Russia on the pathways to carbon neutrality: forks on roadmaps

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Authored by:

Igor Bashmakov

General Director
CENEf – XXI

Vladimir Bashmakov

Legal Counsel
CENEf – XXI

Konstantin Borisov

Leading Researcher
CENEf – XXI

Maxim Dzedzichek

Leading Researcher
CENEf – XXI

Alexey Lunin

Leading Researcher
CENEf – XXI

Oleg Lebedev

Researcher
CENEf – XXI

Anna Myshak

Leading Researcher
CENEf – XXI

Contents

Introduction

More than 160 countries have indicated some form of commitment to achieve carbon neutrality in 2030-2070.[1] The carbon neutrality goal for 2060 is specified in the *Climate Doctrine of the Russian Federation*. However, many of the decarbonization plans are not too specific. As a result, they are progressing too slowly, faced with increased protectionism, aggravated geopolitical problems (security, reliability of supply chains), and all this hampers progress towards carbon neutrality.[2] If low carbon action is to be clear, coordinated at all decision-making and implementation levels, and largely supported, we need a clear and understandable action plan – a roadmap – to transform the current raw material-based model of economic and socio-political development in Russia into an inclusive and fair innovative low carbon economy.

According to the *Cambridge Dictionary*, a roadmap is "a plan for how to achieve a vision or goal".[3] Alternative definitions of roadmap include: "the application of a temporal–spatial structured strategic lens";[4] "a strategic planning technique that places a project's goals and major deliverables (tasks, milestones) on a timeline".[5] The main advantage of roadmapping is not in the deep analysis, but in the use of structured visual representations of the interconnected diverse processes unfolding over time, which are required to achieve the set goals. This paper presents the first iteration, a "pencil sketch" of the future multi-figure composition.

Unlike typical 2D maps, carbon neutrality roadmaps require more dimensions and metrics. In this paper, there are five main pillars, or metrics, of low carbon policies: technologies; regulations, including strategies and programmes; financing and economic incentives to attract investment; institutes to develop and implement the required policies; and human capital to get all low carbon mechanisms moving in the right direction at the desired pace. Roadmaps should ensure coherence not only among all stakeholders within individual sectors, but also coordinate action across the sectors. It is important to ensure the consistency of action over time. Scaling up low carbon technologies requires a certain environment; it must be clear, who is doing what and when. For each sector, a roadmap should be the result of consultations with all stakeholders and experts. Roadmapping clearly incurs a confrontation between the groups with the traditional values of a raw materials-based economy on the one hand, and the emerging groups engaged in green technologies-based business, which are calling for the "de-fossilization" of the economy, on the other.[6]

The development of a Roadmap is urged by the fact that, in compliance with the Paris Agreement, Russia is to prepare the next Nationally Determined Contribution (NDC) in 2025 with a higher, level of GHG mitigation ambition to 2035; the next NDC is likely to be set in a Presidential Decree and will be submitted to the UNFCCC Secretariat. The *Operational Plan* also requires the approval of GHG emission reduction targets across economic sectors and industries by the end of 2024.

A roadmap is different from a plan or a programme. The latter have to provide a detailed description of the activities, set deadlines, specify the performers and resources for plans or programmes. One example is the *Action Plan (Operational Plan) for the implementation of the Russian low carbon development strategy to 2050*. A third version of the *Operational Plan* has

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[1] https://eciu.net/netzerotracker.
[2] ECF annual report 2022: Advancing climate action for a green, democratic and peaceful Europe - European Climate Foundation.
[3] ROAD MAP | English meaning – Cambridge Dictionary.
[4] Roadmapping is *"the application of a temporal–spatial structured strategic lens".* Phaal R. and C. Kerr. Guest Editorial: New Perspectives on Roadmapping: Foreword. February 2022. IEEE Transactions on Engineering Management 69(1):3-5. DOI: 10.1109/TEM.2021.3094961.
[5] Roadmaps – A Complete Guide with Examples, Tools & Tutorials (officetimeline.com).
[6] News (eceee.org).

been developed. This is a document of nearly 200 pages, which includes a list of government activities mostly to 2025, which are to ensure the implementation of the said Strategy (LTS).

It is important to launch a discussion of the pathways to carbon neutrality. This research is an attempt to come up with a carbon neutrality vision to 2060 for further discussion. It may be subject to criticism, perhaps even harsh criticism. But hopefully both the research and the discussion will give momentum to real action and to the transition from rhetoric to practice. The roadmapping process may be even more important, than the resulting roadmap.[7] This process helps imagine and, possibly, agree on a strategic vision of the future, which is not written anywhere. A consensus, as visualized by the government, might incur high risks, if the government only wants to hear its own voice or selects the stakeholders to take part in the discussion on the basis of loyalty. Any strategy or roadmap should be questioned and criticized. The opinion of a sceptic minority may be more valuable, than the opinion of a loyal majority.

There are many forks in the roadmap. The first fork is as follows: does low carbon transition slow down or accelerate economic growth? After a long debate, the latter was favoured in the *Low Carbon Strategy*. The decision taken at COP-28 to gradually phase out fossil fuels means that there is no chance that reliance on fossil fuels as the key driver of economic growth can be preserved. In the future, there will be no economy other than low carbon economy.[8] The next fork is as follows: which policies and sectors should be engaged in to tackle the problem? Here the debate is around whether the priority should be given to the natural solutions in LULUCF or to the low carbon technologies in fuel combustion and industrial processes. In terms of investment, the fork is as follows: maintaining the priority of the fossil technologies or switching to financing new "green" technologies. In each sector, these forks are multiplied.

The main fork is, however, as follows: continue talking or start acting? Improving energy efficiency and increasing sinks by Russian forests have long been proclaimed as the two priorities of GHG mitigation policies. This is pure rhetoric and sounds like a skipping record.[9] Meanwhile, sluggish action has caused Russia to lose out the energy efficiency race. In 2015-2022, energy intensity of Russia's GDP was growing by an average of 1.4% per year. If non-energy fuel use is excluded, then energy intensity was 0.5% down per year versus 2.7% in the EU, 1.9% in the US and Turkey, 2.1% in China, 3.5% in UK, and 3.9% in the Netherlands.[10] Despite the proactive discussion of forest projects, net absorption in LULUCF in 2019-2021 was 213 Mt CO_2eq *down*, rather than *up*. Just before the COP-28, IEA came up with five initiatives: tripling global renewable power capacity in 2030; doubling the rate of energy efficiency improvements; cutting methane emissions from operations by 75%; tripling clean energy investment; and committing to measures that ensure an orderly decline in the use of fossil fuels, including an end to new approvals of unabated coal-fired power plants.[11] 118 countries committed to the first two items.[12] Russia made no pledge, but it can address the first two issues relatively easily.

This paper continues a series of works by CENEf-XXI which look into the prospects of Russia's achieving carbon neutrality in 2060. The 2022 research titled *"Russia's carbon neutrality:*

[7] Roadmapping as process — cambridge roadmapping.
[8] MISSION ZERO - Independent Review of Net Zero (publishing.service.gov.uk).
[9] United Nations Environment Programme (2023). Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again). Nairobi. https://doi.org/10.59117/20.500.11822/43922.
[10] For more detail see Bashmakov I.A., Myshak A.D., Bashmakov V.A., Bashmakov V.I., Borisov K.B., Dzedzichek M.G., Lunin A.A., Lebedev O.V. (2023). Estimated contribution from technological factor to energy efficiency improvement and energy related GHG emission growth in Russia. Fundamental and applied climatology, Vol. 9, No. 4, pp. 210-248, doi:10.21513/2410-8758-2023-4-210-248. (In Russian); Bashmakov I., A. Myshak, V.A. Bashmakov, V.I. Bashmakov, K. Borisov, M. Dzedzichek, A. Lunin, O. Lebedev, and T. Shishkina (2023). Russian energy balance, energy efficiency, and energy-related GHG emission accounting system. Energy Efficiency. 16:67. https://doi.org/10.1007/s12053-023-10132-6.
[11] What does COP28 need to do to keep 1.5 °C within reach? These are the IEA's five criteria for success – Analysis - IEA.
[12] 118 nations commit to triple renewable energy by 2030 at COP28 (aa.com.tr).

pathways to 2060" considered three scenarios: *4S*, *4D*, and *4F*. The analysis showed, that carbon neutrality is achievable in 2060 without increasing net absorption in LULUCF or additional investment demand; however, the focus of investment should be shifted from fossil fuels to low carbon technologies.[13] The paper *"Foreign trade, economic growth, and decarbonization in Russia. Long-term vision"* verified the parameters of Russian economic development to 2060 and showed that under the sanctions, which force the double-headed eagle look only East, on the 2060 horizon the Russian GDP can go down or stay at the current level. Growth is possible only through the low carbon transition.[14] The paper *Low carbon technologies in Russia: current status and perspectives* looked into three gaps: the technological gap (lack of cost-effective low carbon technologies with a high level of technological readiness); supply gap (shortage of technologies and installation and operation services to ensure low carbon progress); and the localization gap. It also explores the methods of bridging these gaps.[15] The paper *"Distributional effects of expected climate mitigation policies in Russia"* showed that the effect of a climate mitigation policy can be made neutral or progressive by modifying social support mechanisms without changing the volume of such support.[16] Many of the parameters used for roadmapping were taken from the above papers.

This paper consists of 9 chapters. In accordance with the tradition established in CENEf-XXI, the first chapter summarizes all the key findings. The second chapter describes the tools and methods of the analysis. The third chapter deals with the system level, shows the evolution of Russia's forecasts and GHG emission control pledges; highlights the key fork in carbon neutrality pathways – *Forest First (2F)* or *Forest Last* – and outlines potential targets and the roadmap to achieving carbon neutrality on the aggregated level. Subsequent chapters present the targets and draft roadmaps for the power and heat sectors, industry, transport, buildings, and hydrogen.

Igor Bashmakov (Introduction and Chapters 1-9), Vladimir Bashmakov (Chapter 7), Konstantin Borisov (Chapter 6), Maxim Dzedzichek (Chapter 5), Alexey Lunin (Chapter 4), Oleg Lebedev (Chapter 9), and Anna Myshak (Chapter 8).

Translation into English – Tatiana Shishkina. Layout – Oxana Ganzyuk.

Igor Bashmakov
General director
CENEf – XXI

Contact information: Tel.: (499) 120-9209; cenef@co.ru; https://cenef-xxi.ru

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[13] Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzichek, A. Lunin, I. Govor. 2022. Russia's carbon neutrality: pathways to 2060. CENEf-XXI. https://cenef-xxi.ru/articles/russia's-carbon-neutrality:-pathways-to-2060.

[14] Bashmakov I.A. Russia's foreign trade, economic growth and decarbonization. Long-term vision. Moscow, April 2023. https://cenef-xxi.ru/articles/russia's-foreign-trade-economic-growth-and-decarbonization.-long-term-vision.

[15] Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzicek, O. Lebedev, A. Lunin, A. Myshak. 2023b. Low carbon technologies in Russia: current status and perspectives. CENEF-XXI

[16] Bashmakov I.A. Distributional effects of expected carbon mitigation policies in Russia. October 2023. https://cenef-xxi.ru/articles/distributional-effects-of-expected-climate-mitigation-policies-in-russia.

1

There is no one road to the future. A roadmap is required to select the right road

1.1 The concept, methods, and roadmapping tools

The logic behind roadmapping necessitates getting clear answers to the following seven questions:

- What do we know about the problem?
- What do we want to change?
- What is in the way?
- What will won't we do?
- Who will be responsible for what?
- Are we doing this right?
- How will we know that we have made the changes we need?

This paper offers roadmaps for the aggregated level and also for:

- Power generation and heat production; carbon intense industries; road transport; residential buildings; and hydrogen.
- A number of technologies are considered for each sector; the target scale of deployment of these technologies ensures that Russia will attain its carbon neutrality target in 2060.
- Similar roadmap templates are used for all sectors.
- Two time intervals are considered: short-term (to 2030) and long-term (to 2060).

A technology roadmap reflects:

- the target scale of deployment;
- the effects of deployment.

In this paper, all of the above are assessed using the 'cloud' of interconnected models developed by CENEf-XXI.

A regulations roadmap –

- is essentially a motivation roadmap, which includes administrative, market, and information mechanisms.

The institutes and human capital roadmap –

- is the one required to provide resources for the policy interventions to give momentum to low carbon policy mechanisms.

1.2 The key fork: *Forest First* or *Forest Last*

The evolution of views on the perspective GHG emission dynamics is reflected in Russia's increased emission control ambition:

- Russian experts have more than 30-years' experience in greenhouse gas emission projections.
- The revision of economic development projections shifted the 2050 upper emission range down by 1.5-3.2 Gt CO_2eq.
- The mitigation ambition was not hampering the economic growth; vice versa, the economic slowdown resulting from the persisting resource-based economic model and subsequent downward revision of economic perspectives led to a substantial correction of GHG emission estimates.

Russia has made an ambitious pledge to attain a balance between anthropogenic emissions and sinks in 2060; these involve not only CO_2 (which would mean attaining carbon neutrality), but all of the greenhouse gases

- This might have happened because in Russia, they do not read the IPCC reports carefully.
- IPCC Sixth Assessment Report of Working Group III shows, that the global warming can be limited to 1.5-2°C without bringing all GHG emissions to zero in 2060. A reduction to zero is only required for CO_2, whereas the emissions of methane, N_2O, and other GHG, are to be cut substantially, yet not to zero.
- The family of scenarios describing the transition to carbon (GHG) neutrality, as developed after Russia made a carbon neutrality pledge in October 2021 and started its military operation in Ukraine in February 2022, is still quite limited.

The first fork was developed during the preparation of the *Russian Low Carbon Strategy to 2050* and produced two fundamentally different visions of the low carbon strategy (Figure 1.1)

- *Forest First (2F)*. This pathway assumes the “freezing” of GHG emissions to 2030 with a subsequent unrealistic increase in net sink in LULUCF. A low carbon strategy should not rely on GHG emissions decline or sink increase in just one sector. *2F* is essentially a scenario of Russia abandoned by its population.
- *Forest Last*. This pathway ensures carbon neutrality, which leads to zero net CO_2 emission in 2060 and significantly reduces net GHG emissions. This reduction is relatively smooth *in all sectors*. Net sinks in LULUCF do not increase, and this sector is viewed as Russia’s last hope to attain carbon neutrality.

In the *Forest Last* pathways, GHG reduction is expected as soon as in 2030, and then will be observed in all sectors along with a certain reduction in net sinks in LULUCF

- A roadmap is a plan to achieve a goal or a given vision of the future. In this paper, the vision of the future is the *4D* scenario from the *Forest Last* group of scenarios.
- In 2060, net balance of emissions and sinks is only achievable for CO_2.
- For all GHG, emissions will be 91% down from the 1990 level, but will remain positive (Figure 1.1 and Table 1.1).

Figure 1.1 Key fork in carbon neutrality pathways

Mining+ includes mining, oil refinery and pipelines, transport (-) excl. pipelines

Target scenario by IEF RAS

4D – Development Driven by Decarbonization and Democratization – by CENEf-XXI

	Net emissions from all sources (all GHG)	
2030	-0%. Net GHG emissions are essentially stable until 2030. Decarbonization is aimed to damper external risks and accelerate social and economic development	-18% from the 2021 level (net emissions – all GHG)
2040	-21% from the 2021 level	-37% from the 2021 level
2050	-62% from the 2021 level	-58% from the 2021 level
2060	-100% from the 2021 level	-83% from the 2021 level – all GHG; -100% - net CO_2 emission
	+74% absorption in forestry	-31% absorption in LULUCF
	+13% industry	-75% energy sector
	-10% agriculture*	-38% industrial processes
	-19% construction and housing and utilities	-80% waste
	-39% power plants	-19% agriculture
	-54% mining, oil refinery, and pipelines	
	-71% transport (excl. pipelines)	
	-100% waste	
	GHG neutrality is achievable	**CO_2 neutrality is achievable**

Source: CENEf-XXI.

Table 1.1 GHG and CO_2 emission reduction targets in the *4D* scenario by sectors

	2021	2030		2040	2050	2060	
Net GHG emissions, Mt CO_2eq	1504	1375	-9%	1003	592	275	-72%
Net CO_2 emissions, Mt CO_2	1180	1001	-15%	642	276	0	-100%
Energy related emission, Mt CO_2	1501	1275	-15%	932	618	353	-76%
Power generation, Mt CO_2	557	482	-13%	371	243	117	-79%
Heat production, Mt CO_2	355	315	-11%	280	228	174	-51%
Industry and construction*, Mt CO_2	344	243	-29%	141	74	49	-86%
Transport*, Mt CO_2	264	207	-22%	149	96	60	-77%
Buildings*, Mt CO_2	516	491	-5%	432	342	245	-53%
Agriculture*, Mt CO_2	27	26	-4%	21	20	15	-44%
Communal*, Mt CO_2	9	6	-33%	3	1,4	0,3	-97%
Industrial processes, Mt CO_2	210	220	+5%	176	126	107	-49%
LULUCF, Mt CO_2	-532	-510	-4%	-479	-447	-415	-22%
CCUS, Mt CO_2				8	31	52	∞

Including indirect emissions. That is why total by sectors exceeds the emissions from the “energy sector”.

Source: CENEf-XXI.

The need for strategic decisions emerges when the existing technological and management systems run into the "limits of growth" or "limits of change"

There are three basic models of making investment and management decisions:

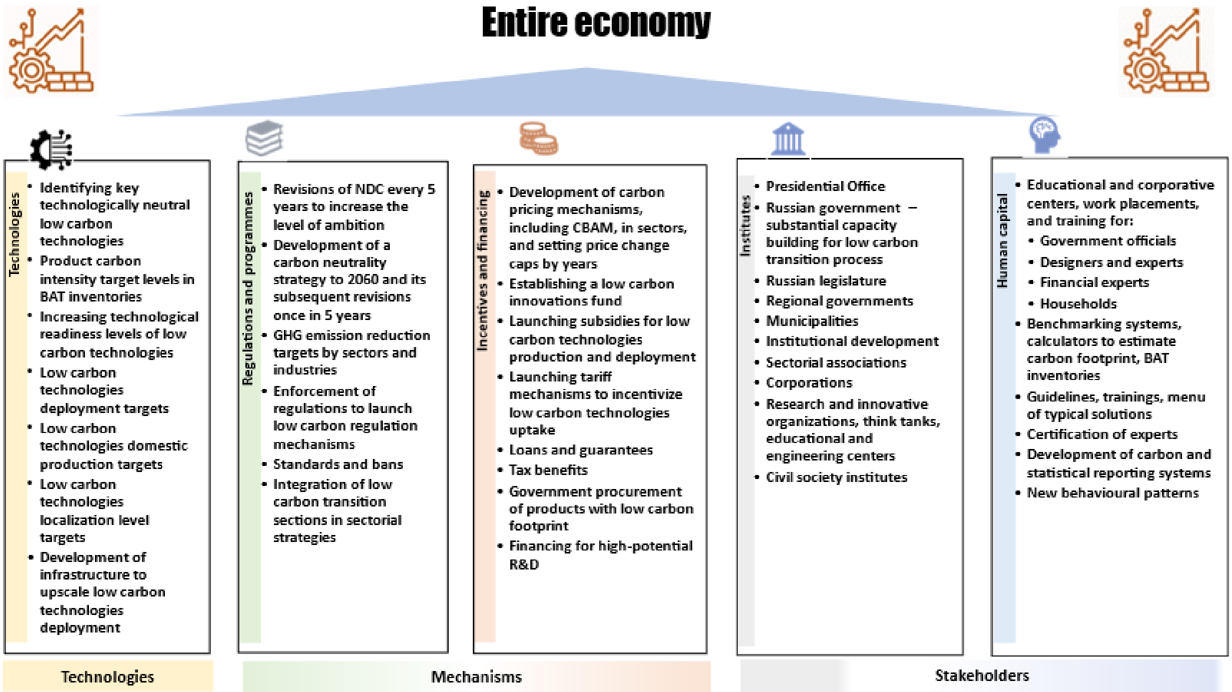
- ***Satisficing*** is a 'non-optimal behaviour', or 'limited rationality', model.
- ***Optimization*** is the area of neo-classical theories and theories of wealth maximization, which assume that a typical market agent (*homo economicus*) aspires to optimize his costs and benefits.
- ***System transformation*** is the restructuring of the technological base and of the economic structure to enable going beyond the "limits of growth" or beyond the existing "limits of change" to address important strategic challenges, such as climate change or lagging behind in the technology race.
- Progress in any sphere helps ensure progress in all other spheres.

A set of low carbon policies should foster the required change in the first two decision-making models and lay a basis to launch the third model

The above targets can be achieved through a variety of policies, which help:

- to introduce the low carbon component into the three decision-making models as specified above; and
- to develop five pillars for sustainable and effective GHG mitigation (Table 1.2).

Table 1.2 Five pillars for economy-wide decarbonization



Source: CENEf-XXI.

1.3 What should be done? Sectorial roadmapping. Technologies and policies

Power sector. Setting GHG mitigation targets	• New generation nuclear power plants; small nuclear power plants; nuclear fuel cycle closure. • National mega-project for renewable energy development. Ultra-megawatt windfarms and off-shore wind. Solar, including with much better performance. • Grid accumulation systems, including pumped storage plants and hydrogen. Battery energy storage systems to flatten the load curve. • Improving tariff and fiscal mechanisms to support the development of nuclear, wind, and solar energy. Power flexibility resource pricing. • Carbon pricing. • Government procurement of ‘green’ energy.
Heat supply sector. Increasing penetration of 4th and 5th generation DHS	• Low temperature heat sources and heat distribution systems. • Integration of heating and cooling systems. • Integration of DHS in smart energy systems. • Setting minimum mandatory requirements to the share of district heat produced from zero carbon sources. • Ban of connecting new MFBs and public and commercial buildings to DHS below 4th and 5th generations. • Development of new heat market models and tariff setting practices. • Carbon pricing.
Energy intense industries. Sectorial low carbon strategies. Long-term BAT agreements or decarbonization plans	• DRI production with hydrogen and CCUS. • Aluminium production using pre-baked and ‘inert’ anode technology. • Cement production with increasing share of additives and secondary resources, using alternative fuel and CCUS. • Ammonia production using ‘green’ hydrogen and CCUS. • Low carbon innovations fund. • Industrial development fund. • Co-financing for R&D. • GHG allowances trading or carbon pricing mechanisms. • Government procurement of low carbon materials.
Road transport. Development of a national mega-project to enhance electric transport	• Development of a wide variety of electric vehicles (EV) for various consumer groups. Development of EV for cold climates. • Development of supply chains for EV production. • Enforcement of low carbon car standards. • Target agreements with car companies or minimum required proportion of EV in cars output. • Launching new plants to produce EV and electric buses and increasing the level of localization to 70-90%. • Government procurement of EV. • Carbon pricing. • Co-financing for R&D.

Buildings. Federal programmes "Active construction of passive buildings" and "Deep and large-scale renovation wave"	• Development and deployment of promising heat transfer resistance technologies: aerogels, foam ceramics, phase change materials. • Development of new technologies to balance heat supply and demand in buildings for 4th and 5th generation DHS, which integrate all energy supply and storage systems in buildings. • Tax benefits for developers who demonstrate high energy efficiency performance. • Co-financing for deep energy efficient capital repair. • "Green" mortgage. • "White" certificates. • Development of a subprogramme "Renewable energy in buildings" with specified low carbon targets under the national mega-project of renewable energy development.
Hydrogen. Providing support based on carbon footprint and localization levels of hydrogen and electrolyzers production	• Launching and increasing mass production of gigawatt class electrolyzers with high localization levels. • Launching large-scale production of equipment and development of infrastructure for safe production, transport, and storage of hydrogen and hydrogen-based products with eventually increasing localization levels. • Launching regional hydrogen clusters (hubs) and first large-scale industrial projects. • Launching production of new generation hydrogen fuel cells. Upscaling hydrogen production and use for energy storage.

1.4 Who is to undertake the responsibility? There has to be enough competent personnel. Institutes and human capital

Making the decarbonization of the economy a national priority integrated in sectorial strategies. A breakthrough in administrative competencies. Setting up decarbonization departments at the national and regional level and improving their competencies	• Russian President's Office. • Russian government, including the Ministry of economy, Ministry of energy, Ministry of industry, Ministry of transport, Ministry of construction, Ministry of finance, and other ministries; Agency for strategic initiatives and subordinate organizations. • Federal Council of the Russian Federation. • Central Bank of the Russian Federation. • Regional and municipal authorities. • Training programmes for these organizations for *ongoing* capacity building using information resources of research organizations, innovative think tanks, educational and engineering centers.
Development and financial institutions	• Taxonomies and decarbonization programmes. • Setting up low carbon innovations fund. • Capacity building for low carbon programmes in institutes, such as Industrial development fund; Sber; VEB.RF; DOM.RF; and other banks.

Professional associations and corporations – sectorial strategies, long-term agreements or decarbonization plans. Decarbonization capacity building (number of employees and their competencies).

- State corporations: Rosatom, Rostech, Rosnano, Skolkovo, Territorial development fund, etc.
- Corporations: power and heat generation, oil&gas, metallurgical, chemical, transport, building materials, innovative equipment, etc.
- Industrial and professional associations: Russian Union of Industrialists and Entrepreneurs; Delovaya Rossiya, Council of energy producers, Aluminium association, RAWI, REDDA, NOSTROY, Russian fuel union, Russian association of car dealers, Machine building union of Russia, Association of industrial parks, etc.

Research, innovative, educational, engineering think tanks, design bureaus. Development of competencies and technologies and transfer to stakeholders.

- R&D – development of low carbon technologies and practices.
- Commercialization of low carbon technologies – jointly with development institutions and corporations.
- Development of syllabuses for training in low carbon development for different sectors.
- Substantial increase in the number of trained specialists in renewable energy, electric vehicles, energy storage, 4^{th} and 5^{th} generation DHS, production of equipment for low carbon technologies and equipment deployment in the industrial sector, including hydrogen production, construction of low carbon buildings and environmentally friendly utilization of retired low carbon equipment, etc.
- Multiple increase personnel training in the development, implementation and monitoring of low carbon policies, development of smart systems, footprint calculators, etc.

Civil society – development of fundamental competencies required for climate-friendly decision-making and to ensure an ability to impact the national GHG mitigation policy

- Development of effective communication channels:
  - Top-down – to inform the civil society of the low-carbon decisions made;
  - Bottom-up – to ensure participation of civil society in decision-making.
- Capacity building of public climate-concerned organizations (such as “Low Carbon Russia”) and environmental movements.
- Significant development of information resources, including personal footprint calculators.
- Analysis of distributional effects of proposed GHG control policies and deployment of policy decisions to make them neutral or progressive by altering the social support mechanisms.
- Networking for the leading GHG emissions experts and journalists to provide media with unbiased and top-quality information.

