

The Potential for Improving Energy Efficiency of the Russian Economy: Sectoral Assessment and Macroeconomic Effects



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Abstract. Russia has substantial room for reducing energy consumption by using energy more efficiently, a task made especially pressing by limited investment resources and the need to strengthen the competitiveness of domestic output. This study aims to establish the upper bound of the technically feasible reduction in energy use in Russia through the deployment of advanced energy-efficient technologies and to identify the macroeconomic effects of their implementation. Existing research tends to be confined to individual sectors or regions, or focuses primarily on technical aspects or institutional barriers to energy saving. The study's novelty lies in developing an integrated framework that combines an assessment of the potential across four sectors (energy, housing and utilities, industry, and transport) with a ranking of measures by economic feasibility and the identification of options offering short payback periods. The methodology draws on a combination of sectoral analysis and a scenario approach, using data from Rosstat, projections by research institutes, and expert estimates. The results indicate that the overall energy saving potential could reach as high as 50% of current consumption, generating a direct economic effect of up to 1.3 trillion rubles annually (roughly 0.6% of GDP) and cutting CO₂ emissions by as much as 65% of the country's total emissions. The priority areas identified include optimizing the load of combined heat and power plants, developing distributed generation, introducing heat pumps and smart metering systems, modernizing industry, and promoting electric transport together with public mobility. A limitation of the study is the absence of a detailed assessment of cross-sectoral multiplier effects and the economic efficiency of each technology. This points to future research aimed at building an input-output model that would capture feedback loops between sectors of the economy.

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Introduction

Russia has substantial room for reducing energy consumption by using energy more efficiently. According to CENEF estimates, the possible reduction in electricity consumption is 36%, with the main driver of reduction being savings in industry and buildings¹. According to IEA calculations, the potential for saving energy in buildings through the construction of more efficient buildings and reconstruction of those already existing reaches 50% of annual global energy consumption until 2060 (Dulac, 2017). The use of energy-efficient technologies reduces energy consumption and associated costs, as well as greenhouse gas emissions, which corresponds to the goals of the “Socio-Economic Development Strategy of the Russian Federation with Low Greenhouse Gas Emissions until 2050”², the “Energy Strategy of the Russian Federation until 2050”³ and the state program “Energy Conservation and Energy Efficiency Improvement in the Russian Federation”⁴, which provides for the reduction of GDP energy intensity by 35% by 2035.

Energy efficiency challenges are of special importance for the Russian economy in current conditions due to a number of factors. First, high energy intensity of GDP, despite its downward trend, reduces the price competitiveness of domestic products in foreign markets. Second, limited investment resources and the need to modernize fixed assets make energy efficiency improvement one of the most accessible sources of economic growth that does not require significant capital expenditures compared to the commissioning of new producing capacities. Third, in the context of externally reduced import of technology and capital, energy efficiency becomes a growth resource that does not require foreign exchange costs and external financing: a significant part of the developments included in this study can be implemented on the basis of domestic solutions or with the help of friendly countries. Thus, energy efficiency acts as a key element of systemic energy sector transformation in response to sanctions pressure.

¹ On the state of energy conservation and energy efficiency improvement in the Russian Federation in 2022 (2024). Ministry of Economic Development of the Russian Federation. Moscow. 154 p. Available at: https://economy.gov.ru/material/file/b2ec92f00344707af95c8d44a6abbde8/Energy_efficiency_2023.pdf (accessed: 11.11.2025).

² Strategy for the socio-economic development of the Russian Federation with low greenhouse gas emissions until 2050: RF Government Resolution 3052-r, dated October 29, 2021. Available at: <http://static.government.ru/media/files/ADKkCzp3fWO32e2yA0BhtIpyzWfHaiUa.pdf> (accessed: 10.12.2024).

³ Energy Strategy until 2050: RF Government Resolution 908-r, dated April 12, 2025. Available at: <http://government.ru/news/54754/> (accessed: 18.06.2026).

⁴ Energy conservation and improving energy efficiency in the Russian Federation: RF Government Resolution 1473, dated September 9, 2023. Available at: http://government.ru/dep_news/49471/ (accessed: 18.06.2026).

The scientific problem is the fragmentary estimates of overall energy saving potential, which includes all key economic sectors (energy, housing and utilities – the building sector, industry, transport) and considers their uneven economic feasibility. Existing studies focus either on technical aspects or institutional barriers, without offering an integrated approach to ranking measures by scale of impact and economic efficiency.

