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OPINION
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Sustainable and Environmental Development of Energy Economy in Smart Regions of Russia

Sergey V. Muzalev[1*†], *Sergey N. Kukushkin*[2†], *Olga A. Grazhdankina*[3†] and *Anastasia V. Nikolaenko*[4†]

[1]*Financial University under the Government of the Russian Federation, Moscow, Russia,* [2]*Department of Economics and Organisation of Production, Plekhanov Russian University of Economics, Moscow, Russia,* [3]*Department of Finances and Credit, Altai State University, Barnaul, Russia,* [4]*North-West Institute of Management—Branch of the Russian Presidential Academy of National Economy and Public Administration, St. Petersburg, Russia*

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****Correspondence:***
Sergey V. Muzalev
msv.com@mail.ru

[†]*These authors have contributed equally to this work*

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INTRODUCTION

The energy economy is undergoing a digital transformation, which contributes to its sustainable and environmental development. This process has been studied in sufficient detail at the level of the national economy in the existing literature (Ram et al., 2022; Zhao et al., 2022). The problem is that the regional level includes specific characteristics of territories that become less noticeable and are not taken into account at the macroeconomics level (Cortese et al., 2022; Li, 2022; Xu, 2022; Zaidan et al., 2022). This is especially true for countries with a large territory.

In this regard, Russia can serve as an example, since it not only has a territory with a diverse geography, but is also a major energy power. Its exports in the field of energy have been studied in sufficient detail and have been the subject of active scientific discussion in recent years (Popkova et al., 2021; Popkova, 2022). At the same time, Russia's internal energy policy related to the energy supply and energy consumption in the Russian regional economy has been studied and developed to a lesser extent, which is a research gap.

The purpose of this article is to study the experience of sustainable and environmental development of the energy economy in the regions of Russia and the role of "smart" technologies in this process. The originality of this article lies in the fact that it reveals a new–mesoeconomic perspective of studying the sustainable and environmental development of the energy economy based on "smart" technologies, and also highlights the best practices of "smart" regions of Russia.

SUSTAINABLE AND ENVIRONMENTAL DEVELOPMENT OF THE ENERGY ECONOMY BASED ON "SMART" TECHNOLOGIES: LITERATURE REVIEW

The research in this paper is based on the Theory of sustainable and environmental ("green") development of the energy economy, which foundations are set in the works of Ajiboye et al. (2022), Ali et al. (2022), Mahmoud et al. (2022), Matsunaga et al. (2022), Qu et al. (2022) and Sharma et al. (2022). In the existing literature, the issues of sustainable and environmental development of the energy economy based on smart technologies are thoroughly elaborated. The scientific concept of the energy economy of a smart region is formed in the works of Bellocchi et al. (2020), Dominković et al. (2018), Guo et al. (2022), Kleineidam et al. (2016), Li (2022) and Ortiz Cebolla and Navas (2019).

In the works of Chen et al. (2022), Elnour et al. (2022), Kabeyi and Olanrewaju (2022), Kamruzzaman and Alruwaili (2022), Nasir et al. (2022), it is noted that "smart" technologies

TABLE 1 | Environmental profile of the "smart" regions of Russia from the standpoint of the energy economy according to data for the winter of 2021–2022.

Region	Industrial and environmental index (PMI), Scores 1-100	The Share of Organizations Implementing Innovations that Provide		Percentage of Organizations Using		
		Reduction of Energy Intensity of Production (Enp), %	Reduction of Carbon Dioxide (CO_2) (Crb) Emissions into the Atmosphere, %	ERP-System (Erps), %	Electronic sales (Ecmc), %	RFID technologies (rfid), %
Yaroslavl region	71	63.6	54.5	17.9	13.0	6.5
Tambov region	69	25.0	25.0	13.2	8.8	5.6
Chukotka Autonomous Okrug	67	100.0	100.0	7.3	4.6	7.1
Vologda region	66	80.0	40.0	13.2	11.6	6.3
Belgorod region	66	75.0	50.0	17.1	14.9	6.6
Perm Region	65	29.4	11.8	23.1	11.1	6.3
Tyumen region	64	22.2	16.7	19.1	14.1	8.1
Republic of Karelia	63	50.0	50.0	13.0	8.9	5.3
Yamalo-Nenets Autonomous Okrug	63	20.0	50.0	17.0	11.6	7.5
Tomsk region	63	80.0	20.0	15.0	12.8	7.4

