DOI: 10.17747/2618-947X-2023-2-164-179

Analysis of key directions and proposals to minimise the economic impact of the global energy transition on large energy-intensive industrial consumers of electricity and capacity

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Abstract

Over the past decade, the global energy sector has undergone major fundamental and structural changes as part of the global energy transition. The energy industry of the Russian Federation, as a key player in the global energy market and the world economy as a whole, is undergoing similar changes. In this case, in terms of ensuring high competitiveness and long-term energy security of the state, it is crucial to set priorities and build models of sustainable development for each of the industries related to the energy sector. Indeed, the process of replacing carbon-intensive energy sources with a systematic increase in the share of new, renewable energy sources (RES) should be gradual and consistent to avoid imbalances in energy systems and maintain equity for all stakeholders. In this context, the search for advanced, low-carbon energy sources is a priority for the vast majority of countries around the world. In addition, the development of renewable energy is one of the goals of Russia's energy strategy until 2035. At the same time, despite the obvious advantages of the Russian power industry such as the absence of dependence on budget funds, the overwhelming majority of private investment in the industry, the availability of effective mechanisms for attracting investment and the basic principle of balancing the interests of all market participants, there are also negative consequences of this approach. The nationwide task of developing the energy system and increasing the availability of electricity on the territory of the Russian Federation in terms of financing is becoming an exclusive burden on electricity consumers themselves; even insignificant risks in their operation can turn into a threat not only to sustainable development, but also to their very existence. In this context, the analysis of key directions and proposals to minimise the economic impact of the global energy transition on large energy-intensive industrial consumers of electricity and capacity is of particular relevance.

Keywords: global energy transition, mechanisms to stimulate investment, low-carbon generation, activities to minimise economic impact.

For citation:

Balashov M.M. (2023). Analysis of key directions and proposals to minimise the economic impact of the global energy transition on large energy-intensive industrial consumers of electricity and capacity. *Strategic Decisions and Risk Management,* 14(2): 164-179. DOI: 10.17747/2618-947X-2023-2-164-179.

大型能源密集型工业用户的全球能源转型重点领域分析与尽量减少经济影响的建议

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摘要

最近十年中作为全球能源转型的一部分，全球能源行业经历了重大的根本性结构变革。作为全球能源市场和整个世界经济的主要参与者之一，俄罗斯联邦的能源工业也面临着类似的变化。优先考虑并建立各能源相关产业的可持续发展模式，对于确保国家的高竞争力和长期能源安全至关重要。应逐步取代传统的高碳排放化石资源（主要是石油产品和煤炭），同时系统地增加新的可再生能源（RES）的比例。尤其重要的是，这一过程必须顺序进行，以避免能源系统失衡，并避免破坏所有参与者的利益平衡。

目前寻找先进的、碳密集度最低的能源是世界上绝大多数国家的优先事项。此外，俄罗斯能源战略的目标之一是发展可再生能源：计划到 2035 年投资超过 1 万亿卢布发展可再生能源。俄罗斯电力工业优势明显：不依赖预算资金、该行业绝大多数为私人投资、存在吸引投资的有效机制以及平衡所有市场参与者利益的基本原则。然而，这种方法的弊端也很大：在俄罗斯联邦，发展能源系统和增加电力供应的国家任务正成为电力消费者自身的唯一负担，在更大程度上，成为能源密集型大消费者的融资负担。同时，即使是很小的风险也可能不仅威胁到可持续发展，而且威胁到它们的整体生存。

因此，大型能源密集型工业用户的全球能源转型重点领域与尽量减少经济影响的建议分析非常有意义。

关键词： 全球能源转型、吸引投资的机制、低碳发电、尽量减少经济影响的工具。

供引用:

Balashov M.M.（2023）。大型能源密集型工业用户的全球能源转型重点领域分析与尽量减少经济影响的建议。战略决策和风险管理，14（2）：164–179。DOI：10.17747/2618-947X-2023-2-164-179。

Introduction

In order to analyse the key directions and proposals for minimising the economic consequences of the global energy transition for large energy-intensive industrial consumers of electricity and capacity, it is necessary to determine the basic conditions of the upcoming energy transition. They will provide the basis for setting the direction for reducing the additional economic burden on energy-intensive industrial consumers associated with the inevitable increase in electricity prices:

1. Major decarbonisation projects will be more expensive and their feasibility will depend heavily on the market value of emissions.
2. In the power sector, the decarbonisation process has two distinct phases. In the first phase, projects are being implemented to convert coal-fired power plants to gas combustion and to replace old generation with lower carbon footprint capacity (NPP, HPP, SPP, WPP). The second stage involves the intensive replacement of fossil fuel-fired generation with carbon-free one. The commissioning of this capacity is a major contributor to the increase in the cost of electricity to end users [Lee, 2026].
3. The decarbonisation of Russia's power industry is inevitable; it has already begun and will continue.
4. Large electricity intensive consumers are most exposed to the negative impact of electricity price increases. If all energy construction and reconstruction plans in the generation sector are implemented, by 2035 the single price in the wholesale electricity and capacity market will increase by 80%, calculated in 2023 prices.[1]
5. The financial burden on electricity consumers from the increase in electricity prices correlates with the share of electricity costs in their production costs.

The task of minimising the economic impact is defined, taking into account the specified conditions.

Before formulating and systematising the main directions of solving the problem of minimising the economic consequences for large energy-intensive consumers in Russia, it is important to note that the valorisation of greenhouse gas emissions and,

[1] Publication of actual and forecast values of the unregulated single-rate price for electricity and capacity for the wholesale market buyers for the period 2011–2035. https://www.np-sr.ru/ru/announce/50135-o-publikacii-fakticheskih-i-prognoznyh-znacheniy-nereguliruemoy-odnostavochnoy-ceny.

accordingly, the transformation of emissions into an additional element of production costs will be formed with the formation of the global emissions trading system. This process inevitably leads to an increase in costs for all manufacturers, i.e. to the growth of the global average cost of production [Marku, 2021].

However, there will be significant competitive advantages result for manufacturers in those countries where the cost of emitting 1 tonne of CO_2-equivalent emissions in their national emissions trading systems will be below the global average [Daumas, 2021].

The key global drivers of these benefits are as follows:

- access to significant primary energy resources for the production of electricity with no carbon footprint (or with a carbon footprint many times lower than conventional technologies): water, wind, solar energy;
- access to modern high-efficiency technologies enabling the implementation of projects for the production, transmission, storage, and efficient consumption of 'decarbonised' electricity (including access to nuclear and thermonuclear technologies);
- availability of significant forest areas that absorb CO_2;
- access to industrial CO_2 capture and absorption technologies and their economically viable deployment.

With regard to the Russian Federation, the following factors should be taken into account:

- availability of significant hydropower potential: according to the Energy Strategy of the Russian Federation for the period up to 2035, the hydropower potential of the Russian Federation is about 9 per cent of the world's potential;
- availability of indigenous and competitive nuclear power generation technologies;
- availability of large woodlands, particularly in Siberia and the Far East.

Thus, the effective use of the above-mentioned potential advantages, as a result of the expected energy transition, allows us to assert that the competitiveness of most Russian energy-intensive producers on the international markets will not decrease, but, on the contrary, will increase [Kodaneva, 2022].

At the same time, industrial energy-intensive consumers with access to relatively cheap sources of 'clean' energy will be the best position.

So, the key directions for solving the problem of minimising the economic burden for large electricity intensive consumers in Russia at the state and corporate level are as follows:

- encouraging access to modern technologies for participants in economic activity;
- formation (at the state level) of effective incentives for participants of economic activity to implement sustainable development programmes;
- development of effective regulatory policy methods;
- formation of effective strategic decisions by electricity intensive consumers themselves.

The correct choice of methods of state regulatory policy and corporate strategies, as well as the use of already implemented market mechanisms of power and capacity trading, will significantly reduce the economic burden of the intensive transformation of the Russian electric power industry. Thus, it will facilitate the process of adaptation to the changing conditions of economic activity.

1. Directions for minimising economic impacts at the state level: stimulation of technology development, regulatory policy, investment attraction and business community activity

1.1. State regulatory policy in planning and implementation of the energy transition programme

As noted above, an important factor determining the conditions and opportunities for effective adaptation of large energy-intensive consumers to changes in the business environment caused by the energy transition is the regulatory policy of the state.

The first step is to improve approaches to influencing the price of electricity for large energy-intensive consumers.

Decarbonisation affects all types of economic activity of the state without exception, and the goal of the process is the consistent achievement of certain emission levels and the formation of optimal (in terms of decarbonisation costs and their impact on the cost of goods produced in Russia) measures in the aggregate for all participants of economic activity.

