

Climate Risk Factor in an Innovative Development Strategy

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Abstract—Climate change as a new factor of innovative development of the global and Russian economies is examined. Adaptive and preventive innovations are defined and analyzed. The former ensure a decrease of the residual risk, i.e. the expected level of damage after the necessary and effective measures for reducing anthropogenic emissions of greenhouse gases have been implemented. The latter ensure the implementation of the mentioned measures and a decrease in the level of the anthropogenic risk of climate changes and economic loss caused by them. The article shows that the practical realization of both types of innovations requires a set of institutional, scientific, and technical innovations, the central issues of which are the improvement of the legislation and normative-legal regulation, and eight “packages” of critical technologies. The particular importance of the studied innovations is proved. Their multiplier effect runs beyond the “just climatic” range, because their development and implementation originally stipulate and practically solve problems of productivity, reduction of environmental pollution, and secure human health.

Keywords: climate, global warming, risks, laws, knowledge, innovations, new technological structure, low carbon economy.

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INTRODUCTION

An effective response to economic development challenges related to climate change is only possible through the integration of the climate risk reduction task and a sustainable economic development strategy. On the one hand, it implies that economic development oriented towards an improvement in the quality of life is a source of means and mechanisms of adaptation of the economic complex and population to climate change and reduction in risks of such changes. On the other hand, it implies that climate change risks are considered and estimated together with other risks related to sustainable socioeconomic development. Only on this ground, the place of the global warming problem within the range of main challenges of this development can be defined. Both cases require conditions, such as a quality improvement of the knowledge base and knowledge management system, primarily, in Earth, natural, and engineering sciences, which ensure the successful development of technologies, in particular, in the energy sector, transport, and construction materials, providing a climate change risk reduction. It is necessary to increase significantly the financing of the corresponding research and development works; in the meanwhile, particular attention should be paid to interdisciplinary research and development.

Moreover, quality changes are necessary in science and education management in areas related to the cli-

mate risk problem, and it is an extremely wide field of innovations, research, and development, which is virtually as large as such a science-based area as defense and security. The knowledge-based economy meets these criteria. Its formation is not only a political and economic imperative, but also an ecological one. Taking into consideration the situation, which emerged in the 2000s when Russia lost its leading positions in a number of key directions of scientific development (especially innovations), and still has a high level of research and development works in other directions, several urgent measures are considered rational to be taken.

At the *federal level*, first of all, it is necessary to amend the Federal Law on Science or to enact a new law where the main emphasis will be on the competitiveness of Russian scientific research results, education system, and academic staff training, which ensure the economy's ability to compete. At this point, the America COMPETES Act of 2007 is worth a close studying, but not copying. Concerning the country's existing risk to lose its leading positions in the area of science and innovation in the foreseeable future, this legislative act stipulates increased investment volumes in research; strengthening of the education system in natural science disciplines, mathematics, in the sphere of technologies and engineering, starting from secondary school and finishing with higher education institutions; and development of the national infrastructure for innovations.

As regards the concerns of the fields of concrete sciences and technological advances, which are directly connected to the climate risk factor, it is necessary to emphasize the need for institutional innovations related to the development of knowledge on alternative energy sources and corresponding technologies. This development will give a new quality level to economic growth in the medium and long term, ensuring a reduction in greenhouse gas emissions (and polluting substances) and simultaneously providing energy saving and energy efficiency of economic activities (this is probably the main issue for the foreseeable future). The following regulatory acts, which determine the state policy in this area, have already been enacted: the Decree of the President of the Russian Federation "On Some Measures to Improve the Energy and Environmental Efficiency of the Russian Economy" no. 889 dated June 3, 2008; the Order of the Government of the Russian Federation "The Main Directions for the State Policy to Improve the Energy Efficiency of the Electric Power Sector on the Basis of Renewable Energy Sources for the Period until 2020" no. 1-r dated January 8, 2009, which makes the former more specific; and also the Federal Law "On Energy Saving and Energy Efficiency Increase and Amending Certain Legislative Acts of the Russian Federation" no. 261-FZ dated November 23, 2009. These regulatory documents constitute the necessary legal basis of actions in the studied area of economic policy, but it is not possible to regard this sufficient; distinctly, it requires development and further concretization.