2 The concept, methods, and roadmapping tools

2.1 Roadmapping boundaries and subject

The development of energy transition roadmaps for the economy has become an important tool for climate policies, as it allows to coordinate the actions of stakeholders both spatially (between the sectors, authorities, business circles, and population, between individual policies, their developers and implementers), **and temporally** (early commercialization of the required low carbon technologies and the development of regulations to expand the market niches for these technologies; setting up institutes that are capable of implementing the developed administrative or market incentives; timely and good-quality personnel training; etc.

This paper describes the roadmaps developed for the entire economy, for the power sector, district heating sector, carbon intensive industries, road transport, residential buildings, and hydrogen production. There are a variety of approaches to the development of roadmaps and different coverage of activities: national,[17] sectorial,[18] to promote individual technologies.[19]

Five metrics, or pillars, of the Russian low carbon transition policy are used:

- technologies;
- regulations, including strategic documents and programmes;
- financing and economic incentives to attract financing;
- institutes responsible for the implementation of the specified policies;
- human capital capable of setting all of the low carbon transition mechanisms to work in the desired direction and at the desired pace.

A number of technologies are considered for each sector; the target scale of deployment of these technologies ensures that Russia will attain its carbon neutrality target in 2060.[20] The list of the technologies, the target scale of deployment to 2060, production and localization levels are specified in "*Low Carbon Technologies in Russia. Current Status and Perspectives*".[21]

A regulations and incentives roadmap is essentially a motivation roadmap,[22] since it includes administrative and economic mechanisms that help push the low carbon goals higher on the decision-makers' agenda by providing additional propulsion with financial incentives and professional status improvement perspectives. An important aspect of the development of effective climate policies is a careful analysis of how these policies can impact the positions of the economic agents and their ability to consolidate – formally or informally – to use a variety of institutes to promote or confront these policies.[23]

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[22] Rinaudo E.K., T. Koller, and D. Schatz. Bias Busters Motivations under the microscope McKinsey. 2023. bias-busters-motivations-under-the-microscope.pdf (mckinsey.com).
[23] Bashmakov I.A. Distributional effects of expected climate mitigation policies in Russia. October 2023. https://cenef-xxi.ru/articles/distributional-effects-of-expected-climate-mitigation-policies-in-russia.

The institutes and human capital roadmap is the one required to provide resources for the policy interventions to both competently design and give momentum to low carbon policy mechanisms. The phrase "Cadre are the key!" is well-known. However, one often has to add: "but a wrong one". So as to set the low carbon transition mechanisms to work, we need institutes to give them momentum. The charters or statutes of these institutes should clearly spell out the low carbon transition objectives. However, even this is not enough. All of these institutes must be provided with well-trained, highly qualified personnel. The importance of this component can be illustrated using the energy efficiency policy in Russia as an example. After the State Programme "*Energy Saving and Energy Efficiency Improvement to 2020*" was adopted in Russia in 2010, followed by a number of regional and municipal programmes, many national and regional ministries and agencies appointed officials responsible for the development and implementation of these programmes. More than 100 energy efficiency agencies were set up on the regional and municipal levels. Dozens of thousands of experts worked to implement these programmes. However, after 2014, these activities were curtailed. Today, one will not see as few as 5 people in all of the ministries and agencies who are working to improve the energy efficiency in Russia. In addition, qualifications are as important, as the numbers. To sum up, Russia has lost the energy efficiency race. In 2021, it was 186th in the list of 193 countries ranked by their energy productivity (energy productivity is the inverse of energy intensity). In 2015-2022, energy intensity of Russia's GDP was not declining.[24] In 2016-2021, in 30 Russia's constituent entities energy intensity increased. And only in two it was more than 5% down over the same period.[25]

2.2 Roadmapping tools

In this paper, the target scale of deployment of low carbon technologies and the effects of using low carbon policies were estimated using a system ("a cloud") of interconnected models developed by CENEf-XXI (see Figure 2.1). The information basis for the models is the MTFK-16-80-PG model.[26] It forms the integrated fuel and energy balance (IFEB) and conducts analysis for 16 sectors and 80 economic activities. Only 12 economic activities (which involve a large variety of products, such as production of electronic equipment, food, beverages, and tobacco) are shown as physical production indices. The other 68 activities are shown as natural physical indicators. This model ensures the full consistency of GHG sources and energy uses by economic activities.

The "cloud" of models is centered around the nucleus – the key multisectoral dynamic simulation model ENERGYBAL-GEM-2060. In addition, the cloud includes a macroeconomic simulation model RUS-DVA (2 sectors – oil-and-gas and non-oil-and-gas, 5 products, 6 blocks – scenario variables; GDP production and distribution; investments; foreign trade; consolidated budget; and prices); a number of engineering-and-economic simulation models for the power and heat sectors (10 types of power and heat generation and energy storage systems); industrial model (around 60 industrial products, technologies, and production processes); transport (13 types of passenger transport and 8 types of cargo transport plus a few powertrains in each transportation mode; buildings – including multifamily and individual; 9 energy end-uses, 4 types of decentralized power and heat generation equipment, and 15 types of public and commercial buildings broken down by 5 processes; and a model to estimate emissions from the waste sector. The model

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[24] Bashmakov I.A., A.D. Myshak, V.I. Bashmakov, K.B. Borisov, M.G. Dzedzichek, A.A. Lunin, O.V. Lebedev, T.B. Shishkina. Assessing the contribution from technological factor to energy efficiency improvement and to the evolution of energy related emissions of greenhouse gases in Russia. Fundamental and applied climatology, Vol. 10, No. 1, 2024; Bashmakov I., A. Myshak, V.A. Bashmakov, V.I. Bashmakov, K. Borisov, M. Dzedzichek, A. Lunin, O. Lebedev, and T. Shishkina (2023a). Russian energy balance, energy efficiency, and energy-related GHG emission accounting system. Energy Efficiency. 16:67. https://doi.org/10.1007/s12053-023-10132-6.

[25] Bashmakov I.A. and A.D. Myshak. Analysis of factors determining the evolution of energy intensity of GRP of Russia's regions. Energosberezhenie, No. 1, 2024.

[26] Bashmakov I., A. Myshak, V.A. Bashmakov, V.I. Bashmakov, K. Borisov, M. Dzedzichek, A. Lunin, O. Lebedev, and T. Shishkina. 2023. Russian energy balance, energy efficiency and energy related GHG emission accounting system. Energy Efficiency (2023) 16:67Vol.: (0123456789)1 3 https://doi.org/10.1007/s12053-023-10132-6.

parameters were calibrated on the 1995-2021(2022) data. The calculation step is one year, the projection horizon – to 2060. These models have been described in detail.[27] In ENERGYBAL-GEM-2060, energy demand in each sector is a function of the economic activity and specific energy consumption (SEC). The latter is a function of technologies improvements reflected in the sectoral models, and also of the capacity load (for industrial activities and pipeline transport), climate, amenities (in the housing sector), and of average energy prices corrected for inflation. Demand for individual energy carriers in each sector is determined by the relative prices. This allows for assessing the effects of market mechanisms on the structure of energy carriers used and thus on GHG emissions.[28] The SEC progress is determined based on capacity retirement, modernization, and addition parameters, as well as price competition between technologies with different energy efficiency performance. It is initially estimated in sectorial models, and then is verified in ENERGYBAL-GEM-2060 depending on the energy price dynamics. The latter includes carbon price. Therefore, the model helps estimate the impact of prices on the energy demand and on the demand for individual energy carriers. Sectorial models use a variety of functions to determine the structure of newly deployed technologies depending on the price competition parameters: levelized costs of power generation for power and heat sectors; levelized costs of manufacturing the major industrial products for industry; car ownership costs for road transport; building lifecycle costs for the buildings sector. ENERGYBAL-GEM-2060 model includes blocks to estimate GHG emissions from all sectors as shown in the national GHG inventory.

Figure 2.1 The "cloud of models" by CENEf-XXI

Scenario variables:

Population

Fuel export

Net export of industrial goods

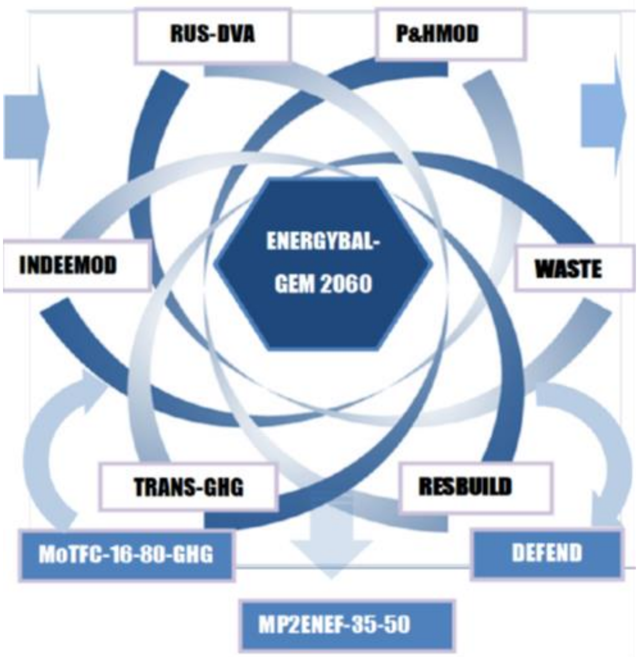
Hydrogen exports

Energy prices

Carbon price

Technological parameters in all sectors

Emission reduction policies



Calculation results:

Macroeconomic indicators

Detailed IFEB

Technological structure by sectors

Energy efficiency and carbon intensity by sectors

GHG emissions from key sources

Capital costs

Consumer energy spending

Source: CENEf-XXI. The angle of incidence is not equal to the angle of reflection. Macroeconomic perspectives.

In order to assess the distributional effects, this system of models was supplemented with a specially designed model – *DEFEND* (distributional effect of national decarbonization).[29] It includes a block of residential buildings and a block of road transport. Rosstat's data on the distribution of incomes, expenses, living area, cars, and energy intense appliances by decile groups

[27] Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzichek, A. Lunin, I. Govor. 2022. Russia's carbon neutrality: pathways to 2060. CENEf-XXI. https://cenef-xxi.ru/articles/russia's-carbon-neutrality:-pathways-to-2060.

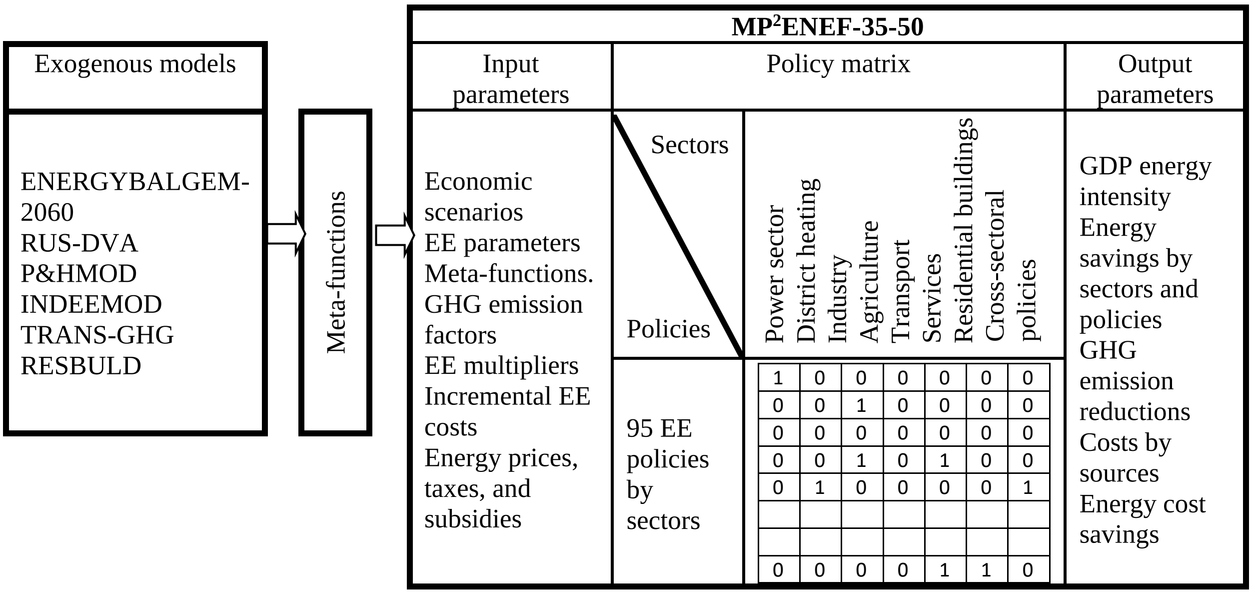
[28] Bashmakov I.A. Low Carbon Russia: 2050. CENEf. Moscow. 2009.

[29] Bashmakov I.A. Distributional effects of expected climate mitigation policies in Russia. October 2023. https://cenef-xxi.ru/articles/distributional-effects-of-expected-climate-mitigation-policies-in-russia.

were used in the DEFEND model to study how evenly the pressure from the decarbonization measures is distributed. In many cases, sufficient information is not available for a good quality analysis. For example, it is important to know, how the cars fuel efficiency, mileage, and price elasticates are distributed by deciles. Some analytical work allowed to reconstruct some of those parameters. In a few instances, distributional effects were estimated using proxy data for other countries.

In this effort, one more model – MP2ENEF-35-50 – was added to the "cloud" (Figure 2.2). It is a simulation model, which allows to calculate the effects of 95 energy efficiency and GHG mitigation policies in different sectors. It covers 7 sectors: power, heat, industry, agriculture, transport, commercial, residential, and also cross-sectoral policies, such as carbon pricing.

Figure 2.2 Architecture of MP2ENEF-35-50 model



Source: the authors.

MP2ENEF-35-50 is a meta-model that includes 95 compact models to reflect the impacts of individual policies. It was developed by CENEf-XXI. The parameters of the compact models are mostly generalized meta-functions estimated through multiple runs of a set of much more complex economy-wide and sectorial models (see fig. 2.1).[30] So complex models are reduced to simplified (meta) functions between major variables which are used in each compact model. Each algorithm can work independently. The results of all calculations are integrated in summary files. A set of control or policy parameters is specified for each measure, and a combination of these parameters determines the architecture, scale and effects of each policy or measure. In some cases, the effect of one measure (for example, of buildings insulation) depends on the implementation of another measure (for example, availability of building-level automated heat supply regulation). The MP2ENEF-35-50 model estimates the incremental costs of all measures. The costs that are covered from power- and heat tariffs or are paid by any-level government are specified separately. In addition, tax revenues are estimated, including VAT, profit tax (where the energy costs of companies go down), and personal income tax are estimated. A specific combination of energy carriers savings is used for each measure; it determines the averaged GHG emission factors and GHG reductions. The model calculation step is one year. The time horizon for the implementation of measures is 2023-2035, and for the evaluation of the effects it is 2023-2050.

[30] Bashmakov I., A. Myshak, V.A. Bashmakov, V.I. Bashmakov, K. Borisov, M. Dzedzichek, A. Lunin, O. Lebedev. 2024. Compact meta-models to estimate the effects of energy efficiency policies and measures. Energy efficiency. Forthcoming.

Market mechanisms involve the introduction of taxes or providing subsidies to cover part of the implementation costs. The level of participation in the programmes and the choice of technologies, and therefore the amount of GHG emission reductions depend on the carbon price or the share of co-financing. The larger they are, the larger the number of the participants, and the higher the effect obtained, other things equal. And vice versa.

The impact of the market mechanisms can be estimated by the following equation:

$$Share_i^t = \frac{a_i * LCOS_{it}^{-2}}{\sum_i a_i * LCOS_{it}^{-2}}, \qquad (2.1)$$

where *LCOS* are levelized energy saving costs, or building lifecycle costs, or car ownership costs, including capital repair, operation costs, as well as carbon emission costs or environmental tax;

a_i are non-price competition and non-economic preference parameters (strategic energy security, environment or climate).

The a_i parameters also reflect the effects of supporting policies (information, administrative and other) to promote energy efficient technologies. These measures have the largest effect, when subsidies cover 40-70% of the costs. A recent analysis revealed the important role of public co-financing for energy efficiency measures.[31] There is little empirical research on how the share of purchased energy efficient equipment is determined by the share of subsidies provided. Based on this scarce research and Equation (2.1), the functions of participation and technological choices were assessed for different policies.

Administrative measures, such as standards, product bans, or energy efficiency agreements, are captured in the model (2.1) through very high *LCOS* for equipment or buildings that fail to meet the requirements. These high values may entail penalties for non-compliance or for a breach of the agreement. Where these penalties are substantial, market competition mostly involves the technologies which have passed the administrative barrier. Regulations are captured in MP2ENEF-35-50 by changing the coefficients in specific energy use functions.

2.3 The roadmapping logic

The logic behind roadmapping necessitates getting clear answers to the following seven questions: what do we know about the problem? what do we want to change? what is in the way? what we will and will not do? who will be responsible for what? are we doing this right? how will we know that we have made the changes we need?[32] We have a clear answer to the first question (What do we know about the problem?) – the climate is changing very dangerously,[33] including in Russia.[34] The answer to the second question – what do we want to change? – is provided in the *Climate Doctrine of the Russian Federation*: "The key long-term goal of the climate policy is to achieve no later than in 2060 – with an account of national interests and social and economic priorities – a balance between the anthropogenic greenhouse gas emissions and absorption".[35] This is an even more ambitious goal, than attaining carbon neutrality (a balance of emissions and absorption for CO_2 alone). The answer to the third question – what is in the way? –

[31] Bashmakov I.A. International experience in improving energy efficiency and recommendations for Russia. // Akademia Energetiki, 2014, No. 1 (57).
[32] How Do We Create Our Roadmap? (Logic Model) (promoteprevent.org).
[33] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3−32, doi:10.1017/9781009157896.001.
[34] Third Assessment Report on climate change and its consequences in the Russian Federation. Summary / Roshydromet. – St.Petersburg: Naukoemkie technologii, 2022. 124 p. od3or.pdf (voeikovmgo.ru).
[35] Executive Decree of the President of the Russian Federation No. 812 of October 26, 2023 "On approving the Climate Doctrine of the Russian Federation".

is as follows: a weak GHG emission control policy. Russia, disorientated by the myths of the past,[36] has long tried to look into the future with its back on it, making ironical comments and looking down on the other countries in a hope that the era of its worshipped fossil fuels will never come to an end and it will be able to skillfully balance on the tip of the oil-and-gas “needle” for a long time or even use this tip for their political purposes.[37]

The roadmap should aim to answer the last four questions: what we will and will not do? who will be responsible for what? are we doing this right? how will we know that we have made the changes we need? The roadmap should ensure: correct prioritization; clear key and intermediate strategic goals; consistency of both goals and tools; division of labour and coordination between all stakeholders to achieve the goals; and it should lay the basis for negotiations with the key parties and provide a basis for compromise, if need be.

The roadmapping logic:

- sector;
- technology;
- policies:
    - regulations, including strategic documents and programmes;
    - financing and economic incentives;
- institutes;
- human capital.

Two time intervals are considered: short-term – to 2030; and long-term – to 2060. Standard roadmap templates are used for all sectors.

[36] Bashmakov I.A. Global energy: myths of the past and lessons of the future. *Issues of Economy*. 2018;(4):49-75. https://doi.org/10.32609/0042-8736-2018-4-49-75 (In Russian).
[37] Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzichek, O. Lebedev, A. Lunin, A. Myshak. Low Carbon Technologies in Russia: Current Status and Perspectives, 2023. https://cenef-xxi.ru/uploads/Technology_gap_b0cf666d23.pdf.

3 The national level

3.1 Evolution of Russia's GHG emission projections and mitigation pledges

Russian experts have more than 30-years' experience in greenhouse gas emission projections. The first forecasts for the Soviet Union were published in the early 1990s and aimed to limit CO_2 emissions in 2020-2030 to the 1990 values or to a level 20% below 1990.[38] Later on, the geographical scope was narrowed to Russia. Until 2009, the number of research efforts with the 2050 horizon was very limited: 2 scenarios by A. Makarov[39] (2008) and 21 scenarios by I. Bashmakov[40] (2009). In addition, long-term projections were provided by the IEA and other organizations. All of these scenarios were grouped into four families: "*Sisyphus' road*", "*Baseline*", "*The carbon plateau*", "and "*Low Carbon Russia*". "*Sisyphus' road*" was given up on in 2009. It was shown that Russia cannot increase its GHG emission by so much; however, it can keep its emission below the 1990 level until 2050 without compromising its economic growth. Having assessed the risks, at 2009 COP in Kopenhagen Russia committed to limit its 2020 emission to 75% of the 1990 level.

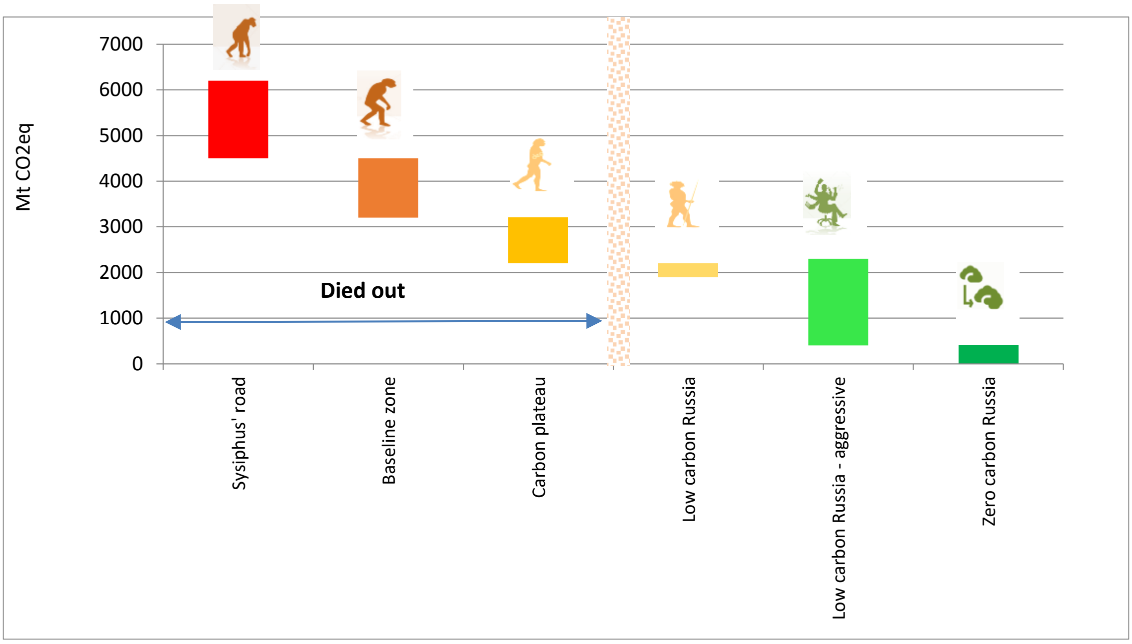
Before the 2015 UNFCCC meeting in Paris, the population of Russian projections grew up significantly. Bashmakov and Myshak[41] analyzed 71 scenarios from 26 research efforts. Another family of scenarios – "*Low carbon Russia – aggressive policies*" – emerged. As the knowledge accumulated, the models and forecasting methods improved, and the assessments of Russia's economic perspectives and low carbon technological progress became more adequate, the families of scenarios with high GHG emission projections to 2050 (such as "*Sisyphus' Road*", "Baseline", and "*Carbon plateau*") died out[42] (Figure 3.1). Some research groups came to a conclusion that there is an absolute upper limit to GHG emissions (below the 1990 level), which will never be exceeded under any circumstances.

In 2014, CENEf implemented a project titled *"Costs and benefits of low carbon transition in Russia"*.[43] It primarily aimed to identify the costs and benefits associated with low carbon development strategies in Russia to the mid-21 century and beyond, and to look into whether or not a focus on low carbon development is a deterrent or catalyst for economic growth in Russia. Several Russian and foreign research groups were invited to participate in order to obtain weighted and balanced answers to this question. One task under this project was to help formulate the position of the Russian delegation in terms of the national pledge under the Paris Agreement. In none of the 30 scenarios (which built on a consistent set of assumptions) was the 2050 GHG emission level higher, than in 1990. GHG baseline was substantially down. **The revision of economic development projections shifted the 2050 upper emission range down by 1,500-3,200 million tCO_2eq**. It was not the mitigation ambition that was hampering the economic growth; vice versa, the economic slowdown resulting from the persisting resource-based economic model and subsequent downward revision of economic perspectives led to a substantial correction

[38] Bashmakov I., A. Makarov. The Soviet Union. Chapter in carbon emissions control strategies. W.U. Chandler Editor. WWF and The Conservation Foundation. Wash., USA. 1990. pp.35-54; Bashmakov I., Makarov A. 1991. An energy development strategy for the USSR: Minimizing greenhouse gas emissions. Energy Policy. Volume 19, Issue 10, December 1991, pp. 987-994.
[39] Makarov A.A. Possibilities to control Russia's energy related GHG emission. Akademia Energetiki. No. 5, 2008. Pp. 26-33.
[40] Bashmakov I.A. Low Carbon Russia: 2050. Moscow, Avis Original, 2009; Bashmakov I. Low-Carbon Russia: Prospects after the Crisis. *Voprosy Ekonomiki*. 2009;(10):107-120. (In Russ.) https://doi.org/10.32609/0042-8736-2009-10-107-120.
[41] Bashmakov and Myshak, 2014. Comparison of Forecasts of Greenhouse Gas Emissions in the Energy Sector of Russia for 2010-2060. Studies on Russian Economic Development; Issue 1 (142), pp. 48-62. (In Russian).
[42] Bashmakov et al. 2021. Russia on the trajectory to carbon neutrality. Prepared for Skolkovo School of Management.
[43] Bashmakov I.A. Editor. Costs and benefits of low carbon economy and society transformation in Russia. CENEf. Moscow, 2014. (In Russian).

of GHG emission estimates (Figure 3.1). Post-2015 scenarios mainly analyzed the possibility of attaining carbon neutrality in 2050-2060.[44]

Figure 3.1 Evolution of energy related GHG emission projections



Sources: Bashmakov I.A. Editor. Costs and benefits of low carbon economy and society transformation in Russia. CENEf. Moscow, 2014. (In Russian); Bashmakov and Myshak, 2014. Comparison of Forecasts of Greenhouse Gas Emissions in the Energy Sector of Russia for 2010-2060. Studies on Russian Economic Development; Issue 1 (142), pp. 48-62; Bashmakov I.A. Russian low carbon development strategy. *Voprosy Ekonomiki*. 2020;(7):51-74. (In Russ.) https://doi.org/10.32609/0042-8736-2020-7-51-74; Bashmakov I. Low carbon development and economic growth. Neftegazofaya Vertikal. No. 12, 2021; VEB RF. Attaining Russia's carbon neutrality no later than 2060. January 2023; ERI RAS and Energy Center of SKOLKOVO Moscow School of Management. 2019. Global and Russian energy sector development. A.A. Makarov, T.A. Mitrova, V.A. Kulagin Editors. ERI RAS – SKOLKOVO Moscow School of Management. Moscow, 2019; Porfiriev B., A. Shirov and A. Kolpakov. Low carbon development: economic perspectives for Russia. World economy and international relations. 2020. Vol. 64, No. 9. Pp. 15-25, https://doi.org/10.20542/0131-2227-2020-64-9-15-25; Shirov A.A., Kolpakov A.Yu. Russia's target scenario of net low carbon social and economic development to 2060. Problemy Prognozirovaniya, 2023, Issue 6; Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzichek, A. Lunin, I. Govor. 2022. Russia's carbon neutrality: pathways to 2060. CENEf-XXI. https://cenef-xxi.ru/articles/russia's-carbon-neutrality: -pathways-to-2060; bp Energy Outlook 2050: January 2023; IEA. 2021. Net-Zero by 2050. A Roadmap for the Global Energy Sector; IEA. 2015-2023. World Energy Outlook; IEA. 2017-2023. Energy Technology Perspectives; Laitner J., Lugovoy O., Potashnikov V. Cost and Benefits of Deep Decarbonization in Russia. Ekonomicheskaya Politika, 2020. No. 2, pp. 86-105. https://doi.org/10.18288/1994-5124-2020-2-86-105; Safonov G., V. Potashnikov, O. Lugovoy, M. Safonov, A. Dorina, A. Bolotov. 2020. The low carbon development options for Russia. Climatic Change. https://doi.org/10.1007/s10584-020-02780-9 Springer Nature B.V. 2020; Veselov F., T. Pankrushina, A. Khorshev. 2021. Comparative economic analysis of technological priorities for low-carbon transformation of electric power industry in Russia and the EU Energy Policy 156 (2021) 112409 https://doi.org/10.1016/j.enpol.2021.112409.

