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SOCIO-ECONOMIC IMPACT ASSESSMENT: APARTMENT BUILDING RENOVATIONS & ENERGY-EFFICIENCY IMPROVEMENTS IN RUSSIA'S URBAN HOUSING STOCK

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SOCIO-ECONOMIC IMPACT ASSESSMENT: APARTMENT BUILDING RENOVATIONS & ENERGY-EFFICIENCY IMPROVEMENTS IN RUSSIA'S URBAN HOUSING STOCK

IMPROVING URBAN HOUSING EFFICIENCY AND FINANCING FACILITATION FOR BUILDING MODERNIZATION IN THE RUSSIAN FEDERATION

RUSSIAN FEDERATION (EUROPE AND CENTRAL ASIA)

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Executive Summary

The presented Report consists of four main parts: (1) the introduction provides important background information about the state of the Russian housing sector and the existing program of retrofits of multifamily buildings; (2) a methodological summary that outlines the approach to estimating the economic, fiscal, social and climate benefits of residential housing retrofits; (3) scenario modelling based on three sets of assumptions; and (4) conclusions drawn from the above sections.

This is the first domestic (and one of few international) analysis of the kind in the urban housing retrofit space. The indicative results are based on a sample of available data collected by the World Bank (WB) research team (especially with regards to the energy efficiency (EE) focused measures). More in-depth analysis would require additional data to be collected on region specific climate features and housing stock conditions.

Russia has a large residential housing stock of about 21 million buildings, including 2.7 million multifamily buildings (MFBs). The housing stock is refurbished through a large-scale homeowner-financed renovation program (RUB 200 billion worth / about 50,000 MFBs annually) but this program includes only negligible investment into energy efficiency (EE) measures (less than 0.5% of the annual retrofit spend).

At the same time, energy consumption in the residential sector is significant (fourth among other sectors, accounting for 17% of the national total) and there is an opportunity to capture climate benefits from improving EE characteristics of the existing housing stock. The key challenge today is to formulate a coherent policy approach which would enable financial support for large-scale EE-related retrofits through the existing refurbishment program. This report aims to inform this policy dialogue by providing quantitative information on the economic, fiscal, social and climate benefits of a potential increase in support for EE-related retrofits.

The main finding of the report is that a focused public investment program to complement existing privately funded retrofit activities would have a very significant positive climate effect without any negative economic or fiscal impacts. The report finds potential impact of up to 562 grams of CO_2 reduced per Ruble of investment, though each of the three scenarios tested has a different range of economic, fiscal, and climate impacts (see part three for more detail). The findings can form the basis for a focused policy dialogue with the relevant Government agencies on a national strategy for reducing the carbon intensity of the housing sector.

Introduction

This study is implemented within the World Bank advisory, and analytics Program “Improving Urban Housing Efficiency and Financing Facilitation for Building Modernization in the Russian Federation” (the Program) designed to reduce greenhouse gas (GHG) emissions in Russia through stimulation of investment in the energy-efficient renovations of residential multi-family buildings (MFBs).

Russia Housing Sector Background Information

Over 140 million people live in Russia, with almost 100 million residing in multi-family buildings (MFBs). Russia’s residential housing stock is rather old (See Table 1) and more than 45% of MFBs were built 40 years ago or earlier, most requiring energy efficiency retrofits.

As of 2019 the Russian residential housing stock consists of approximately 20.8 million buildings (with a total floor area of 3.7 billion m^2),[1] split into:

- 2.7 million MFBs; and
- 18.1 million single family houses.

The housing sector in Russia (represented mostly by MFBs) is the 2nd largest end-user of energy and accounts for approximately one quarter of all energy consumed in the country.[2] Being such a large energy consumer (second only to industry),[3] the housing sector has enormous potential for energy savings and Greenhouse Gas (GHG) reductions[4]. A study by McKinsey & Co.[5] found that of all sectors in the Russian Federation, buildings represent the largest cost-effective abatement potential of all, up to 321 Mt CO_2eq by 2030 – 64% of which would have a negative abatement cost. Coupled with the significant potential in the closely related heat and power sector of 304 Mt CO_2eq, energy efficiency in buildings offers the greatest potential for GHG savings by a wide margin.

[1] According to the Rosstat report on “Residential Housing Sector in 2019” https://rosstat.gov.ru/storage/mediabank/Jil-kom_xoz-vo%202019.pdf . (this report gives figures as of 31.12.2018)

[2] Heat generation in Russia in 2018 amounted to 857,571 thousand Gcal. More than 80% of Russia’s total consumption of fuel and energy resources is accounted for by the four most energy-intensive sectors of the economy: electric and heat energy generation (28%), manufacturing (22%), population (17%), transport (16%). See Federal Report “On energy savings and increasing energy efficiency in the Russian Federation”. Ministry for Economic Development of Russia, 2019. p.18 https://www.economy.gov.ru/material/file/d81b29821e3d3f5a8929c84d808de81d/energyefficiency2019.pdf

[3] The residential housing sector is a major energy consumer accounting for: 23% of primary energy consumption; 21% of final energy consumption; 42% of final heat energy consumption; 16% of final electricity consumption; 25% of final natural gas consumption, and almost a third of the total natural gas consumption. In 2012, 64.6% of energy consumption in the residential sector was used for heating, 18.3% for hot water supply, with other needs accounting for about 17%. See Igor Bashmakov’s “Energy use and energy efficiency in the Russian residential sector. How do you make it low carbon?” // Energosovet No.2 (33) 2014. http://www.energosovet.ru/bul_stat.php?idd=454

[4] Russia’s total greenhouse gas emissions (excluding land use, redesignation and forestry) in 2019 stood at 2,119.4 million tons of CO_2eq. See data from the Russian national inventory of anthropogenic emissions by sources and removals by sinks of greenhouse gases not regulated by the Montreal Protocol (updated as of 16.06.2021). https://rosstat.gov.ru/folder/11194

[5] McKinsey & Co. “Pathways to an energy and carbon efficient in Russia”, 2009 https://www.mckinsey.com/~/media/McKinsey/dotcom/client_service/Sustainability/cost%20curve%20PDFs/CO2_Russia_ENG_final.ashx

TTable 1: Russian residential housing stock by year of construction*

	Construction year					
	Before 1920	1921 – 1945	1946 – 1970	1971 – 1995	After 1995	Total
Single family houses (number)	722,317	1,599,084	7,225,682	4,935,506	3,640,801	18,123,390
Multi-family buildings (number)	103,572	160,115	958,589	1,217,665	263,805	2,703,746
Total area (thousands m^2)	75,160	136,117	965,419	1,434,885	1,212,452	3,733,033

** https://rosstat.gov.ru/folder/210/document/13234*

Current state of retrofits of multifamily buildings

The current Russian system of organizing and financing of EE MFB capital repairs (MFB retrofit system) is based on mandatory targeted contributions from homeowners which are subsequently utilized by specialized regional institutions to perform the repairs. A relatively small share of MFBs (approximately 15%) makes such contributions to specialized bank accounts which can subsequently be used to finance repairs (aka "special accounts"). The rates for the contributions are regulated by regional statutes on annual basis and generally increase in line with inflation, although have been frozen in 2020 as part of broader pandemic-related measures of the Russian government to support the citizens and the economy.

Housing legislation does not separate "regular" retrofits from "energy efficiency" retrofits of MFBs – all depends on scope of works selected by the homeowners and availability of funding.

Based on the practice of implementation of the MFB retrofit system[6] it has become clear that (a) the contribution rates[7] in most of the Russian regions are inadequately low compared to the volume of needed capital repairs and (b) there is no financial infrastructure and products which would allow private banking capital to participate in long-term financing of such activities (as discussed in more detail below). While admittedly there is still a number of legal and regulatory adjustments to be performed in order to address existing barriers to attract additional funding for these purposes global examples illustrate that in the absence of a meaningful public support program, lenders are reluctant to venture into this long-term asset class.

Another mechanism of financing for EE MFB capital repairs, also known to international practice, is a form of energy service contracts under which a contractor – specialized energy service company (ESCO) – undertakes to finance EE measures with a guaranteed energy savings / savings on utility bills and with guaranteed quality of living in renovated buildings. In exchange, the homeowners undertake to reimburse costs incurred by ESCO within a certain period of time (3-5-7 years), depending on amount of financing involved and volume of savings achieved to make the scheme financially viable. Note that typically such contracts provide for a guarantee level of performance by the ESCO which means that in case such levels are not achieved, the payment from homeowners to that ESCO is reduced.

[6] Introduced in 2013 by amending the Housing Code.
[7] Varies from RUB 1.67 to 20.47 per sq.m. per month and on average is RUB 8.16 per sq.m. of total area of individual dwelling.

Development of energy services in residential sector is incumbered by several legal and social problems (e.g., now a structure of social subsidies for utilities does not allow to extend those to payments under ESCO contracts, thus demotivating homeowners from approving EE MFB renovations at scale). However, commercial firms express growing interest in this business, especially in the regions where regional authorities are interested in expedited modernization of municipal heating systems and MFB EE retrofits[8].

Currently the Russian Government implements a limited in scope and volume and technically complicated program of subsidies to facilitate EE MFB capital repairs (Subsidy Program)[9]. The Subsidy Program has been launched in 2017, then suspended in 2018 and relaunched in 2019. Besides the subsidy for actual EE improvements, the Subsidy Program also attempts to provide stimulating effect for the MFBs to use bank loans to finance MFB capital repairs. Total numbers shown below illustrate that compared to the MFB housing stock (about 1 million houses) and annual volumes of regionally provided capital repairs (about 40,000 homes), the Subsidy program is totally inadequate.

Table 2: Federal Subsidy Program EE Results (2017, 2019-2021)

Year	# of regions	# of MFBs	Value of EE repairs USD	Subsidy amount USD
2017	6	35	1'575'834	553'174
2019	16	56	3'447'094	1'059'460
2020	27	121	3'760'247	1'706'309
TOTAL		**212**	**8'783'175**	**3'318'943**

Source: Analysis by the Report authors based on data from ZhKH Fund

Since 2013 only slightly more than 240 loans have been granted by three banks of which only one – the Center-invest Bank continues offering such loans on a sustainable basis.

There is no direct bank lending to ESCOs as such companies lack collateral required by banks and the energy service projects are financed through factoring operations which is a more expensive instrument and still has very limited offer on the market.

Relevance of Russian social-economic development goals to the performed analysis

Increasing the efficiency of primary-resource use is a key area of focus in Russian economic development. In light of the global need to address the issue of climate change, technological modernization is playing an increasingly important role in driving energy efficiency and in economic development strategies more broadly. Accordingly, this issue will be given special attention in the recently adopted "Strategy for the socio-economic development of the Russian Federation with a low level of greenhouse gas emissions until 2050", which in the coming years is expected to become one of the government's most important strategic planning documents.

[8] ESCO mechanism will start working in Yakutia housing sector (В Якутии заработает механизм энергосервиса в жилых домах): https://centerjkh.ru/v-yakutii-zarabotaet-mekhanizm-yenergos/

[9] Russia Government Decree No 18 of January 17, 2017 "On approval of the Rules for the provision of financial support at the expense of the state corporation - the Fund for Assistance to the Reform of Housing and Communal Services for the overhaul of apartment buildings".

It should be noted that Russia's energy sector (excluding LULUCF) accounts for slightly less than half of all GHG emissions.[10] The residential sector, which includes housing, accounts for a further 10% of total emissions. As such, the modernization of the country's inefficient energy generation facilities and associated transmission infrastructure, as well as measures to increase the efficiency of end-consumer energy use, particularly in MFBs, demonstrate strong potential to increase Russia's energy efficiency at the national level.

Currently, according to Rosstat, more than 60% of apartment buildings have a wear rate of more than 30%, and more than 50% of recently commissioned apartment buildings do not have an established energy efficiency class. Energy efficiency requirements have not yet become a key governing parameter of residential-sector renovation programs in most regions of the country. The consequence of this is a generally low level of energy efficiency (EE) in housing.

The challenge of reducing per-unit energy consumption in the residential sector can potentially be addressed through a variety of measures. The first such option is the replacement of old housing stock via demolition and new construction projects carried out in accordance with relevant energy-efficiency standards. However, in the context of budgetary constraints, it is impossible to address challenges of housing energy efficiency this way in the near term.[11] A second potential approach to energy efficiency is through large-scale renovation (capital repair) of apartment buildings in combination with implementation of targeted energy efficiency measures. But once again, practice shows that this approach is also subject to certain limitations, namely low public payment capacity (limited potential for increasing homeowners' contributions) and the difficulty of funding such projects from the regional budgets.

Thirdly, just energy-efficiency renovations (EER) are also a potential solution—that is, a set of less costly, specialized measures aimed at improving the energy efficiency of the nation's existing housing stock without concurrent implementation of other works required by the regional program of capital renovation of MFBs.

For each region of Russia, the choice of which of the above-mentioned energy efficiency strategies to prioritize will be determined by that region's own unique climatic conditions and the current situation of its residential sector. For this reason, this report's methodology should be further refined to consider regional idiosyncrasies so that it may be applied in the framework of regional pilot projects.

Relevance of international practices to the performed analysis

The global examples from comparable (in terms of climate, population, housing stock, urbanization and overall economic development) jurisdictions, e.g. from Germany or Japan, show that in order to engage the private sector stakeholders, there needs to be a meaningful public subsidy program which would (a) provide financial institutional infrastructure for aggregation of the assets and production of capital-market based liabilities and (b) provide efficient direct support to the homeowners. Such subsidy program also provides the lenders with a good understanding on the potential market size and thus serves as a market risk mitigation instrument and allows to take long-term view on this business line.

[10] LULUCF: Land use, land-use change, and forestry

[11] So far, this sort of large-scale program of housing-stock replacement has only been implemented in the city of Moscow. While similar programs have been discussed in other regions, a widespread program to replace of the nation's housing stock through demolition and new construction seems unlikely.

Notably, recent research papers (e.g. in EU[12] and US[13], among many) indicate significant macroeconomic and social benefits of EE modernization of the residential buildings, with a measurable positive impact on unemployment, GDP, public health, climate mitigation and so on. Interestingly, the World Bank's own research in that area[14] confirmed that examples of well-structures systemic approach to providing EE-related financing towards the homeowners (based on data from Germany, some other EU countries, and Japan) indicate that the very design of the subsidies takes into consideration the nature and complexity of the EE measures per se, with the logic (simplistically put) being that the more "serious" the actual works being performed, the greater the economic and ecological benefits can be expected.

Purpose and scope of the Report

The World Bank has been implementing significant technical and analytical support to the federal and regional authorities on the matters of facilitation of energy efficiency improvements in the residential multifamily buildings and collected valuable data about cost and results of capital renovation projects of hundreds of multifamily buildings across the Russian Federation. These projects included regular capital repairs without any specially targeted energy efficiency improvements / results as well as other kind of projects – where energy efficiency and energy savings were put as a priority for buildings' renovation. Using a special tool developed by the ZHKH Fund for the purposes of calculating amounts of state subsidies for energy efficiency improvements of the multifamily buildings, the WB research team received the necessary data about energy savings and corresponding GHG emission reductions achieved in cases where capital repairs of the multifamily buildings were including targeted energy efficiency improvements.

The purpose of this Report is to inform a policy debate around developing and deploying mechanisms of financing for EE retrofit measures, which would contribute to the decarbonization and energy intensity reduction of the residential housing sector. The national system of urban multi-family building (MFB) refurbishment was analyzed from economic, fiscal and climate impact perspectives, followed by recommendations on the adjustment of retrofit policies which would contribute to the climate agenda.

The analytical research endeavors to develop robust methodology to measure such socio-economic effect as applicable to the Russian Federation (specifically the structure of employment, production of relevant materials and services, quantifiable ecological benefits and so on) and determine the drivers for its magnitude. Development of such methodology can be implemented in phases: from a more general high level "scoring" analysis based on a limited data immediately available for the analytics up to an in-depth comprehensive analytics and modelling using a bottom-up approach and detailed data from various regions for building correct estimations of effects.

Such methodology can also be applied to actual MFB capital repairs and EE retrofit data for verification and quantification of the status quo. Additionally, such methodology can be used to estimate the impact of performing Program-designed packages of EE measures in order to illustrate increased economic effect in absolute terms and relative to the required financing.

[12] EU 2016 Macroeconomic and other benefits of Energy Efficiency
[13] ACEEE 2015 Recognizing the Value of Energy Efficiency's Multiple Benefits
[14] The World Bank 2019 Energy Efficient Housing Finance (GreenHF Global Report)

This research will further inform the general principles of design of the financial products and design of a public investment program in residential energy efficiency, as particularly for the latter it is critical to understand the social, fiscal, and economic effects of public expenditure. Proposed investments will be complementary to the existing system of utilizing private resources for urban retrofits and would result in a substantial positive climate impact (reduction of GHG emissions). Based on the consultations with the relevant federal ministries, primarily Ministry of Finance as the ultimate subsidy provider and the Ministry of Economic Development as the champion of the EE measures in the residential sector, further steps in analytical work can be made for detailed modeling and structuring the proposed public investment program in residential energy efficiency.

1. Summary of approaches for estimation of socio-economic impacts of apartment building energy-efficiency renovations

Experts have only recently begun to undertake socio-economic impact assessments of energy efficiency programs in Russia, whether broadly implemented or targeted towards housing in particular. However, this field of research is fast developing, and practitioners can draw on a wealth of relevant insights from existing international experience. Indeed, a wide range of methodological approaches to impact assessment can be found in current literature, with each considering various aspects of this challenge.

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In structuring this field of research, the following groups of publications can be distinguished:

1. Works concerning the assessment of direct and ‘inverse’ effects of improvements to housing energy efficiency.

This body of research includes considerations of the direct effects of apartment building EER projects for participants (homeowners, construction firms, companies generating and supplying power). The emphasis here is often on assessing the costs and benefits to participants; accordingly, standard cost/benefit analyses are employed, including calculations of the net present value of EER project spending. Considerable attention is paid to the impact of EER program cost structures and the employed discount rate on the investment attractiveness of these projects (Morrissey et al., 2013; Liu et al., 2018; Andersen et al., 2020).

These works also assess the direct effects of changes in energy demand, including changes in energy sector GHG emissions resulting from EER projects. These assessments employ a bottom-up approach, relying on a combination of microeconomic data on the scope of an EER project and a modelling of the prevailing energy generation structure and differences in emission rates therein (Bashmakov et al., 2011, Gillingham et al., 2018; Hirvonen et al., 2021).

2. Works concerning a full assessment of the socio-economic impact of improving energy efficiency in housing

The focus of this research is the full range of EER projects' socio-economic impacts, including considerations of intersectoral interactions and the impact of the reallocation to additional consumption of goods and services of household savings on utility bills.

Among these works, two principal approaches to impact assessment can be discerned. The first revolves around the use of macro-econometric or computable general equilibrium (CGE) models to build business-as-usual and energy-efficiency scenarios. Estimates of the total impact are calculated from differences between these two scenarios. CGE models are used to calculate the impact on such macroeconomic indicators as gross output, GDP, and employment (Cambridge Econometrics, 2012; Cambridge Econometrics, 2015; Alexandri et al., 2016), as well as on GHG emissions (Bye et al., 2015).

An important element of many of these studies is the consideration of the 'rebound effect'—that is, the difference between the expected energy savings based solely on an EER project's technical parameters, and the actual energy savings that occur after the initial decrease in demand (and therefore prices) leads to a subsequent uptick in energy consumption. CGE models are also used to calculate the rebound effect (Figus et al., 2017; Brockway et al., 2021). Incorporating changes in energy prices allows for a more flexible analysis of EER projects costs and benefits to homeowners.

The second approach to impact assessment involves the employment of models based on Input-Output Tables. These 'IO models' allow for the estimation of EER project impacts on a wide range of macroeconomic indicators, as well as on GHG emissions. Perhaps owing to its convenience and flexibility, this approach is the most common. Calculations may either be simplified by adopting a static model and excluding the impact of potential price changes and technological shifts (Liu et al., 2009; Garrett-Peltier, 2011; SEEA, 2013: Anderson et al., 2014; Oliveira Henriques et al., 2015; Mikulis et al., 2016; Brown et al., 2020) or made more complex by using either dynamic IO models (Thomas et al., 2013; Hartwig et al., 2017; Uehara et al. 2018) or a combination of IO models and optimization models (Taliotis et al., 2020).

Each of the presented approaches has its advantages and disadvantages. When assessing direct effects, the bottom-up approach (moving from particular to general) is extremely time-consuming and requires representativeness of the collected data. Meanwhile, the top-down approach (models based on generalized estimates and macroeconomic modeling) does not easily allow for a consideration of the peculiarities of an EER project (including regional climatic, price or other specific conditions, or technologies/materials employed). The bottom-up approach is preferable when attempting to capture Russia's pronounced interregional differences: it is more accurate, albeit more demanding from a data standpoint.

In assessing the full impacts of EER projects, CGE models allow for the incorporation of price changes and therefore a consideration of the aforementioned rebound effect. However, this approach is less flexible and transparent than the use of models derived from Input-Output tables. While IO modeling does also allow for the incorporation of price shifts in complex dynamic models, these imply the construction of a basic macroeconomic scenario—the creation of which demands a high volume of input data. Moreover, calculation of the rebound effects in Russia is generally not a useful exercise, as energy tariffs and district heating regimes are regulated, not market based.

Accordingly, this research employs simplified IO models (based on static Leontief models with separate dynamization elements), which are more practical to address questions surrounding socio-economic impacts of EER projects in Russia. These models may also be used as the basis for further, more complex calculations based on broader local data as may be requested by the Russian policymakers.

2. Methodology used to estimate impacts of apartment building energy-efficiency renovations

This section presents the main features of the methodological approach employed in this work. Detailed descriptions of the methodology to assess socio-economic impacts of EER works in apartment buildings and associated calculation tools can be found in Appendices 1 and 2.

Figure 2.1 below illustrates the full system of interactions of effects arising from apartment EER projects. It is divided into three phases:

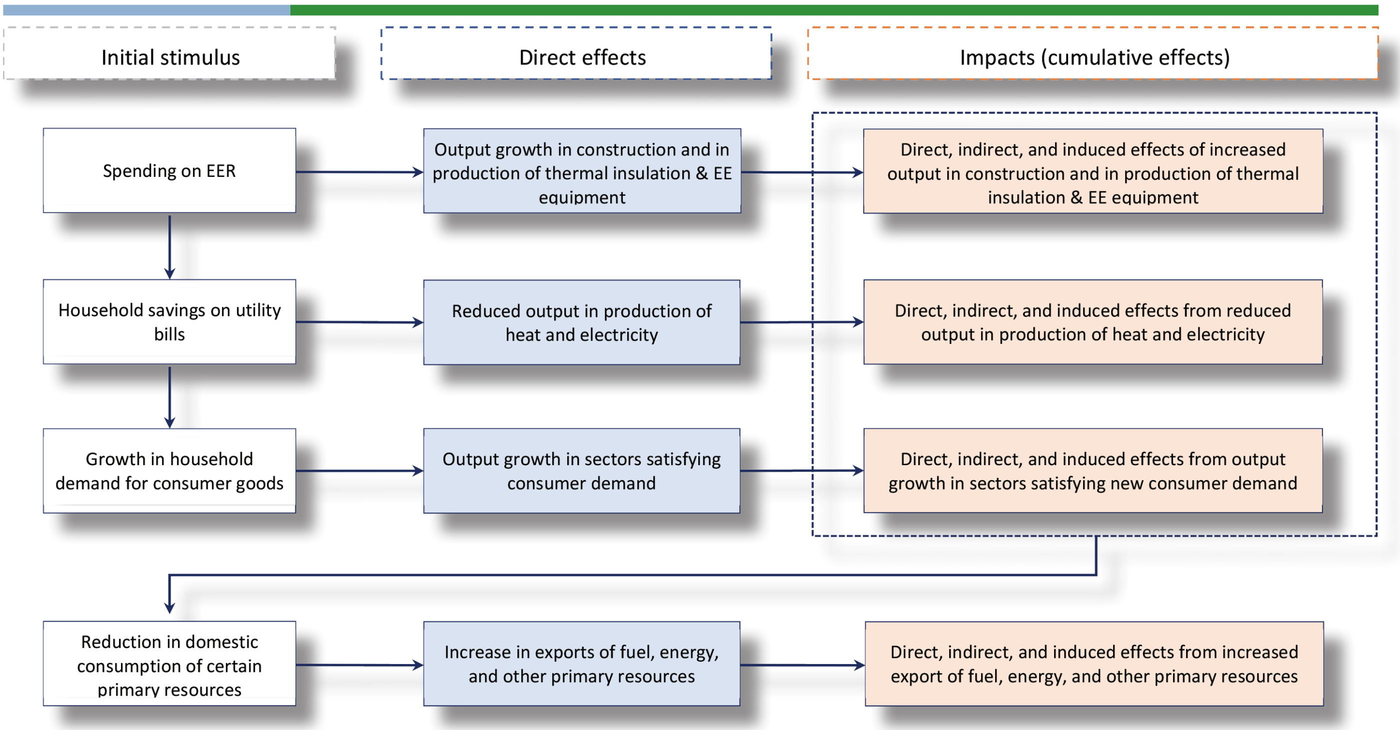
1. Initial stimulus, of which there are four types: a) EER capital expenditures; b) household savings on utility bills; c) growth in household demand for consumer goods; and d) reduction in domestic consumption of certain primary resources.

2. Direct effects, which are formed from the reaction of the economy to changes in final or intermediate demand caused by the influence of each of the specified initial impulses, namely:

- an increase in the output of construction firms, as well as the output of companies supplying the equipment, materials, and services consumed in EER works;
- a reduction of energy sector production and distribution of electricity, heat energy, gas and water;
- an increase in the output of the consumer goods and services sector; and
- an increase in the volume of primary resources exports.

3. Indirect and Induced Effects, reflecting the further spread of initial stimuli throughout the system of intersectoral links (that is, increases in intermediate demand and output in sectors that supply the resources of current material consumption), as well as the distribution of the various modes of income (wages, taxes, corporate profits) associated with these activities and their subsequent spending.

Figure 2.1: Macroeconomic impacts of EER of apartment buildings



Calculations to assess the macroeconomic impact of apartment building EER projects involve the following steps:

1. Estimation of sectoral output multipliers for gross output (aggregate increase in gross output per unit of increased output in a given sector)

The direct, indirect, and induced effects of increased sectoral output are determined in this step. Here the direct effect is by definition equal to a value of one, while indirect effects are estimated using a static Leontief model and a symmetric Input-Output table. Induced effects are calculated in the following stepwise manner: a) estimation of the induced increase in wages, taxes, and corporate profits due to direct and indirect effects; b) estimation of the induced increase in final demand using the average income elasticities of consumption of households, government, and businesses; c) determination of the induced increase in final demand for domestic products; and, finally, d) determination of the induced effect on gross output using a static Leontief model and the obtained estimates of the increase in final demand for domestic products (see Appendix 2 for further detail.)