Corresponding amendments, which take into account the imperatives of the accelerated transition to an innovative way of development, including ecological and climate challenges, should also be added to the Concept of Long-Term Socioeconomic Development of the Russian Federation (until 2020). Fairly giving a priority among the directions of the Russian economy's transition to innovative socially oriented development to improvement in human development, establishment of a highly competitive institutional environment, which stimulates business activity and attracts investments, as well as to structural economic diversity on the basis of innovative technological progress, the document reasonably warns that based on this way during the period 2025–2030 the role of ecological and climate barriers can increase dramatically. At the same time, it is emphasized that, in case of a significant reduction in the environmental capacity of the economy owing to the variety of Russia's natural resources, these barriers create new unique development opportunities for the country. However, the document does not explain what these barriers mean for the economy, its separate sectors, and particular regions, but, otherwise, it is difficult to understand how to use the mentioned development opportunities and avoid the worst consequences. Also, there are no descriptions of ways and methods to lower the "height" of these barriers and to adjust the economy to

the new environmental and ecological conditions arising due to the objective impossibility of the complete removal of climate and other environmental threats and inefficient actions for their prevention (residual risk).

In particular, it is considered necessary to introduce into the legislation and regulatory documents a requirement for midterm development programs and long-term development strategies to include obligatorily packages of adjustment measures. Moreover, there is a need to expand the field of options of innovative technologies (without limiting oneself to only energy saving and renewable energy sources) and the risk reduction policy in general. For this purpose, among regulatory priority directions of scientific and technological development and crucially important technologies, it is necessary to focus attention and energy primarily on areas, such as conservation of nature, energy sector and energy saving, living systems, and also nano- and other technologies and materials, transport, aviation, space, information and telecommunication systems, which are related to the solution of the tasks of monitoring of the natural environment, developing alternative energy sources, and reducing emissions of greenhouse gases and polluting substances into the atmosphere and the world ocean.

At the *regional level*, while designing and carrying out investment projects, it is necessary to take into account and assess climate change risks and associated social and economic consequences in business plans or project documents. Moreover, these risks should be taken into consideration in procedures of environmental impact assessment of projects and environmental auditing of energy companies and other economic entities, which are sources of emissions. There is a particular need to emphasize the importance of government support for innovative (primarily start-up) companies which are carrying out pioneering projects in the area of energy saving and reduction in greenhouse gas emissions, including legislative support, financial state support, and tax exemptions for these companies.

CLIMATE CHANGE AS A NEW FACTOR OF ECONOMIC DEVELOPMENT AND OBJECT OF INNOVATIONS

According to expert estimates, over the period 1900–2008, the long-term average annual temperature in the world increased by 0.8°C, and, according to predictions until 2100, it can rise by 2–4°C causing serious ecological and economic consequences in the 21st century and later (e.g., see [1–3]). Estimates and predictions for Russia show the dynamics of its climate warming in the past, present, and in the near future, and it is higher than the world average. Over the period 1900–2000, temperature increased by 1.2°C vs. 0.6°C in the world on the whole; during the period 2001–2015, it is expected to rise by 0.6°C (vs. 0.4°C during the period 2001–2027 in the world in general).