The evolution of the perspective emission dynamics visions is reflected in Russia's increased emission control ambition (percentage decrease compared with the 1990 level):

- 0% in 2008-2012 – Kyoto, 1997: Russia pledged to keep its emission in 2008-2012 below the 1990 level (attained);

[44] Gaida I., Grushevenko I. Decarbonization scenarios for Russia. Energy Center of SKOLKOVO Moscow School of Management. March 2020, https://esg-library.mgimo.ru/publications/stsenarii-dekarbonizatsii-v-rossii/.

- -25% by 2020 – Copenhagen, 2009: Russia committed to keep its emission below 75% of the 1990 level until 2020 (attained);
- -20-25% in 2030 – Paris, 2015: Russia pledged to limit its emission in 2030 to 70-75% of the 1990 level;
- -30% in 2030 – Presidential Decree No. 666 of November 4, 2020: Russia committed to keep its 2030 emission below 70% of the 1990 level;
- Russia – EU: 1:1. In spring 2021, the pledge was to ensure that total Russian 2050 net GHG emission is below that of the EU;
- -80% in 2050 – *Russian low carbon strategy to 2050* requires that net GHG emission be 80% down from the 1990 level and 60% down from the 2019 level;
- -100%. Carbon (GHG) neutrality in 2060. In October 2021, Russia committed to attain carbon neutrality in 2060. In October 2023, this pledge was enshrined in Russia's *Climate Doctrine* as follows: attaining a balance between anthropogenic GHG emissions and sinks.

Russia's low carbon strategy to 2050 specifies few quantitative parameters and – only to 2050. Therefore, it is hardly possible to develop roadmaps for the entire economy or for individual sectors. In addition, carbon neutrality is not achieved in the *Strategy's* target scenario. The pathways for Russia to achieve carbon neutrality in 2060 have not yet been explored in detail or roadmapped. One reason is the lack of long-term models with the 2060 horizon both for the entire economy and for the key emission sectors. Earlier forecasts were essentially confined to the 2050 horizon. However, after 2022 the first scenario estimates to 2060 emerged; these helped reveal the forks in carbon neutrality strategies.

3.2 Key fork in carbon neutrality pathways

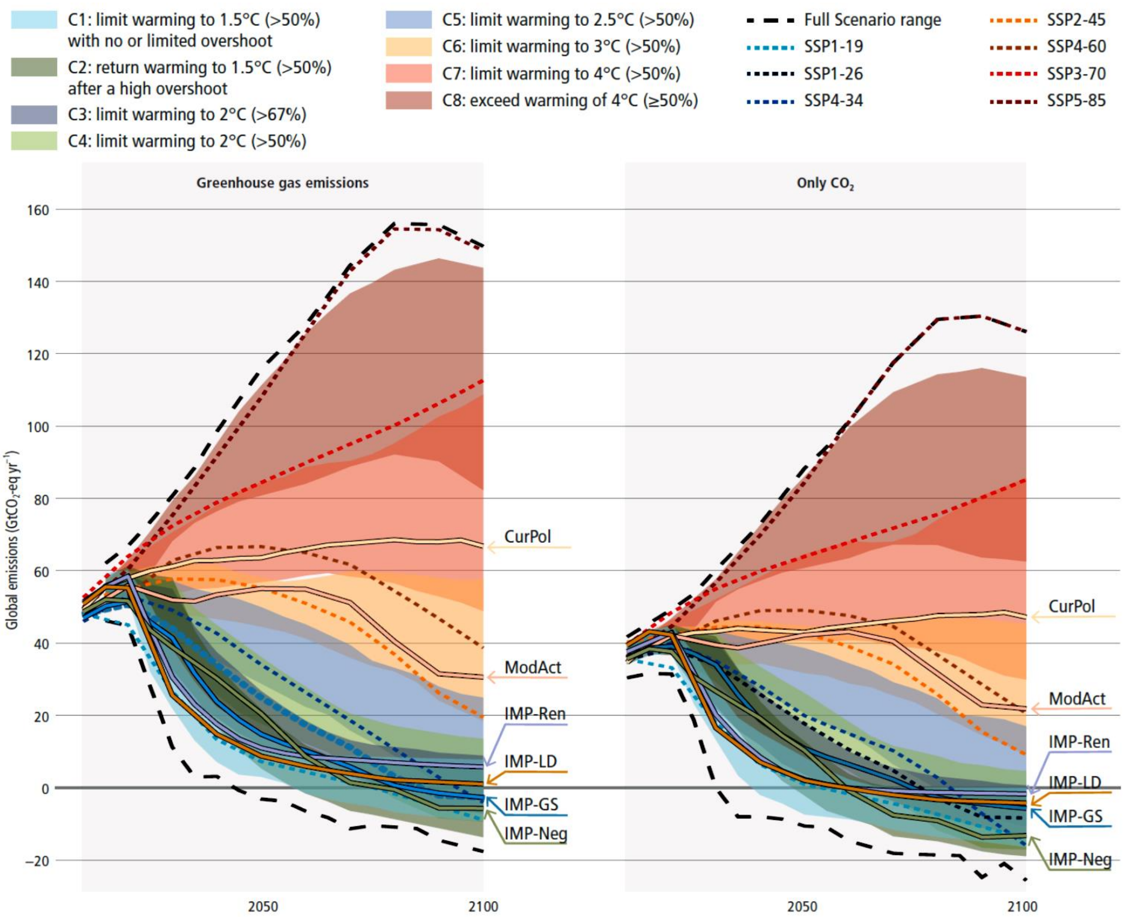
Russia made an ambitious pledge to attain a balance between anthropogenic emissions and sinks in 2060; these involve not only CO_2 (which would mean attaining carbon neutrality), but all of the greenhouse gases:

> The key long-term goal of the climate policy is to achieve, with an account of national interests and social and economic priorities, a balance between anthropogenic greenhouse gas emissions and sinks no later than 2060.
>
> Article 21. Climate Doctrine of the Russian Federation

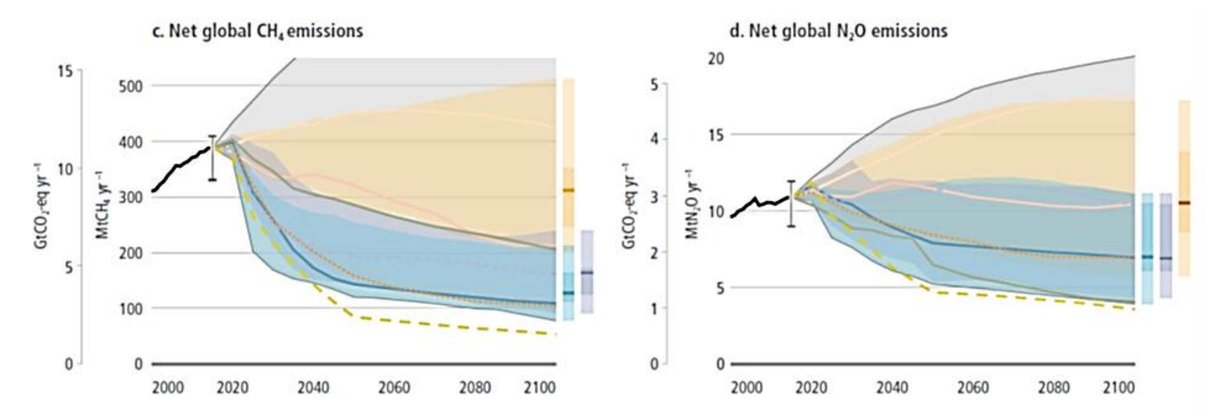
This might have happened because in Russia they do not read the IPCC reports carefully. The Sixth Assessment Report of Working Group III shows, that the global warming can be limited to 1.5-2°C without bringing *all GHG* emissions to zero in 2060. A reduction to zero is only required for CO_2, whereas for methane, N_2O, and other GHG, emissions are to be cut substantially, yet not to zero (Figure 3.2).

In compliance with the cornerstones of the *Russian Climate Doctrine*, additional decarbonization measures in different economic sectors and measures to increase the absorption capacity of managed ecosystems can cause net emissions (the word 'net' is occasionally omitted in the text of the *Doctrine)* to grow from 1,672 million tCO_2eq in 2021 (as per the national inventory) to 1,673 million tCO_2eq. in 2030. In other words, the emissions are essentially to stay at the 2021 level until 2030. In the Presidential Decree of November 4, 2020, the relevant value is 2,162.4 million tCO_2eq., and the same value is specified as the target net 2030 emission in the Russian nationally determined contribution to the Paris Agreement.

Figure 3.2 Total emission profiles as per scenarios are based on climate categories for all GHG (AR6 GWP-100) and for CO2



all GHG CO_2 alone



methane N_2O

Source: Riahi, K., R. Schaeffer, J. Arango, K. Calvin, C. Guivarch, T. Hasegawa, K. Jiang, E. Kriegler, R. Matthews, G.P. Peters, A. Rao, S. Robertson, A.M. Sebbit, J. Steinberger, M. Tavoni, D.P. van Vuuren, 2022: Mitigation pathways compatible with long-term goals. In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.005.

The family of scenarios describing the transition to carbon (GHG) neutrality, as developed after Russia made a carbon neutrality pledge in October 2021 and started its military operation in Ukraine in February 2022, is still quite limited. In fact, as of late 2023, there are three scenarios developed by CENEf-XXI[45] and a few scenarios by IEF RAS[46] which appeared at the very end of 2023 and have a 2060 horizon. The latest research provides the results to 2060 only for the *Target scenario*. The results of the other two scenarios are basically restricted to 2050. The estimates published in January 2023 by VTB[47] are also confined to the 2050 horizon and present rather pessimistic assessments of GHG mitigation possibilities in many sectors (even more cautious, than those by IEF RAS) and an uncertain conclusion on the possibility to attain carbon neutrality.

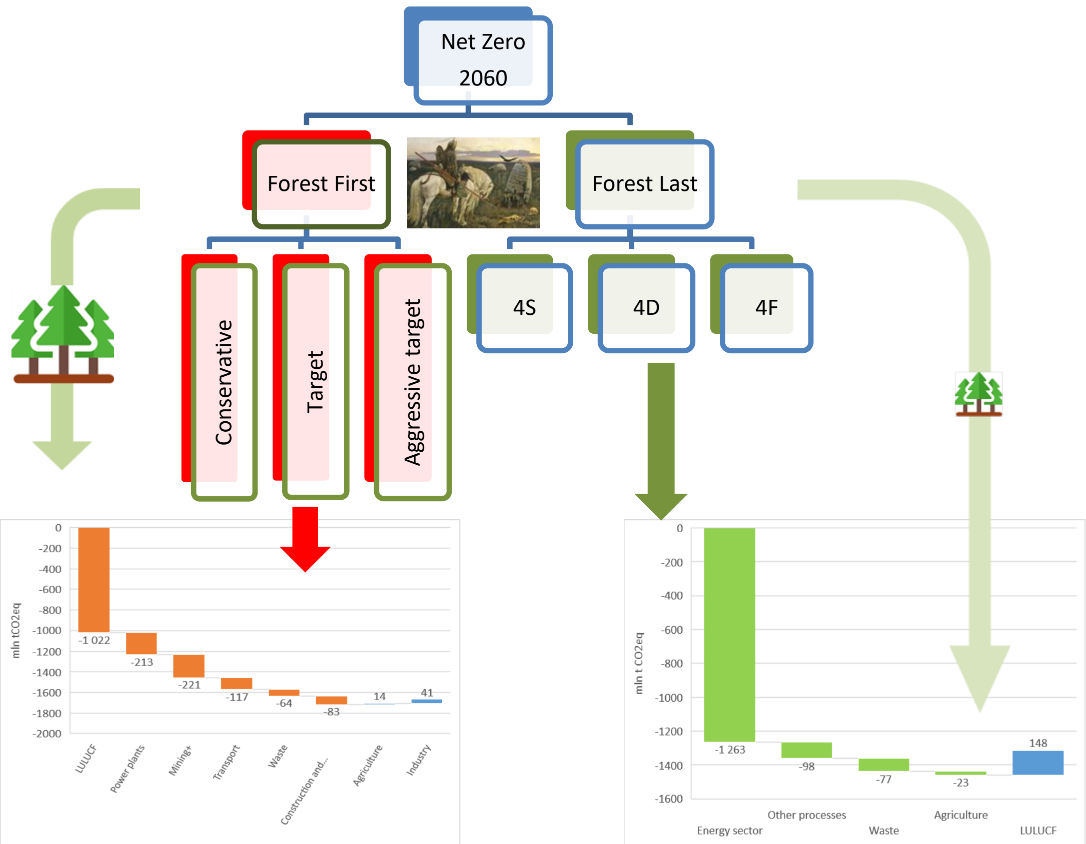
The first fork was developed during the preparation of the *Russian Low Carbon Development Strategy to 2050* and produced two fundamentally different visions of the low carbon strategy. This fork persisted in the scenarios that emerged after the carbon neutrality commitment was made in October 2021 (Figure 3.3):

- *Forest First (2F)*. *Russian Low Carbon Development Strategy to 2050* and the calculations by IEF RAS[48] and VEB that support this document make a focus on doubling CO_2 net sinks in LULUCF on the 2050 horizon along with a moderate reduction, or even increase, of GHG emissions from other sectors which close the balance to achieve carbon neutrality in 2060. Additional sequestration in LULUCF seems an extremely ambitious, not to say unrealistic, target (see below). The entire *Strategy* is practically based on one 'forest' pillar, which entails substantial risks of not achieving carbon neutrality in 2060.
- *Forest Last.* This vision is reflected in the works by CENEf-XXI (*4S, 4D,* and *4F* scenarios), experts from HSE and RANEPA.[49] They focus on substantial reduction of GHG emissions from all sectors, and see reductions in LULUCF as Russia's last hope for achieving carbon neutrality. Therefore, net sinks in LULUCF are defined as those to close the balance to achieve carbon neutrality in 2060.

Take the road on the left – … and you'll find *Forest First.* This pathway ensures that GHG emissions will freeze until 2030. Then there will be an unrealistic growth in LULUCF sinks, an increase in industrial and agricultural emissions, a moderate decline in buildings, a substantial drop in the power sector, other energy and transport sectors with a totally unfeasible drop to zero in the waste sector (Figure 3.3).

[45] Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzichek, A. Lunin, I. Govor. 2022. Russia's carbon neutrality: pathways to 2060. CENEf-XXI. https://cenef-xxi.ru/articles/low-carbon-technologies-in-russia:-current-status-and-perspectives; Bashmakov I. Russia on the way to carbon neutrality: three 'fours' and one 'two'. Neftegazovaya Vertikal. No. 11, 2022. (In Russian); Bashmakov I. Scenarios of Russia's moving towards carbon neutrality. Energosberezheniye. No. 1, 2023. (In Russian).
[46] Shirov A.A., Kolpakov A.Yu. Russia's target scenario of net low carbon social and economic development to 2060. Problemy Prognozirovaniya, 2023, Issue 6. (In Russian).
[47] Klepach A.N. (Ed.). Attaining the carbon neutrality target by the Russian Federation by 2060. VEB RF. January 2023. This paper does not describe, how exactly the estimates were obtained.
[48] Porfiriev B., Shirov A., Kolpakov A. Low carbon development strategy: perspectives for the Russian economy. Mirovaya energetika i mezhdunarodnye otnosheniya. 2020. Vol. 64, No. 9. Pp. 15-25, https://doi.org/10.20542/0131-2227-2020-64-9-15-25.
[49] Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzichek, A. Lunin, I. Govor. 2022. Russia's carbon neutrality: pathways to 2060. CENEf-XXI. https://cenef-xxi.ru/articles/low-carbon-technologies-in-russia:-current-status-and-perspectives; bp Energy Outlook 2050: January 2023; IEA. 2021. Net-Zero by 2050. A Roadmap for the Global Energy Sector; IEA. 2015-2023. World Energy Outlook; IEA. 2017-2023. Energy Technology Perspectives; Laitner J., Lugovoy O., Potashnikov V. Cost and Benefits of Deep Decarbonization in Russia. Ekonomicheskaya Politika, 2020. No. 2, pp. 86-105, https://doi.org/10.18288/1994-5124-2020-2-86-105; Safonov G., V. Potashnikov, O. Lugovoy, M. Safonov, A. Dorina, A. Bolotov. The low carbon development options for Russia. Climatic Change. https://doi.org/10.1007/s10584-020-02780-9 Springer Nature B.V. 2020; Schaeffer R., A. Koberle, H. van Soest, C. Bertram, G. Luderer, K. Riahi, and V. Krey, D. P. van Vuuren, E. Kriegler, Fujimori, W. Chen, C. He, Z. Vrontisi, S. Vishwanathan, A. Garg, R. Mathur, S. Shekhar, K. Oshiro, F. Ueckerdt, G. Safonov, G. Iyer, K. Gi, V. Potashnikov. 2020. Comparing Transformation Pathways Across Major Economies. Climatic Change 162, no. 4:1787–1803.

Figure 3.3 Key fork in carbon neutrality pathways



Mining+ includes mining, oil refinery and pipelines, transport (-) excl. pipelines

	Target scenario by IEF RAS	**4D – Development Driven by Decarbonization and Democratization – by CENEf-XXI**
	Net emissions from all sources (all GHG)	
2030	-0%. Net GHG emissions are essentially stable until 2030. Decarbonization is aimed to damper external risks and accelerate social and economic development	-18% from the 2021 level (net emissions – all GHG)
2040	-21% from the 2021 level	-37% from the 2021 level
2050	-62% from the 2021 level	-58% from the 2021 level
2060	-100% from the 2021 level	-83% from the 2021 level – all GHG; -100% - net CO_2 emission
	+74% absorption in forestry	-31% absorption in LULUCF
	+13% industry	-75% energy sector
	-10% agriculture*	-38% industrial processes
	-19% construction and housing and utilities	-80% waste
	-39% power plants	-19% agriculture
	-54% mining, oil refinery, and pipelines	
	-71% transport (excl. pipelines)	
	-100% waste	
	GHG neutrality is achievable	**CO_2 neutrality is achievable**

* In agriculture, the dynamics is unclear. The article authored by Shirov and Kolpakov (2023) states that the emission is declining, but the relevant figure shows moderate growth.

Sources: Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzichek, A. Lunin, I. Govor. 2022. Russia's carbon neutrality: pathways to 2060. CENEf-XXI. https://cenef-xxi.ru/articles/low-carbon-technologies-in-russia:-current-status-and-perspectives; Bashmakov I. Russia on the way to carbon neutrality: three 'fours' and one 'two'. Neftegazovaya Vertikal. No. 11, 2022. (In Russian); Bashmakov I. Scenarios of Russia's moving towards carbon neutrality. Energosberezheniye. No. 1, 2023. (In Russian); Shirov A.A., Kolpakov A.Yu. Russia's target scenario of net low carbon social and economic development to 2060. Problemy Prognozirovaniya, 2023, Issue 6. (In Russian).

Take the road on the right – … and you will find *Forest Last.* This pathway ensures carbon neutrality, which leads to zero net CO_2 emission in 2060 and brings net GHG emissions 75% down. This decline is relatively smooth in all sectors. Net sinks in LULUCF go down (Figure 3.3).

A low carbon strategy should not rely on emission reduction or GHG sink increase only in one sector. Moreover, the sector which the Russian government is putting high hopes on may become the key driver behind net GHG emission growth. Net sinks in LULUCF were down from the 2010 peak (698 million tCO_2eq) to 485 million tCO_2eq in 2021. In 2021, this decrease was the main factor behind the net GHG emission growth in Russia. On average, the sinks were declining at a rate of 19.4 million tCO_2eq. per year over this period. If this trend persists, the sinks will be 756 million tCO_2eq down in 2060, and so this sector will become a significant emission source (756 million tCO_2eq – 485 million tCO_2eq = 271 million tCO_2eq). Previously, estimates obtained from the ROBUL model runs[50] were used as a baseline;[51] they showed that LULUCF may become an emission source in 2050 with 56 million tCO_2eq, or the sinks will be down to 277 million tCO_2eq. According to V. Korotkov (based on the CBM-CFS3 model runs), net CO_2 sink will not increase in 2050, but will shrink to 367 million tCO_2eq due to ageing forests.[52] However, the *Strategy* relies on the potential increase in LULUCF sinks by amazing 1,200 million tCO_2 in 2050, and in the projection by IEF RAS this logic is extrapolated to 2060 (to fantastic 1,626 million tCO_2eq). This means an increase in sinks by 1,022 million tCO_2eq, using the estimates of IEF RAS for 2021, or by 1,141 million tCO_2eq, using the 2021 national inventory data. With an account of the downward trend in net sinks, LULUCF projects should ensure additional sinks of 1,260-1,900 million tCO_2eq. According to the Center for responsible environmental management of the Institute of Geography of the Russian Academy of Science, by reducing fire emissions, undertaking climate change adaptation measures in the forestry, implementing climate projects in the Russian forests and revising the accounting methodology for GHG absorption by forests, it is possible to increase the sinks by a maximum of 380 million tCO_2 per year.[53] Another research by the staff of this institute indicates, that the potential for cost effective sequestration through climate projects (with costs below USD30/tCO_2) is limited to 200 million tCO_2eq/year to 2050, and the potential for GHG sink increase through methodology revisions is about another 85 million tCO_2.[54] The analysis of data from forest projects against the field measurements shows, that the large part of the projects either did not manage to reduce deforestation, or the results were much below ones expected.[55] A. Romanovskaya believes, that the focus on increased GHG absorption by forest and other ecosystem projects in the Russian strategic documents raises questions, and that these projects incur larger risks, than projects in the industrial sector.[56]

[50] Zamolodchikov D.G., Grabovsky V.I., Chestnykh O.V. (2017). ROBUL-M: a new forest carbon budget projection tool // Russian forests: policy, industry, science, education. Proceedings of the second international scientific and technical conference. Vol. 2. St.Petersburg: St.Petersburg State Forest University. Pp. 125–128.

[51] Bashmakov I.A. Russian low carbon development strategy. *Voprosy Ekonomiki*. 2020;(7):51-74. (In Russ.), https://doi.org/10.32609/0042-8736-2020-7-51-74.

[52] How much CO_2 do Russian forests absorb and how much more can they absorb? (climate-change.moscow).

[53] Shvarz E.A., Ptichnikov A.V. Russia's low carbon development strategy and the role of forests // Scientific papers of the Free economic society of Russia. 2022. Vol. 236, pp. 399-425. DOI: 10.38197/2072-2060-2022-236-4-399-426.

[54] Ptichnikov A.V., E.A. Shvartz, G.A. Popova, A.S. Baibar. Russia's low carbon development strategy and the role of forests. Bulletin of the Russian Academy of Science, 2023, Vol. 93, No. 1, pp. 36–49. DOI: 10.31857/S0869587323010073, EDN: ENEITI; Ptichnikov A.V. and A.E. Shvarz. Decarbonization through natural solutions: national policy and international practice. Izvestia RAS. Geographical series, 2023, Vol. 87, No. 4, pp. 1–18. DOI: 10.31857/S2587556623040040, EDN: UJEAGE.

[55] West, T.A., Wunder P. S., Sills, E.O., Börner, J., Rifai, S.W., Neidermeier, A.N.,Frey, G.P., Kontoleon, A. (2023) Action needed to make carbon offsets from forest conservation work for climate change mitigation, Science, vol. 381, 873-8 (15) (PDF) Action needed to make carbon offsets from tropical forest conservation work for climate change mitigation (researchgate.net).

[56] Romanovskaya A.A. Approaches to implementing ecosystem climate projects in Russia. Izvestia RAS. Geographic series, 2023, Vol. 87, No. 4, pp. 463–478. DOI: 10.31857/S2587556623040118, EDN: BIJJQJ.

***2F* is essentially a scenario of Russia abandoned by its population**. According to Roslesinforg, it takes a forest planted on 2.5 ha to reach the age of 10 years to be able to absorb 1 ton of carbon (3.7 tCO_2). That is, the ratio is 1 tCO_2/0.68 ha. According to other data, given the current species/age structure of mature forests in Russia, it takes 0.56 ha[57] to absorb 1 ton of carbon, or 1 tCO_2/0.15 ha. If this is the case, then it is necessary to plant 857-1,292 million ha of forest (according to the Roslesinforg estimates) or 189-285 million ha (according to the alternative estimates) to increase the sinks by 1,260-1,900 million tCO_2. And this is provided that there will be no losses from wildfires and pests. According to Rosstat, total land area in Russia is 1,712 million ha, farmland is 222 million ha, forest-covered area is 871 million ha, developed property and road-covered land is 14 million ha, water-covered land and swamps are 227 million ha, other land is 393 million ha, including 335 million ha of reindeer pastures in tundra, where forest does not grow, 4 million ha of deserts, and the remaining land is covered by landfills, urban waste disposal sites, ravines, and bare rock.[58] This is to say, that the *2F* pathway requires that a substantial part of, or all of the farmland, and part of other land where forest cannot grow, be planted with forest.