2. Estimation of per-unit direct effects on output in construction and in sectors supplying goods and services consumed by EER projects (rubles per ruble of EER spending)

Based on design estimates, a generalized capital-cost structure for a specific EER project is estimated using individual component expenditures and the types of work to be performed. Per-unit costs are then calculated (i.e., cost per apartment building square meter), which are in turn used to construct a weighted average of capital costs across a sampling of EER projects.

3. Estimation of per-unit impact (indirect, induced, and cumulative effects) of EER capital expenditures on output in various sectors (rubles per ruble of EER spending)

Each element of expenditure is assigned a corresponding multiplier. Multipliers for material costs are derived from sectoral output multipliers corresponding to the production of those materials. Those for wages, taxes, overhead costs, depreciation, and corporate profits, are calculated using a composite, defined as the combination of sectoral output multipliers weighted according to the expected spending of these revenues. For example, for wages, the multiplier is estimated by taking the sum of sectoral output multipliers weighted by the structure of household consumption (excluding imports in consumer spending), multiplied by the income elasticity of household consumption.

Calculation of per-unit indirect and induced effects of EER capital expenditures on total output is performed by weighing the selected output multipliers by the structure of capital expenditures, excluding imports therein. The cumulative effect is calculated by summing these estimates with the direct effect (defined as a one-unit increment of construction output).

4. Estimation of per-unit direct effects of increased apartment building energy efficiency on energy sector output (rubles per ruble of EER spending)

The direct effect of EER works on energy sector output are calculated as annual savings in utility bills in the reporting year in comparison to prior years. This is achieved by first taking the expected annual savings of individual apartment buildings (calculated using the 'EER Assistant' program) and then dividing total savings on utility bills across the entire sample of apartment buildings by total EER program capital expenditures to arrive at an estimate of rubles saved per ruble of EER capital expenditures.[15]

5. Estimation of per-unit indirect and induced effects of decrease in energy sector output on output in various sectors (rubles per ruble EER spending)

This is calculated by multiplying the direct effect on energy sector output obtained in the previous step by the sector's multiplier, which captures indirect and induced effects.

6. Estimation of per-unit direct effects of household savings on utility bills on output in sectors producing consumer goods (rubles per ruble of EER spending)

Household savings on utility bills are redistributed to other areas of consumer spending. It is assumed that this spending aligns with the structure of household consumption presented in the Input-Output table, adjusted to exclude spending on energy.

7. Estimation of per-unit indirect and induced effects of increased household consumer demand on output in various sectors (rubles per ruble of EER spending)

These effects are calculated by first summing the output multipliers of impacted sectors (weighted by the structure of induced consumer demand, excluding imports), and then multiplying the result by the income elasticity of household consumption.

8. Estimation of per-unit reduction in domestic consumption of certain primary resources due to first three areas of initial stimulus (rubles per ruble of EER spending)

The total effects of EER capital expenditures, reduced energy sector output, and increased household consumer demand are added together to calculate the cumulative effect on output.

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[15] The 'EER Assistant' program was developed by specialists of the Fund to Promote Reform of Housing and Communal Services. It allows users to calculate the expected reduction in energy consumption due to EER works in an apartment building with a given level of thermal performance. The program can be accessed here: https://fondgkh.ru/napravleniya- deyatelnosti/energoeffektivnyy-kapremont/pomoshchnik-ekr00/pomoshchnik-ekr/

9. Estimation of per-unit increase in export of certain primary resources due to decreased resource intensity of national economy (rubles per ruble of EER spending)

Here an iterative calculation related to the intermediate consumption of primary resources in the production of exported products is carried out to accurately assess the export potential of primary resources (see Appendix 1).

10. Estimation of per-unit impact (direct, indirect, and induced effects) of increased export of primary resources on output in various sectors (rubles per ruble of EER spending)

Estimated values of the increased export volumes of primary resources are multiplied by the corresponding output multipliers of sectors from which they are derived; the results are then added together.

11. Estimation of per-unit impact (direct, indirect and induced effects) of all four areas of initial stimulus on output in various sectors (rubles per ruble of EER spending)

Estimates for direct, indirect, and induced effects on output in these areas are added together to calculate their total impact.

12. Estimation of per-unit impact (direct, indirect and induced effects) of initial stimuli on value added, taxes, and employment in various sectors (rubles per ruble of EER spending)

An estimate of the total impacts of the four areas of initial stimulus on value added is obtained using the ratios of value added to output by sector derived from an Input-Output table. Similar approaches are used to calculate per-unit effects on taxes and employment. For employment, estimates for labor intensity of various sectors are additionally required for these calculations.

13. Estimation of GHG emissions in various sectors (grams CO2 equivalent [g CO2e] per ruble of output)

Per-unit volumes of direct emissions per ruble of output in various sectors can be derived using data from Russia's National Inventory of Greenhouse Gas Emissions and estimates of sectoral consumption of intermediate products derived from Input-Output tables.

14. Estimation of per-unit impact (direct, indirect, and induced effects) of initial stimuli on GHG emissions in various sectors (g CO2e per ruble of EER spending)

The direct effects of EER works on GHG emissions can be calculated using a sampling of actual projects. A level of emissions reduction for a selected project can be estimated using the EER Assistant program; this value is then expressed on a per-unit basis divided it by the project's capital expenditures. Project-level estimates are then assigned weights based on sample capital-cost structures, from which an estimate of the average per-unit direct effect is obtained.

Indirect and induced effects are calculated using the previously obtained estimates of total per-unit effects of EER works on output by sector and the corresponding values for GHG emissions per unit of output in these sectors.

15. Estimation of absolute impact (direct, indirect and induced effects) of EER spending on gross output, GDP, taxes, employment, and GHG emissions

Finally, the absolute effects of EER projects on various socio-economic indicators are calculated by multiplying obtained estimates of per-unit effects by specified amounts of funding for EER works.

3. Scenario calculations to estimate per-unit impact of apartment building renovations

In conducting the following scenario analyses, values for sectoral output multipliers were first obtained using Russia's official symmetric Input-Output table for 2016 (see Table 3.1).

These calculations then served the basis for the estimation of per-unit macroeconomic impacts of apartment building renovation projects on gross output, value added, tax revenues, GHG emissions, and employment, both in aggregate at the national level and across 98 individual sectors. Three scenarios of apartment building renovation programs were analyzed:

- **Scenario 1:** Standard apartment building renovation projects (i.e., without any energy-efficiency measures), comprised of the following works: repair of building facades; repair/replacement of elevators and repair of elevator shafts; foundation repair; repair of intra-building electrical, heat, gas, and water supply/wastewater disposal systems; roof repair; and repair of basements related to common property.
- **Scenario 2:** Standard apartment building EER projects, comprised of the following works: installation of an automated heating control system; installation of an automated local heat distribution station; increase of insulation in outer walls; repair of piping for interior heating and hot water supply systems; increase of attic insulation; increase of roof insulation; etc.
- **Scenario 3:** Minimal apartment building EER projects, within which just two types of work are performed: installation of an automated heating control system and installation of an automated local heat distribution station.

The analyzed scenarios reflect actual situation with the housing retrofits in Russia and are based on real data: usually capital repairs are implemented without targeted EE works/effect. In more rare cases when households can pretend for state EE subsidy, the capital repair works include targeted EE works and measures aiming to achieve energy savings. The scenario analysis was built on the data collected / developed by the WB research team from the same regions and in regard to compatible types of buildings. Using these homogenic data the authors were trying to understand what effects can be achieved if both types of capital repairs (standard – non-EE and targeted EE capital repairs) are implemented. As shown below, a simple and straightforward model used for this analysis proved that results of such combination will be positive economically wise and climate wise, despite of certain decrease in economic productivity due to smaller energy consumption.

When running modelling and comparative analysis of implementation of MFB retrofits under various scenarios, a hypothetic assumption was applied of what would happen if homeowners would receive public funding amounting up to 20% of current homeowners' expenditures for the MFB retrofits with a specific purpose to finance energy efficiency improvements on top of regular capital repairs needed for the respective MFBs according to scheduled renovation plans depending on the dilapidation level. That is how the amount of hypothetical 40 bln. RUB supplementary public funding appeared.

Table 3.1: Sectoral production multiplier estimates

Per-unit direct, indirect, and induced effects; rubles per ruble of output growth in selected sector

	Per-unit cumulative effects			
	on gross output	on GDP	on taxes	on emissions (g CO_2e)
Agricultural products	2.39	1.27	0.11	11.5
Plant-growing and animal husbandry services (excluding veterinary services, ornamental horticulture services)	2.34	1.31	0.12	13.5
Services related to hunting, catching, and breeding of wild animals	4.06	1.92	0.24	27.0
Forestry, logging, and related services	2.56	1.31	0.18	18.0
Fish and other products of fishing and fish farming; related services	2.41	1.21	0.21	18.2
Bituminous coal and brown coal (lignite); peat	2.69	1.30	0.19	75.8
Petroleum, including petroleum derived from bituminous minerals; oil shale (bituminous) and bituminous sandstone	2.13	1.43	0.39	17.1
Natural gas in a gaseous or liquefied state, including services for the liquefaction and regasification of natural gas for transportation	2.07	1.43	0.37	47.2
Services related to the extraction of oil and combustible natural gas (excluding geological exploration)	2.52	1.39	0.39	46.5
Uranium and thorium ores	2.23	1.28	0.09	19.1
Iron ores	2.40	1.33	0.21	21.6
Non-ferrous metal ores, excluding uranium and thorium ores	2.40	1.39	0.34	20.5
Other mining products	2.22	1.33	0.22	15.4
Meat, meat products and other processed animal products	2.98	1.24	0.12	11.0
Fish and fish products, processed and canned	2.28	1.22	0.14	10.2
Processed and canned fruits, vegetables, and potatoes	2.61	1.16	0.15	10.1
Animal and vegetable oils and fats	2.91	1.16	0.15	11.6
Dairy products and ice cream	2.96	1.23	0.14	12.0
Flour and cereal production, starches, and starch products	2.85	1.25	0.15	12.9
Animal feed	2.67	1.08	0.14	10.2
Other food products	2.72	1.16	0.15	11.7
Beverages	2.34	1.31	0.46	9.2
Tobacco products	1.92	1.37	0.76	5.0
Textiles	2.37	1.02	0.17	13.1
Clothing and accessories	2.38	1.13	0.17	9.6
Leather and leather goods	2.46	1.16	0.16	9.7
Services in forging, pressing, stamping, and profiling of sheet metal, production of products by powder metallurgy; metal processing and coating; processing of metal products using the main technological processes of mechanical engineering	2.78	1.25	0.20	17.7

	Per-unit cumulative effects			
	on gross output	on GDP	on taxes	on emissions (g CO_2e)
Tools, cutlery, and general-purpose hardware; other finished metal products	2.78	1.23	0.20	17.4
Mechanical equipment, machine tools and other general or special purpose equipment	2.63	1.20	0.18	20.3
Household appliances not elsewhere classified	2.23	0.91	0.16	9.0
Office equipment and parts	2.43	1.10	0.21	7.6
Computers and other information processing equipment	2.28	1.12	0.20	7.1
Electrical machines and electrical equipment	2.62	1.19	0.22	15.9
Electronic components; equipment for radio, television and communication	2.34	1.18	0.20	9.0
Medical devices, including surgical equipment, orthopedic appliances	2.32	1.21	0.20	9.3
Devices and instruments for measurement, control, testing, navigation, control, regulation; optical devices, photographic and cinematographic equipment; watch	2.44	1.25	0.21	9.9
Motor vehicles, trailers, and semi-trailers	2.46	0.90	0.16	10.1
Ships, aircraft and spacecraft, other vehicles, and equipment	2.75	1.23	0.16	13.7
Furniture	2.60	1.17	0.15	12.4
Jewelry and similar items	2.87	1.24	0.18	14.7
Miscellaneous industrial products, not elsewhere classified	2.64	1.16	0.16	16.2
Secondary raw materials	3.06	1.25	0.18	18.3
Electricity generation, transmission, and distribution services	2.89	1.39	0.25	128.3
Artificial combustible gases and services for the distribution of gaseous fuels through pipelines	3.03	1.41	0.28	61.6
Steam and hot water (thermal energy), including transmission and distribution services	3.09	1.39	0.22	163.5
Collected and purified water, water distribution services	2.57	1.40	0.27	51.3
Construction works	2.50	1.28	0.18	15.0
Trade, maintenance and repair services of motor vehicles and motorcycles	2.28	1.26	0.21	8.6
Wholesale trade services, including trade through agents, excluding trade in motor vehicles and motorcycles	2.30	1.37	0.18	10.1
Retail trade services (excluding trade of motor vehicles and motorcycles); repair services for household goods and personal items; motor fuel retail services	2.35	1.38	0.17	11.0
Services of hotels, campgrounds, and other places for temporary residence	2.51	1.36	0.22	15.1
Catering services	2.48	1.30	0.16	9.4
Railway transport services	2.38	1.36	0.18	16.5
Other land transport services	2.45	1.34	0.17	41.4
Pipeline transportation services	2.49	1.34	0.16	37.8
Water transport services	2.43	1.29	0.22	13.4

	Per-unit cumulative effects			
	on gross output	on GDP	on taxes	on emissions (g CO_2e)
Air and space transport services	2.57	1.09	0.12	17.0
Transport auxiliary and additional services; travel agency services	2.59	1.32	0.18	12.4
Postal and telecommunication services	2.28	1.30	0.22	8.7
Financial intermediation services	2.01	1.38	0.25	5.5
Insurance and non-state pension services, except for compulsory social insurance services	2.29	1.27	0.20	6.2
Financial intermediation support services	2.16	1.42	0.32	6.1
Real estate services	2.13	1.42	0.16	9.9
Services for the rental of machinery and equipment (without an operator), household goods and personal items	1.82	1.28	0.13	6.0
Computer and information technology software products and services	2.28	1.36	0.18	6.9
Research and experimental development services	2.36	1.29	0.18	9.3
Other services related to business	2.30	1.40	0.18	8.7
Services in the field of public administration, military security, and social security	2.38	1.44	0.15	11.1
Educational services	2.18	1.50	0.21	11.4
Health and social services	2.26	1.37	0.15	11.7
Wastewater and waste disposal, sanitation, and similar services	2.56	1.36	0.17	23.7
Services of public organizations, not included in other groups	2.69	1.44	0.19	11.1
Services for the organization of recreation, entertainment, culture, and sports	2.34	1.38	0.19	10.1
Other personal services	2.19	1.34	0.14	11.4
Household services with employment	2.31	1.74	0.15	8.9

3.1. Scenario 1 assumptions & calculation results

Data reported by regional repair operators for actual projects carried out from 2018 to 2020 was used to estimate the shares of spending on various works in Scenario 1 (non-energy-efficiency) renovations. They are as follows:

- Repair of building interior engineering systems for electricity, heat, gas and water supply, wastewater disposal (24%);
- Repair or replacement of elevators, repair of elevator shafts (19%);
- Roof repair (27%);
- Repair of basements related to common property in apartment blocks (1%);
- Repair of facades (20%);
- Repair of foundations (1%); and
- Other (8%).

Additionally, design estimates from actual projects carried out in 16 apartment buildings were used to estimate cost structures for the above works. These projects were sampled from three Russian regions: Vologda region (10 buildings); Nizhny Novgorod region (5 buildings); and Kaliningrad region (1 building).

An analysis of the design estimates produced the following estimated cost structure for a Scenario 1 renovation project:

- General construction materials (8%);
- Insulation and waterproofing materials (10%);
- Metal structures and other products (14%);
- Pipes and pipeline fittings (6%);
- Lift equipment (12%);
- Other materials, equipment and services (5%);
- Overheads and depreciation (14%);
- Payroll (including personal income taxes and social insurance premiums) (12%);
- Estimated profit (6%); and
- Taxes (excluding personal and corporate income taxes) (13%).

Within this analysis, two further sub-scenarios have been considered with regards to the level of capital-cost localization. Table 3.2 presents low (85%) and full (100%) localization scenarios.

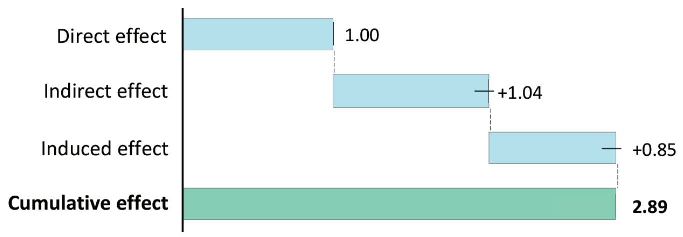
Table 3.2: Shares of imports in Scenario 1 capital cost structure

	Low localization scenario	Full localization scenario
Total share of imports in capital costs (For a given structure of capital costs)	**15%**	**0%**
General construction materials	5%	0%
Assembly and universal glue, paint, mounting foam	30%	0%
Sealant	5%	0%
Metal structures and other products	10%	0%
Mineral wool and polystyrene foam boards	0%	0%
Other thermal insulation materials	25%	0%
Waterproofing materials	0%	0%
Window blocks made of PVC profiles	5%	0%
Other plastic products	25%	0%
Pipeline fittings (except for control valves)	50%	0%
Control equipment (automated control systems, controllers, pumps, control valves)	90%	0%
Sensors, instruments for measurement and accounting	50%	0%
Electrical equipment	40%	0%
LED lamps	95%	0%
Elevator equipment	50%	0%
Machines and mechanisms (depreciation of assembly equipment)	50%	0%
Machines and mechanisms (depreciation of construction equipment)	60%	0%

Using the above assumptions (including 85% cost localization), an estimate of the per-unit impact of spending on a Scenario 1-type renovation on gross output was calculated; its components are presented below in Figure 3.1

Figure 3.1: Per-unit impact of Scenario 1 renovation on gross output

Rubles per ruble of renovation capital expenditures



Here it should be noted that there are significant indirect and induced effects, each of which is comparable to the direct effect of increased output of construction firms carrying out the renovation works: one ruble of renovation-related capital expenditure generates RUB 2.89 of gross output in the Russian economy.

Figure 3.2 contributes the most to the overall impact (due to direct effects), significant output increases are also observed in several other sectors: machinery and equipment manufacturing (primarily due to spending on elevator equipment); wholesale and retail trade and repairs; metallurgy; real estate, science, IT, and other services; public administration, security, education, and healthcare (due to the induced effect from the spending of incremental budget revenues); transportation and storage; and manufacturing of other non-metallic mineral products.

Figure 3.2: Per-unit impact of Scenario 1 renovation on output by sector

Rubles per ruble of renovation capital expenditures

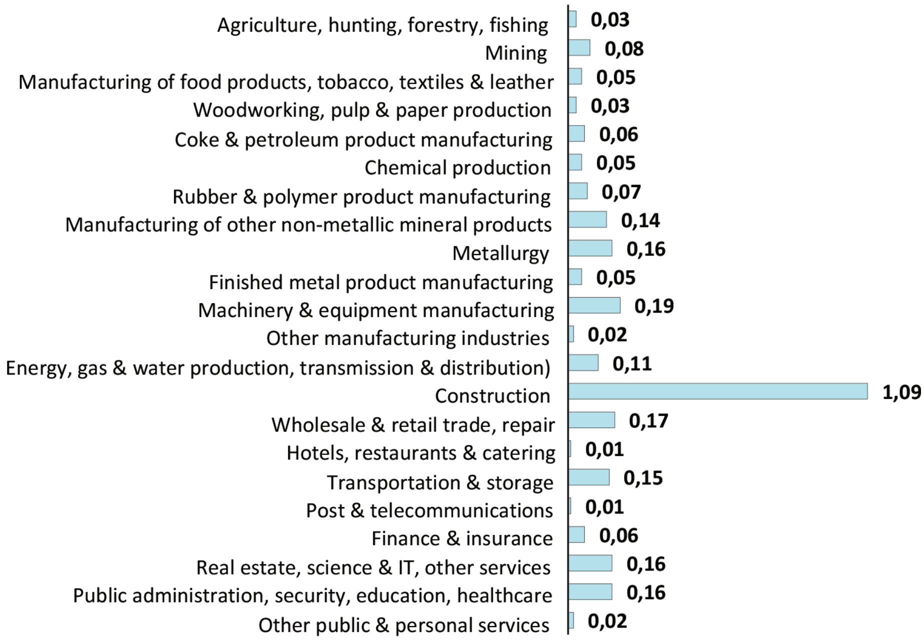


Figure 3.3 below presents estimates of the per-unit impact of a Scenario 1 renovation on GDP. Again, indirect and induced effects have a significant impact: one ruble of renovation-related capital expenditure generates RUB 1.35 in GDP growth.

Figure 3.3: Per-unit impact of Scenario 1 renovation on gross output

Rubles per ruble of renovation capital expenditures

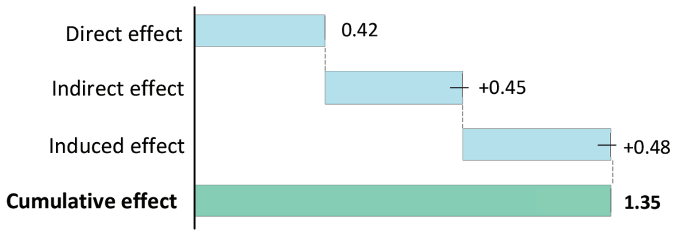
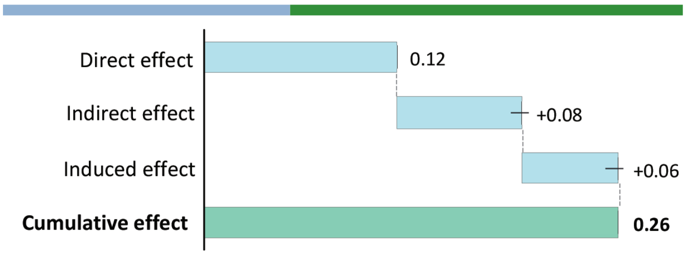


Figure 3.4 presents estimates of the per-unit impact of a Scenario 1 renovation on budget revenues. In this scenario, one ruble of renovation-related capital expenditure generates an additional RUB 0.26 of tax revenues.

Figure 3.4: Per-unit impact of Scenario 1 renovation on budget revenues

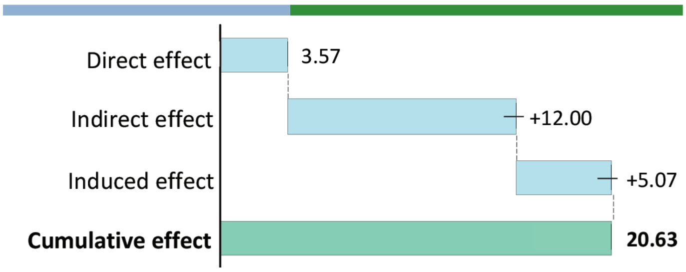
Rubles per ruble of renovation capital expenditures



In carrying out calculations in the context of Scenario 1, it is generally assumed that renovation works do not significantly change the thermal performance of apartment buildings or lead to a reduction in their energy consumption. The impact on emissions in this scenario is therefore due solely to the direct, indirect, and induced effects of renovation works. Figure 3.5 presents an estimate of the per-unit impact of a Scenario 1 renovation on GHG emissions. In this scenario, one ruble of renovation-related capital expenditure is associated with a rise of 20.63g CO_2e in emissions.

Figure 3.5: Per-unit impact of Scenario 1 renovation on GHG emissions

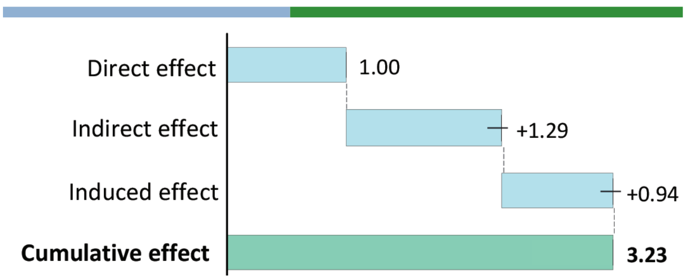
g CO_2e per ruble of renovation capital expenditures



Increasing the level of cost localization from 85% to 100% in Scenario 1 calculations increases the per-unit impact of renovation spending on each of the above socio-economic indicators. The multiplier for gross output increases from RUB 2.89 to RUB 3.23 (see Figure 3.6); for GDP, from RUB 1.35 to RUB 1.53; for budget revenues, from RUB 0.26 to RUB 0.29; for GHG emissions, from +20.6g CO_2e to +23.3g CO_2e.

Figure 3.6: Per-unit impact of Scenario 1 renovation on gross output

Rubles per ruble of renovation capital expenditures with 100% cost localization



3.2. Scenario 2 assumptions & calculation results

To assess the impact of spending on standard EER works, estimates from 30 implemented projects were used. Projects were sampled from six Russian regions: Kaliningrad region (9 buildings); Lipetsk region (7 buildings); Nizhny Novgorod region (6 buildings); Vologda region (6 buildings); Moscow region (1 building); and Tyumen region (1 building).[16]

Analysis of these actual EER projects allowed for the construction of an estimated spending breakdown for a typical project by type of work performed:

- Increased heat insulation in outer walls (62%);
- Increased heat insulation of roof (10%);
- Installation of automated control unit for the heating system (9%);
- Installation of automated local heat distribution station (8%);
- Patching and sealing of inter-panel joints (2%);
- Repair of piping for interior heating and hot water supply systems (2%);
- Increased attic insulation (2%); and
- Other (5%)

The average cost structure for an EER project is estimated as follows:

- General construction materials (17%);
- Insulation and waterproofing materials (12%);
- Metal products (11%);
- Pipes and pipeline fittings (5%);
- Regulating equipment (7%);
- Other materials, equipment, and services (2%);
- Overheads and depreciation (14%);
- Payroll (17%);
- Estimated profit (8%); and
- Taxes (excluding personal and corporate income taxes) (7%).

Despite differences in cost structures (both in terms of areas of work and materials employed), the overall shares of imports in Scenario 2 cost-localization sub-scenarios are identical to those in Scenario 1 (Table 3. 3).

[16] These are typical cases of EER projects carried out using funds accumulated in building savings accounts, which are funded by owners' contributions. Upon completion of these works, calculations were performed when preparing applications for government financial support.