There are predictions of considerable changes not only in temperature, but also in the precipitation regime and wind load. These changes already now lead to alterations in the economic environment, which are so significant that there is a good reason to speak about the formation of a new economy in the rather near future. Its composition will determine the new technological structure, the features of which will not only be postindustrial (or intellectual) society, clean energy, and bio- and nanotechnologies, but also a low-carbon economy on the whole. Beside the energy sector, it involves almost all sectors of the future economic complex, and the energy sector is considered to be based on not only alternative sources of energy instead of fossil fuels, but, in the first place, on energy saving and energy efficiency of the economy. In the meanwhile, climate fluctuations, which cause the above-mentioned fundamental economic changes, vary considerably in different countries and regions of the world, and these changes themselves will be rather contradictory (at least in Russia) [3]. For example, aggrandizement of territories appropriate for planting in Russia's northern regions, certain shortening of the heating period, and energy and fuel saving will be positive economic effects of climate change by 2015 in the agrarian sector, fuel and energy complex, and housing and communal services, respectively¹. The negative effects are the following: more aridity and higher risk of droughts in the south of the country, less wind energy potential, increment of pipeline load, worse preservation conditions of buildings and structures (because of exposure to water logging and deformations) [2, 4].

All this implies the necessity to take into account the climate risk factor in long-term plans of social and economic development, which is designed at all levels, and also in action programs, concrete arrangements of training for emergency situations related to changes in climatic conditions of the stated development and response to these situations [4] to ensure sustainable development. Moreover, it means Russia's transition to a new technological structure ensuring the implementation of the mentioned program activities and a climate risk reduction in two interrelated directions. *The preventive direction* provides for a reduction in the anthropogenic climate change risk which augments and aggravates the damage from its natural fluctuations. *The adaptive direction* provides for a flexible adjustment of the economy and society to the climate change consequences, which are not possible to be escaped because of the insufficient effectiveness of preventive and protective measures or because of limited knowledge about global warming, and also for civil preparedness for crisis situations (disasters).

¹ In the meanwhile, the expected environmental risks of the potential aggrandizement of the plant-growing zone and increased need in conditioning and air cooling, which reduce the mentioned benefits, should not be underestimated.

The implementation of the mentioned directions of economic policy requires enormous expenses. As we estimate, the costs associated with risk reduction and adaptation to climate changes can make at least 0.4–0.5% of GDP. This range of expenses, if they were related exclusively to greenhouse gas emission reduction and adaptation to climate changes, would rather mean economic growth deceleration, which is hardly acceptable for Russia. They only become efficient when they not only ensure a reduction in the damage from global warming, but also resource savings, increase in the production of goods, their more just distribution, and better environmental conditions from the point of view of human health (“double dividend” effect). That is why a higher quality of economic growth should be the main objective of the sustainable development strategy and policy, and mitigation of climate changes and their consequences for the economy should be regarded as an important and inherent complementary effect of this strategy.

A key tool of this policy is the national innovation system, which carries out innovations of both preventive and adaptive directions, while the *innovation* category goes beyond the notion of scientific and technical (including technological) innovations, as it also covers management (or rather organization and management) of innovations. Such a wide interpretation of the notion of *innovation* is based on the concept of innovation as a process of transformation of an idea into a commercial product or service [5], a new or improved process of their production or distribution, or a new mode of rendering of social services. This transformation considers the existence of a flexible network of formal and informal institutions, including rules, regulations, and procedures, which creates an environment for national innovation system formation. Also, this network determines the methods of knowledge creation by individuals and corporations and modes (mechanisms) of their interaction, which ensure the market promotion of new products or new services.

INSTITUTIONAL INNOVATIONS: ADAPTIVE INNOVATIONS

The objective of institutional innovations of the adaptive type is to decrease the residual risk, i.e. expected climate change damage, which emerges after carrying out necessary and efficient measures to reduce industrial emissions of greenhouse gases and which, in any case, will be very significant, taking into consideration the amount of emissions accumulated until the present moment². These innovations include

² According to some estimates, even if all the Kyoto Protocol requirements and associated complicated technological challenges, including beyond 2012, were met, by the end of the current century, greenhouse gas emissions would only be reduced by about 4–5%.

a package of measures designed to improve the legal groundwork; legal, organizational, and economic regulation; and also the insurance protection of the population and economic entities against natural disasters.