Before proceeding to the development of a *4D* roadmap, it is important to make a few comments about the scenario trajectories to carbon neutrality as developed by the IEF RAS.[59] First. The *Aggressive Target* scenario developed by IEF RAS *ensures that Russia achieves carbon neutrality in 2050, providing GDP grows acceleration at a rate of 0.6% per year compared to the Inertial scenario,* in which net emission is 19% up in 2050 (the paper provides no data for this scenario to 2060). Addition in average annual growth rate for household consumption is even higher – 0.8% per year. This is an important result: **according to IEF RAS, carbon neutrality can be attained even in 2050, providing the economic growth is accelerated.** Low carbon investment is 3.5% of GDP. It appears that the models used take no account of the learning curves, which show that specific costs go down as the technology uptake grows. Investment in conventional fuel technologies should go down; however, this is not reflected in the projections, and so the change in the overall investment cannot be estimated.[60] Real electricity price is projected to rise by 61% over 29 years, which means 1.7% growth per year. However, all this does not hamper GDP growth. It is not clear, how fossil fuel costs will be declining, but they should be going down along with the declining demand; therefore, the share of energy costs should not increase.

Second. *The Target scenario* extends the carbon neutrality horizon to 2060 accelerating the growth of GDP and household consumption by another 0.5% per year. The authors conclude that the optimal share of low carbon investment is 1.7% of GDP in 2050. It is not clear, however, how this conclusion was arrived at. Annual GDP growth in Russia of 2.6% in this scenario seems clearly overestimated, because the country faces severe labour shortages on the whole 2060 horizon and has had negative multifactor productivity values for the last 15 years.[61] Average annual GDP growth rates in 2008-2022 did not exceed 1%, while IEF RAS sets 1.5% even for the *Inertial scenario*.

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[57] Schepaschenko D., E. Moltchanova, S. Fedorov, V. Karminov, P. Ontikov, M. Santoro, L. See, V. Kositsyn, A. Shvidenko, A. Romanovskaya, V. Korotkov, M. Lesiv, S. Bartalev, S. Fritz, M. Shchepashchenko & F. Kraxne. Russian forest sequesters substantially more carbon than previously reported. Scientifc Reports | (2021) 11:12825 | https://doi.org/10.1038/s41598-021-92152-9.

[58] State (National) Report on the status and use of land in the Russian Federation in 2021. Federal Service for State Registration, Cadastre, and cartography. Moscow, 2022.

[59] Shirov A.A., Kolpakov A.Yu. Russia's target scenario of net low carbon social and economic development to 2060. Problemy Prognozirovaniya, 2023, Issue 6. (In Russian).

[60] In the IEA's projections, the share of investment in energy supply in GDP is 1% up in 2030 in the NZE scenario, and is back to the 2023 level in 2050 exactly due to the reduced investment in the fossil energy sector. IEA. World Energy Outlook. 2023.

[61] Bashmakov I. Distributional effects of expected carbon mitigation policies in Russia. CENEf-XXI. Moscow. October 2023, https://cenef-xxi.ru/articles/distributional-effects-of-expected-climate-mitigation-policies-in-russia; Bashmakov I.A. Russia's foreign trade, economic growth and decarbonization. Long-term vision. Moscow, April 2023, https://cenef-xxi.ru/articles/russia's-foreign-trade-economic-growth-and-decarbonization.-long-term-vision.

Third. The authors point out that while developing the scenarios to 2060 they used the funds of the most important national innovative project *"Unified National System for the Monitoring of Climate Active Substances"*. However, the description of the methodology which was used for the calculations does not indicate that the set of models was developed any further compared to the earlier research. The core of this set of models is the "intersectorial macrostructural model". While this model is helpful in assessing the effects of structural shifts and individual short-term multipliers, it doesn't address long-term decarbonization problems, because:

- it operates only with aggregated cost parameters and does not reflect the evolution of technologies either by sectors, or by economic activities, or by carbon intensive products, buildings, or vehicles, while it is the technological evolution that is key for decarbonization;
- it does not reflect price elasticity parameters, or price competition between the technologies, or reduction in specific costs as resulting from the learning curves. All additional costs are completely passed over to the production costs leaving no room for either consumer reactions (in the form of demand reduction) or producer reactions (in the form of change of production factors combination and technologies used). Therefore, the costs are substantially overestimated, and judgements regarding the possibility to reduce GHG emissions in sectors other than LULUCF are noticeably underestimated.[62]

Fourth. The authors use a strange indicator – specific capital investment per unit of GHG emission reduction – to assess the costs. This specific capital investment is determined by dividing total investment over the entire projection period by the associated reduction in net GHG emission in 2060. However firstly, the usual practice is to assess incremental capital investment,[63] because money is invested not so much to reduce GHG emissions, but to generate revenues from power generation, products manufacturing, transport work, housing construction, etc. The share of incremental investment associated specifically with GHG emission reductions can vary between 0 and 100% depending on the technology, and so attributing the entire investment to only one effect is incorrect. Secondly, when estimating the costs of GHG mitigation it is typical to assess levelized costs with an account of energy cost savings, reduced emissions of harmful substances, reduced down time, increased product output, etc., rather than specific capital investment. And thirdly, even in the selected method of comparing the costs, the authors do not take into account the fact that the GHG mitigation effects will persist even beyond 2060, for some technologies and buildings for several decades. In other words, specific capital investment as given by IEF RAS is well overestimated, and technologies should be compared using different metrics, such as levelized costs, building lifecycle costs, car ownership costs, etc. If wrong metrics are chosen for cost assessments, optimization of these metrics makes little sense.

[62] Let us give an example. Suppose, some metals are required to produce a certain type of equipment. This could be, for instance, 0.9 t of steel and 0.1 t of aluminium. The price of steel is 70 thousand rubles/t, and the price of aluminium is 250 thousand rubles/t. Let us further assume that, technologically, 0.1 t of aluminium can be replaced with 0.4 t of steel. If aluminium becomes three times more expensive, the technological coefficients in the model of IEF RAS will remain unchanged, and so the cost of the equipment will go 50 thousand rubles up (0.1*(750-250)). However, in real life competition in the equipment market will force the producer change the technological process and replace aluminium with steel, so the equipment cost will be only 3 thousand rubles up (0.4*70,000-0.1*250,000=3,000).

[63] IEA. 2022. Energy Efficiency 2022; IEA. 2023. World Energy Investment 2023; Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzichek, A. Lunin, I. Govor. 2022. Russia's carbon neutrality: pathways to 2060. CENEf-XXI. https://cenef-xxi.ru/articles/russia's-carbon-neutrality:-pathways-to-2060; Safonov G., V. Potashnikov, O. Lugovoy, M. Safonov, A. Dorina, A. Bolotov. The low carbon development options for Russia. Climatic Change. https://doi.org/10.1007/s10584-020-02780-9 Springer Nature B.V. 2020.

3.3 *4D*: roadmap on the aggregated level

3.3.1 Target indicators

A *roadmap* is a plan to achieve a goal or a given vision of the future.[64] In this work, the vision of the future is the *4D* scenario from the *Forest Last* family of scenarios (Figure 3.3). Its parameters in terms of economic growth, changes in the structure of technologies used, the dynamics and structure of GHG emissions, and assessments of the distributional effects of low carbon policies are described in detail in the series of works of CENEf-XXI.[65] The resulting dynamics of GHG and CO_2 emissions by the key sectors as shown in the national GHG inventory is shown in Figures 3.4 and 3.5 along with the milestones by decades. The net balance of emissions and sinks will be achieved in 2060 for CO_2. As to all GHG, net emissions will be 91% down from the 1990 level and will remain positive. There are small amounts of CCS in power and industry sectors. Absorption of CO_2 by concrete is shown only for illustrative purposes as it is not yet part of GHG inventories[66]. Some countries already started evaluation of national potential for such sink.[67]

The less progress is achieved in mitigating emissions from fuel combustion and industrial processes, the larger the light green zone needs to be for 2060 neutrality commitment to be met. Weak progress in emission reduction ultimately would shift the pathway at Fig.2 from *Forest Last* to *Forest First*. But the last has severe limitations in providing needed sinks volumes, thus making neutrality commitment without reach.

Reduction in net emissions is expected as soon as in 2030 with a subsequent continuation by a nearly linear trajectory. At the same time, sinks in LULUCF will be gradually decreasing dark green zone), while the efforts made in this sector will allow for a partial offset (by 248 million tCO_2 - light green zone) of this loss of 396 million tCO_2. Emissions will be going down in all sectors. There is no CO_2 emissions from the waste sector.

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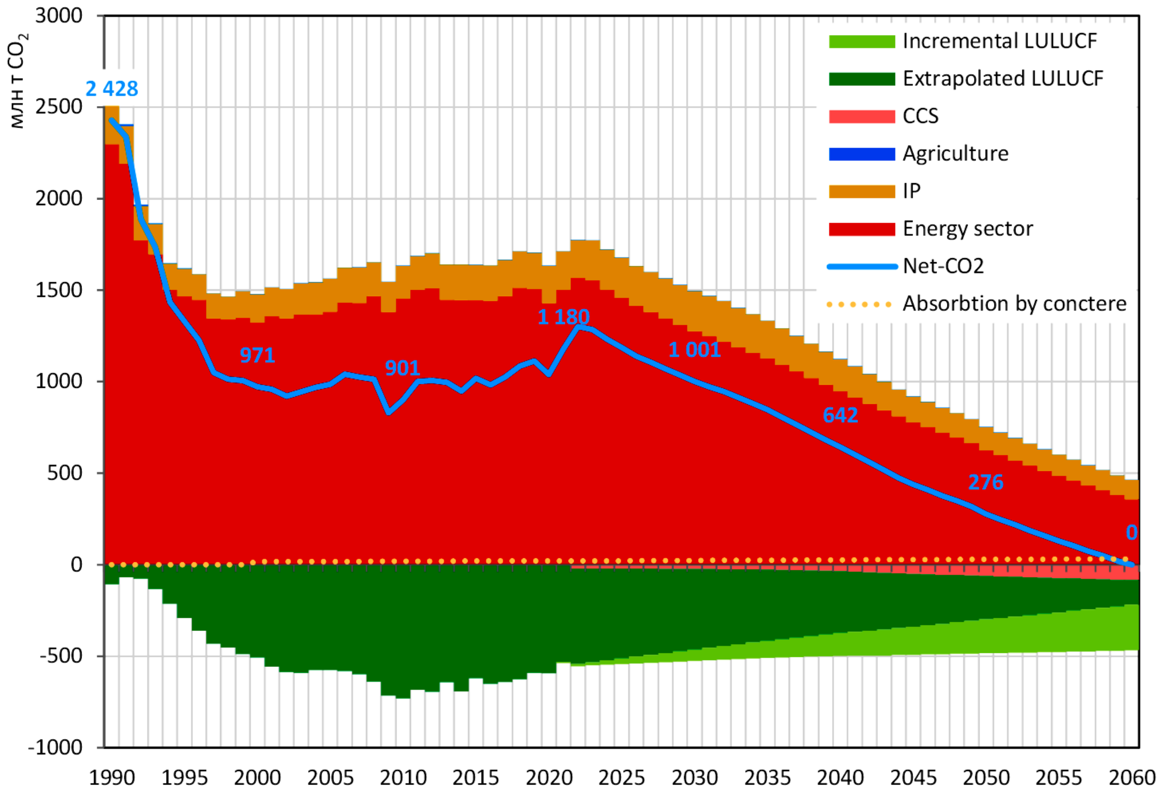
[64] ROADMAP | English meaning - Cambridge Dictionary.

[65] Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzichek, A. Lunin, I. Govor. 2022. Russia's carbon neutrality: pathways to 2060. CENEf-XXI. https://cenef-xxi.ru/articles/russia's-carbon-neutrality:-pathways-to-2060; Bashmakov I.A. Russia's foreign trade, economic growth and decarbonization. Long-term vision. Moscow, April 2023, https://cenef-xxi.ru/articles/russia's-foreign-trade-economic-growth-and-decarbonization.-long-term-vision; Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzichek, O. Lebedev, A. Lunin, A. Myshak. 2023. Low carbon technologies in Russia. Current status and perspectives. https://cenef-xxi.ru/articles/low-carbon-technologies-in-russia:-current-status-and-perspectives; Bashmakov I. Distributional effects of expected carbon mitigation policies in Russia. CENEf-XXI. Moscow. October 2023, https://cenef-xxi.ru/articles/distributional-effects-of-expected-climate-mitigation-policies-in-russia. Bashmakov I. Foreign trade, economic growth and decarbonization in Russia. Long-term prospects. Part 1 and 2. Netegazovaya (Oil and gas) vertical. No. 11 and 12. 2023. Внешняя торговля, экономический рост и декарбонизация в России. Долгосрочные перспективы. Часть 2 (ngv.ru)

[66] (see The GCCA 2050 Cement and Concrete Industry Roadmap for Net Zero Concrete, London, UK, 46 p., available at: https://gccassociation.org/con cretefuture/wp-content/uploads/2021/10/GCCA-Concrete-Future-Roadmap-Docu ment-AW.pdf; Guo, R. et al. (2021) Global CO2 uptake by cement from 1930 to 2019, Earth Syst. Sci. Data, vol. 13(4), pp. 1791-1805, doi:10.5194/essd-13-1791-2021; Bashmakov, I.A. (2023) Global cement industry development and decarbonization perspectives, Fundamental and Applied Climatology, vol. 9, no. 1, pp. 33-64, doi:10.21513/2410-8758-2023-1-33-64

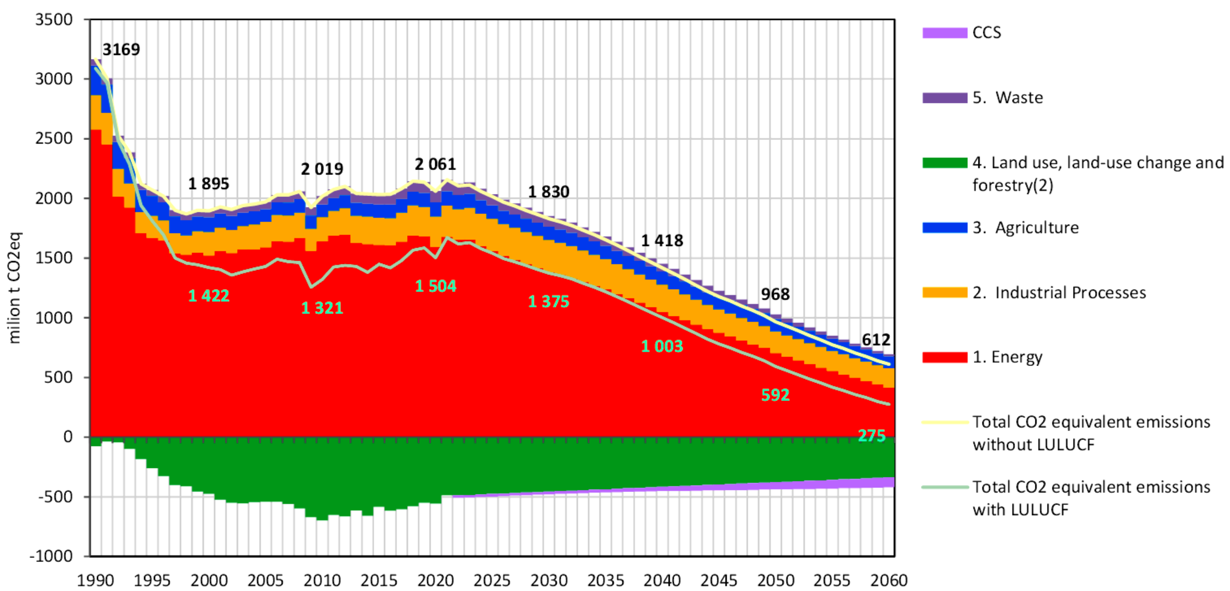
[67] Sanjuan, M.A., P. Mora (2020). Carbon Dioxide Uptake by Cement-Based Materials: A Spanish Case Study, Appl. Sci., vol. 10, p. 339, doi:10.3390/app10010339.

Figure 3.4 Evolution of CO_2 emission by sectors to achieve carbon neutrality



Source: estimated by authors.

Figure 3.5 Evolution of GHG emissions by sectors



Source: estimated by authors.

Table 3.1 GHG and CO_2 emissions reduction targets in *4D* scenario

	2021	2030		2040	2050	2060	
Net GHG emissions, Mt CO_2eq	1504	1375	-9%	1003	592	275	-72%
Net CO_2 emissions, Mt CO_2	1180	1001	-15%	642	276	0	-100%
Energy related emission, Mt CO_2	1501	1275	-15%	932	618	353	-76%
Power generation, Mt CO_2	557	482	-13%	371	243	117	-79%
Heat production, Mt CO_2	355	315	-11%	280	228	174	-51%
Industry and construction*, Mt CO_2	344	243	-29%	141	74	49	-86%
Transport*, Mt CO_2	264	207	-22%	149	96	60	-77%
Buildings*, Mt CO_2	516	491	-5%	432	342	245	-53%
Agriculture*, Mt CO_2	27	26	-4%	21	20	15	-44%
Communal*, Mt CO_2	9	6	-33%	3	1,4	0,3	-97%
Industrial processes, Mt CO_2	210	220	+5%	176	126	107	-49%
LULUCF, Mt CO_2	-532	-510	-4%	-479	-447	-415	-22%
CCUS, Mt CO_2				8	31	52	∞

Including indirect emissions. That is why total by sectors exceeds the emissions from the "energy sector".

Source: CENEf-XXI.

3.3.2 Three domains and five pillars of low carbon policies

On the business-as-usual pathway, none of the decarbonization goals as outlined above can be achieved. Solutions that can help change the inertial trajectory are required. There are three basic models of making investment and management decisions:[68]

- ***Satisficing*** is a 'non-optimal behaviour', or 'limited rationality' model; in this model, people follow the established stereotypes and are not economic locators looking for, and using, every opportunity to reduce costs or maximize their wealth. The role of price factors in decision-making is limited, as long as the energy cost share is low. As a result, excessive amounts of energy and other resources are used due to the lack of information, motivation, access to financing and to centers of decision-making.

- ***Optimization*** is the area of neo-classical theories and theories of wealth maximization, which assume that a typical market agent (*homo economicus*) aspires to optimize his (her) costs and benefits. It is largely used by companies with a relatively high energy cost share, which – in a perfect market – choose the most cost-effective technology. Price and market incentives are key for this model. This is an area dominated by general equilibrium models, in which carbon price is the key GHG emission control tool. In these models, the behavior dictated by the *satisficing* model is typically reflected through low price elasticity coefficients. The values of the coefficients are mainly calibrated using marginal change in the price parameters, while they apply to very high carbon prices. Therefore, the fact that price elasticities are asymmetric and are determined by the energy cost share, is ignored.[69] For this reason, general equilibrium models overestimate the carbon price required to ensure that a given GHG emission reduction is achieved. In addition, part of the additional costs incurred is passed on to the consumers, thus diluting the decarbonization incentives. Another problem faced by general equilibrium models is looking at technological progress as an exogenous "manna from heaven".

- ***System transformation*** is the restructuring of the technological base and of the economic structure to promote going beyond the "limits of growth" or beyond the existing "limits of change" to address important strategic challenges, such as climate change. It is the responsibility of governments and international organizations to handle such strategic tasks. It is not an optimization problem, because both the set of perspective key technologies, and many of their cost parameters may be unknown at the start.[70] This decision-making model relies on the innovation and structural change, creating large markets for new products, and building technological production chains based on the visions of the future and on the strategic investment.

The need for strategic decisions emerges when the existing technological and management systems run into the "limits of growth" or "limits of change". Scarce resources, and resources which can cause significant environmental or climate damage, get so much more expensive (either directly – via the internalization of externalities, or indirectly – through the damage/loss compensation costs), that the economic growth is terminated or substantially slowed down. When

[68] Grubb, M., Poncia, A., Drummond, P., Hourcade, J.C., Neuhoff, K., 2023. Policy complementarity and the paradox of carbon pricing. *Oxford Review of Economic Policy,* Vol.39:4.

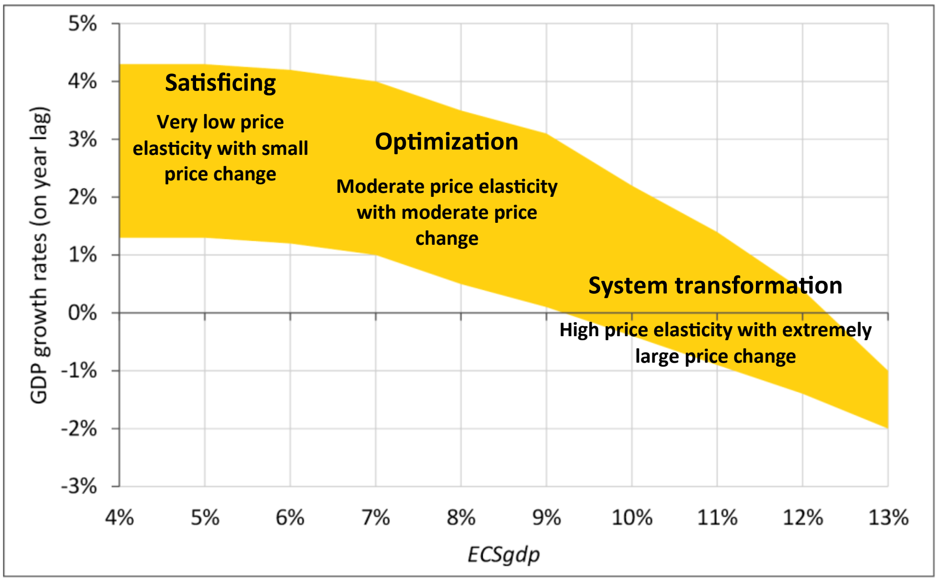
[69] Bashmakov, Igor, Grubb, Michael, Drummond, Paul, Lowe, Robert, Myshak, Anna, and Hinder, Ben. 'Minus 1' and Energy Costs Constants: Empirical Evidence, Theory and Policy Implications. Available at SSRN: https://ssrn.com/abstract=4401851.

[70] "Contrary to the common prescription to begin with the low-cost abatement options and incrementally increase efforts and costs over time, consideration of transition dynamics implies that the most cost-effective strategy may instead be targeted funding of certain key technologies with large potential and prospects for cost reductions". Grubb, M., Poncia, A., Drummond, P., Hourcade, J.C., Neuhoff, K., 2023. Policy complementarity and the paradox of carbon pricing. Oxford Review of Economic Policy, Vol.39:4.

the energy and carbon cost share is low, other factors determine economic growth rates, while the role and effectiveness of price instruments is extremely limited (Figure 3.6).

When the energy cost share, including carbon price, in GDP stays at 6-9%, economic agents optimize their costs trying to avoid going beyond the *ECS* thresholds. When *ECS* gets beyond the thresholds, economic growth slows down and strategic decisions are required to return to the positive dynamics. Thus, the combination of behavioural patterns follows the change in *ECS*. The deployment of carbon pricing mechanisms helps increase *ECS* and move decision-makers from the dormant zone (satisficing) to the invigoration zone. External price shocks (energy price growth, enforcement of *CBAM*, etc.) can provoke going beyond the thresholds, therefore, carbon pricing mechanisms should ensure that *ECS* stays in the pre-threshold zone, including through proactive and effective system transformations.

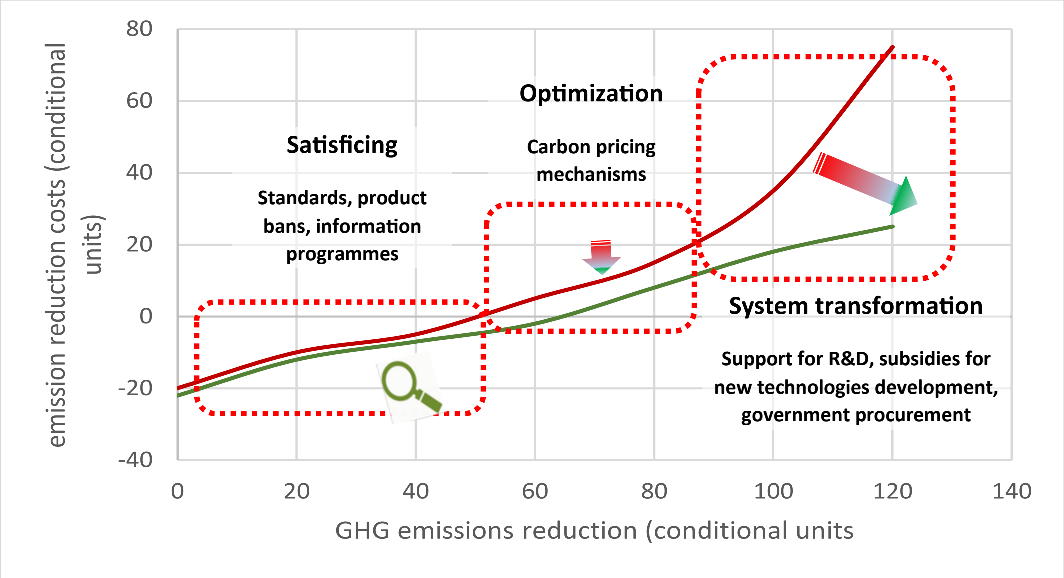
Figure 3.6 **Stylized "wing" function (the function of GDP growth (1 year lag) of ECSgdp) and three types of investment and management decision-making**



Sources: Bashmakov, I. (2017). The First Law of Energy Transitions and Carbon Pricing. International Journal of Energy, Environment and Economics, 25(1), 1–38; Bashmakov, Igor, Grubb, Michael, Drummond, Paul, Lowe, Robert, Myshak, Anna, and Hinder, Ben. 'Minus 1' and Energy Costs Constants: Empirical Evidence, Theory and Policy Implications. Available at SSRN: https://ssrn.com/abstract=4401851 or http://dx.doi.org/10.2139/ssrn.4401851.

A set of low carbon policies should foster the required change in the first two decision-making models and lay a basis to launch the third model. Policies, such as standards, product bans, labeling and other information tools, primarily aim to implement cost-effective measures, which are not being implemented for a variety of reasons under the *"satisficing"* decision-making model (Figure 3.7). Carbon pricing mechanisms make low carbon solution more economically attractive, while strategic policies look to improve the emission reduction potential and to reduce the costs of new technologies.

Figure 3.7 Low carbon policies as a function of GHG mitigation costs



Sources: adapted by CENEf-XXI from: The World Bank. State and Trends of Carbon Pricing. Washington DC. October 2016.

Progress in any sphere helps ensure progress in all other spheres. Carbon pricing mechanisms work much more effectively, if carbon-intensive products are removed from the market by standards and product bans; energy consumption is strictly metered and can be controlled; and there are calculators for timely and effective assessment of solutions. All the above factors help significantly reduce the share of economic agents who rely on the satisficing model. Setting a carbon price at a level that will keep the energy cost share (ECS) close to the upper threshold helps to avoid the rebound effect, encourages R&D in low carbon technologies, and helps reach price parity more quickly.