Source: compiled by the authors based on the materials of the Green Patrol (2022), the Ministry of Statistics of Russia, Rosstat, HSE (2022), Rosstat (2022).

contribute to the sustainable and environmental development of the energy economy. Environmental benefits are also highlighted, which mainly include combating climate change (SDG 13) and protecting ecosystems (SDGs 14-15).

However, uncertainty remains regarding the social and economic benefits. Studies by Ahmad et al. (2022), Rezaei et al. (2022) indicate that responsible corporate management of "smart" technologies allows them to be introduced as environmental ("green") innovations in the activities of energy companies, creating benefits for the environment. The examination of the characteristics of the region as an economic system in which the sustainable and environmentally friendly development of the energy economy on the basis of "smart" eco-innovations occurs is a gap in the literature. To fill the identified gap, a comprehensive quantitative and qualitative study is conducted in this article.

THE ROLE OF "SMART" TECHNOLOGIES IN THE SUSTAINABLE AND ENVIRONMENTAL DEVELOPMENT OF THE ENERGY ECONOMY IN THE REGIONS OF RUSSIA

In this paper, energy efficiency is considered in three aspects: 1) reduction of energy intensity; 2) decarbonization; 3) environmental friendliness of industry as the most energy-intensive sphere of economy. This allows for the most correct research of energy efficiency as the indicator of the sustainable and environmental development of the energy economy.

In a quantitative aspect, this article presents and analyzes the rate of use of "smart" technologies in organizations (based on statistics from the Ministry of Finance of Russia, Rosstat, HSE, 2022), which allows identifying "smart" regions of Russia. Regional statistics of Rosstat (2022) characterizing the introduction of "green" energy innovations in Russia are also being studied. The study is conducted on the example of the top 10 regions of Russia, which are the leaders of the environmental rating of the NGO "Green Patrol" (2022) for the winter of 2021–2022. Statistical characteristics of the sample regions are presented in **Table 1**.

Using the data from **Table 1**, regression analysis for one year—2021—is performed; it reflects the most up-to-date statistics. The data are not studied in dynamics in this paper, for statistics on the previous period (2020) largely reflects the impact of the COVID-19 pandemic and crisis (the study of which goes beyond this paper), and so its consideration might have distorted the treatment of the results of this research.

Using the methods of regression and correlation analysis, it is established that "smart" technologies play an important role in the sustainable and environmental development of the energy economy in the regions of Russia. Firstly, it has been revealed that "smart" technologies contribute to improving the energy efficiency of the regional economy of Russia. This conclusion is based on the determined regularity of the reduction of energy efficiency in the course of dissemination of smart technologies (demonstrated by the example of online sales). Though the proof is given by the example of ten regions in this paper's sample, the conclusion would be correct for all regions of Russia, because the sample is representative of all of them (it includes regions from all federal districts). This is evidenced by the obtained regression model (**Eq. 1**):

$$enp = 102.41 - 6.07erps + 3.95ecmc + 0.41rfid \quad (1)$$

Eq. 1 indicates that with an increase in the share of organizations engaged in electronic sales by 1%, the share of organizations implementing innovations that reduce the energy intensity of production increases by 3.95%. And with an increase in the share of organizations using RFID technologies by 1%, the share of organizations implementing innovations that reduce the energy intensity of production increases by 0.41%. The correlation of energy efficiency with "smart" technologies was 66.27% (high).

