

Challenges and responses of the economy of the Republic of Tatarstan to decarbonization processes

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The processes of global energy transition are increasingly becoming one of the main driving forces of both the transformation of the existing market model and the technological foundations of the functioning of energy facilities. The reorientation of the world economy towards decarbonization threatens the stability of the functioning of many previously seemingly unshakable technological solutions and approaches in the field of system integration of the fuel and energy complex, which, in turn, stimulates the search for a new paradigm of its development.

The manifestations of transformation are observed at various levels of the economic hierarchy: inter-country, country and intra-country. The development of mechanisms for the response of Russian manufacturers to the realities of the energy transition requires testing at real facilities. According to the authors, Tatarstan can become an indicative region for the development of approaches to achieving carbon neutrality.

For a preventive forecast of the attainability of ESG (Environmental, Social and Governance) indicators, the authors propose a conceptual approach to assessing the development of decarbonization technologies, based on a combination of economic and mathematical methods, which allows us to develop an organizational and legal basis for the process, form and evaluate criteria for the effectiveness of innovations and the conditions for their implementation.

Keywords: decarbonization, energy transition, innovation assessment, ecology, threshold analysis, Bayesian networks, learning curves

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Introduction

In Chinese, the word crisis is composed of two symbols: one signifies danger and the other signifies an opportunity. Being on the verge of an environmental crisis, it is important to be aware of the conditions and goals that arise in front of us in the new realities. The creation of regional testing grounds, scientific-industrial and scientific-technological associations, the formation of a new environmental and economic policy are key elements of the transformation strategy towards carbon neutrality.

Global decarbonization, as a response to global warming and the spread of natural disasters, is gradually spreading across the world at all levels and sectors of the economy and politics. Shifting interests of the global financial market, political initiatives (“EU Green Pact”), transformation of transnational companies,

global scientific and technological reorientation, change in business structure. Although the awareness of the challenges and opportunities of decarbonization is developing unevenly, the world is shifting the economic model from short-term priorities to creating long-term global value, the key driver of which in this context is the onset of the “green” technological revolution.

Changing the existing market model: the decarbonization trend

The analysis of steps and measures in the field of energy transition, with all their general focus on reducing greenhouse gas emissions and the factors causing their formation, differs very significantly depending on the level of consideration of this problem: intercountry, country, intra-country and sectoral. In the latter case, we are talking about individual projects and activities related to both reducing carbon emissions and increasing energy efficiency at various stages of energy production and consumption.

At the cross-country level, regulators play a key role. If earlier they consisted in subsidies, now they are in

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toughening environmental requirements by creating a regulatory and legal framework in relation to producers – emitters of CO₂. Particularly widely discussed are EU initiatives in the direction of integrated regulation, namely the introduction of a cross-border carbon tax – a border carbon regulation measure that obliges exporters of goods to the EU to pay a tax on carbon dioxide emissions associated with the production of their products. For Russia, this is more than 40% of exports, which at the end of 2020 amounted to \$571.5 billion. In accordance with the tariffs established in the EU for CO₂ emissions in the amount of \$30 per ton and expert estimates of the carbon footprint of Russian exports to the EU in the amount of more than 1 billion tons of CO₂, the potential damage to the domestic economy seems significant (Safonov, 2020).

In addition to the above, the financial sector is taking an increasingly active position in the energy transition process. The area of climate finance is developing, which is based on instruments and measures aimed at supporting “green” projects: targeted lending, green bonds, tax incentives, national development banks, information disclosure policy and national climate funds (Safonov, 2020). At the same time, for industries and individual enterprises with a low ESG-rating (ESG – Environmental, Social and Governance), especially with regard to the environmental aspect, there is a tightening of credit and investment policy up to the intention of significant divestments. The amount of funds managed by companies with ESG strategies is growing. This significantly affects the long-term trends in demand, the regulatory environment and the availability of financing for oil and gas companies around the world, not excluding Russian ones. The national oil and gas business of vertically integrated oil companies is significantly dependent on international financing, which accounts for more than 50% in the borrowed capital of leading enterprises (Fig. 1), which sets new conditions for them to disclose information to investors and to prioritize the climate strategy (Gaida et al., 2021).

