Innovation and energy efficiency: impact on the sustainability development

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Abstract. New technologies are one of the most significant driving forces of the modern economy, which make it innovative. The main reasons for the low rate of scientific and technological development in Russia are rooted in the inconsistency of the applied organizational and economic mechanisms with the fundamental laws of development of innovative processes, taking into account existing conditions and factors. The long-term experience of leading countries in the field of innovative development reveals certain patterns of successful innovation that seem to be common to most economies in the world. At the same time, according to the foreign practice of creating knowledge and its market implementation, national specifics and specific features of the state and dynamics of economic objects at one or another level of the national economic hierarchy (sectoral, territorial and others) require specific adaptation of the general methodological principles of innovation development, based on a separate problem situation and available resources.

1 Introduction

First of all, the core of the theory and practice of innovation is the idea that it is an interactive process in which all involved agents and organizations must interact with sufficient quality and consistency [1]. This factor significantly hinders the development of innovation in Russia. In the case of a serious difference in interests (objectively inherent in each situation), appropriate control actions are required to direct the innovation system to equilibrium. It is clear that national specifics impose limitations on the content of such influences. At the same time, from foreign experience it has been established that the scientific systems of successfully developing countries are characterized by some common features that differ less than the characteristics of the educational system and the structure of the market in these countries. Labor relations significantly influence the nature and depth of interactions. The mobility of the labor market, as in the USA, significantly expands contacts [2]. Methods of organizing work are generally recognized factors of successful innovative development. If in Sweden they do not pay enough attention to it [3], then in Japan, on the contrary, this is a decisive condition for the thorough improvement of new technologies and mass promotion to the market. As a result, the quality of strategic

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planning and management varies markedly across countries. For example, in Finland it is better than in the UK due to close interaction between the public and private sectors, which develop joint strategies. Along with Finland, France, Singapore, and China are distinguished by the coordination of participants' actions necessary for the development of innovations [3]. In the UK, coordinated interactions are difficult due to the specific nature of labor relations and the traditionally wary (if not to say negative) attitude of the private sector towards the public sector. However, the British innovation system has many other strengths that promote innovation and place the country in second position out of 143 countries, while Finland ranks 4th according to the GII Innovation Index (Figure 1). That is, along with the close interactions of players, other factors influence the development of innovation; they will be discussed in the following sections of the article.

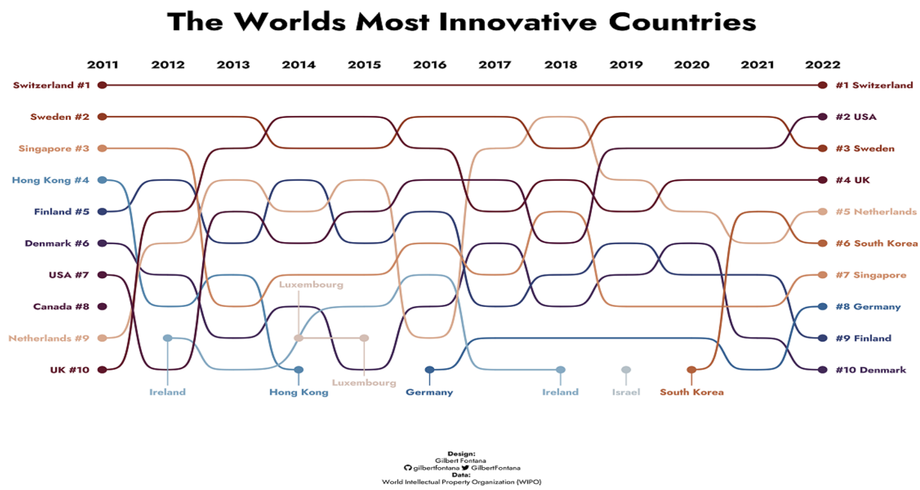

Fig. 1. The most innovative coutries

In Russia, the implementation of a collaborative style of innovation is hampered by a number of negative economic and institutional factors: insufficient quality of institutions, regulatory defects, mistrust of actors, isolationism of thinking and economic behavior, lack of collective solidarity, economic offenses, corruption, lack of motivation, ease of obtaining income from financial speculation and at the initial stages of the value chain (from the export of raw products). As a result, we rank 126th in terms of the level and quality of connectivity of innovation activities (Fig. 2). In particular, the lack of coordination of actions in Russia is characteristic of the macro level.