It is necessary to emphasize the extremely important role of two adaptive innovation groups. The first one contains regulations and procedures, which introduce in national legislation a requirement for midterm development programs and a sustainable development strategy to include obligatorily packages of measures for economic and social adjustment to climate change. These measures should be aimed at improving the organization and increasing the effectiveness of the national system for the protection and saving of people and their property in case of natural disasters, including individuals suffered from a natural disaster, "environmental migrants," and "environmental refugees." The second group of adaptive innovations contains regulations and procedures ensuring the development of the national insurance system, which not only performs the function of damage mitigation *ex post*, but also *ex ante*, thus contributing to a decrease in the expected damage via a system of corresponding agreements (carrying out underwriting requirements by an insurer to ensure preventive measures aimed at a reduction in the expected damage, monitoring of their implementation by risk managers, etc.).

Emphasizing the importance of adaptive innovations and taking into account, on the one hand, the prolonged effect of already happened and happening climate changes on the economy and, on the other hand, the undervaluation of this factor in the current international regulations, we consider that at the same time it would be counterproductive to underestimate the role of institutional innovations of the *preventive type*, which provide for a reduction in the anthropogenic climate change risk and economic damage resulting from it. The question does not only relate to the fact that half of the damage from greenhouse gases emitted by energy companies is caused by miscalculations and oversights in the supervision and organizational management system³, the major part of which is related to legislative inefficiency, or to the fact that a large volume of vehicle emissions is explained by standards for engines and fuel, which are not rigid enough, and by the widespread use of environment-unfriendly second-hand cars. The enormous importance of institutional innovations of the preventive type is also determined by the fact that, to a certain extent, they stimulate the development of new ideas and technologies far beyond the "climate" range.

The designing and using of an overwhelming majority of scientific, technical, and technological

products, which contribute to a reduction in greenhouse gas emissions or improvement of natural resource use (primarily forests, which absorb a significant part of these emissions), are originally aimed at solving a wide range of economic and environmental problems. In the first place, these are problems of productivity enhancement, reduction of environmental pollution, and human health. That is why it is regarded necessary for Russia to improve its regulatory framework for savings fuel and energy resources, increasing efficiency, and expanding renewable energy resource use. The potential of the latter is enormous, but at present the production of electric power with their help comprises no more than 8.5 billion kWh per year (excluding hydropower stations with an output of over 25 MW) which is less than 1% of the country's total volume of electricity generation. A significant role in the energy industry's development in the indicated direction should be played by the above-mentioned regulatory documents of 2008–2009, which stipulate the setting of GDP energy intensity target values and increasing the share of renewable energy sources in the total electricity generation and consumption volume for the period until 2020. The corresponding index values are the following: a 40% decrease in the GDP energy intensity up to 2020 and an increase in the share of renewable energy resources up to 1.5% in 2010, up to 2.5% in 2015, and up to 4.5% in 2020.

During estimating the cited development target guidelines for renewable energy sources in the Russian economy, there is a necessity to emphasize two facts. On the one hand, the above-mentioned decree of the president of the Russian Federation and order of the government of the Russian Federation indicate a significant progress in this area of the Russian energy sector, which was neglected earlier. In particular, they reflect the policy of stimulating the use of renewable energy sources in the field of power industry with the help of budgetary measures of financial government support of the corresponding technologies until they reach real competitiveness with respect to energy technologies based on fossil fuels and also until they reach a necessary rate of investment in alternative energy. In this regard, the following provisions are of particular importance: concerning the fixation and regular refinement of the rate and effective period of the equilibrium price markup in the wholesale market in order to determine the price for electric energy produced by qualified generation facilities, which operate on the basis of renewable energy sources, and concerning the obligation of energy buyers acting in the wholesale market to purchase specified energy volume produced by the indicated facilities. On the other hand, governmentally fixed target growth indices for the share of renewable energy sources in the total electricity generation and consumption volume are regarded too insignificant, if one takes into account the world experience and contemporary challenges, including climate change risks for the economy.