Table 3.3: Shares of imports in Scenario 2 capital cost structure

	Low localization scenario	Full localization scenario
Total share of imports in capital expenditures (For a given structure of capital expenditures)	**15%**	**0%**
General construction materials	5%	0%
Assembly and universal glue, paint, mounting foam	30%	0%
Sealant	5%	0%
Metal structures and other products	10%	0%
Mineral wool and polystyrene foam boards	0%	0%
Other thermal insulation materials	25%	0%
Waterproofing materials	0%	0%
Window blocks made of PVC profiles	5%	0%
Other plastic products	25%	0%
Pipeline fittings (except for control valves)	50%	0%
Control equipment (automated control systems, controllers, pumps, control valves)	90%	0%
Sensors, instruments for measurement and accounting	50%	0%
Electrical equipment	40%	0%
LED lamps	95%	0%
Machines and mechanisms (depreciation of assembly equipment)	50%	0%
Machines and mechanisms (depreciation of construction equipment)	60%	0%

Figure 3.7 shows the results of calculations to estimate the per-unit impact of standard EER projects on gross output, assuming 85% cost localization. Here it should be noted that the effects of EER works are distributed over time in a complex way: while the impact of capital expenditures is observed in the year(s) in which work is carried out, the impacts of increased household consumption (due to savings on utility bills) and increased exports of certain primary resources (due to a decline in the energy intensity of the economy) are felt over time, after completion of the renovation works. The impacts of EER works in Scenarios 2 and 3 on socio-economic indicators are therefore measured cumulatively over a ten-year period.[17]

The figure 3.7 depicts the cumulative effects of four groups of impulses (here, in terms of impact on gross output) identified in Figure 2.1. Three yield positive values; one, a negative value. This is because an increase in the efficiency of energy consumption leads directly to a decrease in energy demand. At the same time, this decrease in energy demand is offset by the redistribution of consumer demand to other sectors of the economy. Additionally, surplus primary resources (previously consumed in energy production) can be redirected to export markets (assuming both static production volumes and sufficient export-market demand); this creates further economic impact.

As shown, the largest per-unit impact on gross output from Scenario 2 (standard EER) renovations is the RUB 2.92 increase (per ruble of spending) derived from the impact of project capital expenditures. However, the consequent reduction in energy sector demand leads to a RUB -2.59 *decrease* in gross output per ruble of spending (cumulative over 10 years). This decrease is partially offset by increases in household demand (RUB +1.80) and exports of primary resources (RUB +0.22). The net impact of these factors is an increase of RUB 2.34 in gross output. This is lower than the impact of Scenario 1 on gross output (RUB +2.89). Figure 3.8 below show a breakdown of these impacts on output by individual sector.

[17] In Scenario 1, the immediate impact of renovation works is roughly identical to the 10-year cumulative impact.

Figure 3.7: Per-unit impact of Scenario 2 renovation on gross output

Rubles per ruble of EER capital expenditures, cumulative over 10 years

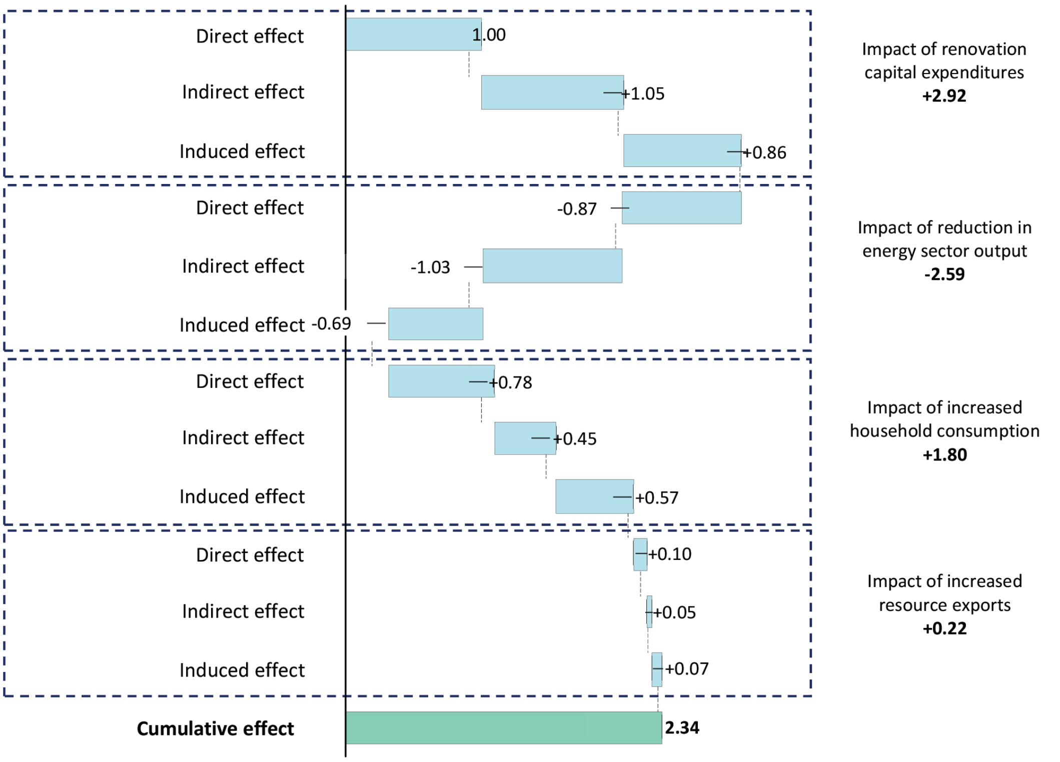


Figure 3.8: Per-unit impact of Scenario 2 renovation on output by sector

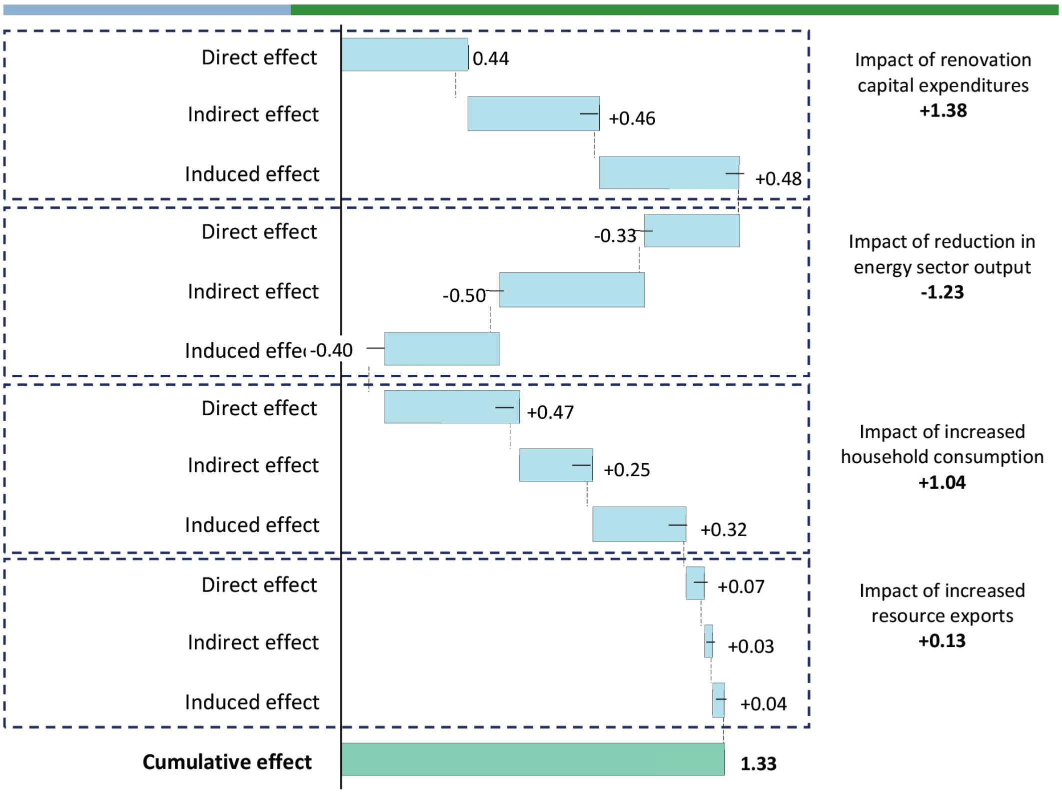
Rubles per ruble of EER capital expenditures, cumulative over 10 years

The strongest impacts on output of Scenario 2 EER spending occur in the construction and energy sectors (RUB +1.13 and RUB -1.22, respectively). The following sectors are also significantly impacted: wholesale and retail trade and repair; real estate, science & IT, and other services; manufacturing of non-metallic mineral products (related to construction and production of thermal insulation materials); transportation and storage; food and manufacturing of food products, tobacco, textiles & leather (light industry).

The impact of standard EER works on GDP is similar to gross output (Figure 3.9). Capital expenditures create a positive impact (RUB +1.38 rubles per ruble of spending); a reduction in energy consumption has a negative effect (RUB -1.23). Increases in household demand and exports of primary resources are also positive (RUB +1.04 and RUB +0.13, respectively) leading to a total positive impact of RUB 1.33. Despite the difference in impact on gross output, the impact on GDP observed in Scenario 2 is close to that of Scenario 1 (RUB +1.35 rubles).

Figure 3.9: Per-unit impact of Scenario 2 renovation on GDP

Rubles per ruble of EER capital expenditures, cumulative over 10 years



Estimates of Scenario 2's per-unit impact on budget revenues is presented in Figure 3.10. The impacts of EER capital expenditures, increased household consumer demand, and increased primary resources exports are positive (RUB +0.25, RUB +0.14, and RUB +0.03 per ruble of spending, respectively) while and reduced energy consumption yields a negative effect (RUB -0.19). The cumulative effect of an RUB 0.22 increase is slightly lower than that of Scenario (RUB +0.26).

Figure 3.10: Per-unit impact of Scenario 2 renovation on budget revenues

Rubles per ruble of EER capital expenditures, cumulative over 10 years

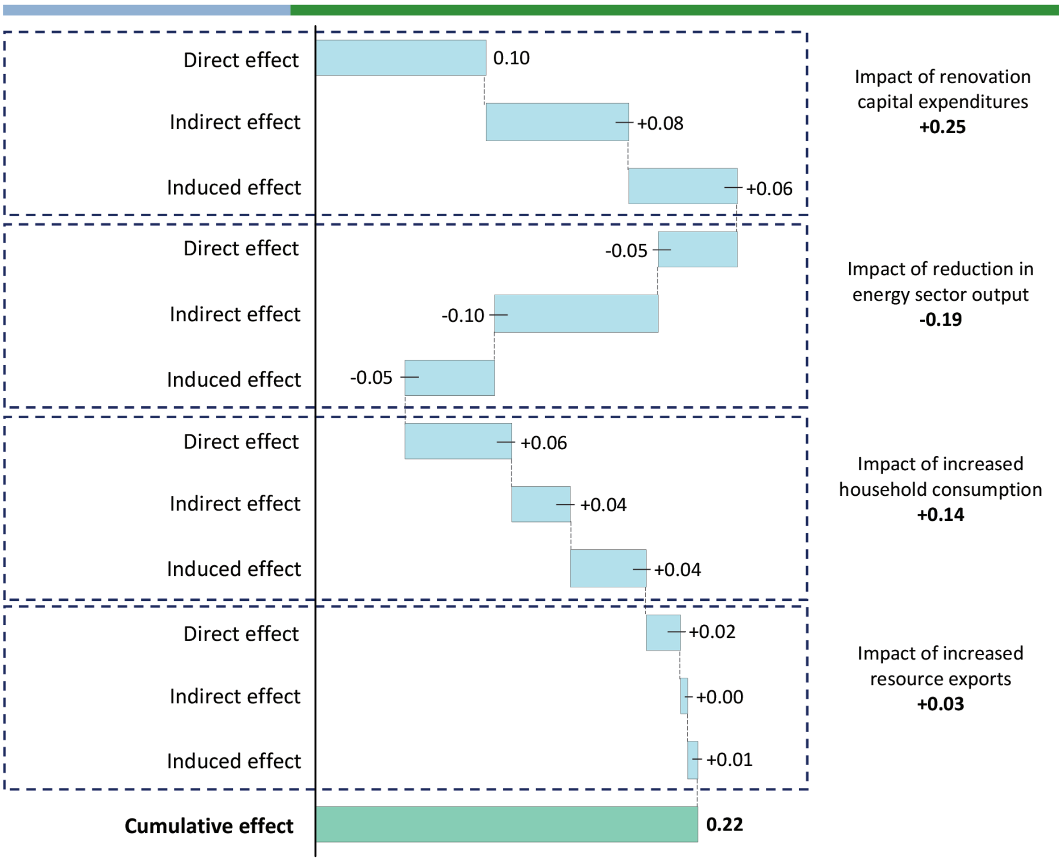


Figure 3.11 presents an estimate of the per-unit impact of Scenario 2 EER works on GHG emissions. According to calculations, improving apartment building energy efficiency leads to a significant reduction in GHG emissions (-203.4g CO_2e per ruble of capital expenditures, cumulative over 10 years). The largest increase in emissions comes from the cumulative effects of project capital expenditures (+21.2g CO_2e per), with the largest sectoral contributors being construction (+4.0g CO_2e); transport and storage (2.7g CO_2e); and production of non-metallic mineral products (+2.3g CO_2e). The total impact of reduced energy sector consumption (-237.7g CO_2e) is, unsurprisingly, largely due to a decrease of sector emissions (-217.0g CO_2e) related to electricity and heat production.

Increasing the level of cost localization from 85% to 100% in Scenario 2 calculations significantly increases the per-unit impacts of renovation spending on each of the above socio-economic indicators, with the exception of GHG emissions. The multiplier for gross output increases from RUB 2.34 to RUB 2.71 per ruble of EER spending, cumulative over 10 years (see Figure 3.12). For GDP, the increase is from RUB 1.33 to RUB 1.51; for budget revenues, from RUB 0.22 to RUB 0.25. All else equal, increasing cost localization also slightly increases GHG emissions, bringing Scenario 2's net impact from -203g to -201g CO_2e.

Figure 3.11: Per-unit impact of Scenario 2 renovation on GHG emissions

g CO_2e per ruble of EER capital expenditures, cumulative over 10 years

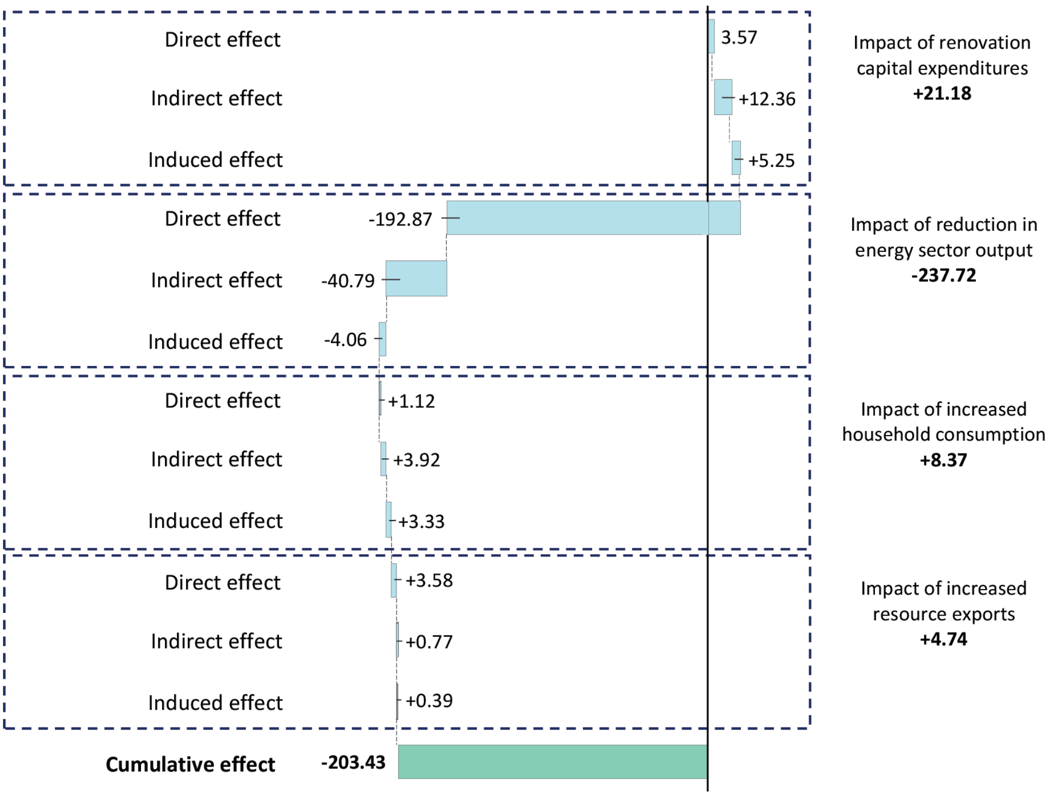
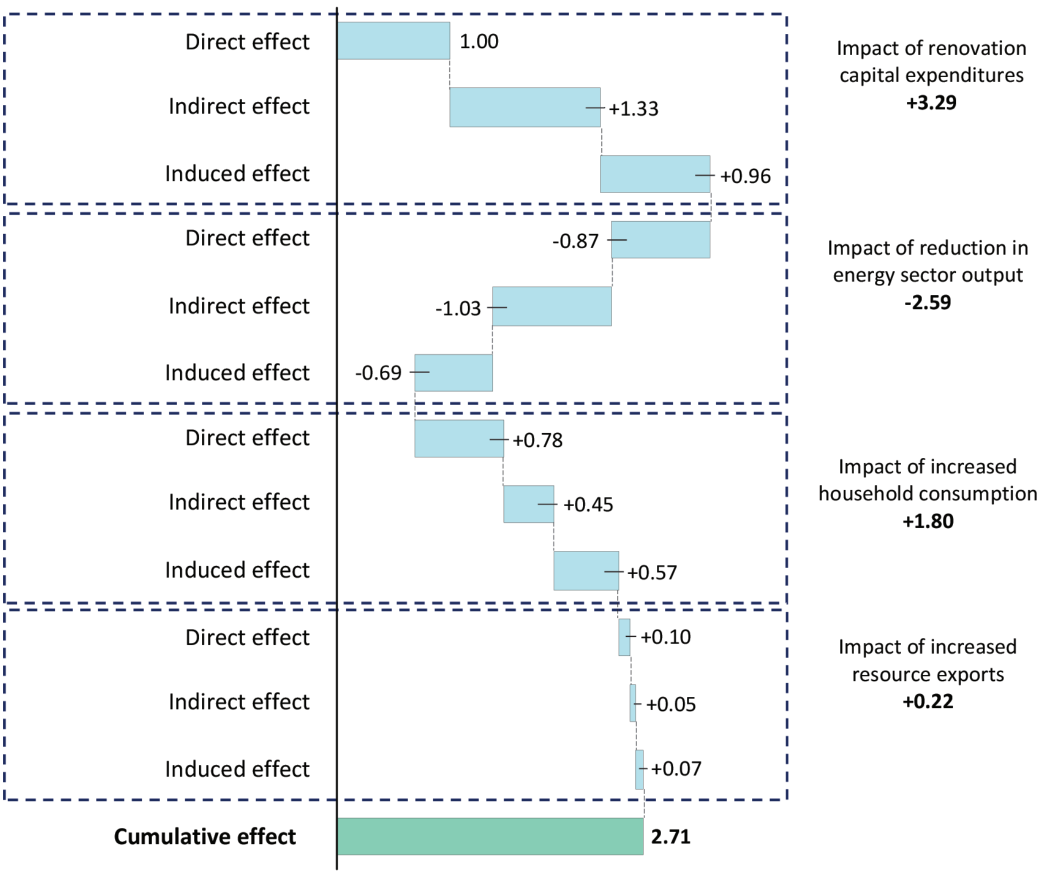


Figure 3.12: Per-unit impact of Scenario 2 renovation on gross output

Rubles per ruble of EER capital expenditures, cumulative over 10 years; 100% cost localization



3.3. Scenario 3 assumptions & calculation results

To assess the socio-economic impacts of minimal energy-efficient apartment building renovations, the same project estimates employed in Scenario 2 (derived from 30 implemented projects) were modified. However, instead of the actual cost structure, the following adjusted structure was employed in constructing Scenario 3: installation of automated control unit for the heating system (50%); and installation of automated local heat distribution station (50%).

Under these assumptions, resources are concentrated on financing less costly but more energy-efficient works. These significantly lower repair costs allow for a larger number of apartments to undergo EER works. The average cost structure for a given line of work is estimated as follows:

- Insulation and waterproofing materials (3%);
- Pipes and pipeline fittings (29%);
- Regulating equipment (38%);
- Other materials, equipment and services (2%);
- Overhead costs and depreciation (9%);
- Payroll, including personal income taxes and social insurance premiums (9%);
- Estimated profit (5%); and
- Taxes (excluding personal and corporate income taxes) (5%).

In Scenario 3's localization sub-scenarios, assumptions regarding the shares of imports in the average project's cost structure mirror those employed in Scenario 2 (see Table 3.4, below), but the proportional differences of materials used leads to the assumption of 50% imports under the low-localization scenario.

Figure 3.13 displays the results of calculations to estimate the per-unit impact of spending on a minimal EER project on gross output.[18] Generally speaking, the dynamic of impacts is similar to the one observed under Scenario 2. At the same time, the positive impact of project capital expenditures is noticeably lower in Scenario 3 (RUB 2.08, compared to RUB 2.89 in Scenario 2) due to the greater proportion of imported regulating equipment. The negative impact of reduced energy consumption is also more pronounced (RUB -6.64, versus RUB -1.23), while the impact of increased household consumer demand is higher due to greater expected savings (RUB 4.60, compared to Scenario 2's RUB 1.80). Still, a low level of cost localization means Scenario 3's total net positive impact of RUB 0.59 is lower than those of the first two scenarios.

[18] As in Scenario 2, estimates of per-unit multiplier effects are cumulative over a ten-year period.

Table 3.4: Shares of imports in Scenario 3 capital cost structure

	Low localization scenario	Full localization scenario
Total share of imports in capital expenditures (For a given structure of capital expenditures)	**50%**	**0%**
General construction materials	5%	0%
Assembly and universal glue, paint, mounting foam	30%	0%
Sealant	5%	0%
Metal structures and other products	10%	0%
Mineral wool and polystyrene foam boards	0%	0%
Other thermal insulation materials	25%	0%
Waterproofing materials	0%	0%
Window blocks made of PVC profiles	5%	0%
Other plastic products	25%	0%
Pipeline fittings (except for control valves)	50%	0%
Control equipment (automated control systems, controllers, pumps, control valves)	90%	0%
Sensors, instruments for measurement and accounting	50%	0%
Electrical equipment	40%	0%
LED lamps	95%	0%
Machines and mechanisms (depreciation of assembly equipment)	50%	0%
Machines and mechanisms (depreciation of construction equipment)	60%	0%

Figure 3.13: Per-unit impact of Scenario 3 renovation on gross output

Rubles per ruble of capital expenditures, cumulative over 10 years

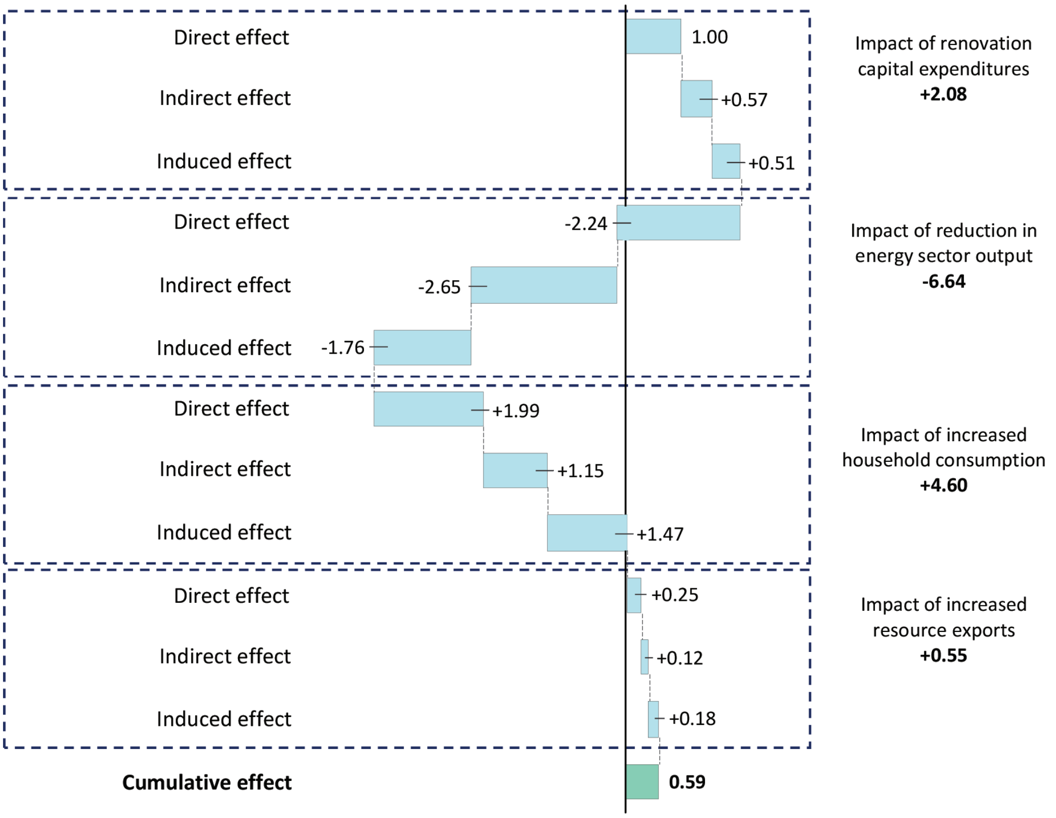
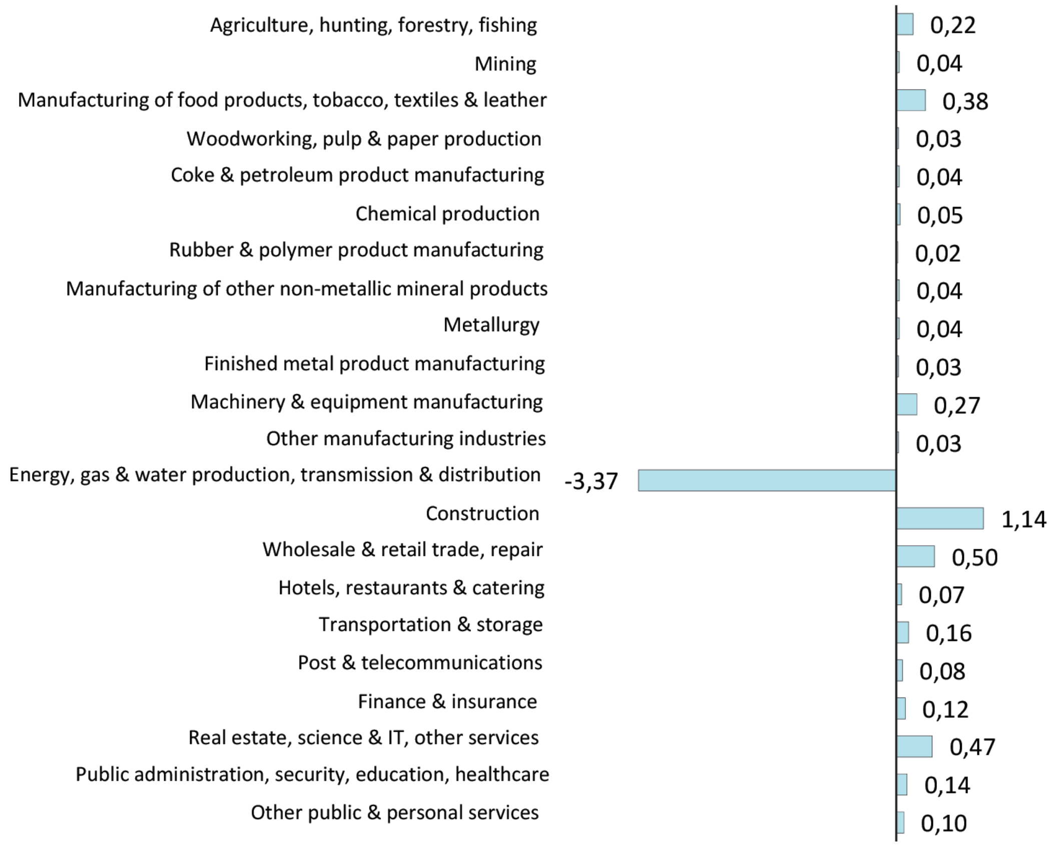


Figure 3.14 below show a breakdown of these impacts on output by individual sector. As with larger-scale projects, minimal EER works have the greatest per-unit impacts on output in the construction sector (positive) and in the energy sector (negative). Other impacted sectors include wholesale and retail trade and repair; real estate, science & IT, and other services; food and manufacturing of food products, tobacco, textiles & leather; and machinery and equipment manufacturing.