GII rank	Economy	Score	Income group rank	Region rank
1	Switzerland	64.6	1	1
2	United States	61.8	2	1
3	Sweden	61.6	3	2
4	United Kingdom	59.7	4	3
5	Netherlands	58.0	5	4
6	Republic of Korea	57.8	6	1
7	Singapore	57.3	7	2
8	Germany	57.2	8	5
9	Finland	56.9	9	6
10	Denmark	55.9	10	7
11	China	55.3	1	3
12	France	55.0	11	8
13	Japan	53.6	12	4
14	Hong Kong, China	51.8	13	5
15	Canada	50.8	14	2
16	Israel	50.2	15	1
17	Austria	50.2	16	9
18	Estonia	50.2	17	10
19	Luxembourg	49.8	18	11
20	Iceland	49.5	19	12
21	Malta	49.2	20	13
22	Norway	48.8	21	14
23	Ireland	48.5	22	15
24	New Zealand	47.2	23	6
25	Australia	47.1	24	7
26	Belgium	46.9	25	16
27	Cyprus	46.2	26	2
28	Italy	46.1	27	17
29	Spain	44.6	28	18
30	Czech Republic	42.8	29	19
31	United Arab Emirates	42.1	30	3
32	Portugal	42.1	31	20
33	Slovenia	40.6	32	21
34	Hungary	39.8	33	22
35	Bulgaria	39.5	2	23
36	Malaysia	38.7	3	8
37	Türkiye	38.1	4	4
38	Poland	37.5	34	24
39	Lithuania	37.3	35	25
40	India	36.6	1	1
41	Latvia	36.5	36	26
42	Croatia	35.6	37	27
43	Thailand	34.9	5	9
44	Greece	34.5	38	28
45	Mauritius	34.4	6	1
46	Slovakia	34.3	39	29
47	Russian Federation	34.3	7	30

Fig. 2. Global Innovation Index 2022 rankings

Historic data, plus the global economic recession, would have led one to expect a prompt cutback in research and development (R&D), intellectual property (IP) filings and venture capital in 2020 and 2021. The opposite happened: • Scientific articles published globally surpassed the 2 million mark for the first time in 2021. • Investments in global R&D in 2020 grew at a rate of 3.3 percent, not falling, but slowing from the historically high 6.1 percent R&D growth rate recorded in 2019. • Government budget allocations for the top R&D spending economies showed strong growth in 2020, as governments vigorously sought to mitigate the economic effects of the crisis on the future of innovation. For 2021 R&D budgets, the picture is more varied, with government spending having continued to grow in the Republic of Korea and Germany, but being cut by Japan and the United States. • In turn, top corporate R&D spenders increased their R&D expenditure by more than 11 percent in 2020, and by almost 10 percent to over USD 900 billion in 2021, which is higher than in 2019 before the pandemic. This increase was primarily driven by four industries: ICT hardware and electrical equipment; Software and ICT services; Pharmaceuticals and biotechnology; and, Construction and industrial metals. Firms that cut

R&D in 2020, including in sectors such as Automobiles; Industrial engineering and transportation; and Travel, generally – but not always – returned to R&D growth in 2021. • IP filing activity grew during the global pandemic in 2020 and in 2021, too. International trademark filings – a good proxy for entrepreneurship – saw particularly strong growth in 2021, up by 15 percent. • The biggest boom was in venture capital (VC). VC deals grew by 46 percent in 2021, recording levels comparable to the internet boom years of the late 1990s. What is more, VC has become more inclusive, with the Latin America and the Caribbean and Africa regions witnessing the strongest VC growth, albeit from a low base. The VC outlook for 2022 is more sober; tightening monetary policies and the knock-on effect on risk capital will lead to a deceleration in VC.