This approach makes it possible to secure consistent results without 'overachieving' in certain sectors of the economy, especially those whose costs are included in the price of products and services for consumers in Russia, such as the electricity industry.

In practice, such a mechanism is proposed to be implemented in the system of inter-sectoral balancing of plans to reduce greenhouse gas emissions and improve energy efficiency, which allows the 'decarbonised' investments of energy producers to be shifted to the right along the time axis. The bonus in this process is the improvement and decreasing cost of RES technologies over time and the resulting reduction in investment costs.

In mathematical terms, the problem can be described by the following expression:

$$T_{gov} - \sum_{i=1}^{n} T_{ni} = \sum_{j=1}^{k} T_{Ej}, \quad (1)$$

where T_{gov} is the state's commitment (in a specific time period) to reduce emissions, $\sum_{i=1}^{n} T_{ni}$ is plans of business community and other consumers (in a specific time period) to reduce emissions, $\sum_{j=1}^{k} T_{Ej}$ is assignment to energy consumers (in a specific time period) to reduce emissions.

As an example of the need for cross-sectoral balancing of GHG mitigation plans, as well as the need for related methodological and accounting measures, we should consider the potential of the Russian forestry sector in terms of its impact on CO_2 emission reductions.

According to the all-Russian organisation Roslesinforg[2], which specialises in the integrated solution of forest inventory tasks in the interests of the state, the leading regions in terms of the volume of carbon dioxide absorption by forests (annual values of emission absorption) are:

– Irkutsk Oblast – 148.6 million tonnes;
– Krasnoyarsk Krai – 114.2 million tonnes;
– Komi Republic – 60.7 million tonnes;

[2] Leading regions in terms of carbon dioxide absorption by forests. https://roslesinforg.ru/.

Table 1
Emission targets for Russian oil and gas companies

Company	Target corporate benchmarks	Target year for achieving carbon neutrality
Gazprom	A 26–30% reduction in carbon intensity by 2030 from 2019 levels	n/a
Rosneft	Reducing emissions and carbon intensity of production by 30% from 2019 by 2035, avoiding 20 million tonnes of CO_2 emissions equivalent (t CO_2e)	Carbon neutrality by 2050
Lukoil	Reducing CO_2 emissions by 10 million tonnes from 2017 levels by 2030, equivalent to a 20% reduction in carbon intensity	Carbon neutrality by 2050
Gazprom Neft	Complete cessation of associated gas flaring by 2030 and reduce Scope 1 and 2 emissions by 30% to approximately 20.2 million tonnes CO_2e, reducing carbon intensity by one third	n/a
Novatek	A 6% reduction in carbon intensity from 2019 levels in mining, a 5% reduction in LNG production, a 20% reduction in air pollution and a 4% reduction in methane emissions	n/a
Tatneft	Reducing Scope 1 emissions from 2016 levels: 10% by 2025 and 20% by 2030	Carbon neutrality by 2050
TMK	Reducing CO_2e emissions by 8% from 2020 levels by the end of 2023	n/a
Transneft	Reducing relative emissions by 0.7% in 2021 by implementing a number of technical measures; developing medium- and long-term GHG emission reduction targets	n/a

Table 2
Emission targets for Russian mining and metallurgical companies

Company	Target corporate benchmarks	Target year for achieving carbon neutrality
Evraz	Reducing carbon intensity by 20% (t CO_2e/t steel; GHG emissions of Evraz's Scope 1 and 2 steelmaking facilities) by 2030 compared to 2019 levels	n/a
NLMK	Reduction of carbon intensity by 1% by 2023 from 2018 levels (kg per tonne of steel)	n/a
Rusal	Reducing direct GHG emissions from existing aluminum plants by 15% from 2014 levels by 2025. 10% reduction for alumina plants. Achieving an average level of direct and indirect GHG emissions of no more than 2.7 t CO_2e per tonne of aluminum (target achieved in 2017). Reducing GHG emissions En+ (scope 1+2) by at least 35% by 2030 compared to 2018	n/a
Severstal	Reducing carbon intensity by 10% by 2030 (–3% by 2023) from 2020 levels (per tonne of steel)	n/a
MMK	Reducing Scope 1 and 2 CO_2 emissions by 15% to 22.9 million tonnes by 2025; reducing carbon intensity to 1.8 tonnes CO_2/tonne of steel by 2025 from 2019 levels (–15%)	n/a
Metalloinvest	Reducing direct and indirect 'energy' GHG emissions from 2019 levels by 2025 by 1.8%, reducing indirect 'non-energy' GHG emissions by 25% from 2019 levels; reducing direct GHG emissions by 15% from 2019 levels by 2036	n/a
Nornickel	Reducing carbon intensity by 23–29% (coverage 1 and 2) from 2020 levels by 2030; achieving GHG emissions of less than 10 million tonnes of CO_2e with a 30–40% increase in production	Carbon neutrality by 2060
Polus	The calculation of Scope 1 and 2 emissions is ongoing; the goal to reduce carbon intensity by 15% by 2020 compared to 2015 levels has been met (actual reduction to 2018 levels was 28%). In 2021, a Scope 3 emissions assessment should be completed and a climate strategy including decarbonisation targets should be developed	n/a
Petropavlovsk	Formalising medium and long term GHG emission reduction targets	n/a

– Perm Krai – 47 million tonnes;
– Khanty-Mansiysk Autonomous Okrug – 45.3 million tonnes.

It should be noted that the annual volume of emissions from coal-fired power plants in Russia is comparable to the absorption capacity of the forests in Irkutsk Oblast alone.

Russia has more than 20% of the world's forests, according to various estimates, ranging from 815 million hectares[3] to 897 million hectares.[4]

It is important to note the lack of reliable data on Russia's forest reserves, even from government authorities. For example, according to the Accounts Chamber of the Russian Federation for 2020, more than 84% of the data on Russia's forests (areas and reserves) have no reason to be considered reliable.

In addition, only so-called managed forests (where accounting and fire protection are organised) are recognised as having a positive effect on the climate. In Russia, hundreds of millions of hectares of forest are unmanaged.[5]

Therefore, in addition to the contribution of forestry to the reduction of greenhouse gas emissions in the cross-sectoral balance, one of the key factors that can facilitate the adaptation of large energy-intensive consumers to the consequences of the energy transition by reducing the overall carbon footprint of their products, is the implementation of so-called NBS

[3] FAO (2020) Interactive Report "Forest resources assessment" https://www.fao.org/3/ca8753ru/CA8753RU.pdf.
[4] National inventory report on anthropogenic emissions by sources and absorption of greenhouse gases not controlled by the Montreal Protocol for 1990–2019.
[5] National anthropogenic greenhouse gas emissions inventory report 1990-2019. Section 6.4.1. 'Forest lands'.

Table 3
Emission targets for Russian fertiliser producers and chemical industry companies

Company	Target corporate benchmarks	Target year for achieving carbon neutrality
Sibur	Reducing carbon intensity in gas production to 0.236 t CO_2e/tonne of product by 2025; in petrochemicals – to 1.54 t CO_2e/tonne	n/a
Akron	n/a	n/a
PhosAgro	A 14% reduction in Scope 1,2 and 3 emissions by 2028 from 2018 levels, a 30.9% reduction in Scope 1 emissions by 2028 from 2018 levels, a 14% reduction in carbon intensity by 2028 from 2018 levels, a 10% reduction in carbon intensity by 2025 from 2018 levels	n/a
Uralkali	The company plans to set goals in 2021	n/a
Eurochem	n/a	n/a

Table 4
Emission targets of Russian transport companies

Company	Target corporate benchmarks	Target year for achieving carbon neutrality
Russian Railways	Reducing carbon intensity by 5–11.7% by 2030 compared to 2018. In the Long Term Development Plan, the goal was set to reduce GHG emissions by at least 4.5% by 2025 compared to 2018 levels (by the end of 2020, the indicator was reduced to 1.6%)	n/a
Aeroflot	n/a	n/a
Sovcomflot	The company has adopted a Green Charter, the objectives of which are in line with the IMO's goal to reduce carbon intensity by 40% from 2008 levels by 2030 and by 70% by 2050 (a 50% reduction in absolute emissions)	n/a

projects (Natural Based Solutions). These projects are based on increasing the absorption capacity of forests (certified by the World Community) through integrated and sustainable management of forests and rural areas. Thus, the full realisation of the above-mentioned advantages requires the implementation of a number of measures, in particular, in the sphere of ensuring the completeness of accounting and certification of the absorption capacity of Russia's forest resources.