The above targets can be achieved through a variety of policies to introduce the low carbon component into the three decision-making models as specified above, and to develop five pillars for sustainable and effective GHG mitigation (Table 3.2):

- **Technologies** – availability of a wide variety of technologies and equipment for GHG mitigation in all sectors;
- **Regulations and programmes** – mandatory requirements that allow for policies and coordinated action to achieve the targets as specified in the national strategies and programmes;
- **Incentives and financing** – measures aiming to improve the economic attractiveness of low carbon technologies and to provide access to financing which is essential to comply with regulations and attain the targets;
- **Institutes** – organizations that are authorized to launch and coordinate decarbonization processes and are responsible for the results, and agencies that represent low carbon transition stakeholders;
- **Human capital** – a sufficient number of experts with adequate training who are engaged in policy development, organization and implementation of low carbon transition; providing these experts with knowledge, information, and tools for decision making.

Table 3.2 Five pillars and three domains of low carbon policies

Five pillars	Investment decision-making models		
	Satisficing	Optimization	Transformation
Technologies	Technologies in place. They are economically attractive, but for different reasons, incl. for low ECS* or high monopolization; their potential is untapped.	Technologies in place. BATs with acceptable payback parameters. They are basically used by market agents with high ECS, who are looking to optimize their costs in sectors with high competition.	New technologies, which can shift the technological border; while they have high upfront costs, they have a potential to bring these costs down through the learning curve, as the deployment scale grows and through additional R&D.
Regulations and programmes	Standards, product bans, licenses, certification, labeling and other information tools to increase the uptake of available technologies.	Regulations to launch incentives and financial mechanisms and to set criteria for investment decision-making to improve the economic attractiveness of the available technologies.	Regulations and programmes to develop innovative technologies, increase the localization levels, and to expand the application niche. Taxonomies.
Incentives and financing	'Green' and 'white' certificates; subsidies; programme financing	Tariff mechanisms; elimination of energy subsidies; carbon pricing mechanisms (emission trade, carbon tax); tax benefits; loan benefits; programme financing.	R&D financing; priority access to the market; government procurement; programme financing, benefits and subsidies, carbon pricing mechanisms.
Institutes	Development and adoption of regulations and programmes: Presidential Office, national government, Federation Council, regional and local governments. Enforcement of regulations and programmes – national executive bodies and agencies. Government support leverage – development agencies and other financial institutions. Monitoring – Rosstat, regional and local governments and subordinate agencies. Stakeholders: industrial and professional associations, civil society institutes. Human capital development – educational institutions and professional training agencies.		Developers of new technologies and strategic technology priorities: Russian Academy of Science (RAS), universities, think tanks in economic sectors, innovative research centers, state research institutes and other development agencies; corporate sector
Human capital	Technological capacity building; personnel training to encourage technology uptake. Fostering new "green" behavioural patterns.		Availability of highly qualified personnel in strategic planning and development of new technologies

*ECS – energy cost share.

Source: CENEf-XXI.

Five pillars of the economy-wide low carbon policy are shown in Table 3.3. They are shown in a quite general way. More details by sectors and technologies are provided in the subsequent chapters.

Table 3.3 Five pillars for economy-wide decarbonization

Entire economy

Technologies	Regulations and programmes	Incentives and financing	Institutes	Human capital

• Identifying key low carbon technologies
• Product carbon footprint upper levels, based on benchmarking
• Increasing technological readiness levels of low carbon technologies
• Low carbon technologies deployment targets
• Low carbon technologies domestic production targets
• Low carbon technologies localization level targets
• Development of infrastructure to upscale low carbon technologies deployment
	• Revisions of NDC every 5 years to increase the level of ambition
	• Development of a carbon neutrality strategy to 2060 and its subsequent revisions once in 5 years
	• GHG emission quotas or reduction targets by sectors and industries
	• Regulation to launch low carbon regulation mechanisms
	• Standards and bans
	• Integration of low carbon transition sections in sectorial strategies
		• Development of carbon pricing mechanisms, including CBAM adjustment, in sectors, and setting price change caps
		• Establishing a Low carbon innovations fund
		• Subsidies for low carbon technologies production and deployment
		• Tariff mecha-nisms to incentivize low carbon technologies uptake
		• Loans and guarantees
		• Tax benefits
		• Government procurement of products with low carbon footprint
		• Financing for high-potential R&D
			• Presidential Office
			• Russian government – substantial capacity building for low carbon transition process
			• Russian legislature
			• Regional governments
			• Municipalities
			• Institutional development
			• Sectorial associations
			• Corporations
			• Research and innovative organizations, think tanks, educational and engineering centers
			• Civil society institutes
				• Educational and corporative centers, work placements, and training for:
				  • Government officials
				  • Designers and experts
				  • Financial experts
				  • Households
				• Benchmarking systems, calculators to estimate carbon footprint, BAT inventories
				• Guidelines, trainings, menu of typical solutions
				• Certification of experts
				• Development of carbon and statistical reporting systems
				• New behavioural patterns

Technologies	Mechanisms		Stakeholders	

Source: CENEf-XXI.

4 Power sector

4.1 Key performance indicators

Key performance indicators (KPI) for the power sector include 14 parameters: primary energy consumption for power generation; power generation; share of power in energy end-use; share of non-fossil power sources; share of renewables; share of variable renewables; share of wind; share of solar; share of geothermal energy; share of hydro; share of nuclear; share of bioenergy; energy storage capacity; and specific emissions (CO_2/kWh). Estimated KPI values are shown in Tables 4.1-4.2.

Table 4.1 Key performance indicators for power generation

	2021	2030		2040	2050	2060	
Primary energy consumption for power generation, Mtce	301	286	x0.95	323	372	401	x1.3
Power generation, billion kWh	1159	1130	x0.97	1296	1540	1723	x1.5
Share of power in energy end-use	14%	15%	x1.1	18%	24%	29%	x2
Share of non-fossil power sources	39%	42%	x1.1	52%	67%	76%	x2
Share of renewables	19%	22%	x1	25%	34%	42%	2x
Share of variable renewables	0,6%	2%	x4	7%	17%	27%	48x
Share of wind	0.3%	1.4%	x4.5	4.6%	10.6%	15.4%	48x
Share of solar	0.2%	0.7%	x3	2.6%	6.7%	11.2%	49x
Share of geothermal	0.04%	0.08%	x2	0.08%	0.08%	0.07%	2x
Share of hydro	19%	19%	x1	17%	16%	15%	0.8x
Share of bioenergy	0.2%	0.2%	x1	0.3%	0.3%	0.4%	1.7x
Share of nuclear	19%	20%	x1.1	27%	33%	34%	1.8x
Power storage systems, thousand kWh	32	169	x2.5	566	1 116	1 700	x10
Carbon intensity of power, gCO_2/kWh	324	282	x0.9	207	121	61	x0.2

Source: CENEf-XXI.

Table 4.2 Average annual growth rate of generation capacity (MW)

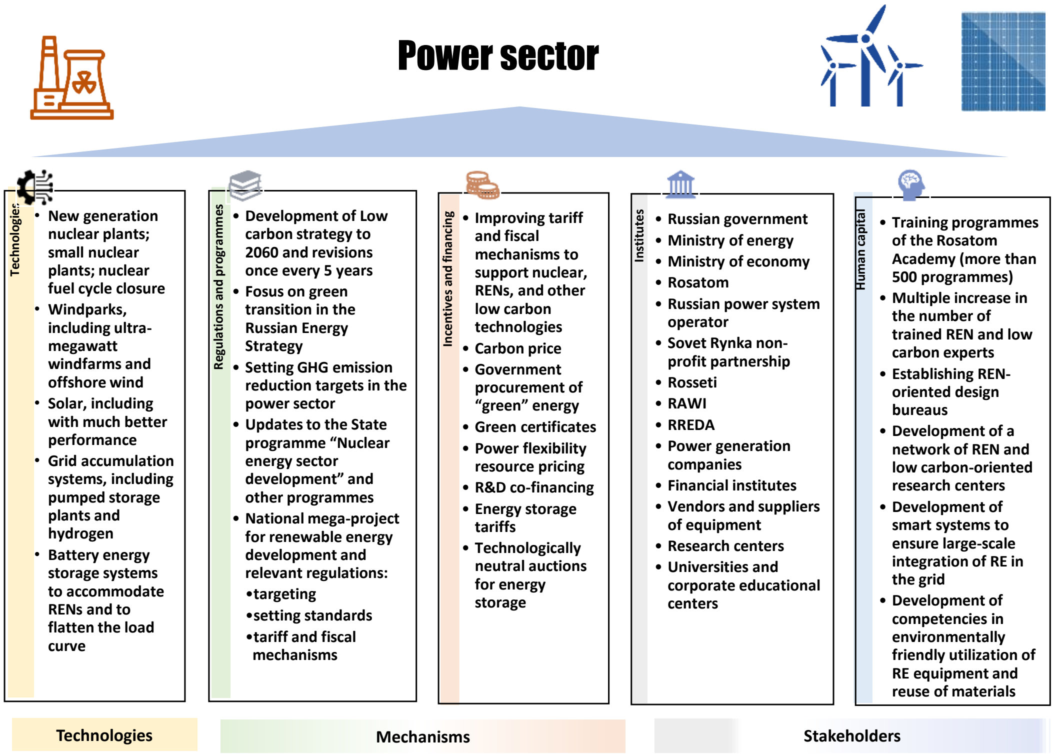
	2015-2022	2023-2030		2031-2040	2041-2050	2051-2060	
Total	3517	3971	x1.1	8024	11300	10536	x3
Renewables	643	1473	x2.2	4201	7124	7983	x12
Share of renewables	18.3%	37.1%	x2	52.4%	63.0%	75.8%	x4
Wind	287	748	x2.6	1 952	2 913	3 626	x13
Solar	229	510	x2	1 448	3 172	3 691	x16
Geothermal	9	3	x0.3	3	3	0	x0
Bioenergy	14	9	x0.6	43	57	51	x4
Hydro	104	204	x2	755	979	614	x6
Nuclear	930	989	x1	2 004	2 804	1 770	x2
Coal-fired thermal power plants without CCUS	497	353	x0.7	280	86	32	x0.06
Coal-fired thermal power plants with CCUS	0	0		13	24	14	
Gas-fired thermal power plants without CCUS	1 344	953	x0.7	733	214	86	x0.06
Gas-fired thermal power plants with CCUS	0	0		38	69	37	
Energy storage systems	3	8	X2.5	20	28	29	x10

Source: CENEf-XXI.

4.2 Roadmap

For the power sector, the roadmap specifies three directions: nuclear, renewable, and energy storage systems. The roadmap provides four tables. The first table shows what each of the pillars to ensure sustainable and effective GHG emission reduction process consists of; the other three provide more detail and show how the measures can be distributed in time.

Table 4.3 Power sector roadmap



Nuclear power

Parameters	Short-term action to 2030	Long-term vision to 2060
Technologies	Increasing the share of 3rd generation nuclear power plants (including renovated energy blocks) to 40% in 2035. Launching 1.8 GW total capacity of 4th generation nuclear plants with fuel cycle closure through parallel operation of thermal and quick neutrons reactors. Construction of nuclear plants with VVER-TOI reactors to replace RBMK-1000 energy block at Kursk power plant.	Increasing the share of 3+ and 4th generation nuclear power plants to 100%. Improving nuclear power plant flexibility. Addition of small offshore nuclear capacity and onshore capacity in remote and inaccessible settlements. Analysis of possibility to use the sites of decommissioned coal-fired power plants for the construction of nuclear plants.
Regulations	Compliance with regulations that determine nuclear energy sector development, including Russian Energy Strategy to 2035, Russian programme "Nuclear energy sector development", Rosatom's Innovative development and technological modernization programme to 2030.	Integration of nuclear power sector development, improving nuclear cycle safety, and improving the cost-effectiveness of nuclear power plants as targets in new regulations, including revised Russian low carbon strategy, Russian energy strategy to 2050, Power sector General plan, revised nuclear energy sector development programmes.
Incentives and financing	Improving tariff and fiscal mechanisms to support nuclear energy development, including carbon pricing. Expansion of power sales contracts (PSC) and contracts for difference (CfD). Increasing the share of (subsidized) loan and corporate financing. Tax investment loans.	
Institutes	Development of policies and monitoring their effectiveness – Russian government and Ministry of energy. Policy implementation – Non-profit partnership "Sovet Rynka", Russian power system operator, Rosatom, research centers and institutes, design organizations, universities and corporate educational centers, vendors.	
Human capital	Using the potential of the Russian Academy of Science and its institutes, and of Rosatom (28 companies and 6 national think tanks), and the potential of Rosatom Technical Academy, which is key for personnel development and training.	

Renewables (wind and solar)

Parameters	Short-term action to 2030	Long-term vision to 2060
Technologies	Addition of at least 9.8 GW renewable energy capacity before 2028 to generate at least 23.5 billion kWh. Bringing windfarms to price parity on the wholesale market and solar plants on the retail market. Development of the grid facilities, energy storage systems, and smart systems which allow for a maximum use of the RE potential. Increasing the level of localization for solar plants to 100% in 2027, and for windfarms to 75%. Development of ultra-megawatt class windfarm projects.	Development of easy to assemble renewable energy and hybrid systems for cold climates. Increasing the level of localization for grid windfarms to 100% in 2040. Production of a full range of elements for the assembling of solar plants and of key elements for ultra-megawatt class windfarms. Pilot windfarm projects in the Arctic and coastal areas. Improving the efficiency of solar plants through perovskite and n-type solar cells and multistage technologies. Construction of smart power grids to integrate renewables.
Regulations	National mega-project for renewable energy development and compliance with the regulations that require renewable energy-based power generation, and development of new regulations to ensure higher ambition of RE development to 2030, including the Russian energy strategy to 2050, Power sector general plan to 2042, and the Power Sector Law (in terms of power generation certificates). Drafting regulations to support renewable energy sources beyond 2035.	New regulations, including revised versions of the Russian low carbon strategy and Russian energy strategy to 2050, to specify ambitious renewable energy goals, R&D plans, RE support to 2060. Specifying the minimum share of RE-based power generation in the power mix and a possibility of carbon trade. Regulations governing smart power grids construction
Incentives and financing	Improving tariff and fiscal mechanisms to support RE energy development. Launching renewable one-rate tariff projects selection in 2024 based on the level of localization and share of exports in the output. “Green” certificates. Tax and investment loans.	Carbon pricing. Contracts for difference (CfD) – the price is set at an auction, and the producer gets an additional payment if the wholesale price is lower than the contracted value, or makes a refund if it is higher. Government procurement of “green” energy. Power flexibility resource pricing. R&D co-financing.
Institutes	Development of policies and monitoring their effectiveness – Ministry of energy and Ministry of economy. Policy implementation – Russian power system operator, Non-profit partnership “Sovet Rynka”, Russian Association of renewable energy and electric transport (RAWI), Russian association of renewable energy development (REDDA), power producers, renewable project developers, vendors and suppliers, research and educational centers, financial institutions.	
Human capital	Multiple increase in the number of trained experts and educational centers. Growing number and improved expertise of think tanks engaged in new RE technologies development. Professional RE training programmes in Russia can be found in 7 universities and one organization under the aegis of the Russian Academy of Science. Russian association of renewable energy generation and electric transport, Association of renewable energy development, Association of solar power producers represent generation companies, RE projects developers, equipment vendors and suppliers, research institutes and financial institutions.	

Energy storage systems (ESS)

Parameters	Short-term action to 2030	Long-term vision to 2060
Technologies	Development of new generation energy storage technologies; increasing the levels of technological and commercial readiness and launching ESS production under the roadmap “Development of ESS technologies, including portable systems”. Development of infrastructure to increase ESS capacity 8-10-fold in 2030.	Increasing total ESS capacity by order of magnitude from the 2030 level; proactive deployment of different ESS technologies in grid and distributed energy systems. Use of consumers’ ESS to flatten the load curve. Development of an environmentally friendly battery utilization and recycling system.
Regulations	Development of safety, reliability, accounting, utilization, and recycling standards and regulations to ensure ESS integration in the grid. Development and enforcement of regulations to determine the requirements and parameters of ESS development and integration in the grid. Setting ESS development targets in the revised Russian low carbon strategy and the roadmap “Development of ESS technologies, including portable systems”. Requirements for energy supply in off-grid remote territories using renewables and ESS.	Specifying ESS development targets in regulations, including revised versions of the Russian low carbon strategy, Energy strategy, Power sector General plan, and ESS development programmes. Enforcement of revised tariff setting schemes for ESS capacity auctions and to set power storage tariffs. Adjustment of energy market regulations to the ESS progress.
Incentives and financing	Improving ESS tariff and fiscal support mechanisms. R&D subsidies for ESS development and pilot installation. Tax credits, subsidized loans. Energy storage deployment will be incentivized through adjustment of energy market regulations to remove barriers and account for the benefits of energy storage.	Setting energy storage tariffs. Tariff schemes development based on time of day. Carbon pricing. Co-financing for R&D. Power flexibility resource pricing. Technologically neutral auctions for ESS resource.
Institutes	Development of policies and monitoring their effectiveness – Ministry of energy and Ministry of economy. Policy implementation – Rosseti, Rosatom, power producers, Russian power system operator, Non-profit partnership “Sovet Rynka”, Russian Association of renewable energy and electric transport (RAWI), Russian association of renewable energy development (REDDA), renewable project developers, vendors and suppliers, research and educational centers, financial institutions.	
Human capital	Professional training in energy storage systems in Russian universities. Educational materials and tools for personnel training. Identifying the best practices and processes in the sector. Development of software to estimate energy storage demand and to ensure effective integration of energy storage in dispatch. Personnel training for R&D in energy storage.	

Source: CENEf-XXI.

5 Heat sector

5.1 Targets

Heat supply is a red-haired stepchild of the Russian Energy Strategy. All of the editions of this document have given very little attention to this vital sector. Federal Law No. 190-FZ "On heat supply" and the Russian Government Decree No. 1985 of November 3, 2022 "On amendments to the Russian Government Decree No. 1562 of December 15, 2017" did not radically improve the energy efficiency and reliability of heat supply. Russian regions are developing detailed roadmaps for the connection to the district heating networks. The best roadmaps can be found on the official website of the Ministry of construction and housing and utility sector. They cover a narrow aspect – only connection to DHS without specifying any targets. At the municipal level, heat supply schemes are being developed, which include a list of promising investment projects.

Targets for the heat supply sector were specified for the 4D scenario using a 'cloud' of CENEf's models and include the following indicators: district heat production, share of boilers, share of district heat in final energy use, biomass consumption for heat production, distribution losses, and share of heat supply from new generation DHS (Table 5.1).

Table 5.1 Key performance indicators for the heat sector

	2021	2030		2040	2050	2060	
District heat production, MGcal	1362	1328	x0.98	1221	1037	820	x0.62
Share of boilers, %	48%	53%	x1.1	55%	53%	48%	x1
Proportion of district heat in final energy consumption	24%	25%	x1.01	24%	22%	19%	x0.77
Biomass consumption for heat production, Mtce	5.8	7.2	x1.24	11.8	18.2	24.5	x3.39
Distribution losses, %	10.4%	8.2%	x0.8	6.7%	5.5%	4.5%	x0.55
Share of heat supply from new generation DHS, %	0% 4G	0.01% 4G		2.5% 4G	7.5% 4G	15% 4G+5G	x150*
Specific GHG emissions, kg CO_2eq/Gcal	261	245	X1,1 x0.94	232	216	193	X1 x0.74

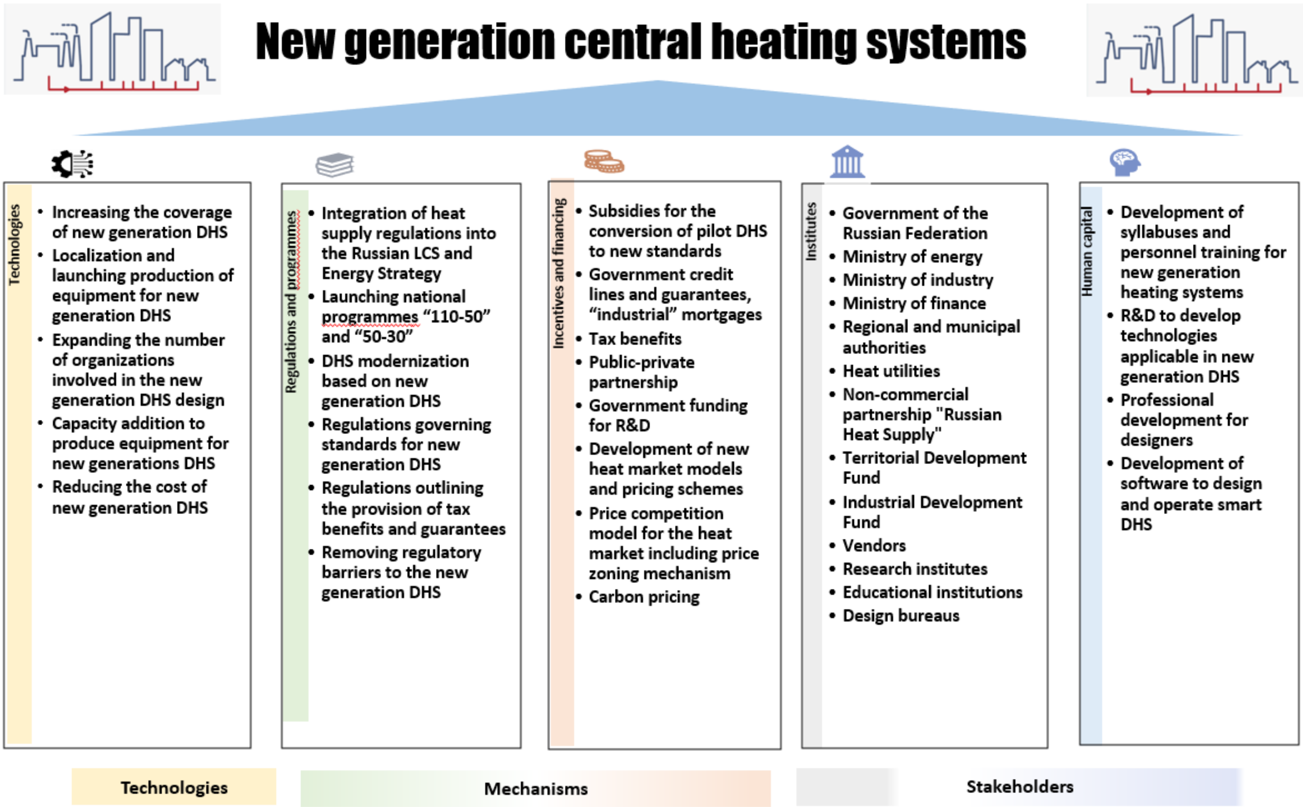
*relative to 2030.

Source: estimated by the authors.

5.2 Roadmap[71]

Heat sector roadmap includes two directions: development of 4th and 5th generation DHS and the use of biomass for district heat production. Below are two tables for each of these directions. The first table describes each of the five ‘pillars’ to yield sustainable and effective GHG emission reductions. The second provides more details regarding the measures and distribution over time.

Table 5.2 Heat sector roadmap



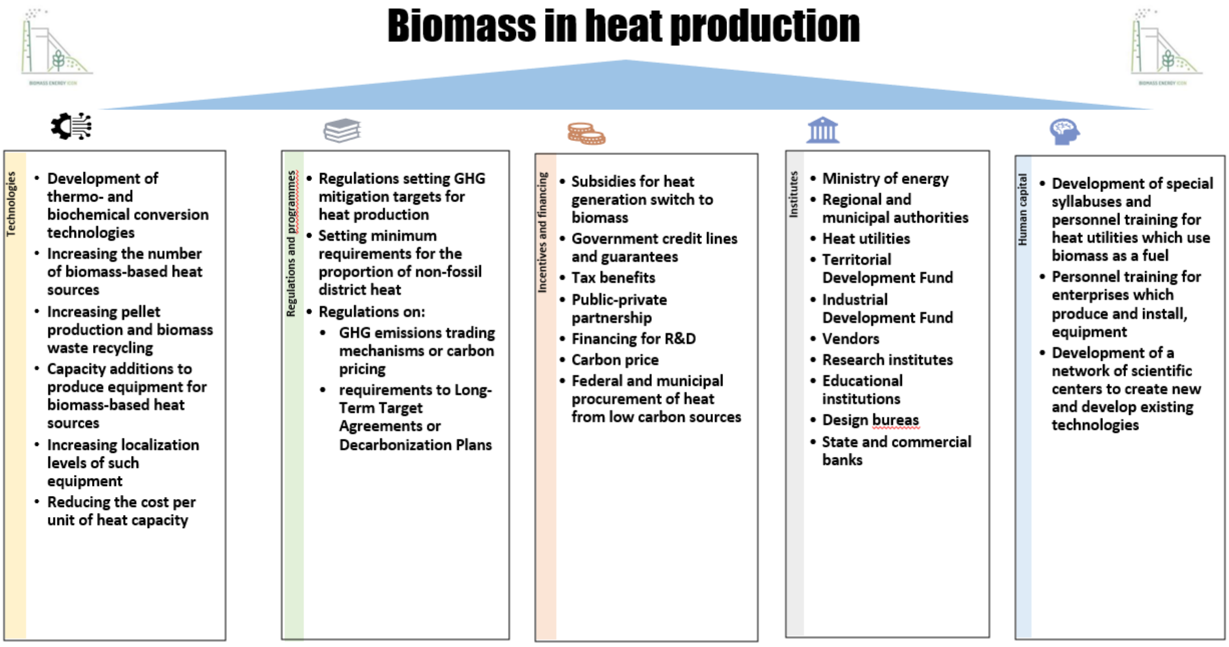
New Generation District Heating Systems

Components	Short-term action to 2030	Long-term vision to 2060
Technologies	Heat supply zoning from the new generation DHS perspective. 4th generation DHS pilot projects. Building new capacity for the production of equipment and materials for new generation DHS (flexible twin pipelines, low temperature radiators, etc.).	Increasing the share of 4th generation DHS (to 15% in total useful heat supply by the end of the period). Capacity addition to produce equipment and materials for new generations DHS. Pilot projects for transition to 5th generation DHS. The emergence of heat prosumers. Increasing the localization level for equipment for new DHS to 75%.
Regulations	Development of regulatory framework for 4th generation DHS. Development of standards for 4th generation DHS. Development of, and launching, national programme “110-50” to upscale 4th generation DHS. Requirement to deploy 4th generation DHS for new buildings from 2031 onwards. Stronger insulation requirements for new and renovated buildings. Regional programmes for the development of 4th generation DHS. Development of syllabuses and personnel training for new generation DHS.	Development of regulations and standards for 5th generation DHS. Expanding the scope of national programme “70-50”. Launching the national program “50-30” to upscale 5th generation DHS. A ban on connecting new MFBs and public and commercial buildings to DHS other than 4th and 5th generations. From 2031 onwards, concession agreements must include a mandatory action plan for the transition to new generation DHS. Regulations to govern incentives and financing for the transition to new generation DHS.
Incentives and financing	Tax benefits and guarantees, investment tax credits, subsidized interest rates, “industrial” mortgage, PPP projects, green bonds. Carbon pricing.	
Institutes	National authorities – financing for R&D and new generation DHS programmes. Territorial Development Fund, banks – financing loans. Industrial Development Fund – co-financing for launching the production of equipment and materials for new generation DHS. Regional and municipal authorities – integration of gradual transition to new generation DHS in heat supply schemes, master plans, and other urban development documents. Regional and municipal authorities – co-financing for transition to new generation DHS. Heat utilities – technical measures for the transition to new generation DHS. Vendors – capacity additions and renovation of existing facilities to launch production of equipment and materials for new generation DHS.	
Human capital	Energy engineering universities – training and professional development of sufficient amount of specialists in the area “New generation heat supply”. Attracting personnel with relevant qualifications to the relevant ministries. Research institutes – development of new types of equipment, materials and software for new generation DHS; integration of renewable energy and other low grade heat sources. Design bureaus – personnel training new generation DHS design. Heat utilities – professional development of employees to operate new generation DHS.	