The decline in innovation linkages during and after the crisis is partly due to some decline in triadic patent registrations and a decline in foreign investment in R&D, but the situation is gradually improving in all countries. Effective interactions rely on the appropriate response of consumers of new products based on feedback mechanisms; Thus, it turns out not a triple, but a quadruple helix, including four types of players: researchers, producers, the state and the population [9]. Thus, in Japan the population actively participates in the so-called. social experiments to develop pioneering carbon-free technologies during the transition to a new energy sector, which helps to find the right forms of interactions and control levers, spread experience to other areas, and form and consolidate innovative consciousness [6]. A significant stimulating effect was obtained through the so-called tied grants, distributed under certain conditions in joint innovation activities of industrial companies and universities [7]. One of the manifestations of the synergy of close cooperation between participants in innovation activities is the phenomenon of open innovation, as a result of which, not limited to the boundaries of their institution, a wide range of different organizations are involved in the innovation process. As a result, an interdisciplinary approach to research is implemented. Typically, such innovations give impetus to the development of new industries and services. Thus, discoveries in optoelectronics and photonics caused a powerful breakthrough in ICT, the aviation industry, laser production, defense industries, energy, astronomy, medicine, and television. The "http" 8 protocol was invented at CERN (Switzerland), but thanks to the principles of open innovation it was widely used in the USA [8]

2 Research Methodology

Energy represents a specific group of economic sectors that determine the functioning of the socio-economic system. The central role of energy in its functioning is to ensure economic and social needs, subject to environmental restrictions, with the aim of sustainable development of all economic entities, sectoral and regional subsystems, as well as society. At the same time, the requirement of environmental sustainability involves minimizing the negative impact of external environmental factors, usually associated with the use of traditional energy resources. The state and dynamics of the fuel and energy complex (FEC) are closely interconnected with the development of the entire national economic organism. This is especially relevant for the national economy of Russia, in which the fuel and energy complex plays a system-forming role. Innovation is considered as the main modern direction of development of the energy industry, reducing threats to energy and environmental security, increasing energy efficiency and sustainability of the economy and its components. Taking into account the special inertia of energy, today the energy complex should be intensively updated to ensure long-term sustainability.

3 Results and Discussions

According to the definition of the International Energy Agency (IEA), the concept of energy security focuses on consumers of energy resources, therefore, first of all, it includes the requirements of accident-free and uninterrupted physical and economic availability of energy at affordable prices, taking into account environmental restrictions [5]. However, a systematic understanding of the long-term sustainability of the socio-economic system at all levels of the hierarchy requires a most comprehensive approach to energy security, namely, from the standpoint of the mutual influence of the four components of social development: social, environmental, economic, technological, which form the basis for the competitive stable development of the energy sector and the country generally. Accordingly, the application of goals and criteria for the development of the fuel and energy complex, as well as control influences, presupposes their justification from the standpoint of system-wide sustainability and national economic efficiency. In the Energy Strategies of Russia for the period up to 2020 and for the period up to 2030, energy security is interpreted as "the state of security of the country, its citizens, society, the state serving their economy, from threats to reliable fuel and energy supply" [4]. Although not so obvious, this still implies saving resources, improving the quality of life, protecting the environment, and balancing regional proportions. However, the measures taken and the mechanisms planned are far from systematic. In a later document, the Strategy for the period until 2030, this understanding of energy security assumes four basic targets: resource sufficiency (no shortage of energy raw materials), economic accessibility (profitability of energy production and generation), environmental and technological admissibility (technical safety; possibility mining, production) [5]. Thus, energy security is closely linked to environmental security, quality of life, efficient use of resources and continuous technological improvement. That is, it includes not only the provision of resources, but also their productivity, timeliness of modernization and replacement of technologies (technical progress), and social responsibility. Characteristics of energy security as the unity of four basic energy pillars of economic sustainability - sufficiency of the volume and quality of energy resources for industrial use and consumption; economic accessibility of energy for enterprises and the population; careful use of resources; resistance to disturbances - makes the category of energy security an integral attribute not only of the state of the economy or the sphere of production, but also of society as a whole. In this understanding of energy security, its acceptable level is ensured by the impact not only on energy facilities, but also on external factors influencing them [11]. The systemic approach involves the analysis of significant influencing factors, connections and interactions of energy facilities in the process of innovative transformations in order to increase the sustainability of the socio-economic system. Structure of the fuel and energy complex and energy efficiency The fuel and energy complex of the Russian Federation itself includes several main subsystems and infrastructure, differing in the types of products produced, resources used, technologies: a) extractive industry: oil, gas, coal, other (using shale, firewood, peat and other local fuels). energetic resources); b) electric power and thermal power engineering: traditional (nuclear, thermal power, hydropower) and alternative energy using renewable energy sources (RES): wind, sun, tides, biomass, Earth energy, as well as small capacities (small hydroelectric power stations, own boiler houses, etc.), energy of hydrogen and thermonuclear fusion (in the future); c) heat supply, where energy is not received, but distributed. Another structuring is possible, according to the types of energy sources used and methods of energy generation: a) non-renewable energy using fossil fuels; b) renewable energy using non-traditional renewable energy sources and hydro resources.