The study aims to determine the upper bound of technically feasible reduction in energy use in Russia through the deployment of advanced energy-efficient technologies and to identify the macroeconomic effects of their implementation. To achieve this aim, the following tasks have been set: 1) to summarize the most promising energy efficiency technologies in four key sectors of the economy; 2) to assess the technically feasible potential for reducing energy consumption in each sector and in the economy as a whole; 3) to rank the considered measures by their economic feasibility, highlighting options offering short payback periods; 4) to determine the macroeconomic effects and barriers to the implementation of the identified potential.

The scientific novelty of the study lies in the integrated approach that both assesses technically feasible reduction in energy consumption (including by sectors) and differentiates measures by payback period and economic efficiency. It contributes to the development of the above approach, and the obtained quantitative estimates can be used by the government and local bodies to adjust state energy conservation policy and concentrate resources on the most effective measures.

The study assesses the potential for energy consumption reduction by using such technologies

for 2024 and analyzes the macroeconomic consequences of its implementation. The obtained estimate is not an action plan, but an analytical upper bound that allows showing the possible limits and focusing on the most achievable and economically feasible measures.

Current energy consumption

Energy consumption in Russia in 2022 amounted to 1028 million toe (tons of oil equivalent). Since 2000, energy consumption has increased by 20%, since 2010 – by 11%. Alongside the growing demand for energy sources driven by economic growth and the rising standard of living, energy-saving processes are developing, leading to a reduction in their use. For example, energy intensity of GDP in 2021 was 7.3 toe per million rubles in constant 2021 prices, a decrease of 8% compared to 2015 and 19% compared to 2005⁵. According to other estimates, there was a 2.7-fold decrease in energy intensity of GDP⁶ between 2000 and 2021 (Sokolov, 2023a).

For comparison, European economies have energy intensity 2.5 times lower, the United States – 1.8, Japan – 2.2, China – 1.2 (Sokolov, 2023b). The energy intensity of GDP in these countries is decreasing: in the period 2000–2022, according to the World Bank, it decreased by an average of 32% in European countries, by 38% in the United States, by 42% in China. These states differ from Russia in their level of economic development, energy and power supply management, climatic conditions, principles of energy consumption in households.

The annual per capita consumption of energy resources has increased by 9% since 2015, reaching 1.2 toe in 2022. At the same time, annual per capita heat supply per living area has decreased by 28% since 2010, being 0.11 Gcal/m² in 2022⁷. Per capita

⁵ According to Rosstat. Available at: <https://rosstat.gov.ru/folder/11189>

⁶ Calculated in US dollars (PPP).

⁷ Terentieva A.S. (2024). District heating sector in Russia: Analysis of the condition and forecast of the development in the context of new investment mechanisms. Candidate of Sciences (Economics) dissertation abstract. Moscow. 147 p. Available at: <https://ecfor.ru/wp-content/uploads/2024/10/investitsionnoe-razvitie-sektora-tsentralizovannogo-teplosnabzheniya-v-rossii.pdf>

energy consumption in Russia is similar to that of Finland, Sweden, Belgium, the Netherlands, and South Korea. It is 1.9 times higher than in Europe and 1.3 times higher than in the United States⁸. This means that the identified potential for improving energy efficiency is concentrated not in physical energy consumption (Russia is close here to the group of developed countries with similar climatic conditions), but in the efficiency of its conversion.

For example, trends of GDP energy intensity and per capita heat consumption show that Russia reduces energy use. At the same time, it still has significant room for increasing energy consumption efficiency when compared to developed and developing countries. As a result of implementing energy efficiency and energy conservation programs, an average of 1–2 million toe is saved annually. Such programs receive annual funding of about 170 billion rubles⁹.

Methodology for assessing potential

We use a combination of sectoral analysis and a scenario-based approach to assess possible reduction in energy consumption. The study identified four key economic sectors that contribute to total energy consumption: energy, housing and utilities, industry, and transport.