According to the Moscow office of the Boston Consulting Group, the creation of *a fully-fledged forest accounting system* will have an effect many times greater than the effect of all energy transition measures in the power sector. *There is an opportunity to triple the estimated absorption capacity of Russia's forests* to 1.8 billion tonnes of CO_2 equivalent per year in the medium term and up to 2.2 billion tonnes of CO_2 equivalent per year in the long term.[6]

Another example confirming the relevance of cross-sectoral balancing of energy transition measures are the plans and target benchmarks of the largest Russian participants in the main industries and sectors of the Russian economy. Tables 1–4 show data obtained from open sources (company websites, analytical review by VTB Capital, Russian Ministry of Economic Development, Russian Ministry of Energy) on the target benchmarks of the largest Russian companies in the oil and gas, mining and metallurgy, petrochemicals and transport sectors.

Table 5 provides an assessment of investment plans for the main industrial sectors and branches of the Russian economy.

Table 5
Emissions and decarbonisation by industry and sector

Sector, industry	CO_2e emissions in 2019		Investment plans up to 2030, trillion rubles per year (estimate)	Annual decarbonisation costs for 100% emissions reduction, trillion rubles
	mln tonnes	% of total by country		
Electric power engineering (networks and generation)	720	34	0.9	1.5
Oil and gas	268	13	3.7	2.4
Transport	185	9	2.0	4.8
Metallurgy	250	12	0.8	1.2
Chemical	87	4	0.4	1.2
Concrete	20	1	0.03	0.1
Total RF	**2119**	—	—	—

[6] Undiscovered wealth: why it is important for Russia to realize the true value of forests. https://web-assets.bcg.com/c4/5a/5fb9ad2e4780944dcaf9a9168100/2021-bcg-forests.pdf.

1.2. The role of government in stimulating technological development

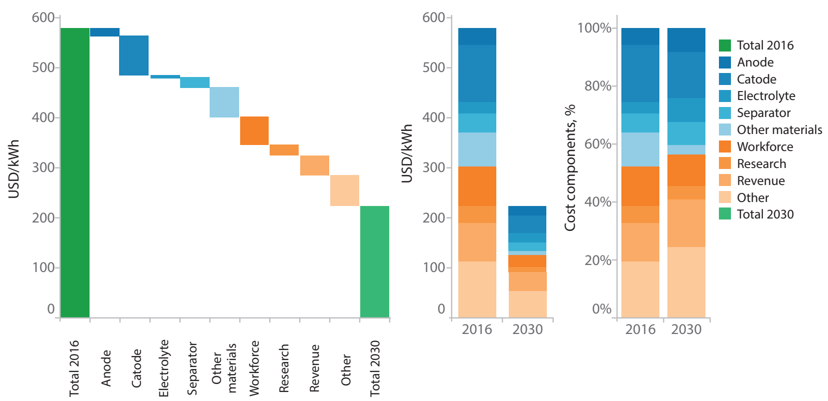
The economic burden on large energy-intensive consumers of implementing the energy transition (decarbonisation) programme will largely depend on its cost, the dynamics of which we believe will be influenced by two key factors:

- innovative reduction in the cost of renewable electricity generation technologies;
- the cost of capital raised during the implementation of the decarbonisation programme.

Accordingly, reducing the cost of energy transition in itself facilitates the adaptation of energy-intensive industries to this process and should be considered as one of the key areas of levelling negative impacts.

Therefore, access to innovation (advanced state-of-the-art technology) and cheap capital is necessary to achieve a cost-effective transition to renewable energy.

Fig. 2 Predicted cost reduction for lithium fermium phosphate battery energy storage systems



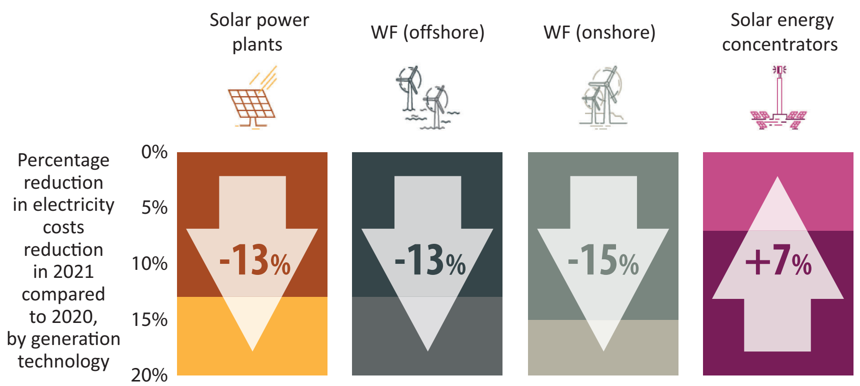
Considerable knowledge has been accumulated worldwide on many aspects of designing, planning and implementing the technological transformation of the energy system.

Over the past decade, renewable energy generation technologies (especially solar and wind) have moved from an expensive niche to become the cheapest source of electricity in most countries today. This has been driven by the rapid expansion of generation capacity, improved performance and lower capital and operating costs, as well as the impact of continuous technological innovation.

In this context, it is important to note that the global experience of the last decade clearly shows a multiple reduction in the cost of technologies for production of energy from renewable primary sources, in particular solar and wind energy.

Figure 1 compares the global weighted average of the levelized cost of electricity (LCOE) produced from renewable sources and the projected LCOE of newly installed renewable electricity generation technologies, 2021 compared to 2010.[7]

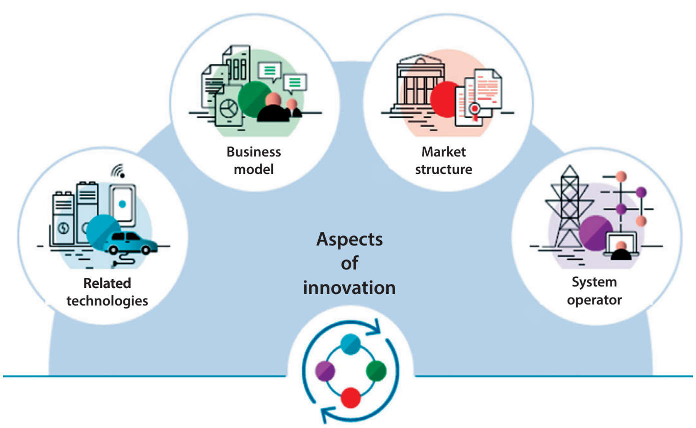
Fig. 1. Comparison of the global weighted average of the present value of electricity from renewable energy sources (2021 compared to 2010)



It should be noted that the situation in the electricity storage segment is developing in a similar way. According to the 2017 IRENA report,[8] by 2030, the unit cost of battery storage systems for electricity is expected to decrease by up to three times compared to the base year 2016 (Figure 2) [Usacheva et al., 2022].

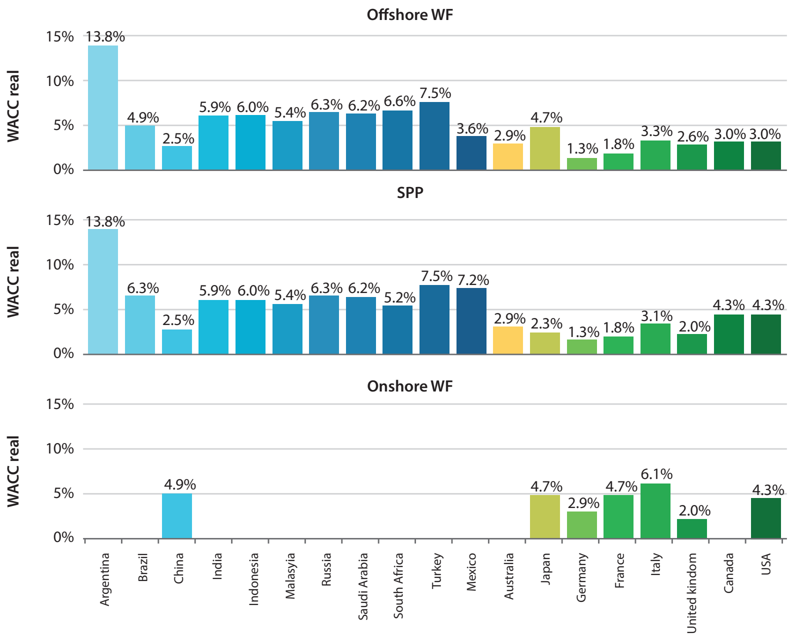
The creation of effective and competitive national innovation structures is an essential component for accelerating the deployment of new and critical technologies for the transition to renewable energy, attracting investment, and reducing the costs of relevant innovative projects [Hund et al., 2020]. At the initial stage, it is of great importance to develop and implement coordinated actions in four areas (Figure 3) – enabling technologies, business models, market structure and system operation – to help solve key problems and support the development of the target technology market, thereby accelerating the transition to renewable energy. In addition, coordinated action in these areas can reduce the transaction costs of technology transfer and encourage foreign direct investment and/or the creation of local private ecosystems.