Secondly, it was revealed that "smart" technologies contribute to the decarbonization of the regional economy of Russia. This is evidenced by the obtained regression model (**Eq. 2**):

$$crp = 86.37 - 3.49erps - 1.86ecmc + 4.57rfid \quad (2)$$

Eq. 2 shows that with an increase in the share of organizations using RFID technologies by 1%, the share of organizations implementing innovations that reduce carbon dioxide (CO_2) emissions into the atmosphere increases by 4.57%. The correlation of decarbonization with "smart" technologies was 72.87% (high). Decarbonization here is treated as a component of energy efficiency in the aspect of an increase in the environmental friendliness of the energy economy.

Thirdly, it is determined that "green" energy innovations contribute to the growth of environmental friendliness of industry in the regions of Russia. This is evidenced by the obtained regression model (**Eq. 3**):

$$PEI = 64.43 + 0.004enp + 0.02crb \quad (3)$$

Eq. 3 indicates that with an increase in the share of organizations implementing innovations that reduce the energy intensity of production by 1%, the industrial and environmental index increases by 0.004%. And with an increase in the share of organizations implementing innovations that reduce the energy intensity of production, reducing carbon dioxide (CO_2) emissions into the atmosphere by 1%, the industrial and environmental index increases by 0.02%. The correlation of the environmental friendliness of industry with the sustainability of the energy economy was 26.77% (moderate).

The reliability of all three obtained regression models (**Equations 1–3**) is confirmed by high values of correlation coefficients, which prove the close connection between the studied indicators. Based on the obtained models, it was revealed that with an increase in the share of organizations engaged in electronic sales by 87.72% (from 11.14% in 2021 to 20.91%), as well as an increase in the share of organizations using RFID technologies by 250.59% (from 6.67% in 2021 to 23.38%), the following advantages will be achieved for the sustainability of the energy economy in the regions of Russia:

→ Increase in the share of organizations implementing innovations that reduce the energy intensity of production by 83.42% (from 54.52% in 2021 to 100%);
→ Increase in the share of organizations implementing innovations that reduce carbon dioxide (CO_2) emissions into the atmosphere by 139.23% (from 41.80% in 2021 to 100%).

Together, this will ensure an increase in the environmental friendliness of industry in the regions of Russia by 2.50% (from 65.70 points in 2021 to 67.34 points).

Case experience of sustainable and environmental development of the energy economy in the "smart" regions of Russia based on EnergyTech and Smart Grid.

In the qualitative aspect, the practical experience of sustainable and environmental development of the energy sector in the "smart" regions of Russia is studied, while special attention is paid to the best practices of Moscow. Successful examples of improving the energy efficiency of the regional economy of Russia involve the use of the following "smart" technologies.

1) Internet of Things (IoT). Moscow United Energy Company (MUEC), in partnership with the mobile operator MTS, has been implementing a project for monitoring energy consumption for more than 10 years (since 2009), within which a unified automated system for monitoring and accounting for the transmission of thermal energy and hot water has been created. The intelligent energy efficiency monitoring system is based on digital sensors (UC)—47 thousand metering devices in municipal houses and social facilities equipped with MTS SIM cards, which continuously transmit data to the server of the Central Electricity Metering System of the MUEC. The consumption indices of thermal energy in residential buildings in Moscow are taken remotely via the Internet (RBC, 2022).
2) Ubiquitous Computing (UC). JSC "Rusnano" is implementing a project for the development of innovative energy storage systems for testing on the railway network in partnership with JSC "Russian Railways" and LLC "Rusenergosbyt". A pilot sample of an energy storage device for testing on the railway has been designed and is being tested. At the same time, PJSC "Rosseti" pays considerable attention to the development of accumulation systems, regulatory systems, distributed generation systems, as well as the development of electric transport (Russian Union of Industrialists and Entrepreneurs, 2022).
3) Blockchain. In a number of "smart" regions of Russia, an experiment is being conducted to test the technology of distributed ledger (blockchain) based on the collection and processing of data on energy consumption in retail electricity markets on the terms of public-private partnership. The experiment is aimed at improving the reliability and quality of power supply to consumers through the introduction of new technologies and optimization of the activities of network organizations (CNews, 2022).
4) Artificial Intelligence (AI). JSC "IDGC Holding" has created a smart distribution grid based on AI. "Smart" electricity metering devices have been introduced, network management centers have been created, and the observability of substations in the Smart Grid network has been increased. The primary task in the "intellectualization" of the distribution network is smart accounting. A unified information landscape of the accounting system using of open-source, flexible multifunctional components (in particular, of metering devices) operating on the "plug and play" principle is being created (Systems and Technologies, 2022).

