly falls on the shoulders of women; not only financial costs, but also huge expenditures of time, health, efforts to overcome family problems are often their prerogative. The development of low-carbon technologies can have many positive effects in terms of gender: increasing employment opportunities for women, reducing household energy costs, improving air quality and the health of family members, especially children.

Russia needs a breakthrough in this area in order to obtain expertise in the field of low-carbon technologies, create scientific schools and begin a long process of building the country's human resources potential. Without this, it will be impossible to achieve a competitive position in the world's low-carbon economy, hence the need for such "fire-fighting" measures as methodological and organizational changes in the work of organizations responsible for the design and technical documentation for all significant investment projects, which often have an extremely insufficient level of competence in the use of low-carbon technologies and alternative energy supply options. It is necessary to expand cooperation with scientific and educational centers of the advanced countries and the leading companies in the low-carbon technology markets, expand the support for international initiatives and programs for the global development and decarbonization, primarily the CIS, SCO, BRICS. For these purposes, the Russian organizations should participate more actively in the work of the Green Climate Fund, through which a significant portion of international assistance is channelled to developing countries for climate change adaptation and reduction of greenhouse gas emissions.

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