Fig. 3. Aspects of innovation



[7] Based on data from the International Renewable Energy Agency. https://www.irena.org/.
[8] Electricity storage and renewables: Costs and markets to 2030. https://www.irena.org/.

Fig. 4. Estimation of the average cost of capital in key countries depending on renewable energy technology for projects implemented in 2021



Among the technologies of the transition to renewable energy in the world and in Russia, solar, wind and hydrogen technologies are the youngest and therefore require the most attention and support.

At the same time, the level of support required also differs between the three technologies mentioned (depending on the current state of development of the respective technology). These are used as examples to illustrate this support.

Support for solar energy

Solar energy is the most mature of the three technologies identified above. In solar energy, technology and business model innovation has occurred in parallel with technology cost reductions. This has not only accelerated the introduction of technologies, but also driven many regulatory decisions. However, for its further development, it is obviously necessary to finalise the structures of the existing traditional electricity markets (due to the instability of the primary energy source on which the technology depends – the sun) and to strengthen the business models that already working. It is important to improve the rules in such aspects as:

- defining medium- and long-term technology development goals;
- creating new sustainable financial support mechanisms;
- making targeted cost reduction and productivity improvement efforts for solar energy technologies (goal for R&D);
- providing infrastructure support: access to the grid for new solar power plants, creation of smart grid models, development of standard solutions for rural electrification based on solar power plants, creation of technical and economic guarantees for new projects.

Wind power support

Wind power is also a relatively mature technology. In many ways, the above applies to solar energy and to the development of wind energy. However, offshore wind farm projects (which are often more efficient than onshore ones) face complex and costly procedures to obtain the necessary permits around the world [Nallapaneni et al., 2020]. For this reason, support in the form of simplification of existing and developing new licensing procedures is very important for offshore wind project participants. Simplifying procedures will reduce project implementation time and accelerate the development of new technologies for the deployment of offshore wind generation facilities.

Support for hydrogen energy

Hydrogen energy is the newest, but most promising technology with huge potential. However, at this stage, in order to establish a hydrogen energy market, it is necessary to first develop a consensus among potential market participants on the environmental friendliness of hydrogen production and a reliable system of environmental certification of such production [Sologubova et al., 2020]. Today more than 90% of hydrogen is produced using fossil fuels with a large carbon footprint. Such a system will be used as a basis for making investment decisions on projects for the production of 'green' hydrogen and its use in the electricity industry of the future. In addition to the environmental aspects of hydrogen production, efforts must be made to support research into the development of hydrogen energy infrastructure and cost reduction in hydrogen production. Reducing the cost of producing 'green' hydrogen may be a key decision in the transition to hydrogen energy [Beloborodov et al., 2021].

2. Key opportunities for the public and private sectors to reduce the cost of capital for renewable energy investment projects

2.1. Cost of capital as a driver for renewable energy investment projects

The cost of capital for renewable energy investment projects is a very important factor in the overall cost of implementing the energy transition. It is the main determinant of the cost of renewable electricity, as the fuel component of its production costs is either minimal or non-existent.

For example, for a solar or onshore wind farm construction project, the levelised cost of electricity (LCOE) increases by 80% if the cost of capital is 10% instead of 2%.[9]

Access to low-cost finance reduces the cost of energy for consumers.

The cost of capital for a renewable energy generation project depends on a number of different factors, the three most important of which are as follows:

1. Country risks: the so-called 'country risk premium' is the total cost above of the risk-free rate due to the country's political, institutional and regulatory risks. In the current geopolitical environment, the country risk for

[9] Based on data from the International Renewable Energy Agency. https://www.irena.org/.

Russia is mainly managed through the effective use of its own financial capabilities, as well as by targeting the capital markets of Northeast Asia (particularly China), as well as the Middle East and West Asia (Republic of Turkey).

2. Withdrawal risks: if the revenue from the project is secured by a bilateral agreement, the perceived risk of investors in relation to the solvency of the consumer will affect the expected rate of return. Regulatory risks may also arise if the buyer is a government entity. Where international developers are involved, currency risk also has an impact, although hedging can reduce this risk for a fee.
3. Technological risks: technologies have different risk profiles based on technological maturity, previous experience in specific markets, the experience of the developer, and confidence in the resource, for example, the extent and quality of local solar radiation data. However, the latter factor is no longer as important as it once was, thanks to the growth of world experience.

Other factors also affect the cost of capital, such as the size of the internal financial market, the experience of developers, cost allocation rules, etc.

Given the critical importance of access to low-cost finance to achieve the necessary capital mobilisation to support the energy transition, understanding the reasons for the high cost of capital and methods to reduce it is essential to determine the direction of public policy to implement the Decarbonisation Scheme and to protect large energy intensive consumers.

An estimate of the average cost of capital in the main countries, depending on the renewable energy technology, for projects implemented in 2021 is shown in Figure 4.

As a result of the above factors and the underdevelopment of national innovation and investment structures, the unit cost of 1 MW of installed renewable energy capacity in Russia is typically significantly higher than the global average.

2.2. Problems of reducing the cost of capital for the implementation of the Energy Transition Programme. The role of the public sector. The role of the private sector

Differences in the cost of financing decarbonisation programmes are, as noted above, mainly due to non-technical risks, of which country risk, exchange rate risk and withdrawal risk are usually the most important and, therefore, the biggest obstacles to mobilising cheap capital. There is therefore a clear need to develop effective public policies and innovative financing schemes to reduce the cost of capital.

The public sector cannot solve the problem alone.

Public-private partnerships will be key. Both private and public sectors have a critical role to play in driving forward the energy transition agenda. One cannot do without the other. This requires close cooperation between the parties in the form of partnerships on specific and clearly defined tasks between sectors, leading to jointly developed action plans with accountability and responsibility for achieving measurable results.

The public sector should play a crucial role as a catalyst, providing a favourable and predictable enabling environment (policy framework) for long-term investment decisions in the private sector. An effective enabling environment will stimulate and facilitate decision making by private investors and developers to finance and deliver the volume of projects required for the energy transition. As public sector financial resources are increasingly limited by macroeconomic and sanctions constraints, the importance of using these public resources to leverage private sector investment becomes even more critical. Well-designed public sector support, which reduces the risks for private investors and increases their financial returns, can play a central role in efforts to adapt and mitigate the effects of the energy transition on energy-intensive industries [Maksimov, 2020].

The private sector, even when presented with attractive investment opportunities in the energy transition, will only invest if the projects meet strict models for the allocation of private sector resources to direct their investments to projects with appropriate risk and reward profiles. Non-investment countries have problems accessing cheap finance because international institutional investors with trillions of dollars under management are often unable or unwilling to invest in such markets. Similarly, smaller and riskier projects and new decarbonisation technologies may also not have access to the capital they need. In these cases, joint public-private financial intervention can play an important role in bridging the gap between the availability and cost of capital and the needs of developers and government.

There are two ways to attract capital: international versus domestic and commercial versus concessional.

Domestic financial markets are the main important source of capital for financing the energy transition. This is because they provide diversified funding sources, access to local equity and corporate bond markets, and much-needed rouble funding to avoid currency risks and mitigate macroeconomic shocks. They are also crucial because international institutional investors are reluctant to invest in projects unless local investors or lenders such as banks, pension funds and insurance companies themselves are involved in financing the projects. International players tend to be concerned about the asymmetry of information in the risk assessment of projects in the market.

In 2021, global pension fund assets will total USD 56.6 trillion (TAI, 2022), while the global insurance sector will manage USD 41.6 trillion in the same year (source: Statista), for a total of more than USD 100 trillion. However, these institutional investors will not put money into small or unprofitable projects and often cannot finance non-investment grade or unrated countries.

Another important distinction is between commercial and concession capital. The energy transition involves major projects that require a balance between risk and return on investment. Some projects are needed to achieve the goals of the global energy transition, but they are not yet being implemented. They remain on a small scale and are located in non-investment grade countries. These are two limiting factors which prevent large international institutional investors from participating in such investments. Given the limited government funding available for such projects, the investment attracted will also have a significant impact on the viability of the energy transfer.