Source: CENEf-XXI.

[71] This section was written with a contribution from V.N. Papushkin.

Table 5.3 Biomass for heat production roadmap



Biomass in heat production

Components	Short-term action to 2030	Long-term vision to 2060
Technologies	Development of technologies using intense methane fermentation; production of torrefied pellets and briquettes; production of efficient multi-fuel burners and biomass gasifiers with low ash melting temperatures and high ash volatility; reducing the metal and energy intensity of digesters and biogas stations in general. Launching production of equipment and materials for the above technologies.	Development of new thermo- and biochemical conversion technologies to use biomass for heat production. Increasing the volume of heat production from biomass. Capacity additions for the manufacturing of equipment for biomass-based heat production. Increasing the localization level to 100%.
Regulations	Regulations setting GHG mitigation targets for heat production. Setting minimum requirements for the share of low carbon district heat production.	Adoption of regulations on GHG emissions trading mechanisms or carbon pricing schemes. Adoption of requirements to Long-Term Target Agreements or Decarbonization Plans.
Incentives and financing	Tax benefits and guarantees, investment tax credits, subsidized interest rates. Financing for R&D. Co-financing for equipment localization programmes. State and municipal procurement. PPP projects. Carbon pricing.	
Institutes	Ministry of energy - development of national regulations and programmes to increase the share of biomass use for heat production, financing for R&D. Regional and municipal authorities – development of programmes to increase the share of biomass use and integration of these programmes in heat supply schemes; co-financing for projects to develop biomass-based heat sources. Territorial Development Fund – co-financing for projects in biomass-based DHS. Industrial Development Fund – co-financing for biomass production and use equipment. Heat utilities – implementation of projects. Vendors – capacity additions and re-equipment of existing facilities to launch production of biomass-based heat producing equipment.	
Human capital	Energy universities – training and professional development of sufficient amount of specialists with the required competencies. Research institutes – development of new types of equipment and assessment of the potential for biomass use by zones.	

Source: CENEf-XXI.

4D scenario assumes reduction in heat consumption through proactive energy efficiency policies, despite significant new construction. The plan is to introduce a target model of heat market in heat supply price zones to ensure the loading of existing thermal power plants and reduce heat distribution losses down to the required minimum. Heat supply schemes show that newly developed territories will be receiving heat from centralized boilers. Construction of thermal power plants (up to 100 MW installed capacity) does not ensure acceptable paybacks. Construction of combined heat and power plants is becoming economically viable, if subsidized.

On the 25-40 years horizon, part of DHS will be transformed into 4th generation (and even 5th generation) DHW. Such systems should be able to supply heat to buildings with improved insulation from tradition and low temperature heat sources with low distribution losses; integrate low temperature RE sources into DHS and integrate DHS into smart energy systems.

The 4G concept requires a revision of the requirements to thermal protection of buildings and to in-house heat supply and ventilation systems in order to ensure that a low temperature heat source can provide indoor thermal comfort. Technical solutions include: use of pipelines made from new long-lived materials (primarily polyethylene- and polypropylene-based); unit heat capacities (up to 25-30 Gcal/hr) of DHS should be reduced, so that the head sections of pipelines from new materials do not exceed 350-400 mm in diameter; all buildings should be connected to heating networks through individual heating points with automatic controls (and to ensure integration with "smart home" and "internet of things"); independent connection to heat supply for space heating and two-step water heating for DHW; a horizontal distribution of heat carrier within buildings. It is important to develop a standard range of sizes for equipment and relevant equipment to intensify heat exchange for ventilation heat recovery in buildings. By 2050-2060, 25% of individual houses should rely on individual hybrid systems for power and heat supply (fuel cell + solar and power/heat storage). All newly built power and heat sources for public, residential, and commercial uses should rely on combined heat and power generation, and in warm climates on combined heat, power, and cold production. Electric capacity of such CHPs should be based on heat consumption by buildings and should not exceed 30-50 MW.

6 Industry

6.1 Targets

Attaining decarbonization of the iron and steel sector in 2060 requires launching, or substantial upscaling of, low carbon technologies, such as:

- Iron and steel:
  - Steel production in electric arc furnaces (EAF);
  - Direct reduced iron (DRI) production using natural gas and CCUS;
  - DRI production using hydrogen.
- Non-ferrous metals (aluminium production):
  - Aluminium production using pre-baked anodes and ultra-high capacity 2nd generation electrolyzers (PA-550, PA-800+).
  - Aluminium production using inert anodes.
- Cement production:
  - Transition to energy efficient cement production technologies (dry and combined).
  - Reducing the clinker/cement ratio by increasing the proportion of mineral additives and secondary resources to replace limestone.
  - Increasing the share of alternative fuels in cement production.
  - Cement production with CCUS.
- Chemical industry (ammonia production):
  - Natural gas conversion in ammonia production by new large modern equipment with CCUS.
  - Use of 'green hydrogen' in ammonia production.

Targets (KPI) for energy intensive industries were set using a 'cloud' of CENEf's models and include 11 indicators (Tables 6.1 and 6.2).

Table 6.1 Key performance indicators for industry

Indicators	2021	2030		2040	2050	2060	
Final energy consumption, Mtce	276	245	x0.9	207	182	162	x0.6
Share of power in final energy consumption	22%	25%	x1.1	33%	41%	49%	x2.2
CO_2 emissions, Mt	340	244	x0.7	131	82	54	x0.2
Steel production, Mt	71	78	x1.1	80	74	70	x1
Share of EAF steel production	35%	53%	x1.5	83%	100%	100%	x3
DRI production, Mt	8	18	x1	37	45	47	2x
incl. using hydrogen				5	12	13	∞
natural gas with CCUS				5	11	12	∞
Primary aluminium production, Mt	3.7	3.7	x1	3.7	4.3	5.0	x1.4
Share of pre-baked anodes technology	0%	38%		58%	71%	64%	∞
Share of “inert” anodes technology	0,1%	6%	x60	13%	26%	36%	x490
Cement production	61	75	x1.2	81	83	83	x1.4
Share of dry cement	58%	70%	x1.2	84%	98%	100%	x1.7
Clinker factor	74%	68%	x0.9	61%	54%	49%	x0.7
Ammonia production	17	14	x0.8	18	22	26	x1.5
incl. using hydrogen				0	2%	4%	∞
natural gas with CCUS				0	22%	43%	∞

Source: CENEf-XXI.

Table 6.2 Average annual capacity additions, Mt/year

Indicators	2015-2022	2023-2030		2031-2040	2041-2050	2051-2060	
Electric arc furnaces	1.4	1.4	x0.4	2.4	3.6	0.4	x1.5*
DRI production	0.3	1.4	x4.6	2.4	1.2	0.4	x8*
DRI – natural gas – CCUS				0.3	0.7	0.8	
DRI – hydrogen – DOE				0.5	0.3	0.1	
Aluminium production using pre-baked anodes technology		0.2		0.1	0.1	0.1	∞
Aluminium production using “inert” anodes technology, thou. t/year	4	43	x11	54	74	102	x50
Cement production – dry method	1.9	1.7	x0.9	2	1,7	1,6	x1
Cement production with CCUS				0.7	0.9	0.7	∞
Ammonia production	0.2	0.3	x1		0.7	0.8	x4.5
using hydrogen					0.04	0.06	∞
using CCUS					0.5	0.7	∞

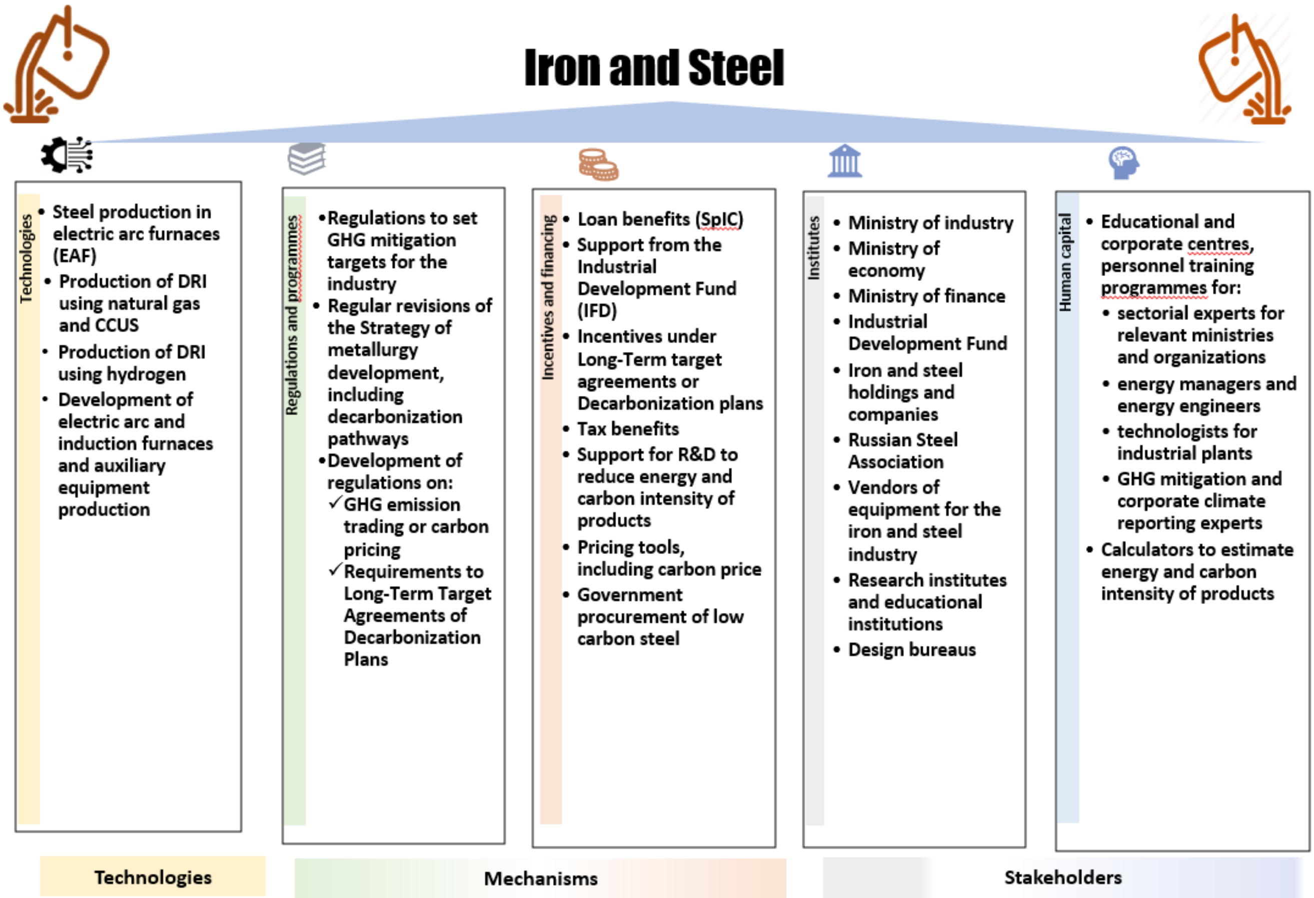
* maximum value for one of the decades.

Source: CENEf-XXI.

6.2 Sectorial plan (roadmap) for complete decarbonization in energy intensive industries

Two tables are shown below for each of the industries under consideration. The first table presents the aggregated policies to ensure sustainable and efficient low carbon transition for industry, while the second provides more details regarding the measures and distribution over time (Tables 6.3 – 6.5). The following policies should be implemented for a complete decarbonization of energy intensive industries and for the development of low carbon technologies.

Table 6.3 Iron and steel roadmap

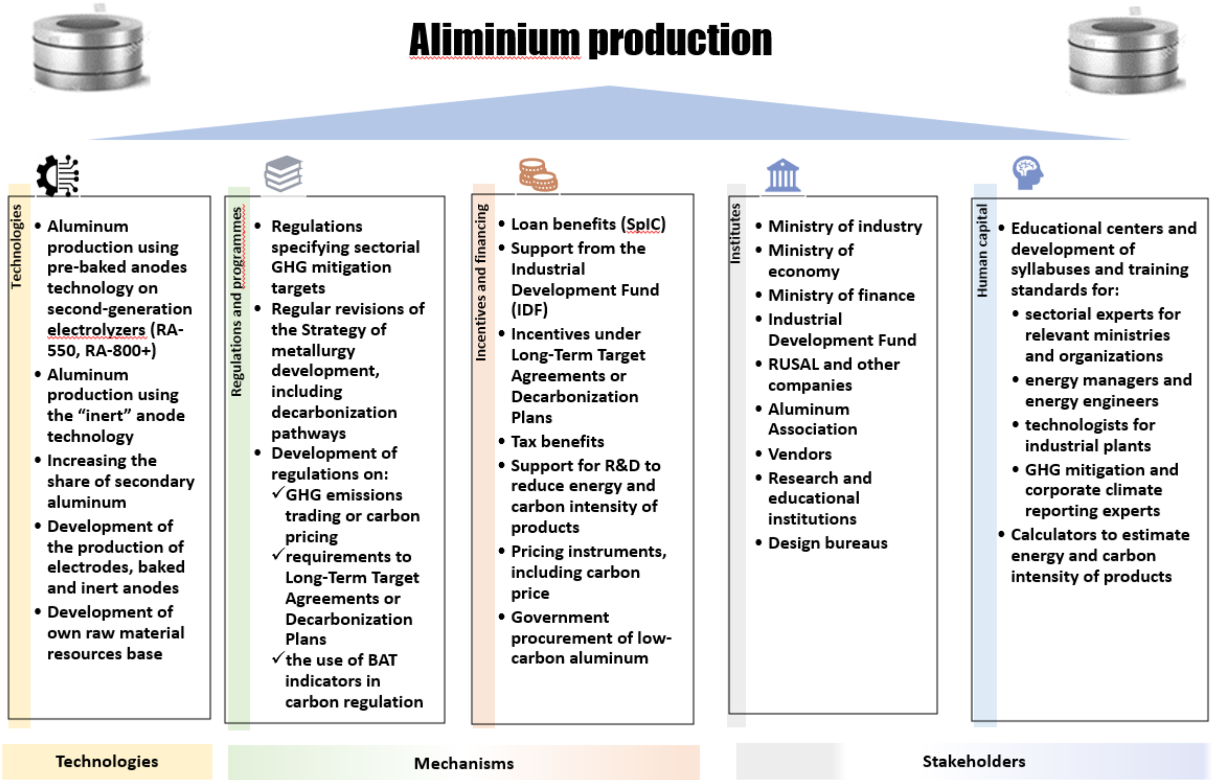


Iron and Steel

Parameters	Short-term action to 2030	Long-term vision to 2060
Technologies	Enhancement of electric arc steel production (the goal is to bring the localization level of equipment for electric arc furnaces up to 80%).	Launching and upscaling DRI production using natural gas and CCUS, as well as hydrogen-based production.
Regulations (laws, strategies, decrees, programmes)	Revisions to regulations to allow for SpIC contracts for highly energy efficient and low carbon technologies. Supplements to the “List of highly energy efficient objects and technologies” to include projects with specific energy consumption and specific GHG emissions not higher than the values for the top 10% of enterprises in the benchmarking system. Setting maximum values for specific GHG emissions for obtaining comprehensive environmental permits. Regulations to set GHG quotas and carbon pricing. Regulations related to Long-term target agreements to improve energy efficiency and reduce carbon intensity or to the development of Decarbonization Plans. Regulations for the uptake of hydrogen-based technologies and CCUS in the iron and steel industry.	Adjustment and revision of carbon pricing regulations to apply carbon price to products traded in international markets. Comprehensive permits; signing and implementation of Long-term target agreements or Decarbonization Plans using tax incentives. Gradually increasing level of ambition in these regulations in terms of energy efficiency and decarbonization. Regulations on government procurement of low carbon metals and support to vendors of equipment for the iron and steel industry with high levels of localization. Regulations to reduce materials intensity and increase scrap use in electric arc furnaces.
Incentives and financing	Providing financial support under SpIC for energy efficiency technologies from the State Industrial Development Fund. Co-financing for R&D for DRI production using natural gas and CCUS, as well as for hydrogen-based technologies.	Tax incentives as part of Long-Term target agreements to improve energy efficiency and reduce carbon intensity (or as part of Decarbonization Plans). Carbon pricing mechanisms. Support to R&D for the production and use of innovative equipment for iron and steel production. Government procurement of low carbon iron and steel.
Institutes	Development of policies and monitoring of their effectiveness – Ministry of industry, Ministry of economy, Ministry of finance. Policy implementation and monitoring – iron and steel plants and holdings, Russian Steel Association, Environmental Industrial Policy Centre; research institutes and educational institutions; design bureaus.	
Human capital	Mandatory personnel training and professional development for the staff of the Ministry of industry, RUSAL Corporate University in cooperation with the Siberian Federal University. Training and professional development of personnel for the Ministry of industry, Environmental Industrial Policy Centre, large iron and steel works, including in own educational centres and corporate universities. Development of special syllabuses, academic disciplines and online courses for personnel training for iron and steel works. Development of carbon reporting systems, benchmarking and carbon footprint labeling of products. Development of special programmes (calculators) to assess the energy and carbon intensity of Russian iron and steel plants, certification systems and carbon footprint verification.	

Source: CENEf-XXI.

Table 6.4 Aluminium production roadmap

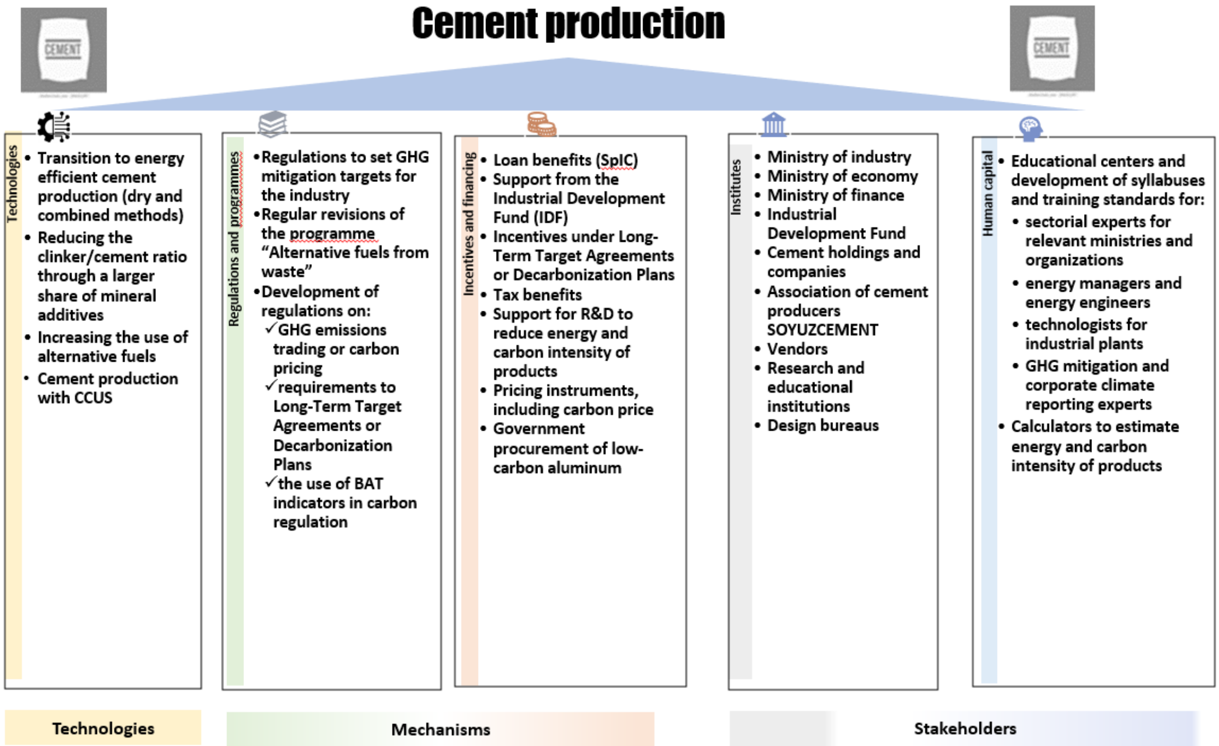


Aluminium production

Parameters	Short-term action to 2030	Long-term vision to 2060
Technologies	Promotion of aluminium production based on the pre-baked anodes technology using 2nd generation superpower electrolyzers RA-550 (the goal is to bring the localization level up to 60-100%). Expansion of aluminum production based on the "inert" anode technology (100% localization level).	Completed transition to the production of aluminium based on the pre-baked anodes technology using 2nd generation superpower electrolyzers RA-800+ and based on the "inert" anodes technology with nearly 100% localization level.
Regulations	Revisions to regulations to allow for SpIC contracts for highly energy efficient and low carbon technologies. Supplements to the "List of highly energy efficient objects and technologies" to include projects with specific energy consumption and specific GHG emissions not higher than the values for the top 10% of enterprises in the benchmarking system. Setting maximum values for specific GHG emissions for obtaining comprehensive environmental permits. Regulations to set GHG quotas and carbon pricing. Regulations related to Long-term target agreements to improve energy efficiency and reduce carbon intensity or to the development of Decarbonization Plans for aluminium production.	Adjustment and revision of carbon pricing regulations to apply carbon price to products which are traded in international markets. Comprehensive permits; signing and implementation of Long-term target agreements or Decarbonization Plans using tax incentives. Gradually increasing level of ambition in aluminium production regulations in terms of energy efficiency and decarbonization. Regulations on government procurement of low carbon materials and support to vendors of equipment for aluminum production with high levels of localization.
Incentives and financing	Providing financial support under SpIC for energy efficiency and low carbon technologies from the State Industrial Development Fund.	Tax incentives as part of Long-Term target agreements to improve energy efficiency and reduce carbon intensity (or as part of Decarbonization Plans). Carbon pricing mechanisms. Support to R&D for the production and use of innovative equipment for aluminium production. Government procurement of low carbon materials.
Institutes	Development of policies and monitoring of their effectiveness – Ministry of industry, Ministry of economy, Ministry of finance. Policy implementation and monitoring – RUSAL and other aluminium companies; Aluminum Association; Environmental Industrial Policy Centre; research institutes and educational institutions; design bureaus.	
Human capital	Mandatory personnel training and professional development at RUSAL Corporate University in cooperation with the Siberian Federal University. Training and professional development of personnel for the Ministry of industry, Environmental Industrial Policy Centre. Development of special syllabuses, academic disciplines and online courses for personnel training for RUSAL, Ministry of industry, and Environmental Industrial Policy Centre. Development of carbon reporting systems, benchmarking and carbon footprint labeling of products. Development of special programmes (calculators) to assess the energy and carbon intensity of Russian aluminium production, certification systems and carbon footprint verification.	

Source: CENEf-XXI.

Table 6.5 Cement production roadmap



Cement production

Parameters	Short-term action to 2030	Long-term vision to 2060
Technologies	Transition to energy efficient cement production (the goal is to bring EE production to 70% and to increase the localization level to 80%). Reducing the clinker/cement ratio to 83% on average across the country. Increasing alternative fuels use (increase the share of cement produced using alternative fuels to 21%).	Further transition to energy efficient cement production (the goal is to bring EE production to 100% and to increase the localization level to 100%). Reducing the clinker/cement ratio to 59% on average across the country. Further increase in alternative fuels use (increase the share of cement produced using alternative fuels to 59%). Launching and upscaling cement production with CCUS.
Regulations (laws, strategies, decrees, programmes)	Revisions to regulations to allow for SpIC contracts for highly energy efficient and low carbon technologies. Supplements to the "List of highly energy efficient objects and technologies" to include projects with specific energy consumption and specific GHG emissions not higher than the values for the top 10% of enterprises in the benchmarking system. Setting maximum values for specific GHG emissions for obtaining comprehensive environmental permits. Regulations to set GHG quotas and carbon pricing. Regulations related to Long-term target agreements to improve energy efficiency and reduce carbon intensity or to the development of Decarbonization Plans. Regulations to enforce CCUS in cement production.	Increasing the use of investment contracts for new cement production projects which are based on EE and low carbon technologies (CCUS). Adjustment and revision of carbon pricing regulations to apply carbon price to products which are traded in international markets. Comprehensive permits; signing and implementation of Long-term target agreements or Decarbonization Plans using tax incentives. Gradually increasing the level of ambition in cement production regulations in terms of energy efficiency and decarbonization. Regulations on government procurement of low carbon cement and support to vendors of equipment for cement production with high levels of localization. Regulations on increasing the use of alternative fuels for cement production.
Incentives and financing	Providing financial support under SpIC for energy efficiency and low carbon technologies from the State Industrial Development Fund. Development of a mechanism to compensate renovation (modernization) costs of cement plants to use alternative fuels. Development of a mechanism to compensate alternative fuels production costs and the costs of alternative fuels delivery to cement plants.	Tax incentives as part of Long-Term target agreements to improve energy efficiency and reduce carbon intensity (or as part of Decarbonization Plans). Carbon pricing mechanisms. Support to R&D for the production and use of innovative equipment for cement production. Compensation of the procurement costs of low carbon materials. Compensation of the costs related to the production and delivery of alternative fuels to cement plants. Compensation of renovation (modernization) costs incurred by cement plants for renovation and modernization of equipment to use alternative fuels.
Institutes	Development of policies and monitoring of their effectiveness – Ministry of industry, Ministry of economy, Ministry of finance. Policy implementation and monitoring – large cement holdings and companies, individual cement plants, Association of cement producers SOYUZCEMENT, Environmental Industrial Policy Centre; research institutes and educational institutions; design bureaus.	
Human capital	Mandatory personnel training and professional development for the staff of the Ministry of industry, Environmental Industrial Policy Centre, large cement companies and plants, including based on the sectorial educational centres and corporate institutions. Development of special syllabuses, academic disciplines and online courses for cement plants employees. Development of carbon reporting systems, benchmarking and carbon footprint labeling of products. Development of special programmes (calculators) to assess the energy and carbon intensity of Russian cement production, certification systems and carbon footprint verification.	