³ According to the estimates carried out by the Institute of Economics and Industrial Engineering, Siberian Branch, Russian Academy of Sciences, 20% more is caused by low-quality equipment and hardware, 15% results from technological imperfections, and 15% is unavoidable emissions.

It is noteworthy that the above-mentioned political decisions were made by Russian leaders during the global financial crisis. To a large extent, it is related to the fact that the development of the energy sector based on renewable sources is not only regarded as an important direction for a transition to a new technological structure, but also as a powerful anticrisis measure and, first of all, as a measure to solve the unemployment problem. However, from our point of view, compliance with the above-mentioned insignificant target values can not only turn out for Russia to be a hindering factor for the economy's prospective modernization, but also extend duration and profoundness, social and financial costs of the economic crisis. In the context of innovative development and Russia's competitive growth tasks, the following steps are considered indispensable:

1. To increase the target growth index of the share of renewable energy sources in the total electricity generation and consumption volume up to 6%. In addition, it is connected with the high capital intensity and long payback period of investments in nuclear power plant construction as compared, for example, to small-scale hydropower stations and wind energy generators;

2. To approve a special program for energy intensity reduction by the largest companies (e.g., by 100 or 200 companies)⁴, which concentrate the major part of industrial production. This program should become a component of the long-term energy strategy with regard to increasing the industrial energy efficiency and can be implemented in terms of public-private partnership;

3. To change the advisory nature of the order of the government of 2009 to a mandatory one⁵. It will allow to raise essentially the effectiveness of the measures stipulated in the Order of the Government of the Russian Federation "The Main Directions for the State Policy to Improve the Energy Efficiency of the Electric Power Sector on the Basis of Renewable Energy Sources for the Period until 2020."

As for the main direction of quality improvement of the regulatory control system of climate change as a part of environmental development risks, apparently, it should be the stimulation of more efficient land use and resource consumption, including preservation of natural ecosystems, first of all, woods, as well as stimulation of efficient usage of fuel and power resources. According to the estimates of Russian scientists,

unpractical land use makes the principal contribution to the global anthropogenic emission of greenhouse gases and it exceeds the level of industrial contribution, primarily as a result of fossil fuel combustion (53 vs. 47%, respectively [6])⁶. Owing to Russia's primary forests, first of all, the taiga, the trade balance of deposition and anthropogenic carbon emissions is about 300 million tonnes per year. This is equivalent to no less than 11 billion USD⁷ of Russia's indirect subsidies to the world economy to mitigate global warming risks. To this figure, it is necessary to add the value of ecosystem services for the preservation of the planet's biodiversity and natural protection of territories from natural disasters. Therefore, the regulatory framework improvement must necessarily provide for a reform of the Kyoto Protocol after the mandatory period of validity, which ends in 2012, or its replacement, as it is necessary to consider the value of environmental services and Russia's interests in their compensation by the international community.

Moreover, the regulatory framework development should ensure a full-scale launch of a quasi-market mechanism of redistribution of the cost burden of owners of energy facilities on energy saving, which also contributes to greenhouse gas emission reduction. Until recently, Russia's lack of a relevant legislation has put obstacles on this way, especially the lack of a legislation which would deal with the crucial issues of ownership of the indicated emissions, a registration procedure, and a joint project (Russia and an investor country or a Russian company and a foreign investor) to reduce emissions. This situation should have been changed by the Decree of the Government of the Russian Federation "On the Procedure for the Approval and Monitoring of the Implementation of Projects in Accordance with Article 6 of the Kyoto Protocol to the UN Framework Convention on Climate Change" No. 332 dated May 28, 2007, which focused on the participation of Russian enterprises and companies in joint projects in order to reduce greenhouse gas emissions in Russia and to attract foreign investors as active players. Nevertheless, in fact, the excessive bureaucracy and complexity of procedures for the implementation of the mentioned projects determined the declarative character of this resolution and caused an enormous loss of profit for Russia.