We selected the most promising energy-saving technologies for each sector based on an analysis of modern Russian and foreign practical technological solutions. The selection criteria were technical efficiency and possibility of within-country distribution with appropriate government support. Each technology potential was calculated by comparing current energy consumption levels and the equipment fleet structure with technology-driven target parameters. The target integration values (hypotheses) were determined based on strategic documents, research institutes forecasts, and expert

assessments regarding the maximum possible level of technology penetration under favorable economic conditions and a consistent incentive policy. The methodological approach for assessing potential is based on balance settlements and combines two direct calculation mechanisms:

- normative effect and scaling method (a “bottom-up” approach), where the result is achieved by increasing energy use efficiency within an existing technology or process (for example, in housing and utilities, industry); it is calculated as the energy saved by technology adoption (for example, a heat pump), multiplied by its total projected technically achievable quantity in Russia.

- structural technological substitution (the “top-down” approach) – the effect is achieved by reformed production or consumption structure, rather than by individual unit efficiency (for example, when coal-based power generation is replaced by renewable energy sources (RES), or when the share of electric vehicles in fleet composition increases); in this case, the effect is calculated as the share of transformed technology or fuel type in the overall structure of the sector (electricity production, fleet composition), given the total volume of sector production or consumption.

Direct calculation based on per unit standards and target structural shares determines physically justified upper limit for primary energy savings in each sector. The choice between two calculation methods depends on a specific technology and its effects. The total sector potential is the sum of factors for all considered solutions and measures. A similar division of effects into “unit efficiency” and “structural shift” is also used in foreign cross-country energy intensity studies (Gonzalez-Torres et al., 2021).

⁸ According to the Statistical review of world energy data – Energy Institute.

⁹ On the state of energy conservation and energy efficiency improvement in the Russian Federation in 2022 (2024). Ministry of Economic Development of the Russian Federation. Moscow. 154 p. Available at: https://economy.gov.ru/material/file/b2ec92f00344707af95c8d44a6abbde8/Energy_efficiency_2023.pdf (accessed: 11.11.2025).

Foreign research on energy efficiency is developing in several directions. N. Apergis and H. Fahmy show that geopolitical risks and energy prices volatility significantly affect energy efficiency at the macro level; however, their analysis is limited to price shocks and does not address structural technological growth points (Apergis, Fahmy, 2024). The foundations of energy-saving policy in buildings, formulated back in the 1980s by A. Rosenfeld and D. Hafemeister, were further developed in the works of J. Dulac and H.-S. Mun and their co-authors, who quantitatively assess the energy-saving potential in buildings and agribusiness – but they consider them in isolation from other economic sectors (Rosenfeld, Hafemeister, 1985; Dulac, 2017; Mun et al., 2025). The industrial segment is examined in the works of D. Ma and colleagues, M. Ali and S. Evans, as well as N. Bolson and co-authors – they provide a detailed analysis of production electrification and decarbonization technologies but remain limited to specific industries or country samples and not compared with other sectors (Ma et al., 2025; Ali, Evans, 2025; Bolson et al., 2026). Other foreign studies examine individual drivers of energy efficiency improvement. For example, M. Sohail and colleagues demonstrate that digital technologies adoption reduces energy consumption without compromising production growth (Sohail et al., 2024). M. Madaleno, M. Robaina, and M. Diaz have proven the effectiveness of subsidies and tax incentives for factories modernization, while L. Zhang and co-authors have assessed energy-saving potential in transport (Madaleno et al., 2024; Zhang et al., 2024).

In Russian science, systematic energy efficiency research is conducted at the Energy Research Institute of RAS, Melentiev Energy Systems Institute of RAS, CENEF-XXI, HSE and other science centers. A methodological contribution

to the analysis of this topic at the macro-level was made by V.S. Arutyunov, A.V. Arutyunov and G.V. Lisichkin, who justified the limited effect of certain clean energy types on economic development, which sets the upper limit for using renewable generation as an energy efficiency tool (Arutyunov et al., 2026). Sectoral assessments of cogeneration technologies in the energy sector are presented in the work by M.D. Dilman and S.P. Filippov (Dilman, Filippov, 2025); low-carbon technologies in buildings are investigated by I. Bashmakov and co-authors (Bashmakov et al., 2023).

To sum up, existing studies (both foreign and Russian) are substantively developed within the boundaries of individual sectors (buildings, industry, agribusiness) or isolated factors (prices, geopolitics), but they do not offer a comparable cross-sectoral assessment. Furthermore, there are no studies among recent works that rank measures according to their economic feasibility and identify options offering short payback periods.