The largest financial corporation BlackRock, in its messages to CEOs and investors, emphasizes the importance of the climate agenda and warns of intentions to exit the securities of companies that do not disclose information or take steps towards carbon neutrality (Anankina, 2021). Also, according to Reuters, there is a threat of termination of financing by the World Bank of projects related to oil and coal, and in the long term – reduction of gas assets, as part of the strategy to combat climate change (Poryadin, Beloglazova, 2021). The New York State Pension Fund announced at the end of 2020 that it would suspend investing in the assets of companies that do not meet its environmental standards. So far, the requirements have only affected the coal industry and the development of oil sands, but will then be extended to oil

and gas companies that are part of the fund’s portfolio. Including if they do not meet environmental standards, shares of large Russian companies may be put up for sale: PJSC NK Rosneft – 0.008% of the total number of shares of the company, PJSC Tatneft – 0.008%, PJSC Novatek and PJSC Surgutneftegaz – 0.003%. Despite the insignificant exchange effect of this one-time incident, the blow to the reputation and ESG rating of companies can be serious (Russia’s Climate Agenda: Responding to International Challenges, 2021).

The shifting interests of investors are reflected in the market value of assets. The carbon footprint is gradually becoming one of the key characteristics of any business – the capitalization of companies with environmental obligations and sustainable development programs is significantly higher compared to competitors. For example, the cost of the American NextEra Energy, which produces and sells energy from renewable sources, has grown by almost 30% since the beginning of 2020, while the capitalization of ExxonMobil during this period showed a downward trend by 20% (Poryadin, Beloglazova, 2021).

In such conditions, the vector of development of the oil and gas sector directly depends on its ability to transform in the direction determined by the need for accelerated decarbonization.

At the country level, the main range of problems is associated with maintaining a balance between the reflection of common approaches and initiatives of the international community in national legislation and the preservation of the key directions of the economic development strategy. The position of domestic experts on Russia’s strategy in the process of the energy transition seems ambiguous (Global Energy Transition for Russia..., 2021). Many of them oppose the “green” agenda, referring to the fact that this is a political step towards reducing the EU’s energy dependence and that the key importance for the country is played only by its own Energy Strategy, which supports its interests and conditions. There is also a position of non-resistance: the energy transition is an urgent direction of the world energy transformation and technological development. In principle, there are two alternatives: to join the process with all its limitations, or to remain outside the world transformation.

According to the authors, the most constructive idea is to form its own vector of development, taking into account the new conditions that are dictated by the energy agenda. At the highest levels (intercountry and country) – maintaining a balance between national interests and the goals of the global climate initiative, coordination with other countries for which the initiative of the international community is a source of forced changes, a proactive dialogue with the European Union. At the in-country level, according to experts from the

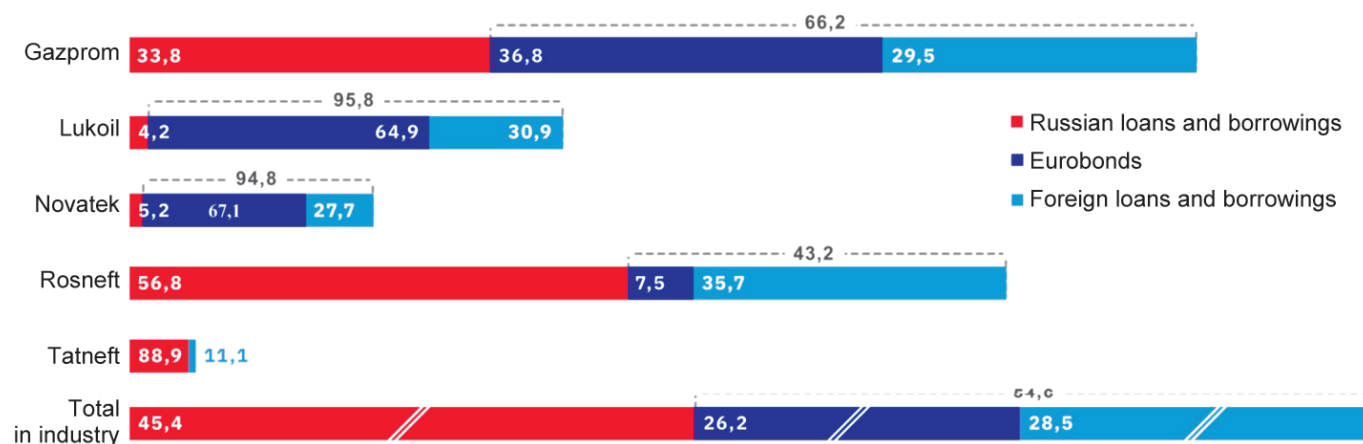


Fig. 1. Share of foreign loans and borrowings in borrowed capital. Source: according to the CSR report together with the Analytical Center of the Fuel and Energy Complex REA of the Ministry of Energy of Russia and the Situational Center (GC Seldon). <https://www.csr.ru/ru/news/klimaticheskaya-povestka-rossii-reagiruya-na-mezhdunarodnye-vyzovy/>