⁶ This is quite comparable with the cost of noncompensable environmental services of tropical forests in developing countries. According to Joseph Stiglitz, if developed countries compensation for these services, developing countries will be willing to accept limitations in land use [7].

⁷ The calculation was based on the interval price of a ton of CO₂ in the global carbon market, which is equal to 10–15 USD (equivalent to 37–55 USD per ton of pure carbon). If we take as a basis for calculating the average price of reduction in emissions of a ton of CO₂ in OECD countries equal to 150 USD (550 USD per ton of pure carbon), the minimum market capacity will increase to 150 billion USD.

⁴ For comparison, in the Public Republic of China, a respective program is approved in relation to the 1000 largest companies, which produce one-third of the country's industrial production.

⁵ The last paragraph of the order is as follows: *Recommend to the executive authorities of the constituent regions of the Russian Federation and to local authorities within their jurisdiction during the formation of regional and municipal development programs to provide for implementation measures concerning provisions of the main directions, which are approved by this order.*

In general, the potential of energy-saving projects in Russia amounts up to 35–45% of the current level of energy consumption (360–430 million tons of oil equivalent, that is, 6 times higher than the world average), and the cost effectiveness of such projects is 4–5 times higher than that of developing new oil and gas fields. It is Russia that has the minimum unit cost of energy saving and greenhouse gas emission reduction; it is related to the high energy intensity of GDP and the significant moral and physical ageing of production equipment. The total investment in the reduction in greenhouse gas emissions in Russia is estimated at 20 billion USD. At the same time, there is demand from the international carbon market for the above-mentioned projects, and this demand is growing rapidly⁸. At the end of 2009, the Ministry of Economic Development of Russia had over 100 investment projects for approval (mainly from the energy sector) with a total potential of greenhouse gas emissions reduction of at least 200 million tons of CO₂ equivalent. In July 2010, the ministry approved 15 of 44 projects selected by Sberbank (the operator of carbon units) in the first contest, in which 35 companies took part. The total emission reduction potential of all approved projects is 77.5 million tons of CO₂ equivalent; at the current price on the open market of 11.8 euro per ton, that constitutes 472 million euro.

In addition to investments in the resource economy, the proposed economic mechanism provides for the introduction and regulatory consolidation of a system of differential tariffs for electricity, depending on the technology of its production, which establishes an advantage (in the form of subsidies) for technologies using renewable energy sources. In the more distant future, one more step could be made: like in Germany, to differentiate tariffs according to certain electricity generation technologies based on specific types of renewable energy sources, as well as according to the place of its generation.

Moreover, the proposed mechanism involves a combination of greenhouse gas emission taxes and creation of a domestic market for trading quotas (permissions) on these emissions. With the introduction of a tax system, it is advisable to use successful foreign experience. For example, Germany's law of 2007 concerning biofuel quotas provides for immunity from taxation until 2015 for companies producing secondary biofuels, which allows reducing emissions of these gases by 80–90%, and for the introduction of a corresponding tax on primary biofuel production [9]. The experience of the United States in the elimination of the use of leaded gasoline in internal combustion engines in the 1980s and the halving of sulfur dioxide emissions from thermal power plants from the 1990s until the early 2000s proved the cost effectiveness of

the quota-trading mechanism compared to a direct administrative ban⁹.

SCIENTIFIC AND TECHNOLOGICAL INNOVATIONS: PREVENTIVE INNOVATIONS

Among scientific, technical, and technological innovations aimed at reducing risks and adjusting the Russian economy to global climate change, the most distinguished ones are the groups of critical technologies, the list of which was approved by the president of the Russian Federation on May 21, 2006. Eight of these 34 groups, as well as an overwhelming part of the main directions of scientific and technological development, within the limits of which the above-mentioned technologies are developed and used, can be rightfully attributed to innovations for climate protection (see table).