In this case, the most promising mechanisms are blended financing mechanisms, which aim to attract private sector capital in the most popular areas and to reduce the cost of capital for the projects concerned.

The state and institutional investors provide capital on preferential terms (i.e., capital at below market rates) in order to change the risk-return ratio of investments so that venture capitalists are interested in financing at normal market rates. The resulting structure combines both types of capital (commercial and preferred) and allows each side of the transaction to achieve its specific objectives.

Typical risk mitigation instruments may include (partial) risk guarantees, compensation for initial project losses, grants, technical assistance, subordinated debt. Subordinated debt is a debt that ranks after other debt in the event of the liquidation or bankruptcy of the company; such debt is called 'subordinated', because lenders have a subordinate status to ordinary debt. They are also subordinated shares, which do not confer voting rights or only partial voting and dividend rights, are not fully liquid and may only be converted into ordinary shares in the future if the company achieves certain performance criteria. The sources of commercial and concessional finance for financing sustainable infrastructure vary depending on the development cycle of energy transition investment projects.

It is expected that the relationship between commercial and concessional (concessional) capital will change as the project moves through the early development and preparation stages, the formation and construction phases, the operational phase and finally the market exit (through appropriate exit strategies).

In the early, high-risk stages of project development, investors can provide grants or technical assistance for project development and preparation on preferential terms. This will enable concessionary and commercial capital providers to participate in equity investments at an early stage to pay for legal and other start-up costs. Providers of commercial capital will take the initiative once the project has entered the construction phase, while the provider of preferential capital can cover the initial losses in the event of project failure. Finally, during the operation and maintenance phase (which can last for decades) and eventual exit, commercial parties jointly monitor the progress of the project.

There are many tools and schemes that can be used to reduce the risks, and therefore the cost of capital when financing an energy transition programme. At the same time, the study will analyse the mechanism for stimulating investment in the energy transition through blended finance through the issuance of green bonds.

Green bonds are part of responsible investment, an approach to selecting securities based on environmental, social and governance factors. They are issued to fund environmental projects, including those that reduce CO_2 emissions.

In terms of mechanics, green bonds are no different from ordinary bonds; they are the same fixed-income debt instruments. The investor lends his money for a certain period of time to issuers – organisations that have issued bonds. In this case, however, the money will be used to improve the environment and minimise damage to nature:

- general adaptation to climate change;
- development of renewable energy;
- increasing the absorption capacity of forests through sustainable management of forests and agricultural land;
- land reclamation;
- introduction of electric transport, etc.

To be officially 'green'; a bond issue must comply with the Green Bond Principles (GBP) developed by the International Capital Markets Association (ICMA) or meet the requirements of the Climate Bonds Initiative. An external expert – a verifier company – must confirm the 'greenness' of the bonds. If an independent audit raises no questions about the use of funds, the project selection process and reporting, the bonds can be considered 'green'. However, even after listing, issuers are required to report regularly on the costs and implementation of their environmental work.

In 2007, the European Investment Bank issued the first 'environmental' bond, called Climate Awareness Bonds. The funds were to finance alternative energy and energy efficiency projects. A year later, the International Bank for Reconstruction and Development issued a 'green' bond. Then other supranational institutions and development banks began to issue similar ones. The turning point came in 2013, when large corporations entered the market with green bonds. Since then, the issue of such bonds has grown steadily.

According to the international organisation Climate Bonds Initiative, the total amount of green bonds issued between 2007 and 2020 reached USD 1.1 trillion, although this figure did not exceed USD 3.1 billion in 2012. Among the regions, Europe ranks first in terms of green bond issuance with USD 432.5 billion, followed by North America (USD 237.6 billion) and Asia-Pacific (USD 219.3 billion).

In the Russian Federation, the responsible investment trend is still in its infancy, but the first steps have already been taken. The first official green bond issue took place in 2018 – the company KhMAO Resource Saving placed a RUB 1.1 billion bond on the Moscow Stock Exchange. Funding was raised for the construction of an inter-municipal landfill for the dumping, neutralisation and treatment of municipal solid waste in the Nefteyugansky District. According to foreign experts, the securities comply with GBP's green principles. In 2019, they were included in the International Register of Environmental Finance Bond Database, and then in the Green, Social and Sustainability Bond Database.

The first Russian company to place green bonds on the foreign market was Russian Railways. The issue took place in May 2019 – the volume amounted to EUR 500 million. Loans for the purchase of electric locomotives and Lastochka passenger trains are to be financed with green money.

In the summer of 2019, a separate 'sustainable development' sector appeared on the Moscow Stock Exchange, where you can find a list of traded green and social bonds. Investors now have access to green bonds issued by the Moscow developer FPC Garant-Invest, the financial company RuSol 1, the bank Center-Invest and the transport company TKK LLC.

In addition, for the first time sub-federal green bonds were issued on the Moscow Stock Exchange – the capital's government placed them for RUB 70 billion. The Moscow authorities intend to allocate funds for the implementation of projects to reduce carbon dioxide emissions and pollutants from motor vehicles. This involved replacing Moscow's bus fleet with electric buses, building new metro stations and renovating old ones. The placement was successful – demand exceeded production by 20%.

According to expert estimates, the total volume of 'green' loans in Russia will amount to about RUB 1.85 trillion by 2023. The volume of issued target bonds in the format of sustainable development of Russian companies and their foreign subsidiaries and dependent organisations for 3 years is estimated at more than RUB 524 billion. These bonds are generally focused on the transport, industrial machinery and energy sectors. The funds raised were used to finance projects in 51 regions of Russia worth more than RUB 223 billion.[10]

Tax incentives applied in world practice for issuers and investors of green bonds are attractive because of their economic efficiency, as they can provide a significant boost to investments with a relatively small impact on public finances.

There are several types of tax incentives the governments can introduce to encourage the issuance of green bonds. Incentives can be provided to both the investor and the issuer.

Tax Credit Bonds: Bond investors receive tax benefits instead of interest payments, so issuers do not have to pay interest on their green bond issues.

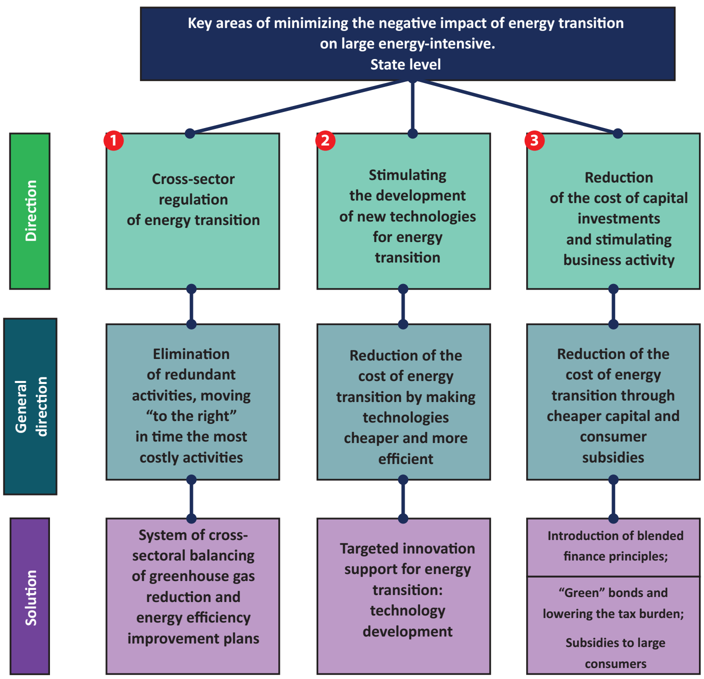
Direct Subsidized bonds: Bond issuers receive cash rebates from the government to subsidise their net interest payments.

Tax-exempt bonds: Bond investors do not have to pay income tax on the interest from green bonds they own (so the issuer can pay a lower interest rate).

For example, as a result of the issuance and placement of government-backed green bonds:

- the state receives a guarantee for the implementation of the necessary project aimed at reducing CO_2 emissions or absorbing greenhouse gases;
- issued on preferential terms;
- investors are tax exempt income.

Fig. 5. Key areas of minimising the negative impact if energy transition on large energy-intensive consumers. State level



2.3. Government instruments to reduce the cost of purchasing electricity for energy-intensive industrial consumer

Another way of reducing the costs of large energy-intensive consumers is to subsidise part of the electricity costs of large energy-intensive consumers, as well as to compensate part of the costs of building new energy infrastructure from the state decarbonisation fund, which is replenished from the collection of carbon payments in the country [Tsakhaeva, 2015].