Source: CENEf-XXI.

Federal Law No. 488-FZ "*On the industrial policy in the Russian Federation*" (hereinafter – Law No. 488-FZ) primarily aims to: develop a high-tech competitive industrial sector to promote Russia's transition from the raw materials export-oriented development to innovative development; ensure national defense and security; provide jobs and improve the living standards of the Russian people. This Law specifies the following types of government support for industrial companies: financial support (earmarked funds for industrial development); information and consulting; and capacity building. However, it does not include energy efficiency or low carbon technologies. Law No. 488-FZ includes an open list of incentives for industrial development and outlines the specific procedures of pursuing the policies which are already in place (for example, providing subsidies) and new policies which are not included in the current regulations (such as special investment contract – SpIC).

The Consolidated Strategy for the development of the manufacturing industry in the Russian Federation to 2024 and for the period to 2035 was approved by Government Decree No. 1512-r of June 6, 2020 (hereinafter – the Consolidated Strategy). It specifies development priorities for 19 sectors of the Russian manufacturing sector, including iron and steel; non-ferrous metals; and the chemical and petrochemical industry. It would be practical to include technologies that can help improve energy efficiency and reduce carbon intensity of products.

The *Strategy for the development of the iron and steel industry of the Russian Federation to 2030* was approved by Government Decree No. 4260-r of December 28, 2022 (hereinafter – the Strategy). It primarily aims to reduce carbon intensity and improve energy efficiency; build capacity; and ensure R&D and technical support for the industry. It highlights DRI/HBI and EAF production, yet does not specify the projected scale of these technologies uptake.

Corporate programmes set low carbon targets. In Table 6.6 below these are compared against the estimates of the Operational plan. For 2030, corporations have set more ambitious goals, than the Operational plan.

Table 6.6 Energy efficiency and low carbon targets for iron and steel industry

Indicators	Units	2021 (fact)	2022 (fact)	2023-2030 (plan)	2031-2060 (plan)
Steel					
		GHG emissions			
Metalloinvest	tCO_2eq/t steel	1.96	2.09	0.56	0.00
Severstal	tCO_2eq/t steel	2.05	2.21	1.86	1.24
Draft operational plan	tCO_2eq/t steel	1.94	1.93	1.85	N/A
MMK	tCO_2eq/t steel	1.95	2.29	1.8	N/A
EVRAZ	tCO_2eq/t steel	2.23	2.23	1.6	N/A
Aluminium					
		Process power consumption			
CENEf-XXI	kWh/t aluminium	15,484	15,495	14,600	12,500
RUSAL	kWh/t aluminium	15,484	15,495	15,000	N/A
		GHG emissions			
RUSAL	tCO_2eq/t aluminium	2.02	2.0	1.43	0.00
Draft operational plan	tCO_2eq/t aluminium	2.21	2.18	1.85	N/A

Sources: estimations by CENEf-XXI; Draft operational plan; RUSAL; Metalloinvest; MMK; Severstal; EVRAZ.

The register of industrial technologies and equipment, which is part of the Government Decree No. 600, can be expanded by adding the data from the regularly updated reference books (ITS) for Russia's best available industrial technologies (BAT). It is important to include the low carbon technologies and equipment from Tables 6.1-6.2 in these reference books. In compliance with the Russian Tax Code, the Government Decree No. 600 grants the following benefits:

- Investment tax credit – to cover 100% of the costs of an energy efficiency technology and/or equipment to improve energy efficiency or reduce energy and carbon intensity or industrial output.
- Special coefficient applied to the basic depreciation rate (not to exceed 2.0) for highly energy efficient objects.
- Property tax exemption for highly energy efficient and low carbon new equipment, as specified in the Government Decree No. 600. This also applies to high energy efficiency class facilities.

When updating ITS reference books, technologies and equipment that help reduce energy and carbon intensity of products should be considered on a part with BAT, which help improve the process parameters and reduce harmful emissions. It is important to annually update the

Government Decree No. 600 and monitor the scale of energy efficiency and low carbon technologies uptake.

For the purpose of complete decarbonization of energy intensive industries it is practical use energy efficiency target agreements of decarbonization plans. In order to launch this scheme in Russia, it is important to:

- Improve energy efficiency benchmarking for energy and carbon intense industries, as well as the process of setting targets and the use of benchmarks to that end;
- Identify the areas in which target agreements can be used;
- Assess the scale of target agreements: schedules; investment demand; expected savings and GHG emission reductions; and BAT promotion;
- Develop a classification of target agreements based on important parameters (individual, sectorial, voluntary, mandatory, etc.), forms and structures of these agreements, and efficiency indicators;
- Determine the control system, both at the stage of signing target agreements and monitoring the implementation – parties to the target agreements (representing the government and (groups of) energy consumers); procedures for joining in and withdrawing from the target agreements; monitoring of compliance and sanctions for non-compliance;
- Draft proposals for government support and incentives for (enforcement) signing and compliance with target agreements (the key mechanisms include: subsidies for energy saving measures; tax benefits; power tariff benefits; etc.);
- Develop target agreements regulations to include all of the success factors.

7 Transport

7.1 Key performance indicators

Key performance indicators (KPI) for transport are limited to road transport, which dominates in CO_2 emissions. They were estimated in the *4D* scenario using a "cloud" of models developed by CENEf-XXI and include 13 parameters[72] (Tables 7.1 and 7.2). Achieving these targets will ensure the carbon neutrality in 2060.

Table 7.1 Key performance indicators for transport

	2021	2030		2040	2050	2060	
Final energy consumption, Mtce	135	101	x0.7	79	58	42	x0.3
Share of power sector in final energy consumption	8%	9%	x1.1	15%	23%	38%	x4.8
CO_2 emission, Mt	236	172	x0.7	125	81	46	x0.2
Cargo turnover, billion t-km	5701	5107	x0.9	4882	4083	3492	x0.6
Passenger turnover, billion pass-km	1327	1198	x0.9	1238	1241	1194	x0.9
Share of road transport in carbo turnover	5%	5%	x1.5	4%	5%	5%	x3
Share of road transport in passenger turnover	51%	46%	x0.8	41%	37%	32%	x0.6
Passenger car fleet, million pcs.	50	41	x0.9	37	32	27	x0.5
Share of electric vehicles	0,03%	6%	x200	22%	37%	53%	x1767

[72] Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzichek, O. Lebedev, A. Lunin, A. Myshak. 2023. Low carbon technologies in Russia: current status and perspectives. https://cenef-xxi.ru/articles/low-carbon-technologies-in-russia:-current-status-and-perspectives.

	2021	2030		2040	2050	2060	
Bus fleet, thousand pcs.	844	760	x0.9	797	811	792	x0.9
Share of electric buses	0,003%	4%	x1300	26%	56%	74%	x26667
Battery capacity for road transport, GWh	2	128	x64	410	637	765	x383
Number of charging stations (10 charging ports per 1 station)	208	25473	x0.9	54845	61363	76049	x0.9

Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzichek, O. Lebedev, A. Lunin, A. Myshak. 2023. Low carbon technologies in Russia: current status and perspectives. https://cenef-xxi.ru/articles/low-carbon-technologies-in-russia:-current-status-and-perspectives.

Table 7.2 Average annual capacity increase in transport

	2015-2022	2023-2030		2031-2040	2041-2050	2051-2060	
Electric cars fleet increase, thousand pcs.	2	247	x124	548	412	236	x247*
Electric buses fleet increase, thousand pcs.	0.02	3	x60	17	22	10	x94*
Battery demand increase, GWh	0.3	18.0	x60	28.2	22.7	12.7	x94*
Increase in the number of charging stations (10 charging ports per 1 station)	1,070	2,526	X2,5	2,937	651	1,468	x3*

* maximum value for one decade.

Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzichek, O. Lebedev, A. Lunin, A. Myshak. 2023. Low carbon technologies in Russia: current status and perspectives. https://cenef-xxi.ru/articles/low-carbon-technologies-in-russia:-current-status-and-perspectives.

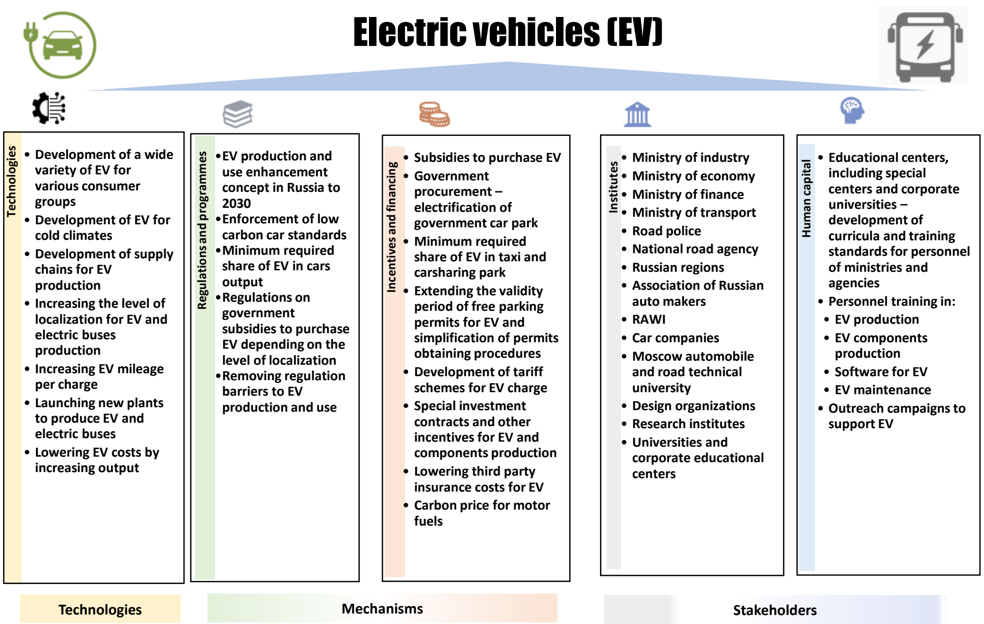
7.2 Roadmap

Resolution of the Russian government No. 2290 dated August 23, 2021, adopted:

- *The Concept of EV production and use enhancement to 2030* (hereinafter called "the Concept");
- Targets for electric vehicles production and charging infrastructure development to 2030;
- Action plan ("roadmap") "*Electric road transport production and use enhancement in Russia to 2024*".

The electrification of road transport is showing a dynamic progress, and decisions need to be made with a longer-term view. An aggregated roadmap for road transport is presented below in Table 7.3. It highlights three directions: production of electric vehicles, traction batteries, and charging stations. Two tables are given for each of these directions. The first table shows what each of the pillars to ensure sustainable and effective GHG emission reduction process consists of; the other provides more detail and shows how the measures can be distributed in time.

Table 7.3 Road transport electrification roadmap



Electric vehicles

Parameter	Short-term action (to 2030)	Long-term vision (to 2060)
Technologies	Development of supply chains for EV and electric buses production to increase the level of localization to 50% in 2030. Launching new plants for EV and electric buses production. Lowering electric transport production costs through increased output and enhanced training.	Development of a wide variety of EV for various consumer groups. Development of EV for cold climates. Increasing EV mileage per charge. Increasing the level of localization to 70-90%. Substantial decline in EV costs. Construction of plants to produce low carbon tyres, plastics, and EV components from low carbon rubber.
Regulations	Development of the national mega-project to enhance electric transport. Revision of the Concept of EV production and use enhancement in Russia to 2030 and of the Action plan (roadmap) "Electric road transport production and use development in Russia to 2030", including expanding the provisions on subsidies to 2030 to encompass EV purchases for cash. Special lanes for low carbon transport.	Updating the regulatory base. New programmes to enhance EV development and incentivize replacement of ICE cars with EV. Introduction of carbon pricing mechanisms for motor fuel. Requirement for the minimum share of EV in cars output and sales and in cars procurement for government and municipal needs, taxi parks, and carsharing companies.
Incentives and financing	Subsidies to cover 35% of EV costs, but no more than 925,000 rubles, with the cap indexation to 2030. Extension of free parking for EV. Reduction of the cost of mandatory third party insurance for EV. Subsidies to taxi and car sharing aggregators to encourage transition to EV. Elimination of tolls on toll roads for EV until 2030. Loan benefits and subsidies for the construction of plants to produce EV and components.	Subsidies to replace ICE cars with EV. Subsidy schemes for some low income groups of families. Reduction of car recycling tax. Undertaking a special analysis and extending the period of providing some of the incentives that were valid before 2030. EV government procurement. Government agreements with car companies to attain the roadmap targets. Incentives for EV exports.
Institutes	Development of policies and monitoring of their effectiveness – Ministry of industry, Ministry of economy, Ministry of transport, National Road Agency, Rosstandart, regional governments. Policy implementation – Association of Russian auto makers, RAWI, car companies. Development of new technologies and personnel training: research centers and institutes, design organizations, Moscow automobile and road university and other universities and corporate educational centers.	
Human capital	Training of engineers, other experts, and workers to enable them produce 250-550 thousand EV per year and provide maintenance to 2-3 million EV in 2030 and 10-15 million EV in 2060. Personnel training for the Ministry of industry, Ministry of economy, Ministry of transport, National Road Agency, Rosstandart, National traffic police, regional and municipal governments. Establishing centers of advanced experience and industrial research centers. 10-fold increase in the amount of trained students and experts in universities and corporate universities by 2030 and 30-fold increase in 2060. Launching marketing campaigns	

Batteries

Technologies
- Construction of plants to produce batteries and components
- Development of new generation batteries (post-lithium, including solid state batteries)
- Development of full technology chains for batteries production, including cathode and anode material
- Development of raw materials base to manufacture lithium batteries
- Development of related cross-sectoral technologies

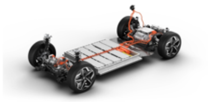
Regulations, programmes
- Revision of the Concept of EV production and use enhancement in Russia to 2030 and of the roadmap "Development of power accumulation systems, including portable batteries"
- Battery standards, including safety issues
- Regulations to incentivize battery production, increase localization levels and remove regulation barriers

Incentives and financing
- Government support to batteries and components production in Russia
- Subsidized loans for battery producers
- Incentives for R&D to produce 4th and 5th generation batteries
- Incentives for R&D to increase the share of battery disposal and to enhance the disposal capacity

Institutes
- Ministry of industry
- Ministry of economy
- Ministry of transport
- Ministry of finance
- Rosstandart
- RENERA State corporation
- RUSBAT - National association of producers of current sources
- RAWI
- Corporations of battery producers
- Think tanks and research institutes
- Design organizations
- Universities and corporate education centers

Human capital
- Educational centers, including special centers and corporate universities
- Development of curricula and personnel training for:
  - Ministries and organizations
  - A wide variety of specialties for companies in individual sectors
- Work placements at the best global companies
- Inviting the best foreign experts
- Setting up scientific centers and schools to launch battery production

Technologies — Mechanisms — Stakeholders



Batteries

Parameters	Short-term action to 2030	Long-term vision to 2060
Technologies	Construction of new plants to produce batteries, fuel cells, cathode and anode materials. Increasing the level of localization for batteries. R&D for safe batteries with high capacity and charge density, short charge time and large number of charge cycles; development of light-weight glass fiber-based materials for battery cases, carbon fibers, new plastics, high-strength steel to ensure strength and light weight.	Launching production of super-high performance, durable, safe, highly recyclable and affordable batteries. Increasing EV mileage per charge beyond 1,000 km. Environmentally friendly battery recycling. New chemical materials – post-lithium, solid state, silicon, sodium, etc. batteries of the 4th and 5th generation. Charging time reduction to 10 minutes.
Regulations	Revision of the Roadmap "Power accumulation systems, including portable systems" and of the Action plan (roadmap) "Electric road transport production and use development in Russia to 2030". Enforcement of the resolution on subsidies to cover part of the costs of establishing the production of batteries, hydrogen fuel cells, cathode and anode materials for EV.	Development of programmes and roadmaps for the production and uptake of 4th and 5th generation batteries. Development of the "battery passport" to track the origin of the components and to more accurately determine the level of localization. Enforcement of battery recycling and materials reuse regulations. Enforcement of regulations on compliance with environmental requirements along the whole battery production chain.
Incentives and financing	Special investment contracts to set up production of battery cells in Russia. Incentives for the exploration for rare metals. Loan benefits and subsidies for the mining of lithium, cobalt, manganese, nickel, graphite, and other materials; for the production of batteries, hydrogen fuel cells, cathode and anode materials.	Incentives for R&D and subsequent production of 4th and 5th generation batteries. Incentives for maximum reuse of materials and for environmentally safe utilization of batteries. Incentives for batteries exports.
Institutes	Development of policies and monitoring of their effectiveness – Ministry of industry, Ministry of economy, Ministry of transport, Ministry of energy, Ministry of finance, National Road Agency, Rosstandart, regional governments. Policy implementation – RENERA State corporation, National association of producers of current sources (RUSBAT), RAWI, battery producers. Development of new technologies and personnel training: research centers and institutes, design organizations, universities, corporate educational centers.	
Human capital	Further university-based training of engineers, other experts, and workers to enable them produce 10-30 GWh of batteries per year and provide maintenance to more than 100 GWh of batteries in 2030 and more than 750 GWh in 2060. Personnel training for the Ministry of industry, Ministry of economy, Ministry of transport, Ministry of energy, Ministry of finance, National Road Agency, Rosstandart, and regional governments. Establishing centers of advanced experience and industrial research centers. 60-fold increase in the amount of trained students and experts in universities and corporate universities by 2030 and 300-fold increase in 2060. Personnel training for research centers and research institutes. Personnel training (engineers and workers) in battery utilization.	

EV charging stations

Technologies
- Serial production of EV charging stations launched
- Increased level of localization
- Launched EV charging stations in developed areas
- Enhancement of power grid infrastructure
- Assimilation of charging technologies:
  - Super- and ultrafast
  - Wireless
  - Bi-directional
  - RE-integrated
- Smart charge infrastructure
- Construction of battery replacement stations

Regulations and programmes
- Revision of the Concept of EV production and use enhancement in Russia to 2030
- "Electric Corridor" Programme
- Removing regulatory barriers to EV charging stations development, including in residential areas
- Power grid development programme for EV charging stations
- Standards to regulate construction and use of new types of EV charging stations, including battery replacement
- Regulation of tariffs for EV charging stations

Incentives and financing
- Increasing the number of free public EV charging stations (to 2030)
- Competitive co-financing (tax exemptions) for the construction of public EV charging stations
- Co-financing for the construction of charging ports in corporate and new MFB parking lots
- Tariff incentive schemes for EV charging services
- Tariff schemes for EV charging stations in corporate and new MFB parking lots

Institutes
- Ministry of industry
- Ministry of economy
- Ministry of transport
- Ministry of energy
- Ministry of finance
- Russian road agency
- Rosstandart
- Regional and municipal governments
- Association for electric transport development
- Corporations producing EV charging stations
- Think tanks and research institutes
- Design organizations
- Universities and corporate educational centers

Human capital
- Educational centers, including special centers and corporate universities – development of curricula and personnel training for:
  - Ministries and organizations
  - A wide variety of specialties for companies in individual sectors
- Work placements at the best global companies
- Inviting the best foreign experts
- Setting up scientific centers and schools to launch EV charging stations production

Technologies | Mechanisms | Stakeholders

Charging stations

Parameters	Short-term action to 2030	Long-term vision to 2060
Technologies	Increasing the number of charging stations in cities and on highways. Installation of charging equipment at petrol stations. Raising the level of localization to 50%. Development of charging technologies: ultra-fast, wireless, bi-directional, RE-integrated. Development of smart charge infrastructure and battery replacement stations.	Saturation of charging stations demand. Increasing the level of localization to 90%. Large-scale construction of super- and ultra-fast charging stations, as well as wireless, bi-directional, and RE-integrated. Development of smart charging infrastructure. Construction of battery replacement stations. Large-scale installation of charging stations in MFB and corporate parking lots.
Regulations (laws, strategies, resolutions, programmes)	Revision of regulations in force to require mandatory installation of EV charges at petrol stations. Simplified procedure of installing charging stations at MFB closed and open parking lots. Launching the "Electric Corridor" programme to ensure that charging stations are available at every 80-100 km. Regulation of EV charging tariffs. Regulation of charging ports installation at petrol stations.	Development of new programmes to further enhance the charging network. Requirements to developers to include MFB and corporate charging stations in their construction plans. Regulations for fast and ultra-fast, wireless, bi-directional, and RE-integrated charging stations installation procedures. Regulation of tariffs for EV charging by new technologies.
Incentives and financing	Increasing the number of free pubic charging stations. Tariff incentives for EV charging services. Competition-based co-financing for the construction of charging stations.	Development of subsidies and tariffs for new charging technologies: super- and ultra-fast charging; wireless, bi-directional, RE-integrated charge. Development of tariffs for charging stations located in MFB and corporate parking lots to flatten the load curve.
Institutes	Development of policies and monitoring of their effectiveness – Ministry of industry, Ministry of economy, Ministry of transport, Ministry of energy, Ministry of finance, National Road Agency, Rosstandart, regional and municipal governments. Policy implementation – Electric transport development association, charging stations producers. Development of new technologies and personnel training: research centers and institutes, design organizations, universities, corporate educational centers.	
Human capital	Training for engineers, other experts, and workers to enable them produce 1-3 thousand charging stations per year and operate 25 thousand charging stations in 2030 and more than 75 thousand charging stations in 2060. Personnel training for the Ministry of industry, Ministry of economy, Ministry of transport, Ministry of energy, Ministry of finance, National Road Agency, Rosstandart, and regional and municipal governments. Establishing centers of advanced experience and industrial research centers. 10-fold increase in the amount of trained students and experts in universities and corporate universities by 2030 and 30-fold increase in 2060. Personnel training for research centers and research institutes. Personnel training (engineers and workers) in battery utilization.	

Source: CENEf-XXI.

8 Residential buildings

8.1 Targets

Resolution of the RF government No. 1473 of September 9, 2023, approved the Comprehensive state programme of the Russian Federation "*Energy conservation and energy efficiency improvement*". It does not specify energy efficiency targets by sectors. One structural element of this programme, "*Improving energy efficiency of buildings and communal structures and facilities*" is to be developed by the Russian Ministry of Construction. Table 8.1 shows the required targets for residential buildings. These targets were determined for 4D scenario using CENEf's "cloud" of models and include 13 indicators:[73] final energy consumption, share of power in final energy consumption; direct and indirect CO_2 emissions; average energy consumption for space heating; average energy consumption for DHW; average energy consumption for other uses; share of MFBs of high energy efficiency classes; share of MFBs with energy efficient capital repair; share of MFBs with heat controls; heat production by heat pumps; heat production by solar energy sources; and power generation in buildings (Table 8.1). Achieving these targets will ensure carbon neutrality in 2060.

Table 8.1 Key performance indicators for residential buildings

	2021	2030		2040	2050	2060	
Final energy consumption, Mtce	153	141	x0.9	132	126	122	x0.8
Share of power in final energy consumption	14%	18%	x1	19%	20%	24%	X1.1
Direct and indirect CO_2 emissions, Mt	315	240	x0.8	207	179	139	x0.4
Average energy consumption for space heating, kWh/m²/year	204	150	x0.7	129	114	94	x0.5
Average energy consumption for DHW, kWh/m²/year	34	18	x0.5	13	11	11	x0.3
Average energy consumption for other uses, kWh/m²/year	66	53	x0.8	42	34	30	x0.5
Share of MFBs with A++ energy efficiency class	0,1%	0,4%	x4	23%	45%	70%	x 700
Share of MFBs with energy efficient capital repairs	0.1%	2.0%	x20	2.0%	2.0%	2.0%	x20

[73] Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzichek, O. Lebedev, A. Lunin, A. Myshak. 2023. Low carbon technologies in Russia: current status and perspectives. https://cenef-xxi.ru/articles/low-carbon-technologies-in-russia:-current-status-and-perspectives.

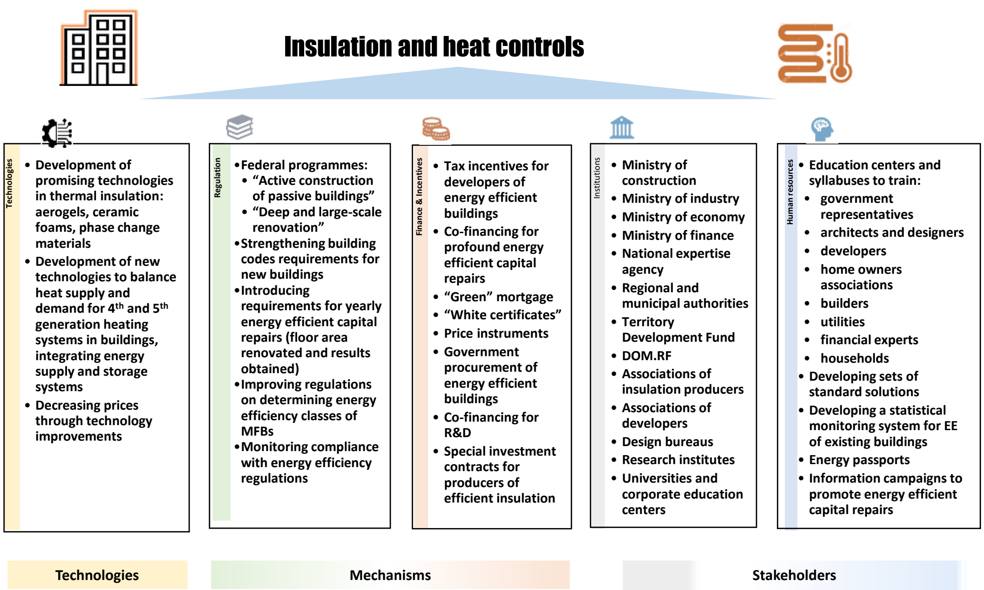
	2021	2030		2040	2050	2060	
Share of MFB with heat controls	14%	43%	x3	65%	84%	99%	x7
Heat production by heat pumps, MGcal	0.2	2.6	x13	9.6	27.0	76.6	x 383
Heat production by solar energy sources, MGcal	0.1	2.0	x20	4.5	8.9	18.6	x 186
Power generation in buildings, billion kWh	0.002	0.15	x75	7.6	20.6	39.5	x 19,750
Share of smart power metering	0,1%	99%	x1,000	99%	99%	99%	x1,000

Source: Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzichek, O. Lebedev, A. Lunin, A. Myshak. 2023. Low carbon technologies in Russia: current status and perspectives. https://cenef-xxi.ru/articles/low-carbon-technologies-in-russia:-current-status-and-perspectives.