Figure 3.14: Per-unit impact of Scenario 3 renovation on output by sector

Rubles per ruble of capital expenditures, cumulative over 10 years



The impacts of minimal EER projects on GDP are similar to those on gross output (Figure 3.15): capital expenditures have a positive impact (RUB 0.82), reduced residential energy consumption has a negative impact (RUB -3.15), and increases in consumer demand and exports again generate positive impacts (RUB 2.67 and RUB 0.34, respectively). The resulting multiplier effect on Russia's GDP is RUB 0.69 per ruble of capital expenditures (cumulative over 10 years). The magnitude of this impact is roughly half that of those for Scenarios 1 and 2; again, this is due to a low level of cost localization.

Figure 3.15: Per-unit impact of Scenario 3 renovation on GDP

Rubles per ruble of capital expenditures, cumulative over 10 years

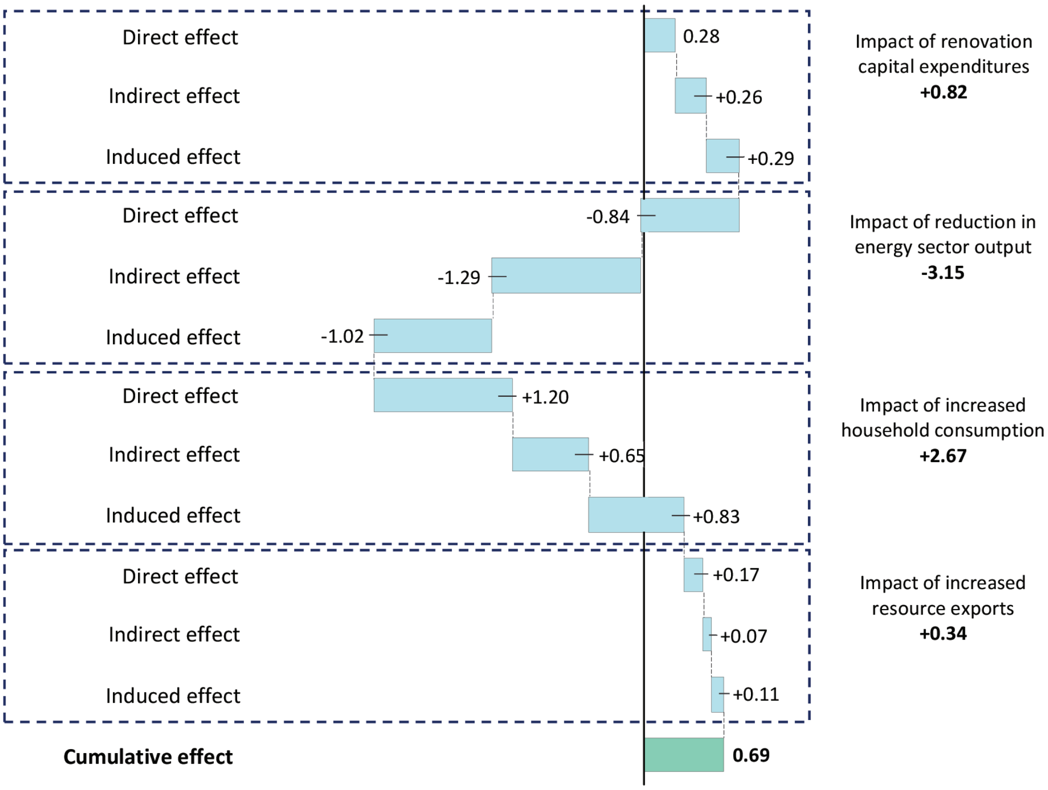


Figure 3.16 presents an estimate of the per-unit impact of Scenario 3 EER works on budget revenues. The impacts of capital expenditures, increased household consumer demand, and an expansion of exports are positive (RUB +0.15, RUB +0.36 rubles, and RUB +0.08, respectively), while the effect of reduced utility sector output is significantly negative (RUB -0.50). Together, these effects produce a net per-unit impact on budget revenues of RUB +0.09 per ruble of capital expenditure (cumulative over 10 years). This is again notably lower than Scenario 1 and 2 calculation outcomes.

The strongest relative impact of Scenario 3 EER works can be observed in their impact on GHG emissions (Figure 3.17, below). Per-unit emissions reductions significantly exceed those observed in Scenario 2 (-562g CO_2e versus -203g CO_2e per ruble of capital expenditures, cumulative over 10 years). This is mainly due to the impact of reduced energy sector output, which accounts for a 609g CO_2e decrease in emissions. (Of this decrease, 573g CO_2e is directly attributable to the energy sector alone, while the balance is due to intersectoral interactions.)

Increasing the assumed level of cost localization in Scenario 3 from 50% to 100% significantly improves the performance of minimal EER projects in terms of impact on other socio-economic indicators: the multiplier for gross output rises from RUB 0.59 to RUB 1.88 (see Figure 3.18, below). For GDP, the increase is from RUB 0.69 to RUB 1.30; for budget revenues, from RUB 0.09 to RUB 0.19. GHG emissions are higher, but only slightly: instead of decreasing by 562g CO_2e, they fall by 554g CO_2e.

Figure 3.16: Per-unit impact of Scenario 3 renovation on budget revenues

Rubles per ruble of capital expenditures, cumulative over 10 years

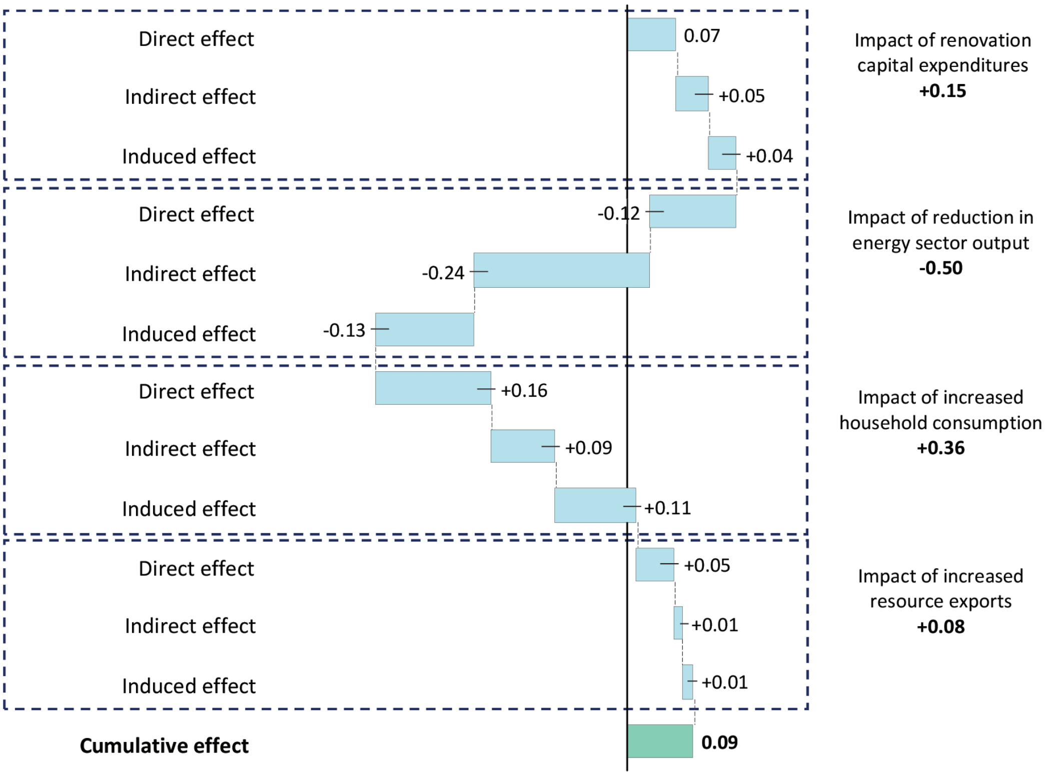


Figure 3.17: Per-unit impact of Scenario 3 renovation on GHG emissions

Tonnes CO_2e per million rubles of capital expenditures, cumulative over 10 years

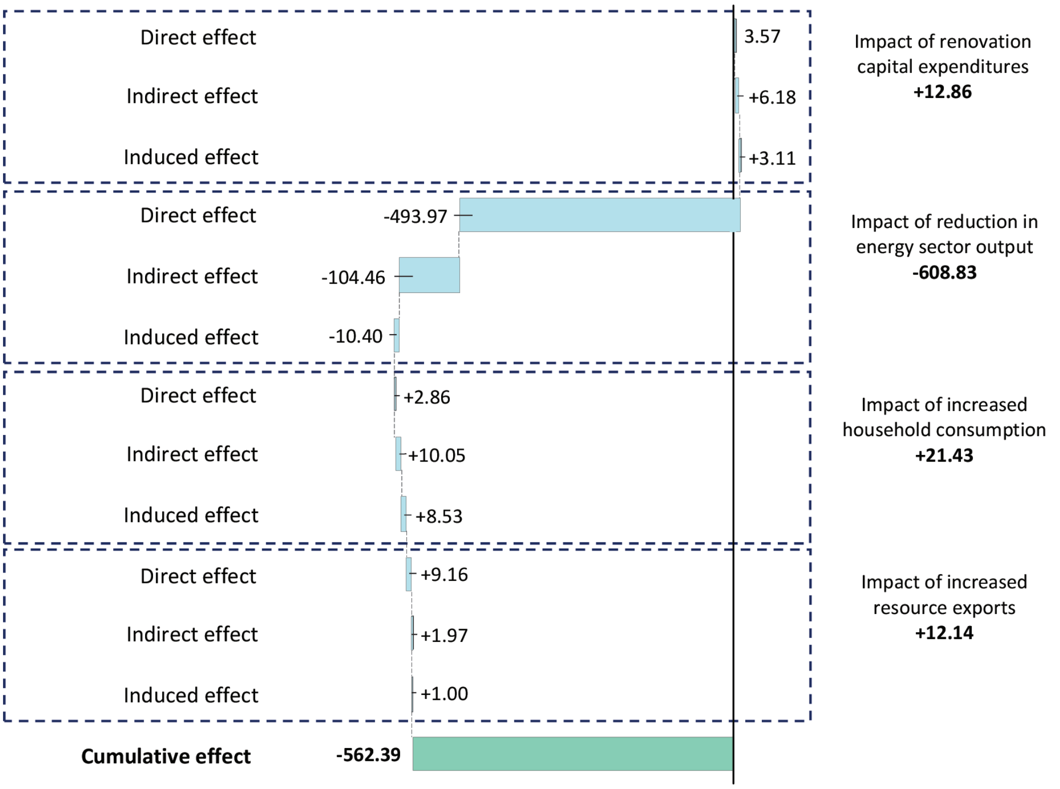
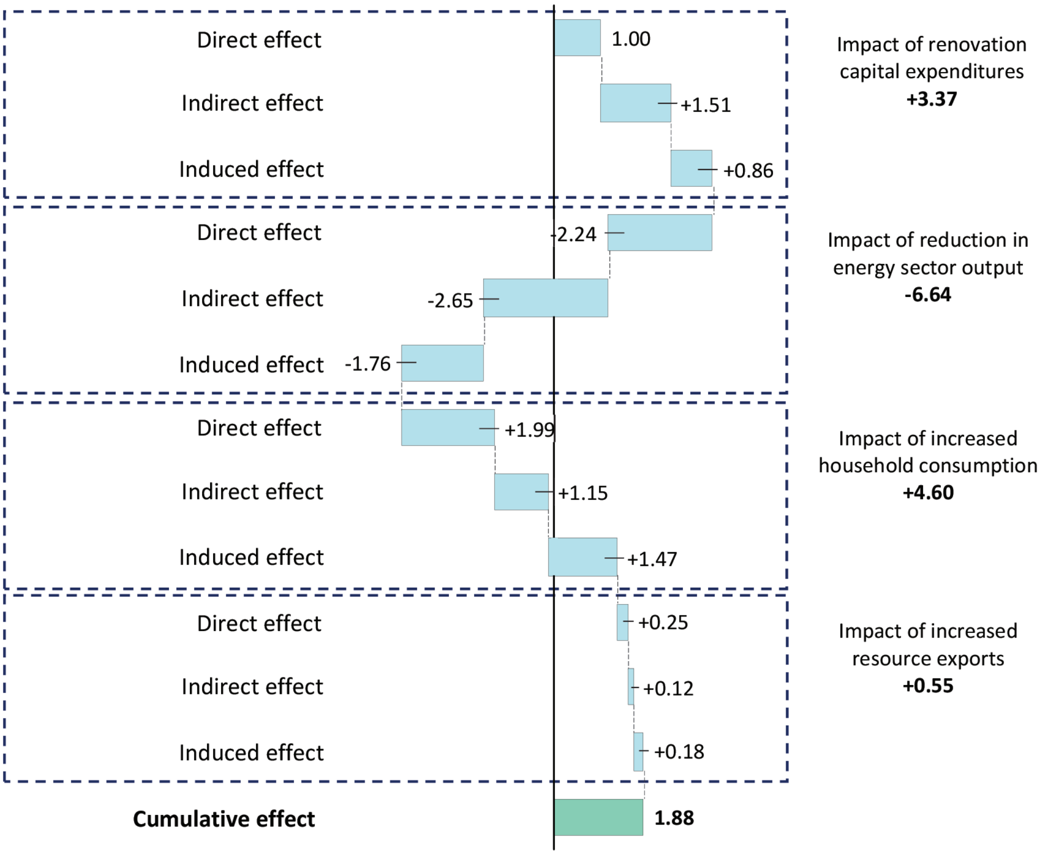


Figure 3.18: Per-unit impact of Scenario 3 renovation on gross output

Rubles per ruble of capital expenditures, cumulative over 10 years; 100% cost localization



3.4. Comparison of scenario result calculations

Estimates of socio-economic impacts for each of this section's three apartment building renovation scenarios are presented in Table 3.5 below. In general, the calculated multipliers for gross output, GDP, and budget revenues do not differ greatly between Scenarios 1 and 2 in aggregate terms. At the same time, they are significantly higher that Scenario 3's multipliers, owing to this scenario's relatively low level (50%) of cost localization.

The slightly higher estimates of per-unit impact on gross output and budget revenues in Scenario 1 compared to Scenario 2 indicate a greater macroeconomic efficiency of spending on standard (non-energy efficient) renovation works. However, Scenario 1 predicts higher GHG emissions, while emissions fall under Scenario 2. Similarly, the macroeconomic efficiency of Scenario 3 renovation works is relatively low, but the benefit in terms of reduced GHG emissions is almost three times higher than in Scenario 2.

From the standpoint of budget revenues, Scenario 1 renovation works yield the greatest impact (RUB 0.26 in additional tax receipts, compared to RUB 0.22 in Scenario 2 and just RUB 0.09 in Scenario 3). However, both Scenario 2 and 3 renovations yield positive impacts in terms of reduced carbon emissions. It is therefore worth considering certain tradeoffs between benefits to the state budget and those to the climate.

Table 3.5: Per-unit impact on key socio-economic indicators

Rubles per ruble of capital expenditures, accumulated over 10 years; localization 85%

	Scenario 1 (Standard renovation)				Scenario 2 (Standard EER)				Scenario 3 (Minimal EER)			
	on gross output	on GDP	on taxes	on GHG emissions*	on gross output	on GDP	on taxes	on GHG emissions*	on gross output	on GDP	on taxes	on GHG emissions*
Impact of renovation capital expenditures	**2.887**	**1.349**	**0.263**	**20.63**	**2.917**	**1.376**	**0.247**	**21.18**	**2.079**	**0.824**	**0.147**	**12.86**
Direct effect	1.000	0.422	0.123	3.57	1.000	0.437	0.100	3.57	1.000	0.276	0.067	3.57
Indirect effect	1.038	0.448	0.079	12.00	1.052	0.457	0.084	12.36	0.568	0.262	0.047	6.18
Induced effect	0.849	0.479	0.062	5.07	0.865	0.482	0.063	5.25	0.511	0.286	0.037	3.11
Impact of reduction in energy demand					**-2.594**	**-1.228**	**-0.195**	**-237.72**	**-6.644**	**-3.145**	**-0.499**	**-608.83**
Direct effect					-0.874	-0.329	-0.047	-192.87	-2.238	-0.842	-0.120	-493.97
Indirect effect					-1.033	-0.502	-0.095	-40.79	-2.647	-1.287	-0.244	-104.46
Induced effect					-0.687	-0.397	-0.053	-4.06	-1.760	-1.016	-0.135	-10.40
Impact of household demand growth					**1.798**	**1.043**	**0.141**	**8.37**	**4.604**	**2.672**	**0.361**	**21.44**
Direct effect					0.776	0.467	0.062	1.12	1.987	1.196	0.159	2.86
Indirect effect					0.448	0.253	0.035	3.92	1.146	0.649	0.090	10.05
Induced effect					0.574	0.323	0.044	3.33	1.470	0.827	0.112	8.53
Impact of export growth					**0.215**	**0.134**	**0.030**	**4.74**	**0.551**	**0.343**	**0.078**	**12.14**
Direct effect					0.096	0.066	0.020	3.58	0.246	0.168	0.052	9.16
Indirect effect					0.047	0.026	0.005	0.77	0.122	0.068	0.012	1.97
Induced effect					0.072	0.042	0.005	0.39	0.184	0.107	0.014	1.00
Cumulative effect	**2.887**	**1.349**	**0.263**	**20.63**	**2.335**	**1.325**	**0.224**	**-203.43**	**0.589**	**0.693**	**0.091**	**-562.39**

** Note: Estimates of per-unit effects on GHG emissions are expressed in grams CO_2e per ruble of capital expenditures*

Table 3. 6 presents a breakdown by sector of per-unit impacts on socio-economic indicators. Noteworthy here are the positive impacts experienced by the construction sector broadly and the negative impacts experienced by the energy sector under Scenarios 2 and 3: apartment building energy-efficiency renovations noticeably reduce both output and employment in this sector.

It is worth noting that data from 2010 to 2019 show a general decline in one segment of Russia's energy sector: heating. During this period, domestic consumption of heat energy (excluding network losses) fell from 1,267 to 1,177 million Gcal, an average annual decline of 0.8%. The most likely explanation for this trend is a tightening of energy efficiency requirements for new housing construction and major renovations of apartment buildings. Looking ahead, as there are currently no drivers for growth of heat energy consumption in Russia, consumption is expected to continue to fall.

According to Rosstat, heat supply tariffs are uneconomical in about 70 of the Russian Federation's constituent entities. This translates into underinvestment in the sector and leads to increases in the depreciation and failure rates of existing infrastructure. To maintain current and projected future levels of intensive use, Russia's energy sector faces the urgent task of modernizing generation and network infrastructure.

However, increased efficiency of heat consumption is not the reason that Russia's energy sector faces this dire situation of aging infrastructure: exceedingly low tariffs—and therefore negative profitability—are the culprits. Indeed, system decentralization and increased efficiency of energy consumption is a natural consequence of the current situation, as these solutions allow consumers to achieve greater reliability and higher quality of heat supply. Moreover, without increases in apartment building energy efficiency, the heating sector can be expected to accumulate large losses, thereby requiring additional state subsidies for continued operations. Therefore, despite the potentially negative impacts of apartment building EER programs on the energy sector, they can also be seen to be benefiting it by alleviating some degree of pressure on its associated infrastructure. In this sense, energy efficiency programs can be seen to correspond to Russia's strategic priorities in economic development.

Table 3.6: Per-unit impact on key socio-economic indicators by sector

Rubles per ruble of capital expenditures, accumulated over 10 years; localization 85%

	Scenario 1 (Standard renovation)				Scenario 2 (Standard EER)				Scenario 3 (Minimal EER)			
	on gross output	on GDP	on taxes	on GHG emissions*	on gross output	on GDP	on taxes	on GHG emissions*	on gross output	on GDP	on taxes	on GHG emissions*
Cumulative effect	2.887	1.349	0.263	20.63	2.335	1.325	0.224	-203.43	0.589	0.693	0.091	-562.39
Agriculture, hunting, forestry, fishing	0.033	0.018	0.001	0.09	0.113	0.064	0.002	0.25	0.223	0.129	0.004	0.48
Mining	0.075	0.050	0.015	1.49	0.083	0.057	0.017	1.52	0.037	0.026	0.009	0.71
Manufacturing of food products, tobacco, textiles & leather	0.049	0.016	0.004	0.03	0.191	0.065	0.018	0.12	0.385	0.132	0.037	0.23
Woodworking, pulp & paper production	0.032	0.012	0.001	0.11	0.027	0.011	0.001	0.09	0.035	0.014	0.002	0.11
Coke & petroleum product manufacturing	0.065	0.018	0.004	0.32	0.074	0.020	0.005	0.37	0.040	0.011	0.003	0.20
Chemical production	0.051	0.016	0.002	0.13	0.107	0.032	0.004	0.17	0.046	0.017	0.002	0.07
Rubber & polymer product manufacturing	0.067	0.018	0.004	0.01	0.059	0.016	0.004	0.01	0.017	0.005	0.001	0.00
Manufacturing of other non-metallic mineral products	0.144	0.053	0.012	1.52	0.223	0.082	0.019	2.33	0.043	0.016	0.004	0.49
Metallurgy	0.160	0.049	0.007	1.44	0.129	0.040	0.006	1.17	0.037	0.012	0.001	0.28
Finished metal product manufacturing	0.046	0.016	0.003	0.05	0.036	0.012	0.003	0.04	0.026	0.009	0.002	0.02
Machinery & equipment manufacturing	0.187	0.067	0.012	0.73	0.275	0.099	0.019	0.93	0.828	0.315	0.058	3.31
Other manufacturing industries	0.015	0.004	0.001	0.03	0.027	0.009	0.001	0.02	0.075	0.025	0.003	0.06
Energy, gas & water production, transmission & distribution	0.114	0.042	0.008	8.20	-3.368	-1.244	-0.198	-573.34	-3.316	-1.225	-0.194	-569.61
Construction	1.092	0.468	0.129	3.90	1.136	0.346	0.076	4.06	1.175	0.370	0.078	4.20

	Scenario 1 (Standard renovation)				Scenario 2 (Standard EER)				Scenario 3 (Minimal EER)			
	on gross output	on GDP	on taxes	on GHG emissions*	on gross output	on GDP	on taxes	on GHG emissions*	on gross output	on GDP	on taxes	on GHG emissions*
Wholesale & retail trade, repair	0.175	0.110	0.015	0.05	0.496	0.308	0.039	0.20	0.599	0.374	0.048	0.23
Hotels, restaurants & catering	0.011	0.006	0.001	0.00	0.074	0.039	0.004	0.02	0.080	0.043	0.005	0.02
Transportation & storage	0.147	0.079	0.008	2.36	0.155	0.078	0.007	2.85	0.216	0.109	0.010	3.61
Post & telecommunications	0.014	0.008	0.002	0.00	0.076	0.045	0.009	0.02	0.084	0.050	0.010	0.02
Finance & insurance	0.064	0.047	0.011	0.00	0.122	0.090	0.020	0.01	0.152	0.112	0.025	0.01
Real estate, science & IT, other services	0.160	0.121	0.012	0.04	0.474	0.380	0.035	0.10	0.572	0.453	0.042	0.13
Public administration, security, education, healthcare	0.161	0.114	0.010	0.11	0.137	0.098	0.009	0.08	0.186	0.133	0.012	0.11
Other public & personal services	0.023	0.015	0.002	0.02	0.097	0.071	0.006	0.04	0.108	0.078	0.007	0.05

** Note: Estimates of per-unit effects on GHG emissions are expressed in grams CO_2e per ruble of capital expenditures*

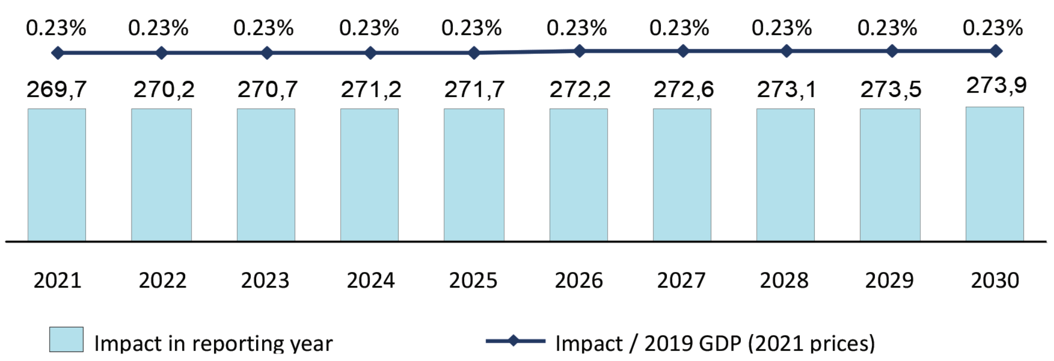
4. Scenario calculations to estimate absolute effects of apartment building renovations

The Government of the Russian Federation is currently in the process of implementing a national program to renovate apartment buildings. From 2018 to 2020, annual spending related to this program averaged approximately 200 billion rubles, with financing for individual projects provided largely by homeowners' compulsory monthly payments. Considering the high levels of deterioration in Russia's housing stock, these levels of funding are insufficient to address the challenge of modernizing the nation's residential sector. Rather, amounts are only able to cover a modest volume of standard (non-energy-efficient) repair works.