In particular, subsidisation involves the conclusion of regulated long-term contracts (RLCs) for the supply of electrical energy and capacity at discounted prices by state-controlled power generation companies that mainly produce 'clean' electricity (Rosenergoatom, Rushydro, etc.), with a phased approach to market prices within 3–5 years. It is clear that such contracts should be limited in nature and scope and should only be concluded with those energy-intensive consumers who are experiencing extreme difficulties in adapting to the increase in electricity costs and whose uninterrupted functioning is of particular strategic and/or social importance.

In addition, one of the subsidy mechanisms could be the regional differentiation of the number of free carbon certificates issued by the state (within the overall country limit on the total amount of emissions in the corresponding year), depending on the absorption capacity of the forests in the region. As the large energy-intensive industries of the Russian Federation are concentrated mainly beyond the Urals, in regions rich in forests with a high capacity to absorb carbon, the increase in the cost of electricity for these consumers will be lower in the context of the energy transition. It will also provide an economic incentive for the relocation of energy-intensive industries from the European part of the country and the Urals to regions with cheap 'clean' energy.

Thus, the main effect of creating a national system of carbon payments and a national decarbonisation fund is the ability to 'keep' the money collected in the country and use it for measures to decarbonise the economy. It is necessary to reduce the financial burden of large consumers on energy transmission through direct state subsidies for the implementation of renewable energy projects in the electricity industry.

Taking into account the analysis, the system of measures at state level to minimise the economic impact on large electricity consumers and key tasks can be graphically presented (Figure 5).

3. Promising corporate actions to adapt energy-intensive industries to the consequences of the increasing share of renewable energy in the electricity balance

3.1. The experience of the Russian energy-intensive industry in adapting to structural changes in the electricity industry

The traditional approach of large energy-intensive consumers to reduce electricity costs (reducing the price of purchased electricity and relocating production facilities to regions with cheap electricity), takes on a new 'dimension' in the context of decarbonisation measures in the electricity industry.

The 'reducing the price of purchased electricity' part (combating cross-subsidisation, participating in the pricing of

[10] ESG, Decarbonisation and Green finance – Summary of results 2022. https://energiavita.ru/2023/03/12/esg-dekarbonizaciya-i-zelenye-finansy-rezyume-itogov-2022/.

individual services, changing the proportions of decarbonisation costs in the final price of electricity, etc.) implies more intensive pricing work by large electricity consumers. The part about 'moving production to regions with cheap electricity' has additional meaning: moving production from the west to the east of Russia means moving from a zone with a larger share of thermal power plants in the regional structure of electricity generation to zones with a larger share of hydroelectric power plants in the regional structure of electricity generation. It helps reduce the country's overall GHG emissions.

It should be noted that the approach of "moving production to regions with cheap electricity" is relevant to all economic systems (not just market ones), which is confirmed by the history of industrialisation and electrification of Russia in the last century.

The key stages (waves) of Russia's industrialisation during the USSR have pronounced resource-geographic features (energy-intensive industries 'run' for cheaper energy):

Stage 1. The beginning of the 20th century. Initial development of the energy potential of the European part of the country (local fossil fuels, linking generation to pre-existing industrial production).

Stage 2. The second quarter of the 20th century. Construction of energy-industrial complexes in the European part of Russia and in the Urals (with the establishment of new large energy-intensive industries in the Urals zone). The main source of primary energy is coal from the Ural region and hydroelectric power plants (HPPs) in the European part of Russia.

Stage 3. The third quarter of the 20th century. Construction of energy-industrial complexes in Western and Central Siberia (with the establishment of new large energy-intensive industries in these regions). It is connected with the development of the energy of Siberian rivers and the development of coal and gas deposits.

Stsge 4. The second half of the third and the first decade of the fourth quarters of the 20th century. In Eastern Siberia and the Far East, large hydroelectric power stations and modern coal-fired power stations are being built in anticipation of industrial production. The fourth stage should be considered as incomplete (a significant part of the HPPs is not in demand by industrial consumers).

Today, the trend continues: new energy-intensive production facilities are located closer to the east of the country, next to large hydroelectric power plants, and large energy-intensive enterprises that were established in the European part of the country and in the Urals in the middle of the last century are gradually being converted or closed down.

Relevant international experience should be taken into account. Companies from countries with quantitative commitments to reduce emissions are incentivised to move production with a significant carbon footprint to developing countries with no such commitments (so-called 'pollution heavens') and then import products back. About 25–30% of global emissions are imported and exported from country to country. The European Union is a net carbon importer, with the main CO_2 exporters to the EU being North America, Russia and China. However, this practice will be significantly reduced following the introduction of cross-border carbon regulation.

3.2. Key corporate to ensure that large energy-intensive consumers adapt to the consequences of the energy transition

Action at company level in all areas can be divided into three main types: management, energy consumption and energy supply.

1. Management actions

These actions tend to be comprehensive and strategic in nature, in particular:

- Change in the management structure of the company to improve the efficiency of the development and implementation of the strategy, in particular in the area of energy efficiency and decarbonisation:
  1) creation of a dedicated unit to manage the energy efficiency and decarbonisation strategy;
  2) assigning responsibility to an internal energy efficiency specialist to ensure the definition and successful implementation of a realistic overall strategy;
  3) expanding the ownership of energy efficiency solutions at senior management level;
  4) aligning energy efficiency and decarbonisation key KPIs with general management key KPIs.
- Encouraging decarbonisation activities in the supply chain, as this will affect the carbon content of each product purchased.
- Providing support to consumers/customers in the decarbonisation process leading to an overall reduction in carbon emissions as a result of the company's activities.

The scheme for organising the management of climate change issues at *Norilsk Nickel* can serve as an example.

Addressing climate change issues at all levels of corporate governance – from the board to senior management.[11]

2. Actions in the field of energy consumption

The main objective of these actions is to save energy, which will translate into reduced carbon emissions and, ultimately lower operating costs.

Typical actions in the area of energy consumption include:

- Replacing and modernising outdated equipment is one of the standard ways of improving energy efficiency in the plant. The measures can range from a simple change to LED lighting to a more complex upgrade of electric motors and their drives in production or improving the efficiency of the building's HVAC system.
- Using intelligent load management systems based on digital solutions allows you to go beyond simple monitoring. With proper management and automation, an enterprise can achieve significant energy savings; modern building energy management systems are able to simulate an object and its response to load changes.
- Electrifying the company's transport fleet can significantly reduce direct CO_2 emissions, especially when combined with intelligent charging systems. A striking example of this is the experience of the mining company Rio Tinto, which, in an effort to reduce the carbon footprint of its production, has ordered shunting locomotives powered by lithium-ion batteries to transport coal within the mine site in Australia.[12]

[11] Report on the sustainable development of PJSC MMC Norilsk Nickel for 2021. https://www.nornickel.ru/files/ru/investors/disclosure/NN_CSO2021_RUS_0706.pdf.
[12] Rio Tinto orders Battery-electric locomotives for Mining Rail in Australia. https://www.energytech.com/emobility/article/21213991/rio-tinto-orders-batteryelectric-locomotives-for-mining-rail-in-australia.

- Analysis of the production process. This means that any energy savings can be achieved by making changes to individual stages of the production process, such as reducing the steam temperature, without compromising the overall quality of the process.

3. Actions in the field of energy supply

The main objective in this case is to reduce the volume of indirect emissions in the overall carbon footprint of the products of a large energy-intensive consumer.

Typical actions in the field of energy supply include:

- Local production of green electricity, i.e. the production of electricity using low-carbon technologies, such as solar photovoltaic energy, wind energy, bioenergy, etc.
- Switching to low-carbon heat can lead to a significant reduction in direct emissions. Decarbonising the heat supply is one of the biggest issues facing the energy industry. Efforts should be made to improve the efficiency of the supply (e.g. using a CHP system), to electrify the heat (e.g. low or high temperature heat pumps, depending on the application) or to decarbonise the fuel source (e.g. switching from natural gas to clean gas).
- Becoming a ‘producing consumer’ on the energy markets, i.e. producing excess electricity that can be sold. This is a typical way for companies to achieve negative carbon emissions in the energy supply sector, which are used to offset carbon emissions in other business areas. It also helps to generate new revenue streams from the sale of excess energy.
- Purchasing zero-carbon electricity involves the signing of contracts with energy suppliers at green tariffs or an agreement to purchase electricity from a renewable energy producer that guarantees of the origin of the energy consumed.
- Introducing energy storage systems alone does not guarantee a reduction in carbon emissions, but it can contribute to a reduction if it is used as a means of optimisation (e.g. optimising the flow of energy from local production).
- Optimising energy supply based on consumption and energy tariffs.
- Implementing the methodology for assessing the impact of climate risks on the company’s financial performance and financial stability based on the recommendations of the TCFD (Task Force on Climate-related Financial Disclosures) at the level of the company, its divisions, subsidiaries and affiliates. This is a working group on the disclosure of financial information related to climate change under the auspices of the Financial Stability Board.