Innovations are fundamentally new (in the country, in the world) developments that have passed the stage of commercialization, i.e. recognized by the market and having a market value. They are qualitatively different from improvements and radically change the production process, the product being manufactured, the organizational structure of the enterprise or the control subsystem and management [10]. Depending on the final goal, there are several types of innovations: process, product, organizational, and management. Almost all innovations, both in the extractive industries, and in oil refining, and in energy production, require additional, above-standard costs, therefore technologically developed societies are characterized by increased consumption of fuel and energy resources, the extent of which is largely determined by national factors associated with differences in economics and geography , technological development of countries. In this regard, cross-country comparisons of GDP energy intensity (in the traditional measurement of its indicator as an inverse indicator in relation to energy efficiency) are not always informative for the analysis and forecast of energy efficiency dynamics and reserves. Thus, the backward economies of Africa occupy adjacent rows to the developed economies of the EU, USA, and Japan. The values of these indicators are influenced by a number of national characteristics and factors: the structure of the economy and exports; geographical scale of the country, climate, fuel and energy balance structure and types of technologies used; etc. However, the same energy efficiency is observed in economies with different levels of development and, conversely, in countries with similar climatic conditions, energy efficiency is different (fig.3).

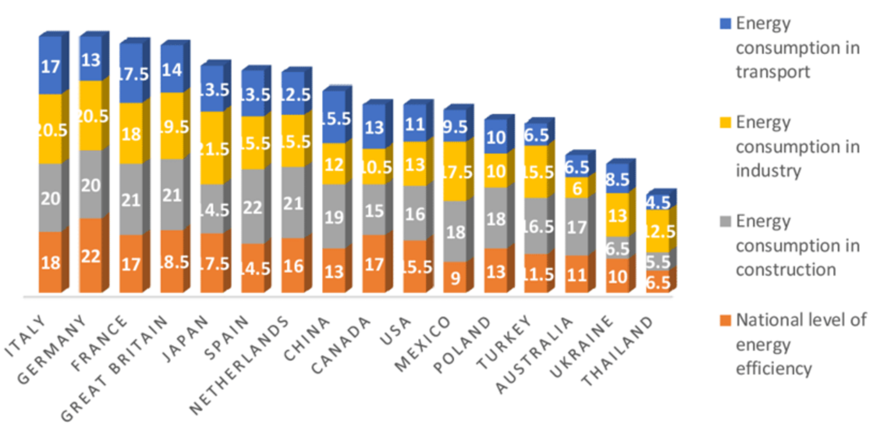

Fig. 3. The world country ranking of energy efficiency

Based on these and other comparisons, the following conclusions can be drawn. Firstly, about the importance of technological factors of energy efficiency, taking into account the fact that structural factors have been exhausted. Secondly, the need to use other types of innovations and qualitative factors of energy efficiency, including improving the quality of strategic planning and management at all levels of the hierarchy, the efficiency of the government and administrative apparatus, the quality of production organization and corporate management. Thirdly, that the management of existing criteria for economical resource use (energy saving) does not always bring a sustainable social effect. To monitor and manage energy efficiency, criteria are required that most adequately meet the goals of system development. In this regard, the cost assessment of energy resource costs more realistically characterizes the scale and, most importantly, the qualitative types of fuel and energy resources consumed, than natural energy units (oil equivalent, standard fuel, joules) [7]. This approach allows us to differentiate the consumed energy production factors and integrate the energy efficiency indicator according to four positions: economic, social, environmental, scientific and technical (innovation) effects. Ecology of production, "green" technologies and clean energy sources, ultimately, especially in the long-term horizon of the operation of an energy facility, lead to increased energy efficiency, since they ensure growth of the company's image, i.e. increase its intangible assets (goodwill), and this is a direct path to capitalization growth. Indeed, the transition to new technologies is accompanied by risks and at the same time requires increased investments with returns delayed indefinitely, but subject to competent management and disposal of assets, the long-term effect will be greater [8]. Along with other points, the determining factor of efficiency here is the range of the planning horizon. Innovation intensity is innovation activity, measured, most often, by the share of a) costs for innovations of one type or another or b) organizations carrying out innovations of one type or another in the total number of organizations in the sector of the economy under consideration, significantly depends on the level of development of the national innovation system , architecture of the energy complex, type of economic activity (industry, production complex). Thus, against the general background of low innovative activity of Russian energy enterprises, the oil refining industry stands out noticeably. At the same time, in developed economies the share of organizations engaged in technological innovation reaches 70% (in Germany).