Technologies for energy efficiency improvement

Many energy-efficient technologies develop acceleratively and do not require special measures to be used. This includes the adoption of more energy-efficient materials and technologies in construction, household appliances, lighting methods, vehicles running on more efficient types of fuel, etc. Other solutions are relatively expensive for widespread adoption. However, they have high efficiency and can be actively used with government support (restrictions, quotas, etc.).

Next, we will examine technologies that will not develop by themselves. They are distributed across sectors in order of their energy consumption level and potential to reduce it: the energy sector (electricity and heat production, including operational fuel consumption, transmission and transformation losses) accounts for 28% of energy consumption; housing and utilities (residential

sector, services, etc.) – 26%; industry – 30%; transport – 16%¹⁰.

Energy-efficient technologies in the energy sector

The most environmentally friendly, modern, and efficient energy sector technologies for generating electricity are considered to be renewable power (wind and solar), biofuels, nuclear power plants, and hydroelectric power plants. Renewable sources do not use fossil resources, while thermal power plants do and release into the environment 40–60% of the fuel burned (Ainullov et al., 2022). However, building expenditures for renewable power plant types are higher than for thermal power plants, although the cost of electricity from wind, solar, nuclear, and hydroelectric power plants is lower. Furthermore, all these renewable energy facilities also have a negative impact on the environment in addition to their positive effects. For example, the construction of hydroelectric plants significantly alters the ecosystem and river flow patterns; nuclear stations carry the risk of radiation accidents; solar panels are produced with a large number of toxic and explosive components¹¹. This is only part of the environmental threats associated with the construction and use of renewable energy generation technologies.

Nevertheless, it is necessary to consider the possibilities of using renewable technologies, taking into account the country's resource capabilities, negative environmental consequences, the current power industry structure and its capacity, as well as the existing power and heat markets.

It would also be advisable to consider options for optimizing the capacity utilization in the power industry and heat supply, since underutilization is common now (Semikashov, Terentieva, 2024). In

this case, some boiler houses can be closed, while others can be converted into mini-CHP (combined heat and power plants), which would allow reducing the per unit fuel consumption at heat supply sources by 21 kg of oil equivalent.

Options for using distributed energy technologies can also be considered. Storage systems at consumers' sites and at differentiated generation facilities allow accumulating and releasing electricity, thereby influencing the capacity market and optimizing the processes of energy production and transmission. Smart grids and demand management technologies optimize consumption processes, which can reduce system costs and peak loads, as well as the need for peak capacity. According to experts from Energy Research Institute of RAS, small distributed power generation based on modern gas turbines provides a systematic reduction in the per unit consumption of oil equivalent due to a higher technological efficiency of the equipment compared to the old steam power assets of large plants (Dilman, Filippov, 2025).

Energy-efficient technologies in housing and utilities

Energy-efficient technologies in terms of housing and utilities can include construction technologies (passive and active houses), heating and energy production technologies (heat pumps), as well as energy consumption regulation technologies (smart systems and meters).

Smart energy consumption regulation systems include meters, smart outlets, various sensors, programmable thermostats, etc. They reduce electricity costs for lighting and electrical appliances by 15–20 %. Programmable thermostats, radiator

¹⁰ Hereinafter, if not specified, the shares of sectors in energy resource consumption are calculated based on the Rosstat fuel and energy balance (2022).

¹¹ Degtyarev K.S. (2015). Renewable energy sources and side environmental effects. SOK, 5. Available at: <https://www.c-o-k.ru/articles/vie-i-pobochnye-ekologicheskie-effekty> (in Russian).

and motion sensors, use of different heating modes can reduce energy costs for indoor heating by 25-35%¹². Technological potential estimates of automation and modernization of buildings are consistent with the expert conclusions from CENEF, where key low-carbon solutions for the Russian housing stock are rigorously analyzed (Bashmakov et al., 2023).

Heat pumps provide heating via temperature difference between the building and the ground or outdoor air. The cost savings are up to 80%¹³. According to IEA estimates, heat pumps will account for up to 45% of heating energy demand by 2050¹⁴.

Passive and active house technologies is a comprehensive construction concept (involving design and materials) which supposes that the building does not use additional energy (passive house)¹⁵, or even generates it enough for others purposes (active house). Such a building effectively utilizes solar energy, internal sources, and heat recovery. The house's energy consumption is minimal due to improved thermal insulation, air-proof building envelopes, and energy-efficient engineering equipment.