Among innovations of the *adaptive type*, a major role is played by a group of crucially important technologies for reducing natural-disaster risks, including the development of early warning systems, means and methods of engineering and health protection of the population and territories from natural hazards, as well as disasters caused by climate change. Innovations of the *preventive type* include seven groups of crucially important technologies. They involve methods and technologies for monitoring and forecasting the atmosphere and hydrosphere; technologies of nuclear energy, nuclear fuel cycle, safe management of radioactive waste and spent nuclear fuel; hydrogen energy technologies; technologies of new and renewable energy sources; technologies of fuel and energy production from organic raw materials; and technologies of energy saving systems, heat and electricity distribution and consumption, transportation systems, and also energy-efficient engines and propulsion systems for vehicles.

By the number of patents for the indicated technologies, Russia ranks sixth in the world. In 2003, Russian technologies accounted for 4.2% of the global portfolio of these technologies, and South Korea and China had 4.6 and 5.8%, respectively [11]. This position of Russia as a world innovation periphery is explained by the fact that most of the considered Russian innovations (particularly in the field of geothermal energy, hydropower, and ocean wave and tidal power) are included in the above-mentioned list of crucially important technologies. Their creation is provided by the fundamental researches conducted at institutes of the Russian Academy of Sciences, which still manage to keep their position, and basic design works of some research and development institutions, which exist because of government contracts in the defense industry.

⁸ In 2006 it reached 30 billion USD, including the cost of joint projects, which totaled 141 million USD (the remaining main part is direct trading of emission quotas) [8].

⁹ Compared to the administrative measures, the savings from the introduction of emission quota trading made 250 million USD per year; for sulfur dioxide, they made about 1 billion USD [10].

Key technologies for energy saving and climate change risk reduction (according to IPCC experts)

Economic sector	Technologies used in global practice	Technologies which are expected to be used before 2030
Energy	Energy supply and distribution improvement; transition from coal to gas; nuclear power; renewable heat and energy (hydropower, solar, wind, geothermal, and bioenergy); combination of heat and energy sources; the initial application of technologies of carbon capture and storage (for example, storing CO ₂ extracted from natural gas)	Carbon capture and storage technologies used in power plants operating on gas, biomass, and coal; advanced nuclear power plants; advanced installations using tidal, wave, and solar energy (including photovoltaic cells)
Transport	Vehicles with more efficient use of fuel, vehicles with hybrid engines and cleaner diesel engines, use of biofuels, a transition from road to rail and public transport, non-motorized transport, land use and traffic flow planning	Second-generation biofuels; more efficient aircraft, advanced electric and hybrid vehicles with more powerful and reliable batteries
Housing sector	Effective devices for day and conventional lighting, more efficient electric appliances, heating and cooling devices, kitchen stoves, improved insulation of buildings, passive and active solar heating and cooling systems, alternative coolants, recovery and recycling of fluorescent lamps	“Smart buildings” (commercial buildings and structures with embedded control and energy-saving devices), houses with built-in photocells

New manufacturing “double-dividend” technologies are of particular importance; they imply a negative marginal cost of resource saving and greenhouse gas emission reduction. This means that the indicated technologies, which include, for example, improved technology for thermal insulation and lighting of buildings and water-heating devices, provide for a solution to both problems and, at the same time, for the saving of funds. In the long term up to 2030, in view of technological capabilities and the potential to reduce greenhouse gas emissions not only in Russia, but also in the whole world, the mentioned priorities of different sectors should be preserved. It is necessary to take the opportunity of not only more efficient resource use in agriculture and forestry, but also of processing waste, which constitutes a very large amount. These technologies are included in all of the above-mentioned lists of crucially important technologies, and, while being energy-efficient, they are obviously among the priority development directions of science, engineering, and technology in Russia.