WWF-Russia Environmental Responsibility Program, it is rational to use regional specifics to accelerate energy transition processes. In other words, to identify the experimental regions, priority for certain energy sources and to work out all the processes (financial, technological etc.) (Global Energy Transition for Russia..., 2021).

This approach is distinguished by the gradual implementation of the main steps and measures in the transition to a low-carbon economy, as well as the “experimental” nature of testing models in various industries and regions.

The structure of the Russian economy, thanks to developed industrial sectors and strong intersectoral ties, allows a comprehensive approach to the problem being solved: by changing one fragment of the structure, transform the entire system as a whole. An important aspect in this issue, as mentioned earlier, is taking into account the spatial (regional) characteristics of the production and consumption of energy resources. For example, it is important to take into account (in the case of hydrocarbons) the stage of development of the resource potential (a new region, growing production, a high degree of “development” of the resource base), as well as the peculiarities of the structure of the economy of a particular region.

According to the authors, the Republic of Tatarstan, as one of the leading regions, has unique features and

characteristics – both of the oil and gas industry and the economy as a whole. With regard to the oil and gas sector, we are talking about a high degree of maturity of the resource base, as well as the presence of unique skills and competencies in working with highly viscous and highly depleted reservoirs. This is reflected in the significant role played by small innovative companies. This circumstance creates a steady demand for new technologies and approaches associated with the efficient (within the framework of a new ecological paradigm) exploration and development of such unconventional reservoirs.

It is extremely significant that the economy of the Republic of Tatarstan also has a diversified nature – in addition to the actual production of hydrocarbons, oil and gas processing and petrochemistry are actively developing. Machine building, agriculture, science and education, and other sectors of the economy are well developed in the Republic (Table 1).

Due to the pronounced domination of industries with a high carbon footprint, developed knowledge-intensive industries and a well-built system of intersectoral interactions, the Republic of Tatarstan can become an indicative region (not to be confused with an experimental area !!!) for the development of approaches to achieving carbon neutrality in the process of cooperation and close interaction of participants from different sectors of the

	Agriculture, forestry, hunting, fishing	Mining and quarrying	Manufacturing	Construction	Knowledge-intensive industry	Other
Russian Federation	4.3	14.8	18	5.6	17.2	40.1
Moscow	0.1	0	16.2	3.4	25	55.3
Saint-Petersburg	0.2	0.3	17.2	4.4	28.6	49.3
Khanty-Mansiysk autonomous district	0.2	73.3	2.3	5.2	6.2	12.8
Moscow Region	1.7	0.2	20.6	5.2	16.3	56
Republic of Tatarstan	5.7	30.5	15.9	8.1	12	27.8

Table 1. Sectoral structure of gross value added by regions-leaders of Russia in socio-economic development in 2020. Source: according to the Federal State Statistics Service. https://gks.ru/bgd/regl/b20_14p/Main.htm

economy within a separate economically self-sufficient and sustainable region.

Technological innovation development model

Following the decarbonization trend, industrialists will have to adapt and introduce expensive technologies, which at the initial stage requires determining the economic effect and the risk component from the upcoming modernization of production. Assessment of technological innovations is a specific task due to the high ambiguity of the forecast of production and financial indicators, which limits the use of conventional methods of investment analysis. According to the authors, it is necessary to consistently solve two subproblems:

- determine the required state of technology development;
- determine the conditions for achieving such a state.

The result should be a practically applicable set of technological, organizational and legal mechanisms for the development of hydrocarbons in a more environmentally friendly way while maintaining an acceptable rate of business profitability.

The author's algorithm for evaluating technological innovations in decarbonization for solving the first subtask uses threshold analysis, and for the second – building a Bayesian network using learning curves (Fig. 2).