Risks assessed using this methodology:

- Physical risks associated with the occurrence of adverse meteorological conditions and natural disasters. They take the form of a reduction in climate predictability and an increase in dangerous hydro-meteorological phenomena (droughts, floods, hurricanes, prolonged torrential rain, large hailstorms, etc.);
- The risks of the transition period in the form of changes in legislation (taxation of greenhouse gas emissions, obligations to use new technologies, bans on certain activities and the use of certain substances); a decrease in public tolerance of ‘dirty’ industries and in investor interest in certain industries. There is also an increase in insurance and borrowing costs as a result of higher risks.

Electricity prices and the reliability of energy supplies are key factors in many strategic decisions faced by large energy-intensive consumers, but they are particularly important in decisions related to the need to adapt to radically changing production conditions.

Possible options for adapting energy-intensive consumers to the increase in energy prices due to the energy transition:

- *Market purchase of electricity through the conclusion of long-term contracts (free or regulated)* – electricity and/or power is usually purchased under a long-term contract with upper and lower price limits. Energy supply conditions and price risk are limited for the duration of the contract. The options for concluding long-term contracts, which allow consumers to temporarily adjust to an increase in the price of electricity, are discussed in more detail in the next subsection.
- *Independent power generation* is when a large energy-intensive consumer builds or buys (leases) a power plant that produces relatively ‘clean’ electricity (ideally hydroelectric). This allows the consumer to ensure a stable supply of energy for production and to fix electricity prices. Electricity can be sold to other users (if connections are available). Example: acquisition of RUSAL (Eurosibenergo) Onda HPP, lease of Bratskaya HPP, construction of Lukoil’s own associated gas generation.
- *Acquiring ownership of a fuel source* – a consumer can own a fuel source (gas field, coal methane absorber, etc.) and ‘convert’ the fuel into electricity using an independent power plant. This can give the consumer some control over the risks of energy supply and electricity prices, and can also provide protection against falling prices for their products (if the fuel is available for sale). PJSC Lukoil’s construction of its own associated gas power plant in the Astrakhan region.
- *Full integration of the main production of a large energy-intensive consumer and a source of cheap and ‘clean’ electricity*. As a result, the consumer is largely protected from the influence of the external electricity market. Example: Boguchansk Energy and Metallurgical Association (BEMA) is an association of a single legal entity and a single production complex of the Boguchansk HPP and the Boguchansk Aluminium Plant.

3.3. Possible options for the unregulated bilateral contracts that balance the interests of electricity producers and consumers and hedge consumer risks

Indexation of energy prices to commodity prices – for consumers of electrical energy and energy producing commodities

This option is based on the adjustment of energy prices according to changes in the prices of electricity consuming products, although it introduces a new risk factor for the seller, as the revenue from energy production will be directly dependent on the price of electricity consuming products. For an electricity supplier directly connected to one specific consumer (without the possibility of selling the electricity produced on the free market), such a risk already exists, since the energy company is dependent on the level of profitability of the customer. If a consumer closes its plant, the energy producer is likely to suffer losses, since the probability of finding a new consumer with the same consumption in the surrounding area is extremely low. In such cases, linking to the share price does not significantly increase the risk. The approximate formula can be described as follows:

Revenue = (Volume for a given period) × (energy price under the contract) × (correction factor for changes in commodity prices).

There are several examples of such contractual price adjustments on the world market.

For example, in Europe, for contracts based on an approximate 25% share of electricity costs in the total costs of aluminum producing companies, the contractual energy price was adjusted by a coefficient of 0.25 (25% increase in electricity prices equals 100% increase in aluminum prices and vice versa). The price is adjusted monthly, which means that every month the price of electricity has to be adjusted according to changes in the exchange market.

The reference price for a commodity is taken from the exchange, for example, if the commodity is metal, then the price is often taken from the London Metal Exchange (LME). Prices for deliveries 3 months ahead can be based on the exchange price. Next, let's look at examples of long-term contracts whose price is linked to the price of metals whose production requires significant energy costs on the LME.

One of the opportunities for the parties is to agree to use spot prices at the exchange rate (or at the rate of another market or point on the network) but with a fixed maximum, i.e. to use the maximum agreed price if prices at the time of payment exceed a certain level. The maximum price then acts as a price limit or ceiling.

Such contracts are similar to an option where the client automatically uses the limit price if prices exceed the agreed maximum level. Under such contracts, the client is obliged to pay a premium equivalent to the premium on option transactions. Depending on level of the limit, the duration and the type of contract, an additional option premium on the maximum price without restrictions on the minimum level can be 5–20% of the current market price. If there is a minimum price limit that works in favour of the seller, the total amount of the premium is reduced compared to the option where there is no minimum limit.

If the price is below the agreed maximum, the following calculation method will be used:

Revenue = (Volume for a certain period) × (price at the time of payment) + (Volume for a certain period) × (option premium).

If the price is above the agreed maximum, then:

Revenue = (Volume for a certain period) × (fixed maximum price) + + (Volume for a certain period) × (option premium).

This structure gives the consumer an extra incentive to buy cheaper energy when the price at the time of payment is low, but still guarantees that the price will not exceed a certain level. The seller has no fixed minimum price and risks prices falling, but receives income from option premiums.

The maximum price can be any price. The higher the ceiling price, the lower the premium. With a very high maximum price, the structure is more like a contract with prices at the time of payment, but with an insurance element to protect against extreme price values. The probability of future price changes is used to calculate the premium.

In addition to the maximum limit, the contract may also include restrictions on the minimum price level.

Like the maximum price, the minimum price is applied when the prices at the time of payment are formed below a certain level.

Bilateral energy supply contracts that give the buyer (or sometimes the seller) the right to decide when to consume energy under the contracts

This freedom is determined by the ratio of the maximum energy supply capacity in MW to the total amount of energy under the contract.

The formula can be described as follows:

Energy volume under the contract (GWh) = capacity limit under the contract (MW) × hours of use.

Base load contract with number of hours

Any contract where the buyer can choose when to use the energy (hours of use less than the annual maximum of 8760), and also undertakes obligations to reduce consumption at certain hours has a lower cost than a baseload contract.

Limiting the level of the price of electrical energy to the share of the cost of purchasing electrical energy in the total production costs of the consumer

An example of a long-term contract with an electricity price limited by the share of electricity costs in the total costs of a large energy-intensive consumer – the company Albras (Brazil): The cost of electricity should not exceed 25% of the company's total production costs.

Fixed-price contracts

Selling at a fixed price reduces the risk for the electricity consumer. A typical calculation approach is described below:

Revenue = (Volumes for a certain period) × (contractual fixed price).

In addition, such contracts can be adjusted annually to reflect changes in general price levels, such as inflation:

Price for the year n+1 = (Fixed contractual price for the year n) × × (100 + percentage change in total price level from year n to year n + 1) / 100.

Indexation can also be more frequent, for example monthly. Contracts may be fully or partially inflation-linked (inflation index less than 100%).

Such indexation is usually only possible with direct bilateral contracts between buyer and seller. Selling electricity at a fixed price also guarantees revenue and reduces the price risk for the energy producer. To spread the risk evenly between the parties, it is possible to split the volumes in half, with one half paid at a fixed price and the other at a variable price (at the time of payment).

Examples of long-term contracts with inflation-adjusted electricity prices:

Aluminium Dunkerque (France) – annually the price of electricity changes anually in proportion to the inflation rate in France, reduced by 1%;

1) Elkem Aluminium (Norway) – the electricity price for the plant in Norway increases annually by 60% of the level of increase in wholesale prices in Norway (but not more than 6% per year).

Linking electricity prices to the interest rates

For the owner of a hydroelectric or nuclear power plant, the main component of the price will be the cost of capital. In this case, in order to compensate the consumer for the increase in the market price of electricity, on the one hand, and to maintain the supplier's income, on the other hand, it is possible to link the energy prices to the interest rate:

Revenue = (volume for a given period) × (price of energy under the contract) × (adjustments due to changes in the interest rate for financing power plants).

The 'synthetic' formula is a multifactorial binding of electricity prices

In the case of long-term contracts for the supply of electricity to large energy-intensive consumers that export a significant volume of manufactured goods at market prices, it is proposed that the following 'synthetic' formula be used to determine the price of electricity.