Energy-efficient technologies in industry

Here technologies provide the most effective and secondary use of resources (circular economy), for example, when producing alumina, cellulose, clinker; transition to the latest technological processes and technologies (cast iron, electric steel, aluminum, fertilizers, synthetic ammonia, synthetic rubber); elimination of some energy-intensive technological processes (replacement of the open-hearth method of steelmaking, efficient

electric motors); automation (iron ore mining); improvement of accounting systems and energy management.

Energy-efficient technologies in transport

Promising transport energy technologies are railroad and electric transportation. We will focus on electric transport developments, since the potential of railroad transport has already been sufficiently realized.

Electric vehicles use modern battery systems and can be considered as a replacement for vehicles with combustion engines. Currently, the technology is being actively implemented in passenger vehicles, but it may be also applied to public, freight, and commercial transportation in the future¹⁶. The use of electric vehicles leads to a reduction in demand for petroleum products and an increase in the need for electricity. Overall, fuel consumption decreases if the country's electric power industry is efficient (with a large share of hydroelectric, nuclear power, high efficiency of thermal power plants with sufficient fuel capacity utilization).

Changes in the structure and concept of road transport can lead to a more efficient distribution of energy resources. For example, transition from personal vehicles to car sharing services, as well as the spread of public transport, can be considered measures to improve energy efficiency.

The list of productive technologies is extensive (those applicable to gas, oil, and coal extraction; agriculture; hydrogen development, etc.), and most of them are not investigated in the article. However, we put our emphasis on the most promising technologies with the greatest potential in the Russian context.

¹² How to save electricity with a smart home system. Inzhenernye seti. Available at: <https://eng-net.ru/blog/kak-economit-s-sistemoi-umnii-dom/> (accessed: 06.12.2024).

¹³ Heat pump for heating a private house. Pros and cons. MAST Dom. Available at: <https://www.mact-dom.ru/advice/poleznaya-informaciya/kupit-teplovoy-nasos-ili-druguyu-sistemu-otopleniya-dlya-doma> (accessed: 06.12.2024).

¹⁴ World Energy Outlook 2025. Paris: IEA, 2025.

¹⁵ A building is considered passive if its thermal load does not exceed 10–15 W/m² of living space.

¹⁶ Rostovski J.-K. (2024). Assessment of the impact of electric vehicle markets on the prospects for Russian industries. Candidate of Sciences (Economics) dissertation abstract. Moscow. 27 p. Available at: <https://ecfor.ru/wp-content/uploads/2024/03/avtoreferat-rostovskij-j.-k.pdf>

Assessment of the potential reduction in energy consumption after technologies adoption

Table 1 shows the estimated potential of the technologies described above and proposes conditions for their adoption.

The growth in the share of renewable sources (including nuclear and hydro power) in electricity generation from 10 to 30% corresponds to the Russian Energy Agency technological development scenario¹⁷. Reduction in the number of fossil fuel power stations while generating the

same amount of electricity and heat saves up to 150 million toe.

Better utilization of existing capacities in the electric power industry and heat supply supposes an increase in the share of CHP from 45 to 80% in heat production and the predominant use of cogeneration at heat supply facilities, which will cause dissolution of some inefficient boiler houses and increase in CHP share of power generation. This will lead to a reduction in fuel consumption by 30–40 million tons.

Table 1. Potential reduction in energy consumption after adoption of energy-efficient technologies by sectors, 2024