Each technology is characterized by a set of indicators that determine the cost of its development, acquisition and subsequent use, applicability to a specific task, performance in certain operating modes. The

combination of indicator values determines the state of technology development. Obviously, in the context of decarbonization, technologies with different initial states can be considered, and most importantly, a directed impact on a particular technology through R&D leads to various changes in its state.

A greener technology that replaces an old one does not have to be identical in terms of production efficiency and cost of use. New technology can be more expensive, but more effective, or vice versa. Thus, the sought-after is the set of all target states – satisfying the given criteria, for example, positive expected profitability (Expected Monetary Value – $EMV > 0$), environmental standards (ESG obligations), corporate budget for production modernization, etc. The computational procedure for such a threshold analysis involves the construction of a production and investment model (Dushenin, Milyaev, 2018) and, with its help, the assessment of scenarios for the introduction of new technologies into production that are in different states of development.

The enumeration method is the simplest way to implement the threshold analysis, but due to the large number of possible scenarios, it is applicable only for degenerate, as a rule, theoretical problems. In practice, you can use the monotonous dependence of the economic result on most of the initial indicators and exclude most of the possible combinations of variable characteristics at the start of calculations (Milyaev, Kidanova, 2017).

Now that the minimum permissible states of technology development have been determined, it is necessary to compare them with objective realities: it



Fig. 2. Scheme for assessing technological innovations for decarbonization

is very likely that all or most of the states cannot be realized at the present time. For example, capturing carbon dioxide directly at the source of emissions will require membranes with a permeability 30% higher than existing ones. Or injection of carbon dioxide into the reservoir will entail the use of anti-corrosion pipes, the cost of which should be half the current cost. Can the target state of the technology be achieved, with what probability, for what time period and by what means? The answers to these questions can be obtained as a result of modeling the joint innovation activity of enterprises in the industry.

Classically, for R&D, an organizational and legal unit is formed, the so-called “scientific cluster”, consisting of one or more agents: subsoil users, R&D centers, service companies, investors, government agencies. The composition of the cluster determines its ability to influence the development of technology in the direction of one or several target states, because each agent brings a unique contribution in the form of its own human, material and technical, financial resources and competencies. As a consequence, each potential cluster composition can be associated with a set of measurable numerical characteristics that affect the rate of technology development by the forces of such a cluster.

In a mathematical setting, this can be implemented in the form of a Bayesian network (Abdulkareem et al., 2019), which has the structure of a directed tree – an acyclic graph with a single root, to each non-root vertex of which exactly one arc will lead (Fig. 3). The number of network levels is made up of the number of agents that form the organizational and legal structure of the cluster, and the number of possible improvements in technology that characterize various options for its development. Each path of a Bayesian network, that is, a sequence of vertices connected by arcs, from root to leaf, corresponds

to a separate scenario for the development of technology by the formed cluster. Several paths allow reaching the target state of the technology.

Any arc of the Bayesian network defines an event. The probability of occurrence of events at the upper N levels of the network is set by binary variables in such a way as to consider all admissible options for the composition of the cluster. For the lower M levels of the network, calculating the probabilities of events is a non-trivial problem solved using learning curves (LC).

LCs provide a mathematical representation of the learning process through the repetition of tasks. These curves were originally proposed by T.P. Wright in 1936 to estimate the cost and lead time savings resulting from repetitive processes in manufacturing plants (Yelle, 1979). Later, this approach was modified to simulate technological development (see, for example, (Kryukov, Gorlov, 2019)).

A retrospective of the development of another technology is taken as a basis, which is close in terms of the concept of development, that is, in terms of the totality of organizational, legal and scientific and production tasks. For example, for some decarbonization technologies, multistage hydraulic fracturing technology can be used as a retrospective basis: there are sufficient statistical data for it linking investments in R&D with an increase in hydraulic fracturing productivity and a decrease in unit costs.