Using the multipliers obtained in the analysis of Scenario 1 above, it is possible to estimate the absolute socio-economic impacts of the current program's implementation. Figure 4.1 presents estimates the total impact on GDP of a program of standard (non-energy-efficient) apartment building renovations with 200 billion rubles (constant 2021 prices) in annual financing.

Figure 4.1: Absolute impact on GDP of implementation of current (non-energy-efficient) apartment building renovation program

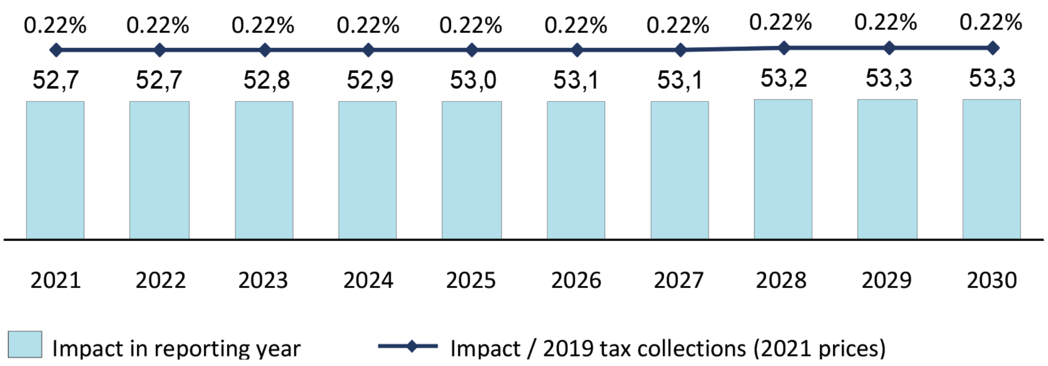
Billion rubles (2021 prices)



As the calculation results show, implementation of the planned program generates about 270 billion rubles annually for the Russian economy, relative to a scenario in which the repair works are not performed. This additional amount is equal to 0.23% of Russia's 2019 GDP. For the period of 2021 to 2030, the cumulative effect is an estimated RUB 2.72 trillion (2021 prices), or 2.3% of Russia's 2019 GDP.

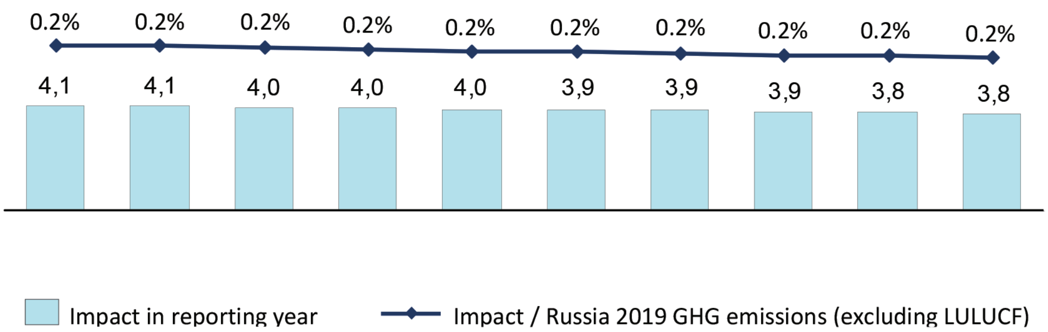
Estimates of the absolute impact on budget revenues are shown in Figure 4.2. Assuming that the program is financed mainly by homeowners, it is estimated to add about 53 billion rubles (2021 prices) annually to the state budget.

Figure 4.2: Absolute impact on budget revenues of implementation of current (non-energy-efficient) apartment building renovation program
Billion rubles (2021 prices)



Estimates of the absolute impact on GHG emissions are shown in Figure 4.3. While the program results in an increase in emissions in each year of the period, the impact is less in later years due to expected increases in the efficiency of primary-resource use.

Figure 4.3: Absolute impact on GHG emissions of implementation of current (non-energy-efficient) apartment building renovation program
Million tonnes CO_2e



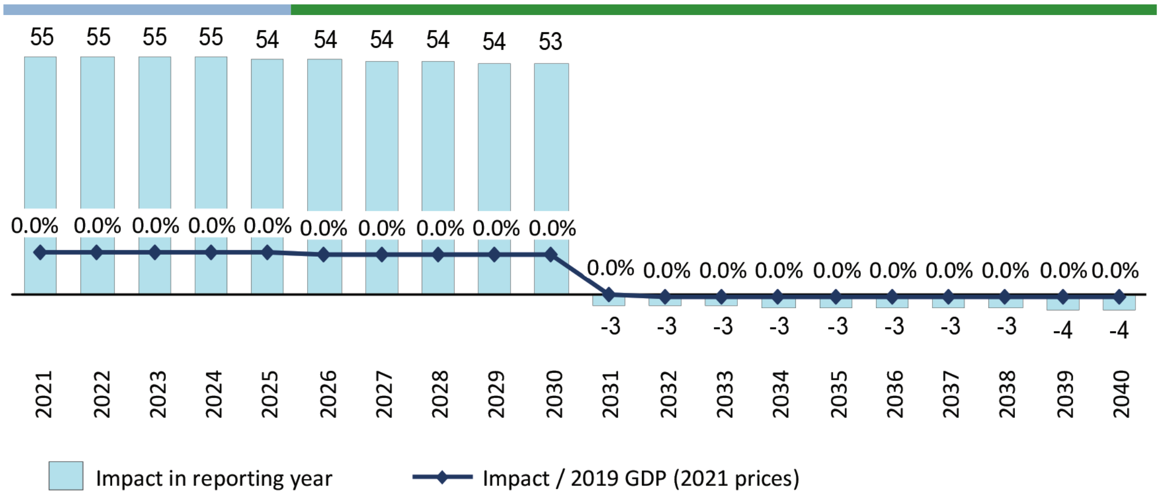
Considering the inadequacy of planned renovation works (relative to current building wear rates) and the need to improve apartment building energy efficiency (both from heating-infrastructure and emissions/climate-change standpoints), the possible implementation of an additional program of EER works, and the impact thereof, should also be considered.

Due to the low payment capacity of homeowners, the burden of financing such an additional program would likely fall to the state. Here it is worth referencing the above calculations, which show that the government's planned renovation programs can be expected to generate 50-55 billion rubles annually in additional tax revenues. (Even with more conservative estimates of indirect and induced effects, calculations of additional tax receipts come out to at least 40 billion rubles per year.) These funds could be used to finance EER works. (While actual mechanisms through which budgetary resources are disbursed may be different, for simplicity of calculations, it is assumed for the following estimates that these funds are used to directly finance energy efficiency measures, without additional funding from homeowners, banks, or private investors.)

Estimates of the impact of additional implementation of a standard (Scenario 2) apartment building EER program on GDP are shown in Figure 4.4.

Figure 4.4: Absolute impact on GDP of additional implementation of standard apartment building EER program

Billion rubles (2021 prices)



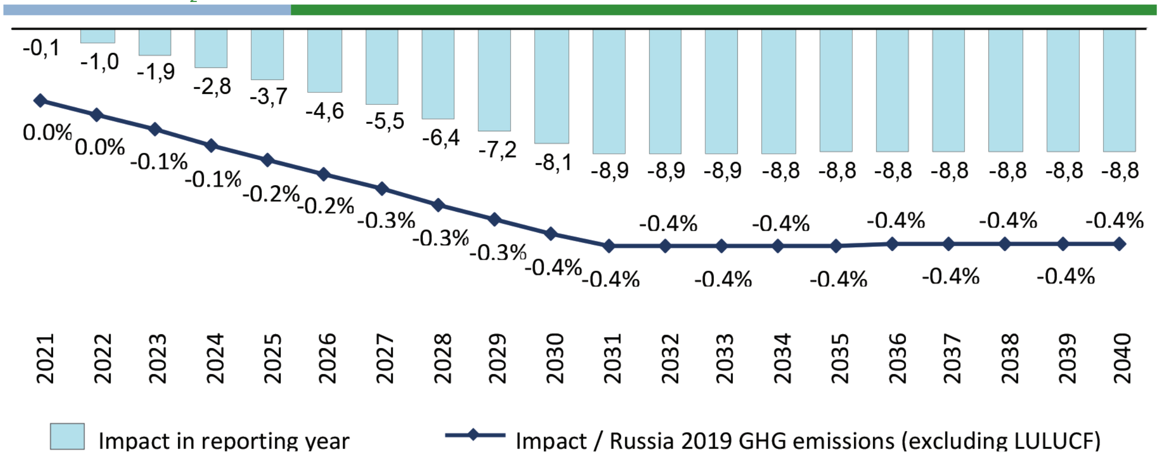
Here, the impact of the planned (non-energy-efficient) program is excluded and the period under consideration is extended to 2040 to capture the long-term impacts of EER works. For the period of 2021 to 2030, annual EER capital expenditures are assumed to be 40 billion rubles (2021 prices). No capital expenditures are assumed from 2031 to 2040; socio-economic impacts are the result of repair works in previous years.

Under this scenario, additional EER spending is expected to generate 53-55 billion rubles of GDP per year from 2021 2030. From 2031 to 2040, the impact on GDP is expected to be negative (3-4 billion rubles) compared to a scenario in which repair works are not carried out. In aggregate, impact of addition spending on EER works is 510 billion rubles, or 0.4% of Russia's 2019 GDP.

The implementation of this program is forecast to lead to nearly a 9 million tonne CO_2e reduction in annual GHG emissions by 2030 (Figure 4.5). This is equal to 0.4% of Russia's total 2019 emissions.

Figure 4.5: Absolute impact on GHG emissions of additional implementation of standard apartment building EER program

Million tonnes CO_2e



The implementation of a standard EER program and the consequential reduction of residential energy consumption negatively impact indicators for the energy sector, including output, value added, taxes, and employment. The magnitude of these declines is fairly moderate, however (see Figure 4.6 and Figure 4.7).

Figure 4.6: Absolute impact on energy sector output of additional implementation of standard apartment building EER program

Billion rubles (2021 prices)

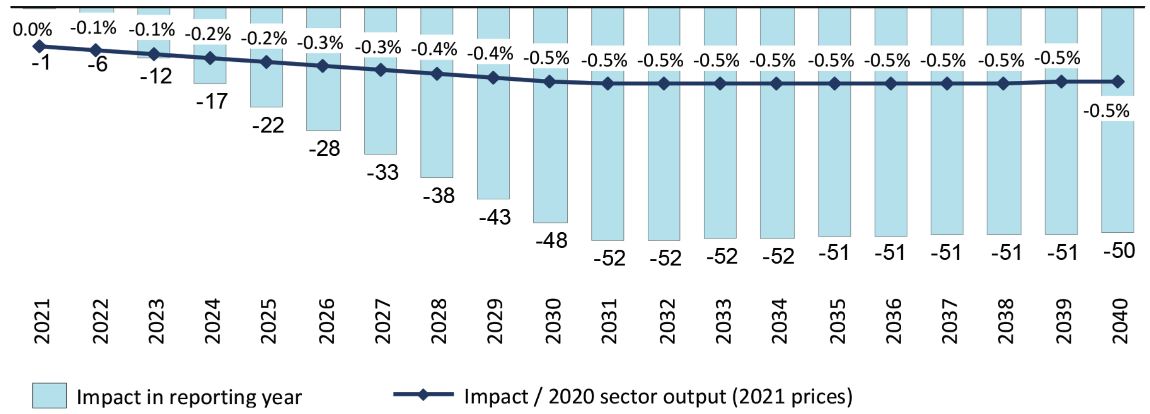
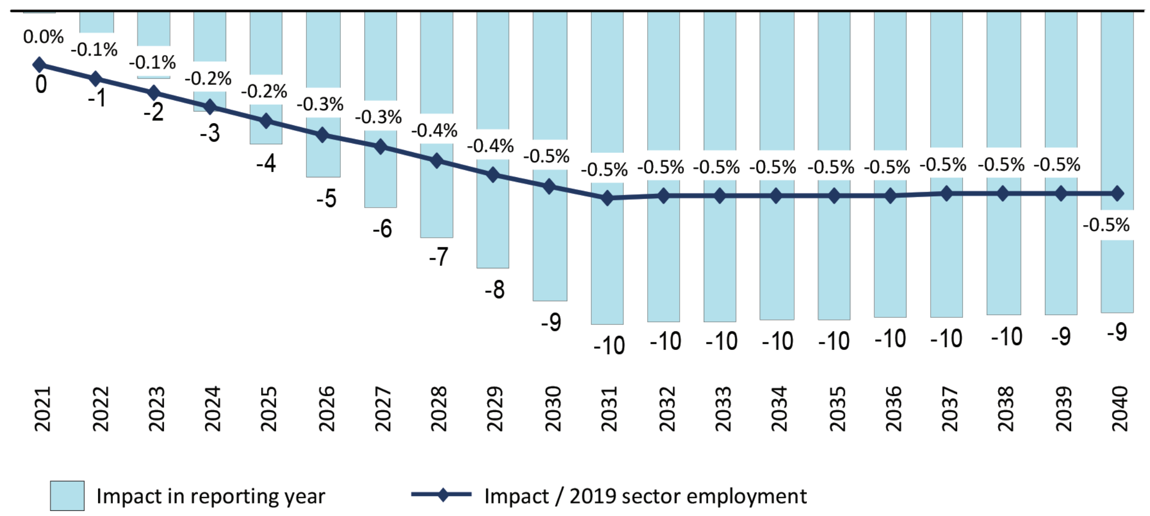


Figure 4.7: Absolute impact on energy sector employment of additional implementation of standard apartment building EER program

Thousand persons employed

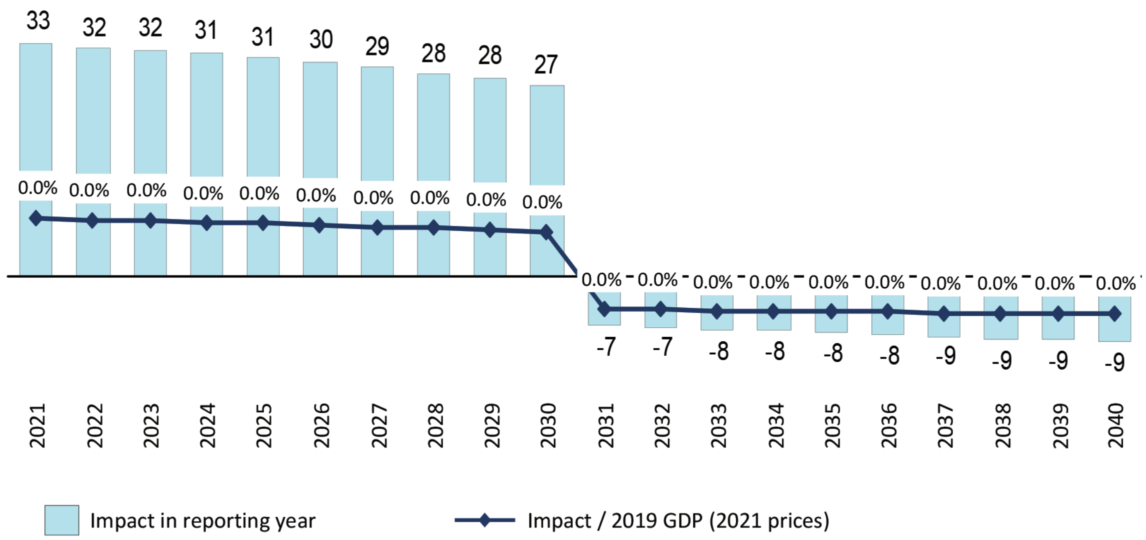


Declines in utility-sector employment are not necessarily negative, as these reductions free up labor resources that may be absorbed by other, more economically productive sectors—many of which face chronic labor shortages. The friction associated with transitioning workers from one sector to another does present challenges, however.

An alternative to a comprehensive housing modernization program aimed at improving energy efficiency is a program of minimal EER works. The latter implies lower per-unit spending per apartment building, but much greater coverage. Figure 4.8 shows an estimation of the absolute impact of such a program, again assuming 40 billion rubles (2021 prices) in annual spending from 2021-2030.

Figure 4.8: Absolute impact on GDP of additional implementation of minimal apartment building EER program

Billion rubles (2021 prices)

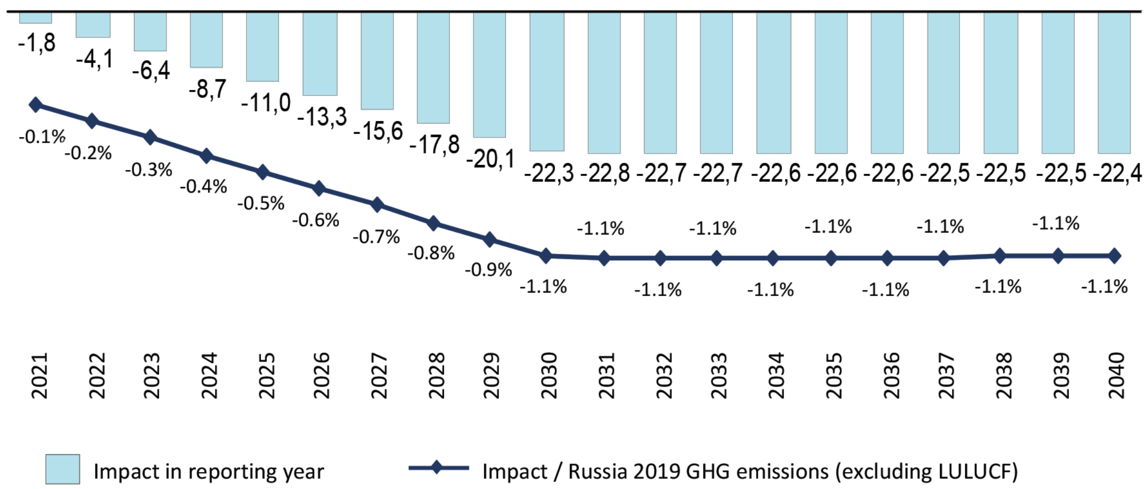


Here, estimated impact on GDP is significantly lower than that of the standard EER program, both for 2021-2030 (due to a lower level of cost localization), and for 2031-2040 (due to a greater reduction in energy consumption). The decline in yearly impact on GDP from 33 billion rubles in 2021 to 27 billion rubles in 2030 is caused by two factors: a decline in residential energy consumption and an assumed increase in the energy efficiency of the broad economy. The cumulative effect over the 2021-2040 period is 218 billion rubles (2021 prices), or 0.2% of Russia's 2019 GDP.

Figure 4.9 presents an estimate of a minimal EER program's impact on GHG emissions. By 2030, these energy efficiency measures will reduce annual emissions by about 22 million tonnes of CO_2e, or 1.1% of Russia's total 2019 emissions. This impact is almost three times larger than that of the standard EER program. Here the program's cumulative effect should be noted: impact of repair works in the reporting year are added to impact of previous years.

Figure 4.9: Absolute impact on national GHG emissions of additional implementation of minimal apartment building EER program

Billion rubles (2021 prices)



As in the case of the standard EER program, the implementation of a minimal EER program negatively impacts the energy sector. Again, the impact is relatively moderate, with declines in output (Figure 4.10), value added, budget revenues, and employment (Figure 4.11) of up to 1.3%. While these impacts can create additional challenges for the energy sector, reductions in demand also have the potential to reduce the volumes of capital expenditures necessary to modernize generation facilities and heating networks.

Figure 4.10: Absolute impact on energy sector output of additional implementation of minimal apartment building EER program

Billion rubles (2021 prices)

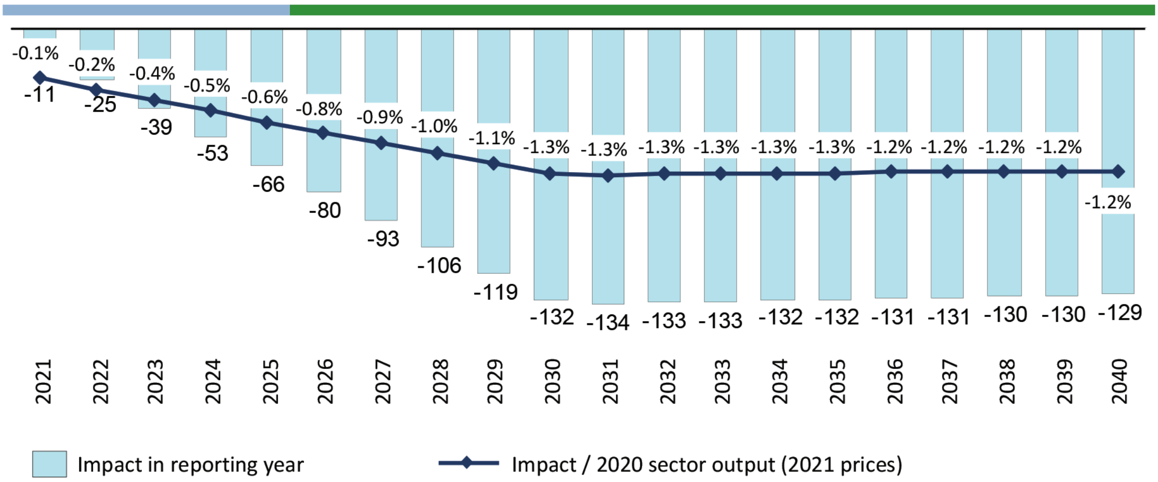
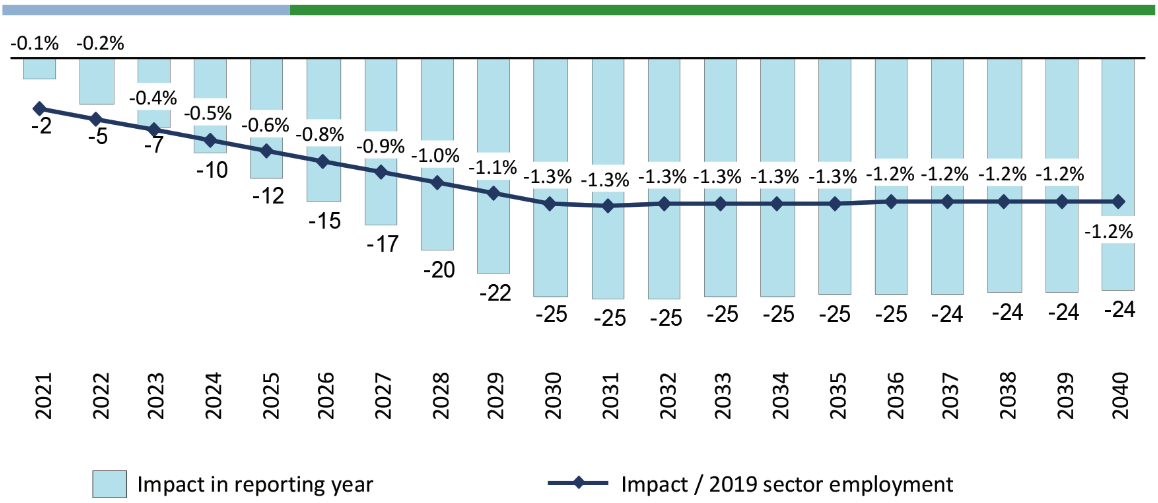


Figure 4.11: Absolute impact on energy sector employment of additional implementation of minimal apartment building EER program

Thousand persons employed



In summary, the macroeconomic impacts from the additional implementation of either standard or minimum energy-efficient renovation programs are significantly smaller than those associated with the current program of standard (non-energy-efficient) renovations (see Table 4.1). At the same time, these programs significantly reduce GHG emissions—enough to compensate for the increased emissions associated with the current program. The annual reduction in GHG emissions is found to be greater under the minimal EER scenario: 22 million tonnes CO_2e by 2030, compared to nearly 9 million tonnes CO_2e in the standard EER scenario. It can therefore be concluded that such a program—even with a limited amount of funding—could significantly contribute to Russia's efforts to pursue a strategy of low-carbon economic development.

Cumulative budget revenues from the additional implementation of standard and minimal EER programs are estimated to be 83 billion rubles and 18 billion rubles (2021 prices), respectively (see Table 4.2). Assuming full budgetary financing, about 21% of standard EER program costs are returned to the budget; the rate is just 5% for the minimal EER program (assuming 50% cost localization). These rates can be increased by reducing the level of subsidies provided for capital expenditures related to EER projects. The burden of financing EER can also be partly shifted to homeowners as long as targeted support is provided to lower-income households and wealthier households clearly understand the benefits of voluntary participation in the program. In other words, the EER program should be structured in such a way as to a) have transparent and stable rules; and b) provide participating homeowners participating with a guaranteed and relatively high level of passive income from their investments.

In Table 4.3 and Table 4.4 below, estimates of the absolute impacts are provided for three scenarios: 1) the current program of standard (non-energy-efficient) apartment building renovations; 2) the current program combined with the simultaneous, additional implementation of a program of standard EER works; and 3) the current program combined with the program of minimal EER works.

For the period of 2021 to 2040, implementation of Scenario 2 repair works yields a cumulative impact on gross output of RUB 6.46 trillion (2021 prices), relative to a scenario in which repair works are not carried out. For GDP, the impact is RUB 3.23 trillion; for budget revenues, RUB 0.61 trillion (RUB 0.21 trillion if full budget financing of EER works is assumed); for GHG emissions, the impact is -89.8 million tonnes of CO_2e. Impacts of Scenario 2 renovations can also be expressed on a per-unit basis. One ruble of capital expenditures yields RUB 2.69 rubles in gross output. For GDP the per-ruble impact is RUB 1.35; for budget revenues, RUB 0.26 (RUB 0.09 assuming budget financing for EER); for GHG emissions, approximately -37g CO_2e per ruble of capital expenditure.