These and other new technologies could hardly make their way, primarily because of the institutional disunion: the costs are incurred by certain market actors (investors, developers), but profits are gained by others (consumers who do not pay the resulting cost savings directly to the former). It is therefore necessary to use actively the management strategy of technological niches, in which these technologies are created, approved, tested, and/or used.

The risks associated with new technologies should also be taken into account when developing and implementing an energy strategy and be reduced to a socially acceptable level. Perhaps, this primarily concerns production and use of biofuels, the main one of which at present is bioethanol; it is produced from crop biomass. At the same time, production of ethanol from food and feed crops consumes a lot of the crop

(especially maize), which causes an increase in the price for maize and other crops (for example, wheat) and, later, for poultry and pork. In 2007, the price for chicken increased by 80–90%, which adversely affected the production and export of this product. By 2016, according to FAO and OECD estimates, for the same reason, food prices can rise by 20–50% [12]. Another consequence of the rapid increase in bioethanol production is a significant and rapid expansion of lands allotted for these needs to the detriment of the interests of agriculture and environmental protection. Associated structural shifts will mean a radical restructuring of the agricultural sector, a part of which will turn into a “green energy farm” with a risk of significant deterioration in the situation for peasants and farmers due to increased competition for lands and food prices, leading to growth in inflation.

There is a need to emphasize the lower energy efficiency (compared to gasoline) of bioethanol (for the same amount consumed, the distance traveled by a car is less for biofuel) and the very limited effectiveness of ethanol in the solution of the global warming problem (according to some estimates, the reduction in greenhouse gas emissions owing to the use of biofuels is 2–9 times less than the reduction obtained while implementing the above-mentioned programs) [9]. Finally, in recent years, some negative environmental impacts of bioethanol production and use have been revealed that have eventually given rise to logical doubts about its effectiveness. They were so serious that in September 2007 the OECD released a special report with the symbolic title “Biofuels: Is the Cure Worse Than the Disease?” [13].

It is important for Russia, which experiences problems both in the development of agriculture (including the crop sector) and in the environment’s protection from hazardous industries, to take into account all of these possible effects and doubts concerning the use of

biofuels. At the same time, if we take into consideration the above-mentioned, it is fundamental that Russia does not waste time and use the opportunities and benefits associated with biofuels in order to ensure a new quality of economic growth based on innovative technologies, especially in energy, which is a key sector of the economy. It is necessary to remember that, in the foreseeable future, biofuels and other renewable energy sources will not be able to exclude, but only supplement, fossil fuel technologies, which will remain actual for a long time. This is not just a technical reality, but a political and economic imperative. Therefore, Russia's strategy concerning the development of the energy sector in the foreseeable future should stipulate the use of all types of energy sources: both nonrenewable and renewable. It is significant that a similar strategy, which is called by international experts an "energy mix," is proposed by them as the most viable and effective one (as well as for the whole Europe) [14, 15].

CONCLUSIONS

Speaking at a meeting on the energy and environmental efficiency of the Russian economy in June 2008, the president of Russia noted that the current situation did not encourage the introduction of environmental and resource-saving technologies; it leads to persistent economic backwardness and waste and ultimately threatens the competitiveness of the Russian economy and negatively affects the country's innovative development. Therefore, stimulation (in different ways) in the use of the indicated technologies is identified as one of the most important directions of solving interconnected problems related to the energy and environmental efficiency of the Russian economy [16]. The above-mentioned measures implemented under the innovation strategy of development and formation of a "knowledge-based economy" in Russia at federal, regional, and local levels seem to be an important part of the corresponding stimulation mechanism and will help to solve economic (energy) and environmental (climatic) problems. It should also be promoted through the development of international cooperation in the field of renewable energy, which received a powerful impetus on January 26, 2009, with the establishment of the International Renewable Energy Agency (IRENA), i.e., an analogue of the International Energy Agency (IEA), which is well-known in the energy sector. Russia did not participate in the foundation conference that formed the IRENA; however, the agency is open for membership in any convenient form for our country and would be more than appropriate to use this promising institution of international cooperation.

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