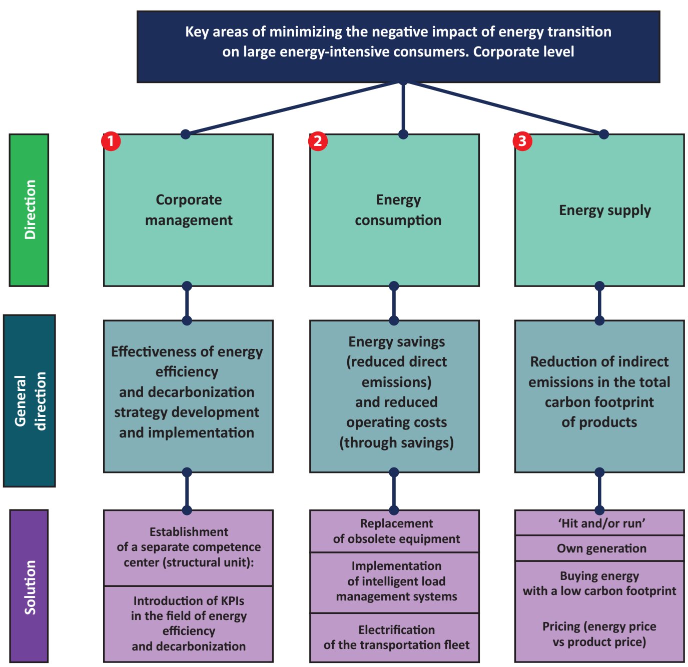
In order to hedge the currency risks of both the electricity producer (seller) and a large energy-intensive consumer (buyer), the contract price for electricity is determined annually by 50% of the volume of electricity consumed in roubles and by 50% of the volume of electricity consumed in US dollars.

The formula for calculating the contract price for electricity is applied *at the level (Minimum price per ton) ≤ (Exchange price per ton) ≤ (Maximum price per ton):*

$$P_c = P_b + \left(0,5 \cdot (Ц_p - Ц_б) \cdot V \cdot \frac{(P_w - P_b) \cdot E}{(P_w - P_b) \cdot E + (T_p - T_e) \cdot V}\right) / E + A, \qquad (2)$$

where P_c is the contract price of electricity, P_b is the initial (base) price of electricity in kopecks / kWh (the projected weighted average price of electricity for the facilities of a large energy-intensive consumer in the base (initial) year); P_w is the weighted average price of electricity on the market in the previous year; T_p is the exchange price of products of a large energy-intensive consumer (cash) in the previous year; V is the volume of production of the exchange product of a large energy-intensive consumer; E is the volume of electricity consumption; A is 'premium' to the contract price (can be positive or negative).

Fig. 6. Key areas of minimising the negative impact of energy transition on large energy-intensive consumers at the corporate level



The premium on the contract price is determined as follows:

1) At *(Exchange price per ton) > (Maximum price per ton)*:

$$A = 0,1 \cdot (T_p - T_{\max}) \cdot \frac{V}{E}, \qquad (2.1)$$

where T_{max} is the maximum exchange price of products of a large energy-intensive consumer used to calculate the contractual price of electricity under a long-term contract;

2) At *(Exchange price per ton) < (Minimum price per ton)*:

$$A = -0,1 \cdot (T_p - T_{\min}) \cdot \frac{V}{E}, \qquad (2.2)$$

where T_{min} is the minimum exchange price of products of a large energy-intensive consumer used to calculate the contractual price of electric energy under a long-term contract.

The ratio between the V and E indicators is defined as the ratio between the documented actual volume of electricity supplied in the base (starting) year and the volume of production of the exchange product of a large energy-intensive consumer in the base (starting) year.

When determining the contract price in roubles and currency (USD), the production volume of the exchange product of a large energy-intensive consumer and the electricity consumption (V and E, respectively) are taken into account at 50% each in the calculations.

Indicators P_b and T_e remain unchanged during the execution of long-term contracts for the purchase and sale of electricity.

When *calculating the hard currency contract price, if the* value $P_w \geq$ *(maximum contract price), then* P_w equals *(maximum contract price)*.

When calculating the *contract price in rubles, if* the value $P_{c\ rub} \geq$ *{(maximum contract price).* Z_{basic}*}*, then P_w = *{ (maximum contract price) .* Z_{basic}*}*.

Z_{basic} – base rate (currency conversion in roubles).

When calculating the hard currency contract price, if the value of $T_p \leq T_{min}$ then $T_p = T_{min}$.

When calculating the contract price in roubles, if the value of $T_p \leq T_{min} \cdot Z_{basic}$, then $T_p = T_{min} \cdot Z_{basic}$.

The proposed formula (2) for determining the price of electric energy within the framework of a long-term contract for the purchase and sale of electric energy, which to a certain extent synthesises the above-mentioned options for the formation of the contract price at the same time:

- makes the contractual price of electricity dependent on both the market (exchange) price of a large energy-intensive consumer's products and the market (exchange) price of electricity, thereby hedging the price risks of both the buyer and the seller;establishes flexible upper and lower limits of the contractual price of electric energy, thereby providing a known price predictability for both parties to the contract;
- hedges the risks of significant fluctuations in the rouble exchange rate for both the buyer and the seller.

Conclusion

The greater the financial burden on large energy-intensive consumers, the more expensive it will be to implement decarbonisation measures. As a result, the cost of electricity consumed by energy-intensive industries will rise.

Two factors have a key influence on the cost of the transition: the reduction in the cost of electricity generation technologies from both traditional and new (renewable) sources due to continuous scientific and technological progress; and the cost of capital required to implement the decarbonisation programme.

We believe that the partnership between the public and private sectors will play a crucial role in solving this problem. The state should play a decisive role in the formation of such a partnership by providing a favourable policy framework for entrepreneurs and investors to take long-term decisions in developing, financing and creating the volume of projects necessary for the energy transition.

The efforts of the state as a catalyst and regulator of innovation processes should aim at creating and supporting effective and competitive national innovation institutions. An equally important area for government attention is reducing the cost of capital required to implement the Energy Transition Programme. As noted in the paper, the main obstacle to mobilising cheap capital is the high level of risk for investors, including country risk, exchange rate risk and withdrawal risk, as well as commercial and purely technological risks. Accordingly, the first and most important task of the government is to implement measures aimed at reducing risks for investors and ensuring a balance between risk and return on investment.

One of the most important methods of ensuring such a balance is the mechanism of blended (concessional) financing, which aims to attract private sector capital where it is most needed and to reduce the cost of capital for such projects. The key principle of blended finance is the provision of capital on concessionary terms (i.e. below market rates) by the government and individual institutional investors (development banks, etc.) in order to change the risk/reward relationship so that private investors are interested in investing their commercial capital on normal market terms.

An effective and actively used (including in Russian practice) method of stimulating investment in the energy transition, reducing the risks of private investors and lowering the cost of attracted capital, is mixed (preferential) financing of the issue of green bonds or sustainable development bonds.

The systemic policy orientations considered in this study will be most effective in supporting energy intensive consumers who are experiencing extreme difficulties in adapting to the increase in electricity costs and whose continued functioning is of particular strategic and/or social importance. Of great interest is the conclusion of long-term contracts by state-controlled electricity generating companies for the supply of electric energy and power to these consumers at discounted prices with a gradual approach to market prices, as well as other direct support measures.

Successful adaptation of large energy-intensive consumers to the consequences of the energy transition also requires changes in corporate policy, management structure and economic behaviour. Access to relatively cheap 'clean' electricity becomes an important competitive advantage, encouraging the gradual relocation of large energy-intensive industries from a zone with a high share of thermal power plants in the regional electricity generation structure to zones with a higher share of hydroelectric power plants and renewable energy sources.

Important ways of adapting large energy-intensive consumers, which can be found both in the world and in Russian practice, are various forms of their integration with producers of cheap electric energy. These range from the conclusion of long-term direct contracts for the purchase and sale of electrical energy and capacity, hedging the risks of the contracting parties, to the purchase or lease of generating capacity and the formation of joint ventures with large generating companies.

The research will help to further improve the concept of integrated transformation of the electric power industry within the framework of the global energy transition, to ensure the application of systemic measures, and to prevent a slowdown in the sustainable development of the energy-intensive industries of the Russian Federation.

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The article was submitted on 15.08.2023; revised on 21.09.2023 and accepted for publication on 28.09.2023. The author read and approved the final version of the manuscript.

文章于 15.08.2023 提交给编辑。文章于 21.09.2023 已审稿．之后于 28.09.2023 接受发表。作者已经阅读并批准了手稿的最终版本。