Technology	Criterion	Potential reduction of energy consumption, million toe
Energy		
Renewable energy (wind, solar, nuclear, hydro, biofuel)	30% of energy is renewable, reduction in fossil fuel utilization	150
Fossil fueled power plants (improved utilization of capacity, dissolution of some boiler houses)	Increase in the share of CHP to 80% in heat production, predominant use of cogeneration	30–40
Smart grids, distributed energy systems (generation), storage and demand management systems	Optimization of distribution on smart grids and energy storage systems, demand management, distributed generation of about 36–68 GW	30–50
Housing and utilities		
Intelligent systems and meters	All households use meters and intelligent energy consumption regulation systems to varying degrees	50
Heat pumps	18 million heat pumps	44
Passive and active houses	10% of zero-energy buildings in the stock of buildings	24
Industry		
Energy-efficient technologies in metallurgy, cement and chemical industries		52
Transport		
Electric vehicles	19 million or 40% of EV in the stock of vehicles	34
Mass transit and car sharing	2–3% of car sharing in million-plus cities, 50% of mass transit	10
Total		424–454 (44% of current consumption)
Calculated based on: Rosstat fuel and energy balance. Available at: https://rosstat.gov.ru/storage/mediabank/5RIE0jgu/en_balans.htm ; (Milyakin, 2022; Milyakin, Skubachevskaya, 2024); Distributed energy in Russia: Perspectives. Moscow: Energy Center of the Moscow School of Management Skolkovo. 87 p. Available at: https://energy.skolkovo.ru/downloads/documents/SEneC/Research/SKOLKOVO_EneC_DER-3.0_2018.02.01.pdf (accessed: 09.12.2025).		

¹⁷ Scenarios for world energy development until 2050. Moscow: Russian Energy Agency. 130 p. Available at: <https://rosenergo.gov.ru/press-center/news/stsenarii-razvitiya-mirovoy-energetiki-do-2050-goda/> (accessed: 05.12.2025).

Distributed energy technologies, according to Energy Research Institute of RAS estimates, can provide 36–68 GW¹⁸, which will ensure fuel savings after the introduction of highly efficient gas turbines with increased efficiency. This will reduce energy consumption by additional 30–50 million tons. To sum up, energy-efficient technologies adoption in the energy sector can potentially save 260–290 million toe.

Intelligent systems, electricity and heat consumption meters can potentially reduce electricity consumption by 15–20% and heat consumption by 25–35%. This effect is extrapolated to 52 million Russian households according to their structure (different values for individual and multi-apartment buildings). The following hypothesis is being tested: 30% of households reduce consumption by 50%, 70% of households – by 25%. Thus, the use of intelligent systems and meters by households could reduce energy consumption by 50 million toe.

The growth in the number of heat pumps from 16 to 18 million supposes their use in 60% of buildings. This heating method reduces costs by 80%. This effect, multiplied by the target number of heat pumps, will reduce energy consumption by 44 million toe.

Passive and active houses expansion in the stock of buildings from 2 to 9% implies a reduction in energy use by 24 million toe due to ultra-low per unit energy consumption compared to standard objects. To sum up, energy-efficient technologies adoption in the housing and utilities sector can potentially save 120 million toe.

The industry uses CENEF technological estimates for basic energy-intensive branches (metallurgy, chemistry, building materials – specific solutions were described in the previous section) – 52 million tons¹⁹ of potentially saved energy – which is based on the possible adoption of the best available developments and energy management systems.

The expansion of electric vehicles from 0.1% to 40.5% predicted by IEF RAS²⁰ in a positive scenario for electric transportation development causes the replacement of cars with combustion engines, which saves 34 million tons of petroleum products.

The transition to mass transit (increase to 50%) and car sharing (from 1.3% to 2–3% – according to works of colleagues from IEF RAS) in million-plus cities suggests a reduction in per unit energy consumption compared to personal vehicles and saves 10 million tons of petroleum products (Milyakin, 2022; Milyakin, Skubachevskaya, 2024).

In total, the potential reduction of fuel consumption in transport after adoption of technologies described above is 44 million toe.

The overall potential reduction in energy consumption, according to the author's estimates (provided that all the above technologies are adopted) can reach 470–500 million toe, which is up to 50% of current energy consumption. It can also decrease carbon dioxide emissions by 1.1–1.4 billion tons per year which is up to 65% of current Russian total CO₂ emissions.

This value is not a forecast or a target indicator, but a calculated upper bound of technically feasible

¹⁸ On the state of energy conservation and energy efficiency improvement in the Russian Federation in 2022 (2024). Ministry of Economic Development of the Russian Federation. Moscow. 154 p. Available at: https://economy.gov.ru/material/file/b2ec92f00344707af95c8d44a6abbde8/Energy_efficiency_2023.pdf (accessed: 11.11.2025).

¹⁹ Low-carbon technologies and potential for reducing greenhouse gas emissions in the Russian Federation. CENEF. Available at: <https://cenef-xxi.ru/categories/11#> (accessed: 03.12.2024).