A simplified analysis of the learning curve is illustrated in Fig. 4:

1. The influencing factors are selected depending on the specifics of the considered event (arc) of the Bayesian network. For example, if the event is a particular budget of the cluster, then it is reasonable to choose the volume of investments in R&D as an influencing factor;

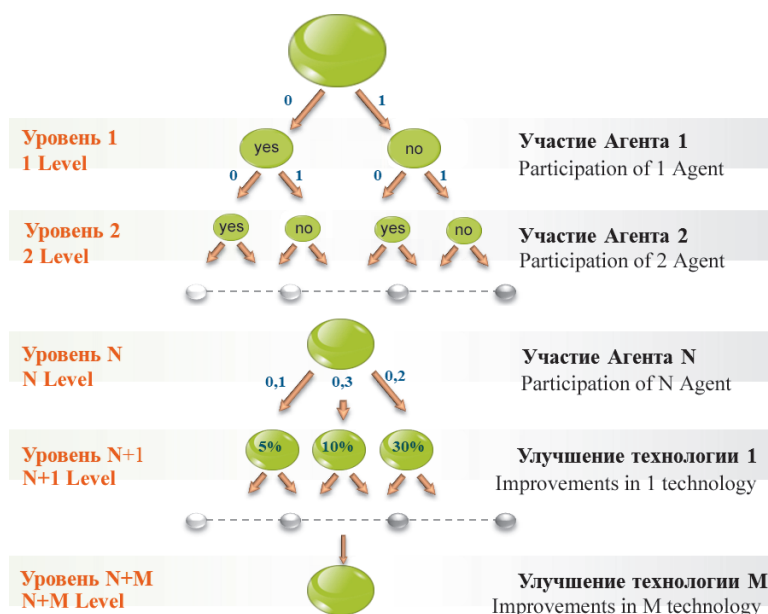


Fig. 3. The structure of the Bayesian network for predicting the technological success of the cluster

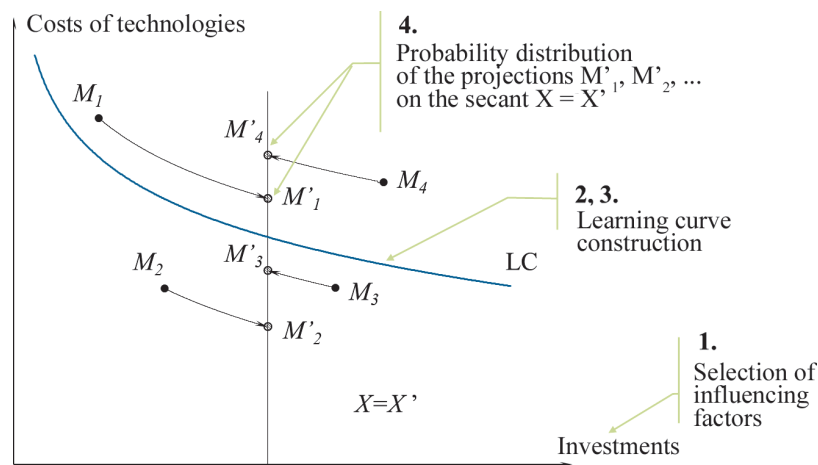


Fig. 4 Probabilistic analysis of learning curves

2. The dependence of the target indicator on one or several influencing factors is built according to the principle of the minimum total deviation from the retrospective points M_1, M_2, \dots ;
3. The resulting curve and all points of M_i are normalized in such a way as to correspond as much as possible to the history of development and the current state of the decarbonization technology to be developed;
4. Considered in turn each value of the influencing factor X' , appearing in the Bayesian network: the projections of points M_1, M_2, \dots on the secant $X = X'$ set the probability distribution of the target indicator. So, on the presented graph, the projections M'_1, M'_2, \dots reflect the set of possible costs of technologies after X' investments.

The application of the learning curve allows you to determine the desired probabilities of events, that is, the weights of the edges of the Bayesian network. Further, the probability of the technology development scenario is calculated by multiplying the weights of all arcs of the selected path.

As a result of the described calculations, the probability distribution of potential states of the technology is found, and most importantly, the probability of achieving its target state. The corresponding path of the Bayesian network characterizes the mechanism of innovation development.

Conclusions

Decarbonization creates technological and economic challenges due to the need to replace traditional hydrocarbon exports with the supply of “green” energy carriers. The new trend has an artificial origin, apparently developing in spite of market mechanisms, primarily due to the announced incentive and coercive measures. In any case, the Russian oil industry will have to adapt and introduce expensive technologies, which raises the question of economic justification for modernizing production or investing in new venture projects.

We formalize the process of technological innovation development using a mathematical apparatus: threshold analysis, agent-based modeling, Bayesian networks, learning curves. This allows us to determine the likelihood of developing and implementing the desired decarbonization technology that meets the requirements for expected profitability, ESG strategy and corporate budget.

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