For the same period, implementation of Scenario 3 repair works produces a cumulative impact on gross output of RUB 5.61 trillion (2021 prices), relative to a scenario in which repair works are not carried out. For GDP, the impact is RUB 2.94 trillion; for budget revenues, RUB 0.55 trillion (RUB 0.15 trillion assuming budget financing for EER); for GHG emissions, the impact is -307.5 million tonnes of CO_2e. On a per-ruble basis, the impact on gross output is RUB 2.34; on GDP, RUB 1.22; on budget revenues, RUB 0.23 (RUB 0.06 assuming budget financing for EER); on GHG, approximately -128g CO_2e.

For comparison, the impact on gross output of one ruble of capital expenditures under Scenario 1 is RUB 2.83. On GDP, it is RUB 1.36; budget revenues, RUB 0.27; and it leads to an estimated increase of 20g CO_2e in GHG emissions.

Table 4.1: Absolute impacts of various scenarios of apartment building renovation, by individual year

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2035	2040
Scenario 1 (status quo): RUB 200 billion (2021 prices) annual spending on standard (non-energy-efficient) renovations of apartment buildings												
Capital expenditures (billion rubles)	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	0.0	0.0
Cumulative effects												
on gross output (billion rubles)	577.5	574.7	572.0	569.4	566.8	564.3	561.9	559.5	557.2	554.9	0.0	0.0
on GDP (billion rubles)	269.7	270.2	270.7	271.2	271.7	272.2	272.6	273.1	273.5	273.9	0.0	0.0
on taxes (billion rubles)	52.7	52.7	52.8	52.9	53.0	53.1	53.1	53.2	53.3	53.3	0.0	0.0
on GHG emissions (million tonnes CO_2e)	4.13	4.09	4.05	4.01	3.97	3.94	3.90	3.87	3.84	3.80	0.00	0.00
Scenario 2: RUB 40 billion (2021 prices) annual spending on standard EER program for apartment buildings												
Capital expenditures (billion rubles)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	0.0	0.0
Cumulative effects												
on gross output (billion rubles)	114.2	111.3	108.4	105.6	102.8	100.1	97.5	94.9	92.3	89.8	-21.3	-20.4
on GDP (billion rubles)	54.9	54.8	54.7	54.6	54.5	54.3	54.1	53.8	53.6	53.3	-3.2	-3.7
on taxes (billion rubles)	9.8	9.7	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0	-1.1	-1.2
on GHG emissions (million tonnes CO_2e)	-0.06	-0.97	-1.88	-2.78	-3.68	-4.58	-5.47	-6.36	-7.24	-8.13	-8.84	-8.76
Scenario 3: RUB 40 billion (2021 prices) annual spending on minimum EER program for apartment buildings												
Capital expenditures (billion rubles)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	0.0	0.0
Cumulative effects												
on gross output (billion rubles)	76.9	70.5	64.3	58.1	52.1	46.2	40.4	34.7	29.2	23.7	-54.5	-52.2
on GDP (billion rubles)	32.6	32.2	31.8	31.2	30.6	30.0	29.3	28.5	27.6	26.8	-8.1	-9.4
on taxes (billion rubles)	5.8	5.6	5.4	5.1	4.9	4.6	4.4	4.1	3.8	3.5	-2.8	-3.0
on GHG emissions (million tonnes CO_2e)	-1.81	-4.12	-6.43	-8.73	-11.02	-13.29	-15.57	-17.83	-20.08	-22.33	-22.61	-22.43

Note: Volumes of capital expenditures and impacts on output, GDP, and taxes are indicated in 2021 prices and assume 85% cost localization.

Table 4.2: Absolute impacts of various scenarios of apartment building renovation, cumulative by year

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2035	2040
Scenario 1 (status quo): RUB 200 billion (2021 prices) annual spending on standard (non-energy-efficient) renovations of apartment buildings												
Capital expenditures (billion rubles)	200	400	600	800	1,000	1,200	1,400	1,600	1,800	2,000	2,000	2,000
Cumulative effects												
on gross output (billion rubles)	577	1,152	1,724	2,294	2,860	3,425	3,987	4,546	5,103	5,658	5,658	5,658
on GDP (billion rubles)	270	540	811	1,082	1,354	1,626	1,898	2,171	2,445	2,719	2,719	2,719
on taxes (billion rubles)	53	105	158	211	264	317	370	423	477	530	530	530
on GHG emissions (million tonnes CO_2e)	4.13	8.21	12.26	16.27	20.25	24.18	28.09	31.96	35.79	39.59	39.59	39.59
Scenario 2: RUB 40 billion (2021 prices) annual spending on standard EER program for apartment buildings												
Capital expenditures (billion rubles)	40	80	120	160	200	240	280	320	360	400	400	400
Cumulative effects												
on gross output (billion rubles)	114	225	334	440	542	643	740	835	927	1,017	909	805
on GDP (billion rubles)	55	110	165	219	274	328	382	436	490	543	528	510
on taxes (billion rubles)	10	19	29	39	48	58	67	76	85	94	89	83
on GHG emissions (million tonnes CO_2e)	-0.06	-1.03	-2.91	-5.69	-9.37	-13.95	-19.41	-25.77	-33.02	-41.14	-85.44	-129.36
Scenario 3: RUB 40 billion (2021 prices) annual spending on minimum EER program for apartment buildings												
Capital expenditures (billion rubles)	40	80	120	160	200	240	280	320	360	400	400	400
Cumulative effects												
on gross output (billion rubles)	77	147	212	270	322	368	409	443	473	496	219	-47
on GDP (billion rubles)	33	65	97	128	158	188	218	246	274	301	263	218
on taxes (billion rubles)	6	11	17	22	27	32	36	40	44	47	33	19
on GHG emissions (million tonnes CO_2e)	-1.81	-5.93	-12.36	-21.09	-32.11	-45.4	-60.97	-78.79	-98.88	-121.21	-234.65	-347.14

Note: Volumes of capital expenditures and impacts on output, GDP, and taxes are indicated in 2021 prices and assume 85% cost localization.

Table 4.3: Cumulative absolute impacts of various scenarios of apartment building renovation, by individual year

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2035	2040
Scenario 1 (status quo): RUB 200 billion annual spending in 2021-2030 on standard (non-energy efficient) renovations of apartment buildings												
Capital expenditures (billion rubles)	200	200	200	200	200	200	200	200	200	200	0	0
Cumulative effects												
on gross output (billion rubles)	577	575	572	569	567	564	562	559	557	555	0	0
on GDP (billion rubles)	270	270	271	271	272	272	273	273	274	274	0	0
on taxes (billion rubles)	53	53	53	53	53	53	53	53	53	53	0	0
on GHG emissions (million tonnes CO_2e)	4.13	4.09	4.05	4.01	3.97	3.94	3.90	3.87	3.84	3.80	0.00	0.00
Scenario 2: RUB 200 billion annual spending in 2021-2030 on standard renovations + RUB 40 billion on standard EER												
Capital expenditures (billion rubles)	240	240	240	240	240	240	240	240	240	240	0	0
Cumulative effects												
on gross output (billion rubles)	692	686	680	675	670	664	659	654	649	645	-21	-20
on GDP (billion rubles)	325	325	325	326	326	326	327	327	327	327	-3	-4
on taxes (billion rubles)	62	62	62	62	62	62	62	62	62	62	-1	-1
on GHG emissions (million tonnes CO_2e)	4.07	3.12	2.17	1.23	0.29	-0.64	-1.57	-2.49	-3.41	-4.32	-8.83	-8.76
Scenario 3: RUB 200 billion annual spending in 2021-2030 on standard renovations + RUB 40 billion on minimal EER												
Capital expenditures (billion rubles)	240	240	240	240	240	240	240	240	240	240	0	0
Cumulative effects												
on gross output (billion rubles)	654	645	636	628	619	611	602	594	586	579	-54	-52
on GDP (billion rubles)	302	302	302	302	302	302	302	302	301	301	-8	-9
on taxes (billion rubles)	58	58	58	58	58	58	57	57	57	57	-3	-3
on GHG emissions (million tonnes CO_2e)	2.32	-0.04	-2.38	-4.72	-7.04	-9.36	-11.66	-13.96	-16.25	-18.53	-22.61	-22.43

Note: Volumes of capital expenditures and impacts on output, GDP, and taxes are indicated in 2021 prices and assume 85% cost localization.

Table 4.4: Cumulative absolute impacts of various scenarios of apartment building renovation, cumulative by year

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2035	2040
Scenario 1 (status quo): RUB 200 billion annual spending in 2021-2030 on standard (non-energy efficient) renovations of apartment buildings												
Capital expenditures (billion rubles)	200	400	600	800	1,000	1,200	1,400	1,600	1,800	2,000	2,000	2,000
Cumulative effects												
on gross output (billion rubles)	577	1,152	1,724	2,294	2,860	3,425	3,987	4,546	5,103	5,658	5,658	5,658
on GDP (billion rubles)	270	540	811	1,082	1,354	1,626	1,898	2,171	2,445	2,719	2,719	2,719
on taxes (billion rubles)	53	105	158	211	264	317	370	423	477	530	530	530
on GHG emissions (million tonnes CO_2e)	4.13	8.21	12.26	16.27	20.25	24.18	28.09	31.96	35.79	39.59	39.59	39.59
Scenario 2: RUB 200 billion annual spending in 2021-2030 on standard renovations + RUB 40 billion on standard EER												
Capital expenditures (billion rubles)	240	480	720	960	1,200	1,440	1,680	1,920	2,160	2,400	2,400	2,400
Cumulative effects												
on gross output (billion rubles)	692	1,378	2,058	2,733	3,403	4,067	4,727	5,381	6,030	6,675	6,567	6,463
on GDP (billion rubles)	325	650	975	1,301	1,627	1,954	2,280	2,607	2,934	3,261	3,247	3,229
on taxes (billion rubles)	62	125	187	250	312	375	437	500	562	624	619	613
on GHG emissions (million tonnes CO_2e)	4.07	7.18	9.35	10.58	10.88	10.24	8.67	6.18	2.77	-1.55	-45.84	-89.77
Scenario 3: RUB 200 billion annual spending in 2021-2030 on standard renovations + RUB 40 billion on minimal EER												
Capital expenditures (billion rubles)	240	480	720	960	1,200	1,440	1,680	1,920	2,160	2,400	2,400	2,400
Cumulative effects												
on gross output (billion rubles)	654	1,300	1,936	2,563	3,182	3,793	4,395	4,989	5,576	6,154	5,877	5,611
on GDP (billion rubles)	302	605	907	1,210	1,512	1,814	2,116	2,418	2,719	3,019	2,982	2,937
on taxes (billion rubles)	58	117	175	233	291	349	406	463	520	577	563	549
on GHG emissions (million tonnes CO_2e)	2.32	2.28	-0.10	-4.82	-11.86	-21.22	-32.88	-46.84	-63.09	-81.61	-195.06	-307.55

Note: Volumes of capital expenditures and impacts on output, GDP, and taxes are indicated in 2021 prices and assume 85% cost localization.

Conclusion

Improving the energy efficiency of the residential sector has become an increasing priority for governments globally, due to the associated implications for the sustainability of economic growth, the productive use of non-renewable energy resources, and the need to address environmental challenges. In higher-income countries, it is often the government setting the energy-efficiency agenda through the creation of policies that impact a wide variety of actors involved in the decision-making, planning, financing, and execution of apartment building renovation programs.

Actual delivery of these policies supporting EER to the end-user can take various forms, including comprehensive programs offered to homeowners by commercial lenders backed by concessional financing. Such programs are in place at the national level in Germany and Japan, and at the municipal level in New York and Paris. International experience shows that subsidies are the prevailing mechanism for supporting apartment building EER works. Funding often comes from multiple sources, including federal, regional, and municipal budgets, as well as from multilateral financial institutions in many developing nations. In Germany and Japan, the determination of the economic rationale for a given subsidy policy is clear and transparent; this can be considered best practice.

For example, in Germany, the most significant EER program is supported by the state-owned development bank KfW (originally founded in the postwar years as Kreditanstalt für Wiederaufbau, or 'Credit Institute for Reconstruction'). Annually, KfW oversees the granting of €1.5-2.0 billion in federal subsidies for energy-efficient construction and modernization works. KfW program beneficiaries can choose between grants and concessional loans. In 2016, the bank issued approximately 126,000 concessional loans. On average, KFW subsidy amounts to 25-30% of project costs. While is it imprecise to compare directly KFW actuals and projected effects as per this report, they broadly match, at least in terms of the climate impact. Thus, estimated marginal climate effect impact of the proposed EER program is about the same[19].

The volume of annual financing for apartment building renovations (largely derived from homeowner contributions) in Russia is currently of about 200 billion rubles, of which less than 0.2% purposefully is spent on energy-efficiency measures. According to rough estimates, these renovation works contribute over 50 billion rubles to the state budget each year. Using these financial resources to finance an additional apartment building energy-efficiency renovation program would make a significant contribution towards the strategic goal of national carbon-emissions reduction.

While the presented estimates require further investigation to more accurately reflect the specific conditions of Russia's regions, they demonstrate the strong potential socio-economic impacts of energy-efficient renovation works in the residential sector. Each ruble spent on standard EER generates GDP growth of RUB 1.33 (RUB 0.69 for minimal EER). A portion is also returned to the budget in the form of RUB 0.22 in additional tax revenues (RUB 0.09 for minimal EER). But the

[19] Germany KFW 12-year averages – 0.59 million tons CO_2 eq per year for RUB 460 billion equivalent annual investment (1.4 tons CO_2 eq per RUB million). Projected Russian figures– 0.45 million tons CO_2 eq per year for RUB 240 billion annual investment – 1.9 tons CO_2 eq per RUB million.

greatest consequence of these projects is their impact on greenhouse gas emissions: with annual financing for these projects of 40 billion rubles, Russia's annual emissions can be reduced by as much as 22 million tons of CO_2e, or 1.1% of the nation's 2019 emissions total[20].

Policies related to energy-efficiency renovation works must be formulated with specific regional challenges in mind, especially in the context of their incorporation into regional pilot projects. Doing so will require analysis of the socio-economic consequences of renovation and other energy-efficiency measures at the level of the Russian Federation's constituent entities.

[20] Detailed regional assessment of the housing stock conditions and appropriate EER measures will likely lead to region-specific quantification of the effects, which may materially differ from the presented top-level country-wide figures and should be taken into account in design of the region-specific investment programs. Additionally, operational inefficiencies in program delivery present a significant risk for its success and should be assessed and mitigated as appropriate.

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APPENDIXES

Appendix 1. Methodology for estimating the macroeconomic impact of measures to improve apartment building energy efficiency

The cumulative macroeconomic impact of the implementation of measures to improve the energy efficiency of apartment buildings consists of the following components:

1) The impact of EER project capital expenditures (formation of additional demand for resource-saving equipment, thermal insulation materials, construction and assembly works, and other goods and services employed in the renovation process);

2) The impact of EER capital expenditures in stimulating new manufacturing of materials necessary for energy-efficient renovation projects (formation of additional final demand for capital goods);

3) The impact of changes in the structure of household consumption (reduction in spending on utilities and formation of additional demand for various consumer goods and services); and

4) The impact of growth in export volumes of primary resources due to a decrease in the resource intensity of the national economy.

In addition to these impacts, measures to improve the efficiency of apartment buildings may also have the following second-order effects:

- Impact on the financial sector (wider use of loans, green bonds, and other financial products); and
- Impact on the service sector (formation of additional demand for services in the field of EER project certification).

In calculating the macroeconomic impact of the main components listed above, the following assumptions are employed:

- Decreases in household energy demand will not lead to significant shifts in the structure of electricity or heat generation, or to a change in the technological coefficients for the sector's direct spending on various inputs of production (*i.e.*, the current general structure of national energy production costs); and
- A decrease in the physical volumes of domestic consumption of primary resources leads to comparable growth in the export of these resources holding domestic production volumes constant, with Russian raw-material price competitiveness and export market demand capacity also assumed.

Methodology for assessing per-unit macroeconomic impacts

Impact of capital expenditures on apartment building energy-efficiency renovation works

This impact includes:

- Direct effects of increased construction-sector output (proximate incremental output, value added, and tax revenues; employment in firms carrying out EER works);
- Indirect effects of increased output in sectors that directly and indirectly (*i.e.*, through a chain of inter-industry links) supply resources consumed in EER works, including production of insulation, building materials, fuel, and weather-linked automation equipment, etc.; and
- Induced effects throughout the whole economy due to emergence of new final demand from households, government, and businesses (due to expenditure of additional income received in the form of wages, taxes, and corporate profits) in sectors impacted by direct and indirect effects.

The direct effects on GDP from spending on EER of apartment buildings is calculated using the following formula:

$$\Delta GDP_{capex}^{dir} = W + SIP + Tax + Pr$$

where:

ΔGDP_{capex}^{dir} – direct effect on GDP of EER capital expenditures;

W – wages paid by construction firms carrying out EER works (labor costs excluding social insurance premiums and personal income taxes);

SIP – social insurance premiums paid by construction firms carrying out EER works;

Tax – tax payments by construction firms carrying out EER works (including employee personal income taxes); and

Pr – construction firms' profit and fixed-asset depreciation.

The indirect and induced effects on GDP from spending on apartment building EER works are calculated using the following formula:

$$\Delta GDP_{capex}^{ind} = \sum_{j=1}^{m} Cost_j \cdot \left(1 - imp^j\right) \cdot multva^j + W \cdot \gamma \cdot multva_{HHC} +$$

$$+ Tax \cdot \sigma \cdot multva_{GC} + Pr \cdot \mu \cdot multva_{inv}$$

where:

ΔGDP_{capex}^{ind} – indirect and induced effects on GDP of EER capital expenditures;

$Cost_j$ – renovation project spending on product type *j* (equipment, thermal insulation, etc.);

imp^j – share of production cost of product *j* attributable to imports;

$multva^j$ – production multiplier for *j* (increase in GDP per incremental unit output of *j*);

γ – average income elasticity of household consumption (calculated using data on individual elements of institutional accounts for Russia; a value of 0.91 is recommended);

$multva_{HHC}$ – household consumption multiplier (increase in GDP per incremental unit of household consumption);

σ – average income elasticity of government consumption (calculated using data on individual elements of institutional accounts for Russia; a value of 0.65 is recommended);

$multva_{GC}$ – government consumption multiplier (increase in GDP per incremental unit of government consumption);

μ – average elasticity of fixed-capital investment by profit (calculated using data on individual elements of institutional accounts for Russia; a value of 0.52 is recommended); and

$multva_{inv}$ – construction fixed-capital investment multiplier (increase in GDP per incremental unit of investment).

Production multipliers for various types of goods and services employed in EER works are calculated using data on the structure of their production costs, as well as sectoral production multipliers:

$$multva^j = \sum_{i=1}^{n} \alpha_i^j \cdot \left(1 - imp_i^j\right) \cdot multva_i +$$

$$+w^j \cdot \gamma \cdot \sum_{i=1}^{n} \beta_i \cdot (1 - imp_{c\,i}) \cdot multva_i +$$

$$+tax^j \cdot \sigma \cdot \sum_{i=1}^{n} \omega_i \cdot \left(1 - imp_{gc\,i}\right) \cdot multva_i +$$

$$+pr^j \cdot \mu \cdot \sum_{i=1}^{n} t_i^j \cdot \left(1 - imp_{gfcf\,i}\right) \cdot multva_i$$

where:

α_i^j – share of product *j* sales revenues allocated to purchases of intermediate products from sector *i*;

imp_i^j – share of imports in intermediate products of sector *i* used in the production process of output *j*;

$multva_i$ – sectoral production multiplier for sector *i* (increase in GDP per incremental unit of output for sector *i*);

w^j – share of product *j* sales revenues allocated to labor costs (excluding social insurance premiums and employee personal income taxes);

β_i – share of sector *i* products in household consumption expenditures (estimated using the 'household consumption' column of the symmetric Input-Output table);

$imp_{c\,i}$ – share of imports in household consumption of sector *i* products (estimated using the Input-Output table and import matrix);

tax^j – share of product *j* sales revenues allocated to taxes (including employee personal income taxes, excluding social insurance premiums);

ω_i – share of sector *i* products in government consumption expenditures (estimated using the 'government consumption' column of the symmetric Input-Output table);

$imp_{gc\ i}$ – share of imports in government consumption of sector *i* products (estimated using the Input-Output table and import matrix);

pr^j – share of product *j* sales revenues allocated to net profit and amortization;

t_i^j – share of product *j* fixed-capital costs attributable to products of sector *i* (estimated using data on the specific structure of fixed-capital formation in different sectors and the structure of fixed-capital formation within the following sectoral groups: 'Construction and assembly works', 'Machinery and equipment', and 'Other');

$imp_{gfcf\ i}$ – share of imports in sector *i* product capital expenditures (estimated using a input-output table and import matrix);

Sectoral production GDP multipliers, as well as household consumption, government consumption, and construction investment multipliers, are estimated using the symmetric Input-Output table and a static Leontief model.[21] Variances in climatic and other conditions in Russian regions in which EER projects are implemented are taken into account by assuming capital expenditure volumes and structures typical of these regions.

EER project capital expenditure amounts and associated cost structures depend on the activities performed (*e.g.*, installation of control and regulation units in heating and hot-water supply systems, improvement of roof thermal insulation, improvement of external wall thermal insulation, etc.). The cost structure for each of these activities is estimated by the types of products consumed, associated labor costs, expected profits, and taxes, with values derived from cost estimates from a sampling of actual EER projects. In calculating multiplier effects, an EER project's total capital expenditure and cost structures by activity are specified; from these spending by product type is calculated.

Sectoral production GDP multipliers and other calculation parameters can change markedly over time. For this reason, multiplier calculation must be carried out for each year of a given period, using data on EER projects not for the entire period, but rather for specific years.

[21] Sectoral production multipliers can also be calculated using the Input-Output table. These can reflect not only on impact on GDP, but also on gross output, tax revenues, employment, and greenhouse gas emissions (through sectoral proportions between these indicators and value added). These multiples can be used to estimate the impact of renovation works on corresponding macroeconomic indicators.

The cumulative effect on GDP from capital expenditures on apartment EER works in region *q* in reporting year *t* is calculated using the following formula:

$$\Delta GDP_{capex}^{q}(t) = \Delta GDP_{capex}^{dir\ q}(t) + \Delta GDP_{capex}^{ind\ q}(t) =$$

$$= W^{q}(t) + SIP^{q}(t) + Tax^{q}(t) + Pr^{q}(t) +$$

$$+ \sum_{j=1}^{m} Cost_{j}^{q}(t) \cdot \left(1 - imp^{j}(t)\right) \cdot multva^{j}(t) +$$

$$+ W^{q}(t) \cdot \gamma \cdot multva_{HHC}(t) + Tax^{q}(t) \cdot \sigma \cdot multva_{GC}(t) +$$

$$+ Pr^{q}(t) \cdot \mu \cdot multva_{inv}(t)$$

Impact of capital expenditures in stimulating new manufacturing of materials necessary for energy-efficient renovation works

Meeting the growing demand for resource-saving equipment, thermal insulation materials, and other products employed in apartment building EER projects requires investment in new manufacturing capacity, which creates additional final demand for financial-sector products. These in turn generate new multiplier effects—direct, indirect, and induced.

The cumulative effect on GDP from capital expenditures related to the investment in new production capacity of EER project inputs in the reporting year *t* is calculated using the following formula:

$$\Delta GDP_{inv}(t) = \sum_{s=1}^{n} Inv_{s}(t) \cdot \sum_{i=1}^{n} t_{is}(t) \cdot \left(1 - imp_{gfcf\ i}(t)\right) \cdot multva_{i}(t)$$

where:

$\Delta GDP_{inv}(t)$ – impact on GDP of capital expenditures related to investment in new production capacity of EER project inputs in reporting year *t*;

$Inv_{s}(t)$ – investments in fixed assets in sector *s* related to the development of new production capacity of EER project inputs in reporting year *t*; and

$t_{is}(t)$ – share of sector *s* capital expenditures attributable to spending on outputs of sector *i* (estimated using data on the specific structure of fixed-capital formation in different sectors, and the sectoral structure of fixed-capital formation in the 'Construction and assembly works', 'Machinery and equipment', and 'Other' sectoral groups) in reporting year *t*.

The volume of fixed-capital investments in sectors providing inputs for EER projects can be determined using assumed annual levels of input consumption under a given scenario and the corresponding capital intensity of the production of such inputs. Capital intensity is estimated as the ratio of fixed-asset investments to average real output growth over a period of five to seven years.

Impact of changes in the structure of household consumption

The implementation of EER works in apartment buildings further implies a decrease in the intensity of residential heat and electricity consumption on a per-unit basis. This then leads to reduction in household expenditures on utilities (in terms of intersectoral balance, a decrease in the final demand for energy sector output), assuming unchanged tariffs. Household savings on utility bills can be channeled into additional consumption of other goods and services. Put differently, the resulting decline in energy sector final demand and increase in final demand in other sectors creates further multiplier effects—direct, indirect, and induced.

The cumulative effect on GDP from changes in the structure of household consumption driven by capital expenditures on apartment EER works in region *q* in reporting year *t* is calculated using the following formula:

$$\Delta GDP_{HHC}^{q}(t) = -\Delta C_{e}^{q}(t) \cdot multva_{e}(t) +$$

$$+\sum_{k=1}^{n}\left(\Delta C_{e}^{q}(t) - D^{q}(t)\right) \cdot \rho_{k} \cdot \left(1 - imp_{c\,k}(t)\right) \cdot multva_{k}(t)$$

where:

$\Delta GDP_{HHC}^{q}(t)$ – impact on GDP of changes in structure of household consumption in region *q* in reporting year *t*;

$\Delta C_{e}^{q}(t)$ – household savings on utility bills resulting from apartment building EER works in region *q* in reporting year *t*;

$multva_{e}(t)$ – sectoral production GDP multiplier for sector *e* (energy sector) in reporting year *t*;

$D^q(t)$ – household savings on utility bills allocated to servicing of loans used to finance EER works in region *q* in reporting year *t* ($D^q(t) \leq \Delta C_e^q(t)$);[22]

ρ_k – share of sector *k* output in structure of household consumption, less spending on utility services, where *k* ≠ *e* (*i.e.*, sectors other than energy);

$imp_{c\,k}(t)$ – share of imports in household consumption of sector *k* output, (where *k* ≠ *e*) in reporting year *t*; and

$multva_k(t)$ – sectoral production GDP multiplier of sector *k* (where *k* ≠ *e*) in reporting year t.

Impact of growth in export volumes of primary resources

Assuming constant levels of production, a reduction in domestic consumption of primary resources from EER works creates the potential for those resources to be sold in export markets. The export of volumes released due to the impact of the three types of multiplier effects described above creates yet another new set of direct, indirect, and induced multiplier effects.