4 Conclusions

The vector for increasing energy efficiency is determined by two directions: energy saving and increased productivity in energy production. Unlike energy saving, which is aimed at reducing the costs of fuel and energy resources, energy productivity is aimed at increasing product output at the same costs. In this regard, productive methods of extraction, processing and generation ensure economic growth, and the use of new technologies for these purposes contributes to the development of the fuel and energy complex and related industries. At the same time, all areas of energy efficiency improvement contribute to the sustainable development of an integral economic system. Motivation for energy efficiency measures is closely related to the criteria for the functioning of the system as a whole and its units, therefore indicators of energy efficiency dynamics require careful justification from the standpoint of system-wide interests of sustainability and corporate goals of increasing competitiveness. From this point of view, in works , energy efficiency indicators are specified by levels of the national economic hierarchy, taking into account a more reasonable inclusion of types of energy costs in the total energy costs in the corresponding subsystem. At the macro level, energy efficiency is proposed to be measured as the increase in national wealth to the costs of national wealth that caused the increase; at the fuel and energy complex level - as the ratio of GDP growth to the consumption and export of fuel and energy resources; at the regional level - as the ratio of the increase in the quality of life to the costs of fuel and energy resources; at the level of business units - as the ratio of capitalization and costs of fuel and energy resources in value terms; at the level of an individual installation - as its efficiency. The capitalization of a company depends on the quality of three types - management, resources used, and product produced. Thus, energy efficiency is significantly determined by the degree of recognition of the product by the market (hence the increase in competitiveness) and society (the level of satisfaction of social and production needs) in relation to the amount of corporate capital spent on these purposes. Therefore, the growth of energy efficiency is closely related to the quality of life, the development of human potential and social capital.It is important to note that measures aimed at supporting this sector of the economy require special attention. The USA has a number of programs that provide effective assistance to small and medium-sized enterprises in all sectors of development, with a special focus on biotechnology. Under these programs, the U.S. government allocates various grants during the business development period or as part of individual budget plans. Similar programs aim to strengthen and expand the capacity of relationships between national research institutions and the SME sector through public-private partnerships. Similar programs are organized through public-private contracts to strengthen the relationship between non-profit research institutes and the SME sector and expand their profitability. Bioindustry support programs in the U.S. also vary in their level of implementation. In the United States, due to the structure of the federal government, programs developed at the state level (hereinafter referred to as regions) have the greatest impact on the development of the bioindustry. In our view, the high success of the U.S. biotechnology industry is the result of close contact and integration of biotechnology companies into industry clusters. Today this process of clustering affects more than 50% of the industrialized countries of the world, which shows the advantages of this form of organization of scientific and production activities. According to statistical surveys, it is noted that enterprises included in clusters function more actively in contrast to autonomous ones. For example, such firms more often offer product and technological innovations to other members of the group, more actively apply for patents and ensure higher competition in national and international markets. In addition, this becomes possible due to close contacts with other cluster members.

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