8.2 Roadmap

Below are three tables, each composed of two blocks. The first block presents the aggregated policies to ensure sustainable and efficient low carbon transition for buildings, and the second provides more details regarding the measures and distribution over time (Tables 8.2 – 8.4).

Table 8.2 Insulation and heat controls roadmap

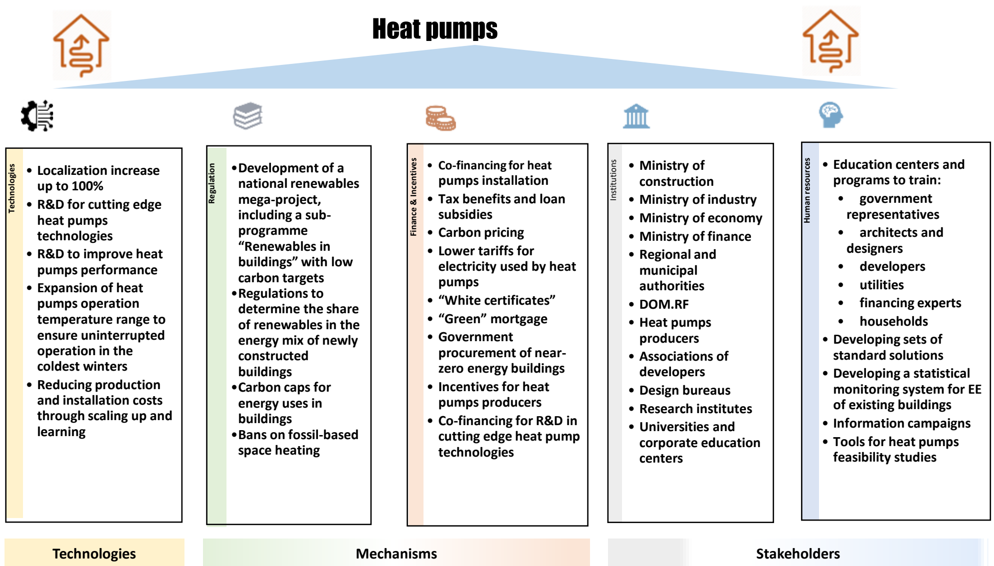


Insulation and heat supply regulation

	Short-term action to 2030	Long-term vision to 2060
Technologies	Insulation improvements and development of new promising technologies, such as aerogels, ceramic foams, phase change materials. Raising localization levels up to 100%. Bringing down production and installation costs through scaling up and learning.	R&D and transition to high technical readiness. Using durable, lightweight, recyclable, low cost and low carbon insulation materials. Large-scale deployment of new technologies to control heat supply and heat use in buildings.
Regulations	Launching national programmes “Active construction of passive buildings” and “Deep and large-scale renovation”. Strengthening building codes for new buildings to halve specific energy consumption by 2030. Improving regulations on determining energy efficiency classes of MFBs. Improving regulations for monitoring energy efficiency compliance. Enforcing requirements to increase annual energy efficient capital repairs to 2% of MFBs and reduce energy consumption by at least 30%. Enforcing mandatory use of lifecycle cost assessment methods to determine the optimal levels of buildings insulation.	Strengthening building codes for new construction to bring energy efficiency up to “passive” buildings levels in 2060. Requirement for annual energy efficient capital repairs in 2% of MFB floor area with subsequent reduction in energy consumption by at least 37% in 2040, 50% in 2050, and 60% in 2060. Integration of residential EE and renewables projects into the list of climate projects. Government procurement of low carbon buildings.
Incentives and financing	Tax benefits for developers for achieving target levels of EE for new buildings. Co-financing EE renovations to ensure required annual renovation rates. “Green” mortgage. “White certificates” to encourage homeowners’ investment into insulation improvement. Government procurement of “green” buildings and insulation materials. Co-financing for R&D.	Financial (credit lines and guarantees, tax benefits and subsidies) and non-financial incentives for ‘passive’ buildings developers and producers of effective insulation materials. Tax benefits and other financial incentives for innovative insulation technologies. Promoting safe utilization and recycling of insulation materials. Co-financing for R&D. Government procurements of low carbon buildings.
Institutes	Development and monitoring of policies – Ministry of construction, Ministry of industry, Ministry of economy, Ministry of finance, National expertise agency, regional and municipal authorities. Policy implementation – Territories Development Fund, DOM.RF, associations of insulation producers (ROSIZOL, RAPEX, NAPPAN, APPP, etc.), associations of developers (NOSTROY, etc.), energy utilities. Development of new technologies and personnel training – research institutes, design bureaus, universities and corporate education centers, professional organizations. Outreach campaigns – think tanks, education centers, vendors, mass media.	
Human capital	Education centers and programs to train government officials, architects and designers, developers, energy utilities, homeowners associations, financial experts, and households. Certification of specialists to encourage participation in educational programmes. Developing sets of standard insulation solutions for “green” construction and EE CR. Raising public awareness of the benefits of living in “green” buildings and investing in EE CR. Development of EE monitoring for residential buildings, particularly, improving energy passport practices. EE benchmarking for buildings. Informing people of MFB EE rating and energy saving potential. Encouraging people to take account of MFBs energy efficiency rating in their purchase/rent decisions. Benchmarking for EE CR decision-making. Improving the methods of buildings lifecycle cost assessment. Educational programmes and personnel training for low carbon buildings construction and EE CR. Development of tools to determine the optimal levels of insulation in buildings.	

Source: CENEf-XXI.

Table 8.3 Heat pumps roadmap

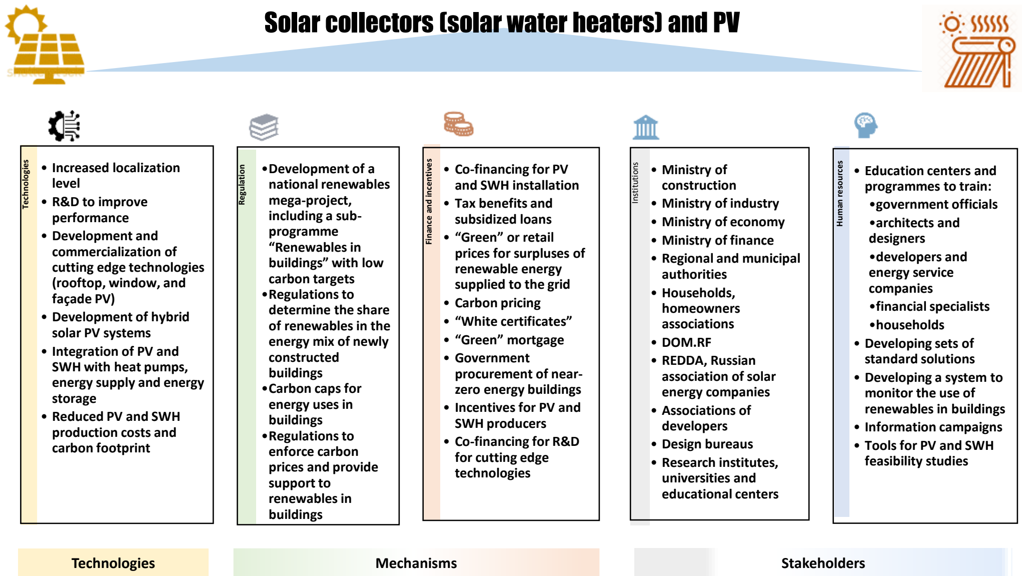


Heat pumps

	Short-term action to 2030	Long-term vision to 2060
Technologies	Increase in localization level up to 50%. R&D for expansion of heat pump types (air, water, ground-source) and unit capacity range for Russian buildings. R&D for new heat pump technologies (reverse cycle absorption heat pumps that can also be used for space cooling), heat pumps equipped with smart controls and integrated with other renewable energy systems within the building; using CO_2 as a refrigerant; applicable in a wider temperature range to ensure reliable performance in the coldest days. Reduced production and installation costs through scaling up and learning.	Reduced heat pumps production and installation costs through scaling up production and use. R&D for highly efficient, quiet, small, and low carbon heat pumps (carbon footprint is determined by the materials and refrigerant used). Increased heat pumps service life and subsequent utilization level. Commercialization of innovative technologies: elastocaloric, magnetocaloric, thermoelectric, Brighton and Stirling cycles, etc.
Regulations	Development of a national renewables mega-project, including "Renewables in buildings" sub-programme. Mandatory requirements for the proportion of renewables in the energy balance of new buildings, and carbon caps for carbon intensity of energy used in buildings. Regulations requiring the use of renewable energy proportion to determine energy efficiency classes of buildings. Regulations to support the use of heat pumps. Integration of residential EE and renewables projects into the list of climate projects. Enforcing mandatory use of lifecycle cost assessment methods to determine the optimal levels of renewable energy use in buildings.	Gradual capping of specific direct and indirect GHG emissions from buildings. Bans on fossil-fired space heating equipment. Carbon pricing. Development of "green" real estate market. Requirements for government procurements of low carbon buildings.
Incentives and financing	Co-financing for heat pumps installation: credit lines, guarantees, tax benefits and subsidies for developers and heat pumps producers. Lower tariffs for electricity used by heat pumps. "White certificates" pilot projects (energy supply contracts with elements of energy service agreements) and "green" mortgage. Governmental procurement of near-zero energy buildings. Incentives for heat pumps producers. Co-financing for R&D in cutting edge heat pump technologies.	Financial mechanisms – credit lines, guarantees, tax benefits and subsidies for production and installation of new generation heat pumps. Co-financing R&D for cutting edge heat pump technologies. Carbon pricing. Trade-in coupons for fossil-fired boilers in exchange heat pumps. Government procurement of low carbon buildings.
Institutes	Policies development and monitoring – Ministry of construction, Ministry of industry, Ministry of economy, Ministry of finance, Rosstat, regional and municipal authorities. Policy implementation: associations of heat pump producers, energy utilities. Technology developments and personnel training – think tanks and research institutes, design bureaus, universities and corporate education centers, professional organizations. Outreach campaigns: think tanks, education centers, vendors, mass media.	
Human capital	Training and professional development in universities and corporate education centers for engineers, experts and workers to enable production and installation of up to 3,200 MW heat pumps per year to 2060 and operate 1 GW of installed heat pump capacity to 2030 and up to 35 GW to 2060. Setting up education centers and programmes to train architects and designers, developers, government officials, representatives of energy utilities, homeowners associations, households and financial experts. Certification of specialists to encourage participation in educational programmes. Developing sets of standard solutions for heat pumps use in different climates. Informing homeowners about the advantages of investing in the installation of heat pumps and how to obtain financial support. Collection of success stories about heat pumps installation in buildings, creating a "library of success stories" with sets of ready-made managerial solutions. Introduction of educational programmes at all levels of education to raise awareness of the general benefits of renewable energy sources.	

Source: CENEf-XXI.

Table 8.4 Solar collectors and PV roadmap



Solar collectors (solar water heaters) and PV

	Short-term action to 2030	Long-term vision to 2060
Technologies	Increase in localization level up to 40% for SWH and up to 80% for PV. Localization of absorbers production. Development of new SWH technologies using nanoliquids and new alloys. Further development of thermal energy storage technologies (molten salts, thermochemical, etc.). Development of new technologies: PV cells (TOPCon with silicon heterojunctions, Back Contact, based on quantum wells, inorganic films, organic solar cells, plasmonics, thermophotovoltaics, etc. Increased service life and safety parameters and reduced costs.	Further increase in localization levels for existing PV and SWH technologies up to 90-100%. Commercialization and upscaling of new PV (rooftop, window, façade PV) and SWH technologies. Deployment of hybrid PV and thermal systems. Integration of PV and SWH with heat pumps, energy supply and energy storage systems in "smart" buildings. Development of virtual distributed power plants and microgrids and integration into larger energy supply systems.
Regulations	Development of a national renewables mega-project, including "Renewables in buildings" sub-programme with microgeneration targets; capping carbon intensity of energy used in buildings. Regulations to account for renewable energy use in determining energy efficiency classes of buildings. Building codes to include a requirement for mandatory proportion of renewable energy used to meet buildings energy demand. Regulations to support the use of renewables in buildings. Requirements for energy utilities to develop specifications for connecting RE-based microgeneration sources to the grid; to purchase surplus power generated by micro RE; to organize net billing for microgeneration sources. Enforcing mandatory use of lifecycle cost assessment methods to determine the optimal levels of renewable energy use in buildings.	Increasing the level of ambition in regulations regarding microgeneration development targets and capping carbon intensity of energy used in buildings. Requirement for renewable energy use in new and renovated buildings in regions with high potential for renewables use. Government procurement of low carbon buildings. Ban on fossil-fired space and water heating equipment in regions with high potential for renewables use. Regulations to support the use of renewable energy in buildings. Regulations for "white certificates", carbon pricing, and development of "green" real estate market.
Incentives and financing	Co-financing for PV and SWH installation – credit lines, guarantees, tax benefits and subsidies for developers and PV and SWH producers. "Green" tariff for selling surpluses of renewable energy to the grid. "White certificates" pilot projects (energy supply contract with elements of energy service agreements).	Financial mechanisms – credit lines and guarantees, tax benefits and subsidies for producers of new generation PV and SWH. Carbon pricing. Incentives for the development of safe utilization and recycling of collectors, PVs, and storage systems. Large-scale "white certificates" programmes (energy supply contracts with elements of energy service agreements) and "green" mortgage. Government procurement of near-zero energy buildings and low GHG emissions. Co-financing for R&D in innovative PV and SWH technologies.
Institutes	Policy development and monitoring – Ministry of construction, Ministry of industry, Ministry of economy, Ministry of finance, regional and municipal authorities. Policy implementation – REDDA and Russian association of solar energy companies; development institutions (DOM.RF, etc.), energy utilities. Technology developments and personnel training – research institutes, design bureaus, universities and corporate education centers, professional organizations. Outreach campaigns: think tanks, education centers, vendors, mass media.	
Human capital	Training and professional development in universities and corporate education centers for engineers, experts, and workers to enable production and installation of up to 3.8 GW PV and 1.8 GW SWH per year to 2060. Development of education centers and programmes for architects and designers, developers, government officials, energy utilities, energy service companies, homeowners associations, households and financial specialists. Certification of specialists to encourage participation in educational programmes. Developing sets of standard solutions for the integration of renewable energy into buildings energy supply for new construction and EE CR, for various building types and climates. Collection of statistics about renewables use in buildings. Introduction of classes on the role of renewable energy in buildings energy supply into school curricula.	

Source: CENEf-XXI.

The proposal is to launch two national programmes: "*Active construction of passive buildings*" and "*Deep and large-scale renovation*" with a gradual increase in thermal protection requirements to reach the level of a "passive" building and increased proportion of MFBs with energy efficient renovation to result in substantial decline in specific energy consumption. It is important to improve the review practices for the design documents and energy efficiency compliance. The nationwide share of new buildings that meet the energy efficiency requirements is unknown. Control is relatively effective in relation to multi-storey MFBs, but it practically does not cover low-rise apartment or individual residential buildings.

Current Rules for determining the energy efficiency class of multi-family buildings need substantial improving to ensure reduction in baseline energy consumption by adjusting the values of heat consumption for DHW.

Neither National target programme "*Dwelling*", nor the Comprehensive State programme "*Construction*", which was adopted in 2022, do not include energy efficient renovations. It is important to set an energy efficient renovation (EEREN) requirement at the legislative level: at least 7,500 MFBs per year to 2035 and 2% of total Russia's housing area per year beyond 2035. The results of EEREN (minimum savings) should be regulated (at least 30% to 2045 and at least 40% beyond 2045), and so should the minimum list of the required measures, including insulation of buildings envelopes. The mechanism included in the Government Decree No. 18 of January 17, 2017 (amended on December 21, 2020) "*On approval of the Rules for providing financial support from the funds of the State Corporation "Fund for promoting housing and utility sector reform" to finance capital repair of multi-family buildings*" has been tested and debugged and has shown its effectiveness; yet after the scarce budget of the programme was exhausted, this mechanism was abandoned.

In 2022, the DOM.RF agency developed a regulation titled GOST R 70346 "*Green multifamily residential buildings*", which lists specific criteria for 'green' MFBs construction and operation. These criteria can be voluntarily used to evaluate new construction projects and for green building ratings. DOM.RF hopes that "with the support from the Russian Government, GOST R can become a channel to introduce 'green' financial products to all of the real estate market agents". In particular, this involves green mortgage bonds, green mortgage, and green project financing.

"Governments lead by example" is a phrase frequently met in foreign roadmaps. The underlying idea is that government buildings should be flagships towards achieving the targets specified for the buildings sector. 'Green' procurement serves an example for other companies, both private and public. This also applies to energy efficient capital repairs: in addition to energy savings *per se*, profound EE CR programmes encourage other companies to follow suit.

People need to be aware of the benefits of living in energy efficient and 'green' buildings and of the programmes they are eligible for, how and who can help obtain financing. Residents should have access to the information about their MFB's energy efficiency benchmarking-based rating and the energy cost saving potential.

9 Hydrogen

9.1 Targets

Hydrogen energy development targets were revised downwards in the recent years.[74] In 2022, draft Comprehensive programme for low carbon hydrogen development in the Russian Federation to 2050 was prepared. It sets the target to increase the share on hydrogen in the Russian end-use energy consumption to 2-5% in 2050 and thus reduce GHG emissions by 18 Mt CO_2eq per year.[75]

The Russian Hydrogen Energy Concept requires the creation of at least four territorial hydrogen production clusters for comprehensive development of the hydrogen energy sector, including RE-based generation, electrolysis, hydrogen production, storage, and transport:

- North-Western cluster (focused on exports to EU countries).
- Eastern cluster (focused on exports to Asia and development of hydrogen infrastructure for the transport and energy sectors).
- Arctic cluster (with a focus on the development of low carbon energy supply in the Russian Arctic and hydrogen exports).
- Additionally, a Southern cluster can be developed and will rely on natural gas and renewables for energy.

However, the Concept and roadmaps lack low carbon hydrogen production targets. It is important to develop a technical reference book for the hydrogen energy sector to include low carbon technologies and equipment listed in the table, in particular, different types of electrolyzers, hydrogen storage and transport systems.

The hydrogen production targets as specified below were determined using CENEf's "cloud" of models and include 8 parameters[76] (Table 9.1). Achieving complete decarbonization of hydrogen production in 2060 requires setting up mass production of industrial electrolyzers, development of large-scale production of equipment for the production, storage, and transport of "green" hydrogen and eventual increase in the localization levels; and launching production of a new generation of hydrogen fuel cells.

[74] Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzichek, O. Lebedev, A. Lunin, A. Myshak. 2023. Low carbon technologies in Russia: current status and perspectives. https://cenef-xxi.ru/articles/low-carbon-technologies-in-russia:-current-status-and-perspectives.

[75] Draft Comprehensive Programme for low carbon hydrogen energy development in the Russian Federation to 2050. 0_QtAQRTQe1F8hvStYtGbWjMrFkmBkyWjt.pdf (bigpowernews.ru).

[76] Bashmakov I., V. Bashmakov, K. Borisov, M. Dzedzichek, O. Lebedev, A. Lunin, A. Myshak. 2023. Low carbon technologies in Russia: current status and perspectives. https://cenef-xxi.ru/articles/low-carbon-technologies-in-russia:-current-status-and-perspectives.

Table 9.1 Key performance indicators for hydrogen

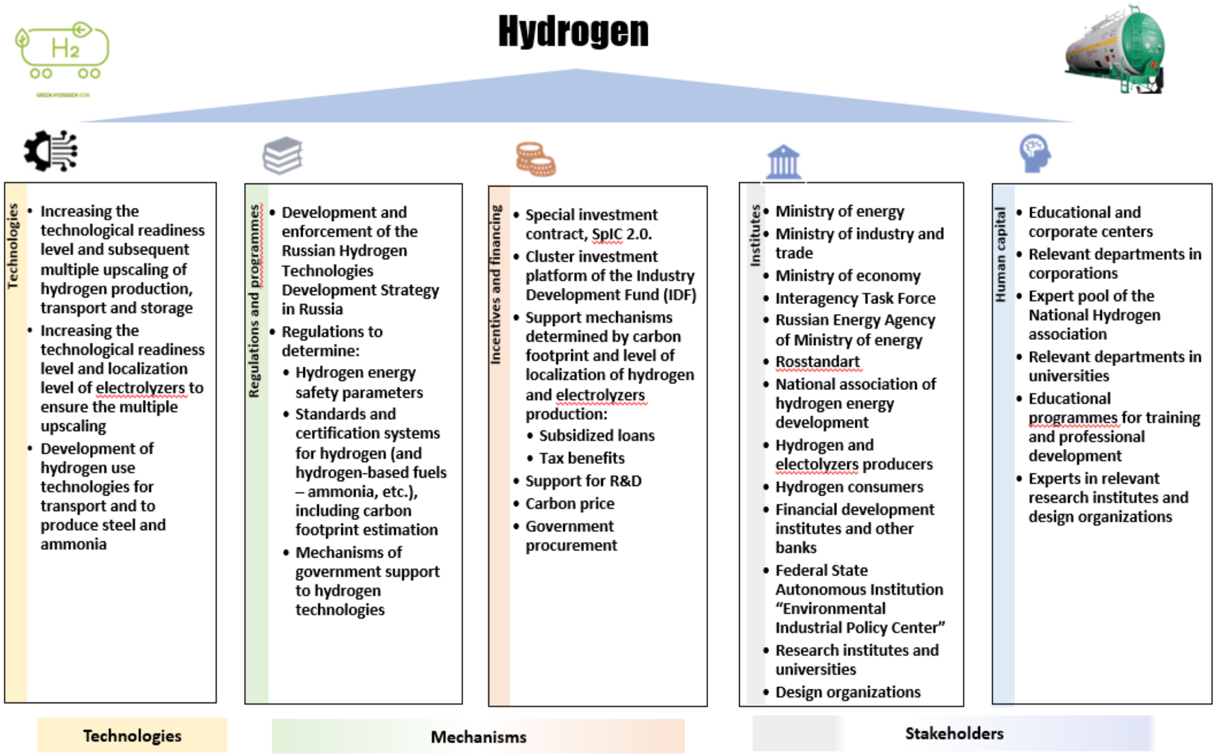
	2021	2030		2040	2050	2060	
Hydrogen production	174	366	x2	659	974	1,289	x7.4
"Blue" hydrogen*	174	358	x2	630	888	1,010	x5.8
"Turquoise" hydrogen		4		8	19	37	
"Yellow" hydrogen		4		9	22	55	
"Green" hydrogen		4		12	45	186	
Share of CCUS for "blue" hydrogen	0%	19%		46%	73%	100%	
Exports		123		312	500	688	
DRI and HBI		0		64,5	149	159	
Oil refinery	174	172	X1	174	172	127	x0.7

Source: CENEf-XXI.

9.2 Roadmap

Hydrogen energy development policies to 2030 are described in the *Hydrogen Energy Roadmap to 2030*, which was developed in 2023 by the Russian government in cooperation with Gasprom and Rosatom. Policies to 2050 are outlined in the *Hydrogen Energy Concept* approved by the Order of the Government No. 2162-R of 05.08.2021 and presented in more detail in the *Draft Comprehensive Programme for the development of low carbon hydrogen sector in the Russian Federation to 2050*. Many of these policies were included in the roadmap (see below), which integrates two tables. The first table presents the policies that support measures to ensure sustainable and efficient low carbon hydrogen production, and the second provides more details regarding the measures and distribution over time (Table 9.2).

Table 9.2 Hydrogen production roadmap



Hydrogen

Parameter	Short-term action to 2030	Long-term vision (to 2060)
Technologies	Development of domestic low carbon hydrogen production technologies; setting first hydrogen clusters and launching hydrogen production pilot projects. Mass production of electrolyzers and other equipment for hydrogen energy with up to 80% level of localization. R&D for competitive hydrogen use technologies and increased level of localization for iron and steel, chemical industry, and transport. Development of hydrogen blending into gas distribution grid. Development of reliable delivery chains.	Organization of mass production of gigawatt class electrolyzers with high levels of localization. Organization of large-scale production of equipment and development of infrastructure for safe production, transport and storage of hydrogen and hydrogen-containing products with eventually increasing levels of localization. Launching regional hydrogen clusters (hubs) and first large industrial projects. Launching production of new generation hydrogen fuel cells. Upscaling hydrogen production and use for energy storage.
Regulations	Development and enforcement of regulations to determine the safety parameters; standards and certification system for hydrogen and hydrogen-based fuels; methodology of estimating carbon footprint compatible with foreign systems; mechanisms of government support to hydrogen-based technologies. Development of regulations to set GHG allowances and to introduce a carbon price. Enforcement of regulations to develop Russian long-term target agreements and Decarbonization plans to support hydrogen technologies producers who have high levels of localization to enhance domestic demand.	Development of regulations to promote large-scale hydrogen infrastructure and government procurement of materials with low carbon footprint, and to support producers of hydrogen equipment with high levels of localization; to launch carbon pricing mechanisms and integrate carbon price in the exports of hydrogen and hydrogen-based products and in comprehensive permits. Revision of regulations on Long-term target agreements and Decarbonization plans to include tax benefits. Gradual increase in the level of ambition in terms of hydrogen-based technologies uptake and the level of localization.
Incentives and financing	Expansion of Special Investment Contract (SpIC) mechanisms, as well as schemes encompassing energy efficiency technologies and the resources of the State Fund for industrial development, to the hydrogen energy sector. Mechanisms to enhance the development of transport and storage infrastructure for hydrogen, ammonia, and other hydrogen-based substances, and fuel cells production. Development of additional government support mechanisms. Co-financing for pilot projects and R&D.	Tax and loan benefits for advanced hydrogen, electrolyzers, etc. production technologies and for hydrogen pilot projects under Long-term target agreements or Decarbonization plans. Enforcement of carbon pricing mechanisms. Support to R&D for the production and deployment of innovative equipment for hydrogen energy. Government procurement of hydrogen equipment with low carbon footprint. Auction mechanism for hydrogen contract for difference.
Institutes	Setting hydrogen technologies working groups (departments) in the Ministry of energy, Ministry of industry, Russian energy agency of the Ministry of energy, Rosstandart, development agencies. Increasing the membership and expanding the functions of the Inter-Agency working group. Increasing the membership of the National hydrogen energy development union to include a large number of hydrogen producers and consumers. Hydrogen capacity building for research institutes, universities, design organizations, engineering centers.	
Human capital	Development of relevant engineering and scientific competencies and capacity building. Training and professional development for the experts of the Ministry of energy and Ministry of industry, personnel of corporations, based on educational centers and universities. Development of special programmes and syllabuses to train relevant workers. Development of carbon footprint assessment and benchmarking systems.	

Source: CENEf-XXI.