The cumulative effect on GDP from growth in export volumes of primary resources is calculated using the following formula:

$$\Delta GDP_{exp}(t) = \sum_{i=1}^{l} \Delta Exp_i(t) \cdot multva_i(t)$$

where:

$\Delta GDP_{exp}(t)$ – impact on GDP from an increase in volumes of primary resources resulting from EER works to apartment buildings;

$\Delta Exp_i(t)$ – change in export volumes of sector *i* output due to EER-related decreases in national-economy resource intensity, where $i = \overline{1, l}$ (sectors producing primary resources such as gas, oil and oil products, coal, basic chemical products, metals and ores, agricultural raw materials, wood products, etc.) in reporting year *t*.

[22] This value depends on the chosen financing model for EER works. If works are funded using either previously accumulated savings or a financing method that does not require additional contributions from households, D^q (t)=0. If additional contributions are necessary, the value is positive.

Calculating the potential export volumes of primary resources requires an iterative approach:

Step 1: Determination of the level of demand reduction for primary resources due to EER capital expenditures, investments in new production capacity, and changes in the structure of household consumption (summation of changes in output in impacted sectors);[23]

Step 2: Calculation of primary-resource sector output under the assumption that a volume equal to that of reduced domestic demand (Step 1) is exported (multiplying primary-resource volumes by their corresponding sectoral output multipliers and summing the obtained estimates for all sectors);[24]

Step 3: Calculation of adjustment factors to normalize export volumes, taking into account the intermediate consumption of exported raw materials in the production of export products (dividing Step 2 sectoral output volumes by Step 1 output volumes);[25]

Step 4: Calculation of normalized primary-resource export volumes, taking into account intermediate consumption (dividing Step 1 volumes by their corresponding Step 3 sectoral adjustment factors).[26]

[23] Effects on output are calculated similarly to effects on GDP. Here, however, sectoral output multipliers are used, rather than GDP multipliers. (A detailed description of the methodology for calculating sectoral production output multipliers can be found in Appendix 2.) Using these values, output growth in various sectors (including those that produce primary resources) can be calculated.

[24] Intermediate raw-material consumption is therefore taken into account in the production of export products.

[25] It is assumed that raw-material production volumes remain unchanged.

[26] For a more exact calculation of potential primary-resource export volumes, 2-3 iterations of such calculations may be necessary.

Methodology for assessing cumulative macroeconomic impact

The final multiplier effect on GDP from apartment building EER projects across all regions in the full period under consideration is calculated using the following formula:

$$\Delta GDP_{tot} = \sum_{t=1}^{T}\sum_{q=1}^{Q}\left[\Delta GDP_{capex}^{q}(t) + \Delta GDP_{inv}(t) + \Delta GDP_{HHC}^{q}(t) + \Delta GDP_{exp}(t)\right]$$

$$\Delta GDP_{tot} = \sum_{t=1}^{T}\sum_{q=1}^{Q}[W^{q}(t) + SIP^{q}(t) + Tax^{q}(t) + Pr^{q}(t) +$$

$$+\sum_{j=1}^{m} Cost_{j}^{q}(t)\cdot\left(1 - imp^{j}(t)\right)\cdot multva^{j}(t) +$$

$$+ W^{q}(t)\cdot\gamma\cdot multva_{HHC}(t) + Tax^{q}(t)\cdot\sigma\cdot multva_{GC}(t) +$$

$$+ Pr^{q}(t)\cdot\mu\cdot multva_{inv}(t) +$$

$$+\sum_{s=1}^{n} Inv_{s}(t)\cdot\sum_{i=1}^{n} t_{is}(t)\cdot\left(1 - imp_{gfcf\ i}(t)\right)\cdot multva_{i}(t) +$$

$$+\sum_{k=1}^{n}\left(\Delta C_{e}^{q}(t) - D^{q}(t)\right)\cdot\rho_{k}\cdot\left(1 - imp_{c\ k}(t)\right)\cdot multva_{k}(t) -$$

$$-\Delta C_{e}^{q}(t)\cdot multva_{e}(t) + \sum_{i=1}^{l}\Delta Exp_{i}(t)\cdot multva_{i}(t)]$$

Key aspects of calculations

Most of the calculation parameters described above—including production GDP multipliers, shares of imports in intermediate and final consumption, and shares of wages, taxes and profits in sales revenues are obtained using a national-level symmetric Input-Output table.[27]

One of the key aspects of these calculations is their dynamization: exogenous parameters within the forecast period are adjusted in accordance with future development trends. Foremost, this includes an overall increase in the efficiency of primary-resource use in the

[27] A table for 2016 can accessed at: https://rosstat.gov.ru/storage/mediabank/baz-tzv-2016.xlsx.

broader Russian economy. This trend is reflected in calculations of sectoral production GDP and other multipliers through adjustments to coefficients for direct costs (*i.e.*, multiplying coefficient base values by an index value for broad economy resource intensity in a given reporting year). Additionally, the calculation of GDP multipliers allows for exogenous specification of the share of imports in domestic consumption. Various scenarios of import substitution can therefore be considered.

Another key aspect of these calculations is their scenario-oriented nature. This allows for the modeling of various approaches to financing apartment building EER works as well as a comparative analysis of their effectiveness. The key exogenous parameters that determine the magnitude of the multiplier effect of measures for apartment building EER works are as follows:

- Type and volume of EER project financing. The program's financing scheme—the use of debt (including green bonds), the presence of any state subsidies, and/or the use of building's capital-expenditures savings fund—are relevant to calculations.

- Investments in the production of inputs of EER works. Higher levels of investments/lower shares of imports yield greater levels of final macroeconomic impact.

- Structure of EER costs. This influences the impacts of EER project capital expenditures, as well as that of increases in consumer demand and exports of primary resources.

Methodology for assessing budgetary efficiency of support for energy-efficient renovation of housing stock

The final multiplier effect on tax revenues from apartment building EER projects across all regions in the full period under consideration is calculated using the following formula:

$$\Delta Tax_{tot} = \sum_{t=1}^{T}\sum_{q=1}^{Q}\left[\Delta Tax_{capex}^{q}(t) + \Delta Tax_{inv}(t) + \Delta Tax_{HHC}^{q}(t) + \Delta Tax_{exp}(t)\right]$$

$$\Delta Tax_{tot} = \sum_{t=1}^{T}\sum_{q=1}^{Q}\sum_{j=1}^{m}[Tax^{q}(t) + Cost_{j}^{q}(t)\cdot\left(1 - imp^{j}(t)\right)\cdot multtax^{j}(t) +$$

$$+ W^{q}(t)\cdot\gamma\cdot multtax_{HHC}(t) + Tax^{q}(t)\cdot\sigma\cdot multtax_{GC}(t) +$$

$$+ Pr^{q}(t)\cdot\mu\cdot multtax_{inv}(t) +$$

$$+\sum_{s=1}^{n} Inv_{s}(t)\cdot\sum_{i=1}^{n} t_{is}(t)\cdot\left(1 - imp_{gfcf\ i}(t)\right)\cdot multtax_{i}(t) +$$

$$+\sum_{k=1}^{n}\left(\Delta C_{e}^{q}(t) - D^{q}(t)\right)\cdot\rho_{k}\cdot\left(1 - imp_{c\ k}(t)\right)\cdot multtax_{k}(t) -$$

$$-\Delta C_{e}^{q}(t)\cdot multtax_{e}(t) + \sum_{i=1}^{l}\Delta Exp_{i}(t)\cdot multtax_{i}(t)]$$

where:

ΔTax_{tot} – impact on tax revenues from apartment building EER work across all regions in the full period under consideration;

$\Delta Tax_{capex}^{q}(t)$ – impact on tax revenues of EER project capital expenditures in region *q* in reporting year *t*;

$\Delta Tax_{inv}(t)$ – impact on tax revenues of capital expenditures related to investment in new production capacity of EER project inputs in reporting year *t*;

$\Delta Tax_{HHC}^{q}(t)$ – impact on tax revenues of changes in structure of household consumption in region *q* in reporting year *t*;

$\Delta Tax_{exp}(t)$ – impact on tax revenues of growth in export volumes of primary resources resulting from EER projects in reporting year *t*; and

$multtax_i(t)$ – sectoral production multiplier for tax revenues of sector *i* (increase in total tax revenues per unit of increased output in sector *i* according to the symmetric Input-Output table [see Appendix 2]) in the reporting year *t*.

The budgetary efficiency of government support for EER works is determined by the ratio of budget expenditures to the present value of incremental tax revenues resulting from such works.

Final assessment of the effectiveness of budget expenditures depends on the sign of the indicator *E*, which is calculated as follows:

$$E = \sum_{t=1}^{T} \sum_{q=1}^{Q} \frac{-Subs(t) + \Delta Tax_{capex}^{q}(t) + \Delta Tax_{inv}(t) + \Delta Tax_{HC}^{q}(t) + \Delta Tax_{exp}(t)}{(1+r)^{t-1}}$$

where:

$Subs(t)$ – budgetary expenditures to cover costs of apartment building EER works, as well the cost of any interest-rate subsidy granted to loans used to finance EER projects across all regions in reporting year *t*;[28] and

r – discount rate (yields of ruble-denominated OFZ treasury bond with maturities of less than one year may be used here).

[28] A detailed description of the methodology for assessing the amount of budgetary spending to support apartment building EER works is presented in Appendix 2.

Appendix 2. Methodology for estimating sectoral production multipliers based on Input-Output tables

Basic definitions

Sectoral production multipliers for key macroeconomic indicators are defined as follows:

- Gross output – total increase in gross output (rubles per ruble of initial increase in sector output);
- GDP – total increase in GDP (rubles per ruble of initial increase in sector output);
- Budget revenues – total increase of national tax revenues (rubles per ruble of initial increase in sector output);
- Employment – total increase in national employment (measured in thousands of persons employed per million rubles of initial increase in sector output); and
- Greenhouse gas emissions – total increase in national greenhouse gas emissions (measured in tonnes of CO_2e per million rubles of initial increase in sector output).

Calculation tools

In estimating sectoral production multipliers, the symmetric Input-Output table (intersectoral balance) is used. Its structure is schematically shown in Table A.1. The intersectoral balance is comprised of three segments:

- Intermediate consumption (first quadrant), which consists of elements X_{ij}, which are estimated values for sector *j* consumption of sector *i* outputs ($i, j = \overline{1, n}$);
- Final consumption (second quadrant), which consists of estimated values for individual components of final demand, namely: household consumption, government consumption, fixed-capital formation, increases in inventories, and exports; and
- Value added (third quadrant): consists of estimated values for components of value added in various sectors, namely: wages, social insurance premiums, taxes, and profits (including depreciation).

Table A.1. Structure of symmetric Input-Output table

Sector	Intermediate consumption					Final demand					Imports	Gross output
	1	2	3	…	n	HH consumption	Gov't consumption	Fixed-capital formation	Increases in inventories	Exports		
1. Sector 1	X_{11}	X_{12}	X_{13}	…	X_{1n}	C_1	GC_1	$GFCF_1$	St_1	Exp_1	$\mathbf{Imp_1}$	X_1
2. Sector 2	X_{21}	X_{22}	X_{23}	…	X_{2n}	C_2	GC_2	$GFCF_2$	St_2	Exp_2	$\mathbf{Imp_2}$	X_2
3. Sector 3	X_{31}	X_{32}	X_{33}	…	X_{3n}	C_3	GC_3	$GFCF_3$	St_3	Exp_3	$\mathbf{Imp_3}$	X_3
…	…	…	…	…	…	…	…	…	…	…	**…**	…
…	…	…	…	…	…	…	…	…	…	…	**…**	…
n. Sector *n*	X_{n1}	X_{n2}	X_{n3}	…	X_{nn}	C_n	GC_n	$GFCF_n$	St_n	Exp_n	$\mathbf{Imp_n}$	X_n
Value added	$\mathbf{VA_1}$	$\mathbf{VA_2}$	$\mathbf{VA_3}$	**…**	$\mathbf{VA_n}$							
including: Wages	W_1	W_2	W_3	…	W_n							
Social insurance premi-ums												
Taxes (less subsidies)	Tax_1	Tax_2	Tax_3		Tax_n							
Profits	Pr_1	Pr_2	Pr_3		Pr_n							
Gross output	X_1	X_2	X_3		X_n							

For each sector in the table, each row of intersectoral balance (values in the first and second quadrants) reflects the structure of the use of the sector's output. Each sector's intersectoral column (values in the first and third quadrants) shows the distribution of sales income resulting from its production. The main identity of the table's intersectoral balance is that the sum of a given sector's row elements is equal to the sum of its column elements: these are two breakdowns of the value of the sector's output.

Methodological basis for calculations

The methodology for calculating sectoral production multipliers for various sectors of the economy is derived from the basic equation of Leontief's static model of intersectoral balance:

$\vec{X} = (E - A)^{-1} \cdot \vec{Y}$,

where $\vec{X}$ – vector of output in various sectors;

$\vec{Y}$ – vector of final demand for outputs of various sectors, minus imports;

$$\vec{Y} = \vec{C} + \overrightarrow{GC} + \overrightarrow{GFCF} + \overrightarrow{St} + \overrightarrow{Exp} - \overrightarrow{Imp}$$

$\vec{C}$ – household consumption vector;

$\overrightarrow{GC}$ – government consumption vector;

$\overrightarrow{GFCF}$ – fixed-capital formation vector;

$\overrightarrow{St}$ – inventory growth vector;

$\overrightarrow{Exp}$ – export vector;

$\overrightarrow{Imp}$ – import vector;

E – unit matrix of *n* x *n* dimension, where *n* is the number of sectors outlined in the intersectoral balance; and

A – matrix of technological coefficients (coefficients of direct input spending), consisting of elements a_{ij}, which show how much production of sector *i* is required to produce a unit of output in sector *j*: $a_{ij} = X_{ij}/X_j$.

$$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n1} & \cdots & a_{nn} \end{pmatrix}$$

The basic equation of the static model of the intersectoral balance can be transformed and expressed as:

$$\vec{X} = (E - A^{*})^{-1} \cdot \vec{Y}^{*} ,$$

where $\vec{Y}^*$ – vector of final demand for domestic products of various sectors, the components of which are:

$$Y_i^* = C_i \cdot (1 - imp_{C\,i}) + GC_i \cdot (1 - imp_{GC\,i}) + GFCF_i \cdot (1 - imp_{GFCF\,i}) +$$

$$+St_i \cdot (1 - imp_{St\,i}) + Exp_i \cdot \left(1 - imp_{Exp\,i}\right)$$

$imp_{C\,i}$ – share of imports in household consumption of sector *i* output;

$imp_{GC\,i}$ – share of imports in government consumption of sector *i* output;

$imp_{GFCF\,i}$ – share of imports in investment consumption of sector *i* output;

$imp_{St\,i}$ – share of imports in increases in inventories of sector *i* output; and

$imp_{Exp\,i}$ – share of imports in exports of sector *i* output;

A^* – import-adjusted (domestic) matrix of technological coefficients of direct input spending, consisting of elements a_{ij}, multiplied by the share of domestic products in the corresponding intersectoral flows:

$$A^* = \begin{pmatrix} a_{11} \cdot (1 - imp_{11}) & a_{12} \cdot (1 - imp_{12}) & \cdots & a_{1n} \cdot (1 - imp_{1n}) \\ a_{21} \cdot (1 - imp_{21}) & a_{22} \cdot (1 - imp_{22}) & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} \cdot (1 - imp_{n1}) & a_{n1} \cdot (1 - imp_{n1}) & \cdots & a_{nn} \cdot (1 - imp_{nn}) \end{pmatrix};$$

imp_{ij} – share of imports in sector *i* outputs in intermediate consumption by enterprises of sector *j*.

The shares of imports in individual flows of intermediate and final consumption are calculated as a ratio of the corresponding values in the import matrix (see Table A.2, below) and the symmetric Input-Output table.

Table A.2. Import matrix structure

Sectors	**Imports in intermediate consumption**				**Imports in final consumption**					**Gross imports**
	1	**2**	**…**	***n***	**Household consumption**	**Government consumption**	**Fixed-capital formation**	**Increase in inventories**	**Exports**	
1. Sector 1	Imp_{11}	Imp_{12}	…	Imp_{1n}	$Imp_{C\,1}$	$Imp_{GC\,1}$	$Imp_{GFCF\,1}$	$Imp_{St\,1}$	$Imp_{Exp\,1}$	$\mathbf{Imp_1}$
2. Sector 2	Imp_{21}	Imp_{22}	…	Imp_{2n}	$Imp_{C\,2}$	$Imp_{GC\,2}$	$Imp_{GFCF\,2}$	$Imp_{St\,2}$	$Imp_{Exp\,2}$	$\mathbf{Imp_2}$
…	…	…	…	…	…	…	…	…	…	**…**
…	…	…	…	…	…	…	…	…	…	**…**
n. Sector n	Imp_{n1}	Imp_{n2}	…	Imp_{nn}	$Imp_{C\,n}$	$Imp_{GC\,n}$	$Imp_{GFCF\,n}$	$Imp_{St\,n}$	$Imp_{Exp\,n}$	$\mathbf{Imp_n}$

Methodology for assessing multiplier effects of initial increase in final demand for domestic products

In accordance with the transformed equation of the static model of intersectoral balance, an increase in final demand for domestic products (assuming constant coefficients of direct input spending) leads to the following change in output volumes:

$$\Delta\vec{X} = \vec{X} - \vec{X}_0 = (E - A^*)^{-1} \cdot \vec{Y}^* - (E - A^*)^{-1} \cdot \vec{Y}_0^* = (E - A^*)^{-1} \cdot \Delta\vec{Y}^* ,$$

where $\vec{X}$ and $\vec{X}_0$ – output vectors in reporting and base periods;

$\vec{Y}^*$ and $\vec{Y}_0^*$ – vectors of final demand for domestic products in reporting and base periods; and

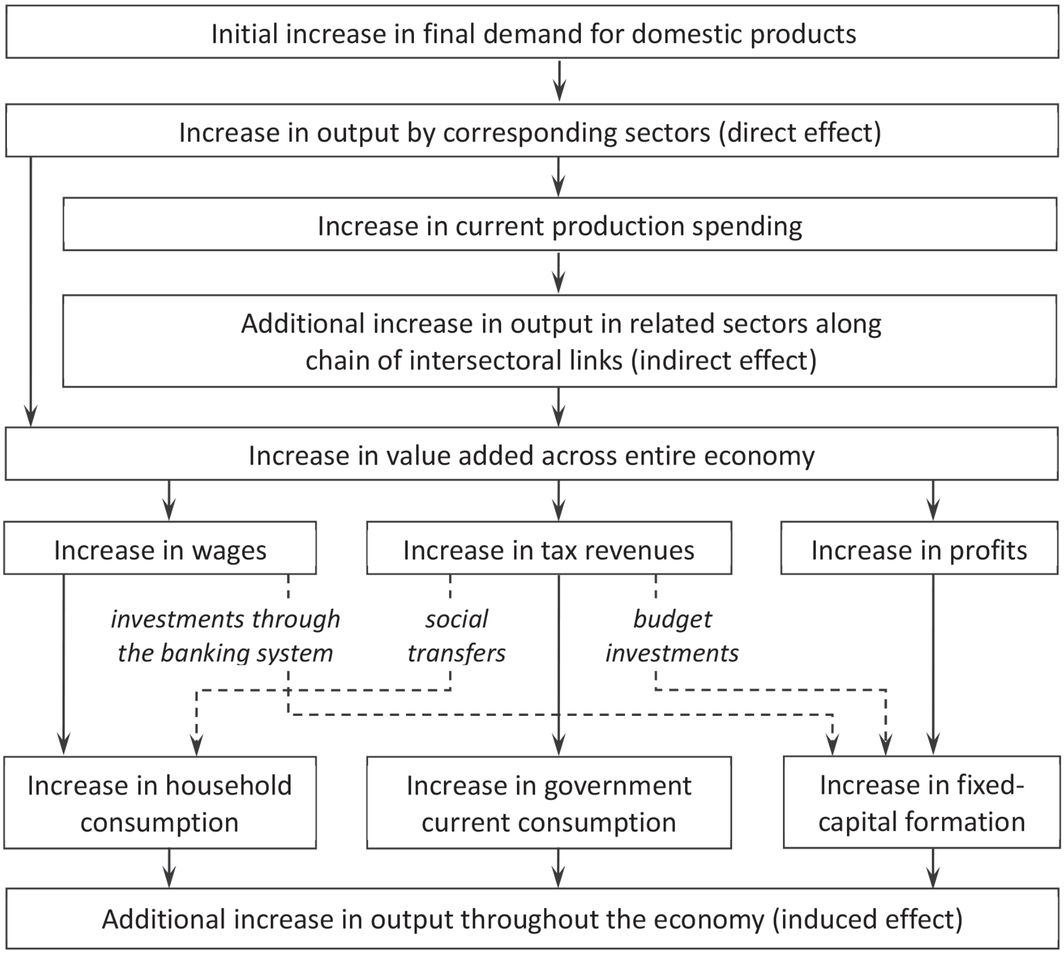
$\Delta\vec{X}$ and $\Delta\vec{Y}^*$ – growth vectors of output and final demand for domestic products in comparison with the base period.

This effect – the indirect effect – occurs due to the increased intermediate consumption necessary to meet the additional final demand for domestic products. It causes not only an increase in output, but also an increase in value added in various sectors, which is distributed to wages (less social insurance premiums and personal income taxes), social insurance premiums, tax revenues (including personal income taxes), and profit (including depreciation) in line with the prevailing distribution in the structure of the economy.

Additional incomes of the population (in the form of growth in wages), of the state (a growth in tax revenues), and business (a growth in profits) are then converted into an additional, induced increase in final demand. This leads to the emergence of a new macroeconomic effect – the induced effect. This can also be calculated using the basic equation of the static intersectoral balance model. The cumulative effect (impact) on gross output is calculated by summing up the direct, indirect, and induced effects.

The compounding macroeconomic effects of an initial increase in final demand for domestic products is illustrated in Figure A.1, below.

Figure A.1. Formation of multiplier effect related to increase in final demand for domestic products



The direct and indirect multiplier effect on gross output is estimated as the sum of the components of vector $\Delta\vec{X}^1$:

$$\Delta\vec{X}^1 = \begin{pmatrix} \Delta X_1^1 \\ \Delta X_2^1 \\ \dots \\ \Delta X_n^1 \end{pmatrix} = (E - A^*)^{-1} \cdot \Delta\vec{Y}^{1*} ,$$

where $\Delta\vec{Y}^{1*}$ – vector of initial increase in final demand for domestic products (direct effect).

The direct and indirect multiplier effect on GDP is estimated as the sum of the components of vector $\Delta\overrightarrow{VA}^1$:

$$\Delta\overrightarrow{VA}^1 = \begin{pmatrix} \Delta X_1^1 \cdot va_1 \\ \Delta X_2^1 \cdot va_2 \\ \dots \\ \Delta X_n^1 \cdot va_n \end{pmatrix},$$

where va_i – share of value added in sector *i* output.

The direct and indirect multiplier effect on wages is estimated as the sum of the components of vector $\Delta\vec{W}^1$:

$$\Delta\vec{W}^1 = \begin{pmatrix} \Delta X_1^1 \cdot w_1 \\ \Delta X_2^1 \cdot w_2 \\ \dots \\ \Delta X_n^1 \cdot w_n \end{pmatrix},$$

where w_i – share of labor costs (excluding social insurance premiums and personal income taxes) in sector *i* output.

The direct and indirect multiplier effect on social insurance premiums is estimated as the sum of the components of vector $\Delta\overrightarrow{SIP}^1$:

$$\Delta\overrightarrow{SIP}^1 = \begin{pmatrix} \Delta X_1^1 \cdot sip_1 \\ \Delta X_2^1 \cdot sip_2 \\ \dots \\ \Delta X_n^1 \cdot sip_n \end{pmatrix},$$

where sip_i – the share of social insurance premiums in sector *i* output.

The direct and indirect multiplier effect on tax revenues is estimated as the sum of the components of vector $\Delta\overrightarrow{Tax}^1$:

$$\Delta\overrightarrow{Tax}^1 = \begin{pmatrix} \Delta X_1^1 \cdot tax_1 \\ \Delta X_2^1 \cdot tax_2 \\ \dots \\ \Delta X_n^1 \cdot tax_n \end{pmatrix},$$

where tax_i – share of taxes (including personal income taxes) in sector *i* output.

The above-mentioned shares are estimated using intersectoral balance data, as well as data on the volumes of tax and insurance deductions.

The vector of profits due to direct and indirect effects is found by taking the value-added growth vector $\Delta\overrightarrow{VA}^1$ and subtracting the growth vectors for wages $\Delta\overrightarrow{W}^1$, social insurance premiums $\Delta\overrightarrow{SIP}^1$ and taxes $\Delta\overrightarrow{Tax}^1$.

$$\Delta\overrightarrow{Pr}^1 = \Delta\overrightarrow{VA}^1 - \Delta\overrightarrow{W}^1 - \Delta\overrightarrow{SIP}^1 - \Delta\overrightarrow{Tax}^1 = \begin{pmatrix} \Delta X_1^1 \cdot (va_1 - w_1 - sip_1 - tax_1) \\ \Delta X_2^1 \cdot (va_2 - w_2 - sip_2 - tax_2) \\ \dots \\ \Delta X_n^1 \cdot (va_n - w_n - sip_n - tax_n) \end{pmatrix}$$

An estimate of the increase in final demand is necessary to calculate the induced effect. This is calculated by summing increases in household consumption, government consumption, and fixed-capital formation (derived from investments of excess household savings, budget revenues, and corporate profits).

The aggregate increase in wages is calculated by summing the components of vector $\Delta\overrightarrow{W}^1$: $\Delta W^1 = \sum_{i=1}^{n}(\Delta X_i^1 \cdot w_i)$. The total increase in taxes, meanwhile, is calculated by summing the components of vector $\Delta\overrightarrow{Tax}^1$: $\Delta Tax^1 = \sum_{i=1}^{n}(\Delta X_i^1 \cdot tax_i)$.

The vector for the induced increase in household demand for domestic and imported products $\Delta\vec{C}^2$ is calculated using the growth of wages ΔW^1; the elasticity of consumer spending in terms of household income γ; and vector $\vec{\beta}$, which captures the structure of household consumption by product.

$$\Delta\vec{C}^2 = \Delta W^1 \cdot \gamma \cdot \vec{\beta} = \begin{pmatrix} \sum_{i=1}^{n}(\Delta X_i^1 \cdot w_i) \cdot \gamma \cdot \beta_1 \\ \sum_{i=1}^{n}(\Delta X_i^1 \cdot w_i) \cdot \gamma \cdot \beta_2 \\ \dots \\ \sum_{i=1}^{n}(\Delta X_i^1 \cdot w_i) \cdot \gamma \cdot \beta_n \end{pmatrix}$$

Here β_i – share of sector *i* output in the structure of household consumption.