²⁰ Rostovski J.-K. (2024). Assessment of the impact of electric vehicle markets on the prospects for Russian industries. Candidate of Sciences (Economics) dissertation abstract. Moscow. 27 p. Available at: <https://ecfor.ru/wp-content/uploads/2024/03/avtoreferat-rostovskij-j.-k.pdf>

reduction in consumption. The economic efficiency of the considered technologies is out the scope of this study. However, we assume that only a small piece of the identified potential is economically feasible in the current market environment. Intersectoral, environmental, social and budgetary effects should be considered when implementing the solutions discussed.

The level of localization of the proposed developments is also important. It is indicative that a large part of distributed energy technologies, renewable energy sources, industry technologies, electric vehicles, heat pumps and passive houses can be implemented using Russian inventions or the help of friendly countries.

Consequences and barriers

The realization of this energy efficiency potential can have a significant effect on key macro-economic and cross-sector parameters.

The defining consequence will be the transformed energy budget with lower demand for fossil fuels and higher electricity consumption. This process creates fundamentally new conditions for power industry development, requiring not only an increase in generating capacity to meet energy needs but also changes in their operation modes, grid infrastructure improvement, the adoption of smart demand management systems.

Fuel industries will face the reduction in domestic demand and the need to focus on export markets, which will be challenging in the context of the global energy transition and sanctions. Lower energy intensity of GDP caused by reaching the potential will contribute to domestic producers' price competitiveness and independence from energy prices fluctuations. More efficient energy consumption in housing and utilities will reduce the burden on household budgets and improve the standard of living.

An important macroeconomic consequence will be the multiplier effect of investments in

energy efficiency, which, unlike investments in the extraction and transportation of energy resources, is characterized by a higher job creation rate per invested ruble and contributes to the localization of equipment in manufacturing industries and construction.

The environmental effect, accompanied by a reduction in greenhouse gas emissions, allows Russia to participate in international climate projects and reduces the risks associated with carbon regulation measures. At the same time, the listed effects are possible only to the extent that the set of constraints hindering energy-efficient technologies adoption is overcome in the current economic and institutional conditions.

Economic constraints are associated with significant initial capital expenditures and relatively long payback periods, despite the high efficiency in the long term. Even projects with a positive return on investment may remain unimplemented due to expensive loan proceeds and limited investment resources. Institutional barriers include the absence of economic incentives to improve energy efficiency, the existing pricing pattern, the ownership structure, and state regulation principles in the power industry and heat supply.

A significant limitation in industry is the production structure inherited from the Soviet period, within which many technological processes were originally designed without considering energy efficiency, and their deep modernization requires not just replacing equipment, but restructuring the entire production chain. Technological limitations include dependence on imported key components of energy-efficient equipment, which may create risks for large-scale programs under conditions of sanction pressure.

The barrier in housing and utilities is the low purchasing power: only subsidies and preferential lending programs allow making even potentially profitable investments.

Table 2 presents the areas that have the greatest potential in terms of the combination of economic effect and feasibility factors. They were selected based on three criteria: contribution to reducing energy consumption; the presence of a clear economic agent that can realize the potential; the possibility of applying support measures in the medium term. An aggregated cost assessment of the potential energy consumption reduction has also been provided, which helps to translate technical indicators into budget planning values and investment decisions. Technologies that require strategic planning and long-term investments, such as large-scale power generation construction, should be considered separately.

The institutional barrier is apparently the most challenging among the listed constraints: even in the context of accessible loan proceeds, the existing

model of tariff regulation and the ownership structure in the power and heat sector do not create a direct economic incentive for most market participants to improve energy efficiency, whereas economic and technological barriers can be largely addressed through targeted support measures.

Conclusion

The calculated potential for the adoption of energy-efficient technologies demonstrates the possibility of significantly reducing energy consumption in Russia – by up to 50% of the current level. This figure represents the estimated upper bound, which shows the actual limits and contributes to a realistic understanding of the scale.