The vector for induced investments in various sectors from household savings $\Delta\overrightarrow{HInv}^2$ is calculated using the growth in wages ΔW^1, the elasticity of investments from household savings by wages ε, and the vector $\vec{\tau}$, which captures the sectoral distribution of investments originating from household savings.

$$\Delta\overrightarrow{HInv}^2 = \Delta W^1 \cdot \varepsilon \cdot \vec{\tau} = \begin{pmatrix} \sum_{i=1}^{n} (\Delta X_i^1 \cdot w_i) \cdot \varepsilon \cdot \tau_1 \\ \sum_{i=1}^{n} (\Delta X_i^1 \cdot w_i) \cdot \varepsilon \cdot \tau_2 \\ \dots \\ \sum_{i=1}^{n} (\Delta X_i^1 \cdot w_i) \cdot \varepsilon \cdot \tau_n \end{pmatrix}$$

Here τ_i – share of sector *i* in the sectoral distribution of investments originating from household savings.

The vector of the induced increase in government consumption of domestic and imported products of various sectors $\Delta\overrightarrow{GC}^2$ is calculated using tax increases ΔTax^1, the tax elasticity of government consumption σ, and the vector $\vec{\omega}$, which captures the structure of government consumption by product.

$$\Delta\overrightarrow{GC}^2 = \Delta Tax^1 \cdot \sigma \cdot \vec{\omega} = \begin{pmatrix} \sum_{i=1}^{n} (\Delta X_i^1 \cdot tax_i) \cdot \sigma \cdot \omega_1 \\ \sum_{i=1}^{n} (\Delta X_i^1 \cdot tax_i) \cdot \sigma \cdot \omega_2 \\ \dots \\ \sum_{i=1}^{n} (\Delta X_i^1 \cdot tax_i) \cdot \sigma \cdot \omega_n \end{pmatrix}$$

Here ω_i – share of sector *i* output in the structure of government consumption.

The vector of induced budget investments in various sectors $\Delta\overrightarrow{GInv}^2$ is calculated using the increase of budget revenues ΔTax^1, the tax elasticity of budget investments π and the vector $\vec{\varphi}$, which captures the sectoral distribution of budget investments.

$$\Delta\overrightarrow{GInv}^2 = \Delta Tax^1 \cdot \pi \cdot \vec{\varphi} = \begin{pmatrix} \sum_{i=1}^{n} (\Delta X_i^1 \cdot tax_i) \cdot \pi \cdot \varphi_1 \\ \sum_{i=1}^{n} (\Delta X_i^1 \cdot tax_i) \cdot \pi \cdot \varphi_2 \\ \dots \\ \sum_{i=1}^{n} (\Delta X_i^1 \cdot tax_i) \cdot \pi \cdot \varphi_n \end{pmatrix}$$

Here φ_i – share of sector *i* in the sectoral distribution of budget investments.

The vector of the induced increase in corporate investment in various sectors $\Delta\overrightarrow{BInv}^2$ is calculated using the vector of profit growth $\Delta\overrightarrow{Pr}^1$ and the elasticity of corporate investments in terms of profit μ.

$$\Delta\overrightarrow{BInv}^2 = \Delta\overrightarrow{Pr}^1 \cdot \mu = \begin{pmatrix} \Delta X_1^1 \cdot (va_1 - w_1 - sip_1 - tax_1) \cdot \mu \\ \Delta X_2^1 \cdot (va_2 - w_2 - sip_2 - tax_2) \cdot \mu \\ \dots \\ \Delta X_n^1 \cdot (va_n - w_n - sip_n - tax_n) \cdot \mu \end{pmatrix}$$

The vector of cumulative induced investment in various sectors $\Delta\overrightarrow{Inv}^2$ is calculated by summing the vectors for induced investment from household savings $\Delta\overrightarrow{HInv}^2$, budget investments $\Delta\overrightarrow{GInv}^2$, and corporate investment $\Delta\overrightarrow{BInv}^2$.

The vector of the induced increase in fixed-capital formation in various sectors $\Delta\overrightarrow{GFCF}^2$ is calculated by multiplying the matrix of the technological structure of fixed capital accumulation *T* (consisting of elements t_{ij}, representing how much investment demand for sector *i* output is formed by a unit of investment in sector *j*) by the vector of cumulative induced investment growth $\Delta\overrightarrow{Inv}^2$.

$$\Delta\overrightarrow{GFCF}^2 = T \cdot \overrightarrow{Inv}^2 = \begin{pmatrix} \sum_{j=1}^{n} t_{1j} \cdot inv_j^2 \\ \sum_{j=1}^{n} t_{2j} \cdot inv_j^2 \\ \dots \\ \sum_{j=1}^{n} t_{nj} \cdot inv_j^2 \end{pmatrix},$$

where inv_j^2 – cumulative induced investment sector *j* (*i.e.*, component *j* of vector $\overrightarrow{Inv}^2$).

The next step is calculation of the vectors of induced increases in final demand for domestic products.

The vector of the induced increase in household consumption of domestic products $\Delta\vec{C}^{2*}$ is obtained by multiplying the components of vector $\Delta\vec{C}^{2}$ by the share of domestic products in the corresponding consumption flows:

$$\Delta\vec{C}^{2*} = \begin{pmatrix} \sum_{i=1}^{n}(\Delta X_i^1 \cdot w_i) \cdot \gamma \cdot \beta_1 \cdot (1 - imp_{C\,1}) \\ \sum_{i=1}^{n}(\Delta X_i^1 \cdot w_i) \cdot \gamma \cdot \beta_2 \cdot (1 - imp_{C\,2}) \\ \dots \\ \sum_{i=1}^{n}(\Delta X_i^1 \cdot w_i) \cdot \gamma \cdot \beta_n \cdot (1 - imp_{C\,n}) \end{pmatrix}$$

where $imp_{C\,i}$ – share of imports in household consumption of sector *i* output.

The vector of the induced increase in government consumption of domestic products $\Delta\overrightarrow{GC}^{2*}$ is obtained by multiplying the components of the vector $\Delta\overrightarrow{GC}^{2}$ by the share of domestic products in the corresponding consumption flows:

$$\Delta\overrightarrow{GC}^{2*} = \begin{pmatrix} \sum_{i=1}^{n}(\Delta X_i^1 \cdot tax_i) \cdot \sigma \cdot \omega_1 \cdot (1 - imp_{GC\,1}) \\ \sum_{i=1}^{n}(\Delta X_i^1 \cdot tax_i) \cdot \sigma \cdot \omega_2 \cdot (1 - imp_{GC\,2}) \\ \dots \\ \sum_{i=1}^{n}(\Delta X_i^1 \cdot tax_i) \cdot \sigma \cdot \omega_n \cdot (1 - imp_{GC\,n}) \end{pmatrix}$$

where $imp_{GC\,i}$ – share of imports in government consumption of sector *i* output.

The vector of the induced increase in investment demand for domestic products $\Delta\overrightarrow{GFCF}^{2*}$ is obtained by multiplying the components of the vector $\Delta\overrightarrow{GFCF}^{2}$ by the share of domestic products in the corresponding consumption flows:

$$\Delta\overrightarrow{GFCF}^{2*} = \begin{pmatrix} \sum_{j=1}^{n} t_{1j} \cdot inv_j^2 \cdot (1 - imp_{GFCF\ 1}) \\ \sum_{j=1}^{n} t_{2j} \cdot inv_j^2 \cdot (1 - imp_{GFCF\ 1}) \\ \dots \\ \sum_{j=1}^{n} t_{nj} \cdot inv_j^2 \cdot (1 - imp_{GFCF\ 1}) \end{pmatrix}$$

where $imp_{GFCF\ i}$ – share of imports in investment consumption of sector *i* output.

The vector of the cumulative induced increase in final demand for domestic products $\Delta\vec{Y}^{2*}$ is calculated by summing the vectors of induced increases in household, government, and investment consumption of domestic products.

$$\Delta\vec{Y}^{2*} = \Delta\vec{C}^{2*} + \Delta\overrightarrow{GC}^{2*} + \Delta\overrightarrow{GFCF}^{2*}$$

The induced multiplier effect on gross output is the sum of the components of vector $\Delta\vec{X}^{2}$.

$$\Delta\vec{X}^{2} = \begin{pmatrix} \Delta X_1^2 \\ \Delta X_2^2 \\ \dots \\ \Delta X_n^2 \end{pmatrix} = (E - A^*)^{-1} \cdot \Delta\vec{Y}^{2*}$$

The induced multiplier effect on GDP is the sum of the components of vector $\Delta\overrightarrow{VA}^{2}$.

$$\Delta\overrightarrow{VA}^{2} = \begin{pmatrix} \Delta X_1^2 \cdot va_1 \\ \Delta X_2^2 \cdot va_2 \\ \dots \\ \Delta X_n^2 \cdot va_n \end{pmatrix}$$

The induced multiplier effect on wages is the sum of the components of vector $\Delta\vec{W}^{2}$.

$$\Delta\vec{W}^{2} = \begin{pmatrix} \Delta X_1^2 \cdot w_1 \\ \Delta X_2^2 \cdot w_2 \\ \dots \\ \Delta X_n^2 \cdot w_n \end{pmatrix}$$

The induced multiplier effect on social insurance premiums is the sum of the components of vector $\Delta\overrightarrow{SIP}^2$.

$$\Delta\overrightarrow{SIP}^2 = \begin{pmatrix} \Delta X_1^2 \cdot sip_1 \\ \Delta X_2^2 \cdot sip_2 \\ \dots \\ \Delta X_n^2 \cdot sip_n \end{pmatrix}$$

The induced multiplier effect on budget revenues is the sum of the components of vector $\Delta\overrightarrow{Tax}^2$.

$$\Delta\overrightarrow{Tax}^2 = \begin{pmatrix} \Delta X_1^2 \cdot tax_1 \\ \Delta X_2^2 \cdot tax_2 \\ \dots \\ \Delta X_n^2 \cdot tax_n \end{pmatrix}$$

Based on the outputs from the above formulas, estimates of the cumulative multiplier effects of an initial increase in final demand for domestic products are calculated.

The cumulative multiplier effect on gross output is the sum of the components of vector $\Delta\vec{X}$.

$$\Delta\vec{X} = \begin{pmatrix} \Delta X_1 \\ \Delta X_2 \\ \dots \\ \Delta X_n \end{pmatrix} = \Delta\vec{X}^1 + \Delta\vec{X}^2 = \begin{pmatrix} \Delta X_1^1 + \Delta X_1^2 \\ \Delta X_2^1 + \Delta X_1^2 \\ \dots \\ \Delta X_n^1 + \Delta X_1^2 \end{pmatrix} = (E - A^*)^{-1} \cdot \left(\Delta\vec{Y}^{1*} + \Delta\vec{Y}^{2*}\right)$$

The cumulative multiplier effect on GDP is the sum of the components of vector $\Delta\overrightarrow{VA}$.

$$\Delta\overrightarrow{VA} = \begin{pmatrix} \Delta VA_1 \\ \Delta VA_2 \\ \dots \\ \Delta VA_n \end{pmatrix} = \Delta\overrightarrow{VA}^1 + \Delta\overrightarrow{VA}^2 = \begin{pmatrix} (\Delta X_1^1 + \Delta X_1^2) \cdot va_1 \\ (\Delta X_2^1 + \Delta X_2^2) \cdot va_2 \\ \dots \\ (\Delta X_n^1 + \Delta X_n^2) \cdot va_n \end{pmatrix} = \begin{pmatrix} \Delta X_1 \cdot va_1 \\ \Delta X_2 \cdot va_2 \\ \dots \\ \Delta X_n \cdot va_n \end{pmatrix}$$

The cumulative multiplier effect on household income is the sum of the components of vector $\Delta\vec{W}$.

$$\Delta\vec{W} = \begin{pmatrix} \Delta W_1 \\ \Delta W_2 \\ \dots \\ \Delta W_n \end{pmatrix} = \Delta\vec{W}^1 + \Delta\vec{W}^2 = \begin{pmatrix} (\Delta X_1^1 + \Delta X_1^2) \cdot w_1 \\ (\Delta X_2^1 + \Delta X_2^2) \cdot w_2 \\ \dots \\ (\Delta X_n^1 + \Delta X_n^2) \cdot w_n \end{pmatrix} = \begin{pmatrix} \Delta X_1 \cdot w_1 \\ \Delta X_2 \cdot w_2 \\ \dots \\ \Delta X_n \cdot w_n \end{pmatrix}$$

The cumulative multiplier effect on social insurance premiums is the sum of the components of vector $\Delta\overrightarrow{SIP}$.

$$\Delta\overrightarrow{SIP} = \begin{pmatrix} \Delta SIP_1 \\ \Delta SIP_2 \\ \dots \\ \Delta SIP_n \end{pmatrix} = \Delta\overrightarrow{SIP}^1 + \Delta\overrightarrow{SIP}^2 = \begin{pmatrix} (\Delta X_1^1 + \Delta X_1^2) \cdot sip_1 \\ (\Delta X_2^1 + \Delta X_2^2) \cdot sip_2 \\ \dots \\ (\Delta X_n^1 + \Delta X_n^2) \cdot sip_n \end{pmatrix} = \begin{pmatrix} \Delta X_1 \cdot sip_1 \\ \Delta X_2 \cdot sip_2 \\ \dots \\ \Delta X_n \cdot sip_n \end{pmatrix}$$

The cumulative multiplier effect on budget revenues is the sum of the components of vector $\Delta\overrightarrow{Tax}$.

$$\Delta\overrightarrow{Tax} = \begin{pmatrix} \Delta Tax_1 \\ \Delta Tax_2 \\ \dots \\ \Delta Tax_n \end{pmatrix} = \Delta\overrightarrow{Tax}^1 + \Delta\overrightarrow{Tax}^2 = \begin{pmatrix} (\Delta X_1^1 + \Delta X_1^2) tax_1 \\ (\Delta X_2^1 + \Delta X_2^2) tax_2 \\ \dots \\ (\Delta X_n^1 + \Delta X_n^2) tax_n \end{pmatrix} = \begin{pmatrix} \Delta X_1 \cdot tax_1 \\ \Delta X_2 \cdot tax_2 \\ \dots \\ \Delta X_n \cdot tax_n \end{pmatrix}$$

In determining sectoral production multipliers, the initial increase in final demand for domestic products is set to a value of one and stems solely from a given sector:

$$\Delta\vec{Y}^{1*} = \Delta\vec{X}^0 = \begin{pmatrix} 0 \\ 0 \\ \dots \\ \Delta X_k \\ \dots \\ 0 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ \dots \\ 1 \\ \dots \\ 0 \end{pmatrix}$$

Here $\Delta\vec{X}^0$ – vector of initial increase of economic output, and ΔX_k – initial increase in output of a given sector.

Substituting this vector into the corresponding formulas for the calculation of direct, indirect, and induced effects, we obtain estimates of specific multiplier effects on gross output, GDP, budget revenues, and household income (per unit of output in a given sector). These are sectoral production multipliers.

The effects of increased output in a given sector of the Russian economy on national greenhouse gas emissions (measured in CO_2e) can be expressed as follows:

$$\Delta\overrightarrow{GHG} = GHG \cdot \Delta\vec{X}$$

$$\Delta GHG = \sum_{i=1}^{n} \Delta GHG_i$$

where:

ΔGHG – cumulative effect on national greenhouse gas emissions due to of an increase in output in one sector;

ΔGHG_i – increase in greenhouse gas emissions in sector *i* of the Russian economy (component *i* of the vector $\Delta\overrightarrow{GHG}$);

GHG – diagonal matrix of greenhouse gas emissions per unit of output of various sectors of the Russian economy:

$$GHG = \begin{pmatrix} GHG_1/X_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & GHG_n/X_n \end{pmatrix}$$

GHG_i/X_i – greenhouse gas emissions per unit of output of sector *i* of the Russian economy; and

GHG_i – greenhouse gas emissions in sector *i* of the Russian economy.[29]

The formula yields an estimate of the sectoral production multiplier of greenhouse gas emissions when vector $\Delta\vec{X}$ is equal to the cumulative increase in output in various sectors due to a single initial increase in a given sector's output.

[29] Data on annual greenhouse gas emissions of various sectors of the Russian economy can be found in the country's National Inventory Report, prepared according to United Nations Framework Convention on Climate Change (UNFCCC) reporting guidelines.

The effects of increased output in a given sector of the Russian economy on national employment can be expressed as follows:

$$\Delta\overrightarrow{Emp} = Emp \cdot \Delta\vec{X}$$

$$\Delta Emp = \sum_{i=1}^{n} \Delta Emp_{\,i}$$

where:

ΔEmp – cumulative effect on national employment due to of an increase in output in one sector;

$\Delta Emp_{\,i}$ – employment growth in sector *i* of the Russian economy (component *i* of vector $\Delta\overrightarrow{Emp}$);

Emp – diagonal matrix of labor intensity in various sectors of the Russian economy:

$$Emp = \begin{pmatrix} Emp_{\,1}/X_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & Emp_{\,n}/X_n \end{pmatrix}; \text{ and}$$

$Emp_{\,i}/X_i$ – direct labor intensity (*i.e.*, employment per unit of output) in sector *i* of the Russian economy.

The formula yields an estimate of the sectoral production multiplier of employment when vector $\Delta\vec{X}$ is equal to the cumulative increase in output in various sectors due to a single initial increase in a given sector's output.

Methodology for assessing multiplier effects of an initial increase in household consumption, government consumption, and fixed-capital formation in a selected sector

The cumulative multiplier effect on gross output from an increase in household consumption is the sum of the components of the vector of increased sectoral output $\Delta\vec{X}$:

$$\Delta\vec{X} = Multx \cdot \Delta\vec{X}^0 = \begin{pmatrix} multx_{11} & \cdots & multx_{1n} \\ \vdots & \ddots & \vdots \\ multx_{n1} & \cdots & multx_{nn} \end{pmatrix} \cdot \begin{pmatrix} \Delta C_1^0 \cdot (1 - imp_{C\,1}) \\ \Delta C_2^0 \cdot (1 - imp_{C\,2}) \\ \cdots \\ \Delta C_n^0 \cdot (1 - imp_{C\,n}) \end{pmatrix} =$$

$$= \begin{pmatrix} \sum_{j=1}^{n} multx_{1j} \cdot \Delta C_j^0 \cdot \left(1 - imp_{C\,j}\right) \\ \sum_{j=1}^{n} multx_{2j} \cdot \Delta C_j^0 \cdot \left(1 - imp_{C\,j}\right) \\ \cdots \\ \sum_{j=1}^{n} multx_{nj} \cdot \Delta C_j^0 \cdot \left(1 - imp_{C\,j}\right) \end{pmatrix}$$

where:

$Multx$ – matrix of sectoral output multipliers;

$multx_{ij}$ – final multiplier effect on sector *i* output from a unit increase in sector *j* output;

$\Delta C_j^0 = \Delta C^0 \cdot \beta_j$ – initial increase in household consumption of sector *j* output;

ΔC^0 – total initial increase in household consumption;

β_j – share of sector *j* output in current structure of household consumption; and

$imp_{C\,j}$ – average share of imports in household consumption of sector *j* output.

The per-unit multiplier effect on gross output from an increase in household consumption is the sum of the components of vector $\overrightarrow{multx}_{HHC}$:

$$\overrightarrow{multx}_{HHC} = \begin{pmatrix} \sum_{j=1}^{n} multx_{1j} \cdot \beta_j \cdot \left(1 - imp_{C\,j}\right) \\ \sum_{j=1}^{n} multx_{2j} \cdot \beta_j \cdot \left(1 - imp_{C\,j}\right) \\ \cdots \\ \sum_{j=1}^{n} multx_{nj} \cdot \beta_j \cdot \left(1 - imp_{C\,j}\right) \end{pmatrix}$$

Per-unit impacts of increases in household consumption on other macroeconomic indicators (*i.e.*, GDP, budget revenues, household incomes, employment, greenhouse gas emissions) are calculated using estimates of sector multiplier effects and the sectoral shares of a given indicator's composition. For instance, the household consumption multiplier for GDP is the sum the components of the following vector:

$$\overrightarrow{multva}_{HHC} = \begin{pmatrix} \sum_{j=1}^{n} multx_{1j} \cdot \beta_j \cdot \left(1 - imp_{C\ j}\right) \cdot va_1 \\ \sum_{j=1}^{n} multx_{2j} \cdot \beta_j \cdot \left(1 - imp_{C\ j}\right) \cdot va_2 \\ \dots \\ \sum_{j=1}^{n} multx_{nj} \cdot \beta_j \cdot \left(1 - imp_{C\ j}\right) \cdot va_n \end{pmatrix}$$

Here va_i – share of value added in sector *i* output.

The cumulative government consumption multiplier effect on gross output is the sum of the components of the vector of increased sectoral output $\Delta\vec{X}$:

$$\Delta\vec{X} = Multx \cdot \Delta\vec{X}^0 = Multx \cdot \begin{pmatrix} \Delta GC_1^0 \cdot (1 - imp_{GC\ 1}) \\ \Delta GC_2^0 \cdot (1 - imp_{GC\ 2}) \\ \dots \\ \Delta GC_n^0 \cdot (1 - imp_{GC\ n}) \end{pmatrix} =$$

$$= \begin{pmatrix} \sum_{j=1}^{n} multx_{1j} \cdot \Delta GC_j^0 \cdot \left(1 - imp_{GC\ j}\right) \\ \sum_{j=1}^{n} multx_{2j} \cdot \Delta GC_j^0 \cdot \left(1 - imp_{GC\ j}\right) \\ \dots \\ \sum_{j=1}^{n} multx_{nj} \cdot \Delta GC_j^0 \cdot \left(1 - imp_{GC\ j}\right) \end{pmatrix}$$

where:

$\Delta GC_j^0 = \Delta GC^0 \cdot \omega_j$ – initial increase in government consumption of sector *j* output;

ΔGC^0 – total initial increase in government consumption;

ω_j – share of sector *j* output in structure of government consumption; and

$imp_{GC\ j}$ – average share of imports in government consumption of sector *j* output.

The per-unit multiplier effect on gross output from an increase in government consumption is the sum of the components of vector $\overrightarrow{multx_{GC}}$:

$$\overrightarrow{multx_{GC}} = \begin{pmatrix} \sum_{j=1}^{n} multx_{1j} \cdot \omega_j \cdot (1 - imp_{GC\ j}) \\ \sum_{j=1}^{n} multx_{2j} \cdot \omega_j \cdot (1 - imp_{GC\ j}) \\ \dots \\ \sum_{j=1}^{n} multx_{nj} \cdot \omega_j \cdot (1 - imp_{GC\ j}) \end{pmatrix}$$

Per-unit impacts of increases in government consumption on other macroeconomic indicators (*i.e.*, GDP, budget revenues, household incomes, employment, greenhouse gas emissions) are calculated using estimates of sector multiplier effects and the sectoral shares of a given indicator's composition. For instance, the government consumption multiplier for GDP is calculated by summing the components of the following vector:

$$\overrightarrow{multva_{GC}} = \begin{pmatrix} \sum_{j=1}^{n} multx_{1j} \cdot \omega_j \cdot (1 - imp_{GC\ j}) \cdot va_1 \\ \sum_{j=1}^{n} multx_{2j} \cdot \omega_j \cdot (1 - imp_{GC\ j}) \cdot va_2 \\ \dots \\ \sum_{j=1}^{n} multx_{nj} \cdot \omega_j \cdot (1 - imp_{GC\ j}) \cdot va_n \end{pmatrix}$$

The cumulative multiplier effect on gross output from investment in a given sector is the sum of the components of the vector of increased sectoral output $\Delta\vec{X}$:

$$\Delta\vec{X} = Multx \cdot \Delta\vec{X}^0 = Multx \cdot \begin{pmatrix} \Delta GFCF_1^0 \cdot (1 - imp_{GFCF\ 1}) \\ \Delta GFCF_2^0 \cdot (1 - imp_{GCF\ 2}) \\ \dots \\ \Delta GFCF_n^0 \cdot (1 - imp_{GFCF\ n}) \end{pmatrix} =$$

$$= \begin{pmatrix} \sum_{j=1}^{n} multx_{1j} \cdot \Delta GFCF_j^0 \cdot \left(1 - imp_{GFCF\ j}\right) \\ \sum_{j=1}^{n} multx_{2j} \cdot \Delta GFCF_j^0 \cdot \left(1 - imp_{GFCF\ j}\right) \\ \dots \\ \sum_{j=1}^{n} multx_{nj} \cdot \Delta GFCF_j^0 \cdot \left(1 - imp_{GFCF\ j}\right) \end{pmatrix}$$

where:

$\Delta GFCF_j^0 = \Delta Inv_s^0 \cdot t_{jk}$ – initial increase in investment consumption of sector *j* output;

ΔInv_k^0 – initial investment in fixed assets in a given sector (sector *k*);

t_{jk} – share of sector *j* output in current structure of sector *k* capital expenditures; and

$imp_{GFCF\ j}$ – share of imports in investment consumption of sector *j* output.

The per-unit multiplier effect on gross output from an increase in fixed-assets investment in the given sector is defined as the sum of the components of vector $\overrightarrow{multx}_{\text{инв}\ k}$, which is calculated as follows:

$$\overrightarrow{multx}_{\text{инв}\ k} = \begin{pmatrix} \sum_{j=1}^{n} multx_{1j} \cdot t_{jk} \cdot \left(1 - imp_{GFCF\ j}\right) \\ \sum_{j=1}^{n} multx_{2j} \cdot t_{jk} \cdot \left(1 - imp_{GFCF\ j}\right) \\ \dots \\ \sum_{j=1}^{n} multx_{nj} \cdot t_{jk} \cdot \left(1 - imp_{GFCF\ j}\right) \end{pmatrix}$$

Per-unit impacts of increases in investments in fixed assets in a given sector on other macroeconomic indicators (*i.e.*, GDP, budget revenues, household incomes, employment, greenhouse gas emissions) are calculated using estimates of sector multiplier effects and the sectoral shares of a given indicator's composition. For instance, the investment multiplier for GDP is calculated by summing the components of the following vector:

$$\overrightarrow{multva}_{\text{инв}\ s} = \begin{pmatrix} \sum_{j=1}^{n} multx_{1j} \cdot t_{jk} \cdot \left(1 - imp_{GFCF\ j}\right) \cdot va_1 \\ \sum_{j=1}^{n} multx_{2j} \cdot t_{jk} \cdot \left(1 - imp_{GFCF\ j}\right) \cdot va_2 \\ \dots \\ \sum_{j=1}^{n} multx_{nj} \cdot t_{jk} \cdot \left(1 - imp_{GFCF\ j}\right) \cdot va_n \end{pmatrix}$$

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