It is crucial to comprehend the heterogeneity of this potential. On the one hand, there are some simple options offering short payback periods: adoption of metering, elimination of losses,

Table 2. Key sectors contributing to energy consumption reduction: expected effects and proposals

Sector	Key technologies	Economic effect*	Agent responsible for realization	Content	Proposals
Energy	CHP optimization, distributed generation, dissolution of inefficient boiler houses	150–250 billion rubles	Generating companies, municipalities, transmission system operator	Reduced per unit fuel consumption, fewer losses in networks and inefficient capacities	Tariff solutions (stimulation of cogeneration); preferential lending for modernization projects; development of technical regulation
Housing and utilities	Heat pumps, smart metering systems	470 billion rubles	Households, management companies, developers	Reduced utility payments, saved budget funds for subsidies	Subsidies for households; mandatory installation of metering systems within major repairs; preferential lending and interest rate subsidies for developers; inclusion of heat pumps in social gasification programs
Industry	Modernization, energy management	260 billion rubles	Large industrial enterprises	Reduced product costs, increased competitiveness in foreign markets	Tax incentives (income tax benefits); preferential loans for modernization; support for energy management
Transport	Electric vehicles, development of mass transit and car sharing	220 billion rubles	Automakers, taxi fleets, population, regional authorities	Reduced petroleum imports, fuel savings	Development of charging infrastructure; subsidies for EV production; support for car sharing and mass transit programs
* The annual economic effect is calculated as the cost of saved fuel at the average price of natural gas converted to industry oil equivalent in 2024 and does not include additional effects (reduction of investments in new generation, environmental effect, etc.). Source: own compilation.					

optimization of operating modes, basic automation systems. These measures can produce a tangible effect without large-scale capital investments – and economic policy should focus on them in the short term. On the other hand, there are technologies that require a profound modernization of facilities and energy supply, which is feasible only in the long term with effective financing mechanisms available.

Even partial realization will lead to significant macroeconomic consequences: a transformation of the energy budget with a reduced demand for fossil fuels and increased electricity consumption, enhanced price competitiveness of producers, a lighter burden on household budgets, a multiplier effect on employment in manufacturing industries and construction, as well as a significant environmental effect.

A set of barriers constrain the realization. First, economic constraints, manifested in significant initial capital expenditures, long payback periods, and the high cost of loan proceeds, which often prevent even profitable projects from being implemented. Second, the institutional barrier, reflected in the existing tariff regulation system and the ownership structure in the power and heat sector, which does not create a direct economic incentive to improve efficiency. This constraint is the most challenging: even financial well-being cannot resolve it. Third, a technological barrier – dependence on the import of key equipment components under conditions of sanctions pressure. Fourth, a barrier in manufacturing, which modernization requires restructuring the entire technological chain, rather than just replacing equipment on an individual basis. Fifth, a barrier in housing and utilities, manifested in the low purchasing power, which makes even profitable measures unaffordable without subsidies.

Economic and technological barriers can be overcome using targeted support measures, whereas the institutional barrier requires reorganization of

the entire electricity and heat markets. When developing support measures, the specific nature of the barriers in different sectors should be considered. In the power industry, the emphasis should be put on the reorganization of its market, as well as on economic incentives for capacity optimization. In the housing and utilities sector, targeted subsidies for low-income households should be accompanied by a system of technical regulation and accessible credit mechanisms for implementing energy-saving elements within major repairs. In industry, the most effective tools seem to be tax incentives and voluntary energy management mechanisms. In the transport sector, the priority is to create charging infrastructure for electric transport and to develop mass transit as the most energy-efficient in large cities.

The key principle of the policy should be the idea that a large part of the technically feasible energy savings will not be implemented for economic reasons, since the cost of the saved energy may exceed the cost of its production. The goal is not to reach the calculated upper bound at any cost, but to create conditions for the implementation of economically efficient measures, including those that influence the development of the Russian economy – both by increasing the output of Russian energy-efficient equipment, by reducing energy costs, and ultimately by enhancing the efficiency and competitiveness of energy-consuming industries.

The direct economic effect of implementing the described measures (the cost of fuel saved annually) could be up to 1.3 trillion rubles, or about 0.6% of GDP. This estimate does not consider complex cross-sector interactions and demonstrates the general value of the direct effect. After taking into account multiplier effects, the total contribution to GDP can be comparable to several percent, but such an assessment requires a separate cross-sector study.

The remaining potential will then remain a budget funds and keep a focus on truly achievable reserve in case of changes in relative prices or results that can ensure a real increase in the the emergence of more efficient technologies. competitiveness of the Russian economy and an This approach will help avoid the inefficient use of improvement in the quality of life.

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