The described technologies are used in smart regions of Russia. Thus, in "smart Ulyanovsk" (Ulyanovsk Region, Povolzhye of Russia), there is one system of consumption records, which allows reducing expenses for energy consumption, and a modernised system of street lighting helps control the state of networks (Com News, 2022). Moscow's (Moscow Region, Central Russia) strategy "Smart city 2030" already provides the following (Moscow City Government, 2022):

– Increase in energy efficiency, environmental friendliness and effectiveness of real estate objects management;
– Implementation of the principles of "green construction" through using energy-effective technologies and reduction of waste and emissions during the construction and exploitation of buildings;
– Information modelling will be used during the planning and design of energy effective buildings and city transport infrastructure, reconstruction and capital repair;
– Construction of the pilot road infrastructure with the use of technologies of solar generation of energy, which allows providing electric energy to the objects of road infrastructure (lighting, control systems) and charging electric vehicles.
– Use of photoelectrical covering for electric energy production through collecting solar power.

In the Sverdlovsk Region (North of Russia), a regional information system of energy-saving is functioning successfully; it consolidates data on the municipal systems of the region, which allows forming the ranking of municipalities' energy efficiency, performing heat and hydraulic calculations online and creating an interactive regional scheme of heat and water supply (All Events, 2022).

DISCUSSION

The contribution of the article to the literature consists in clarifying the features of Smart Grid and EnergyTech in the sustainable development of the energy economy in "smart" regions and increasing their environmental friendliness. Unlike Chen et al. (2022), Elnour et al. (2022), Kabeyi and Olanrewaju (2022), Kamruzzaman and Alruwaili (2022), Nasir et al. (2022), it has been proven that "smart" technologies contribute much more to the sustainable and environmental development of the energy economy (than previously supposed in the literature), providing not only environmental but also socio-economic benefits. Owing to "green" energy, the "smart" region becomes a favorable socio-economic environment for responsible production and consumption (implementation of SDG 12), as well as sustainable human settlement (implementation of SDG 11). The scientific value of the conclusion is that it has expanded the relationship of SDG 7 with other SDGs.

Unlike Ahmad et al. (2022), Li et al. (2022), Rezaei et al. (2022), it is justified that the management of "smart" technologies for sustainable and environmentally friendly development of the energy economy should be carried out at the regional level. Public management in the "smart" region harmoniously complements the corporate management of energy companies, and public-private partnership also demonstrates high efficiency. The scientific value of the conclusion is that he expanded the idea of the boundaries of EnergyTech and Smart Grid management, transferring them from the micro level to the meso level.

CONCLUSION

Thus, the results of the study on the example of the "smart" regions of Russia demonstrated that the EnergyTech and Smart Grid markets have not only technological but also territorial boundaries. The theoretical significance of the results obtained in the course of the study is in the fact that they revealed the features of the region as an economic system in which there is a sustainable and environmentally friendly development of the energy economy on the basis of "smart" eco-innovations. If "smart" technologies provide advantages at the level of energy companies, this does not mean advantages on the scale of the region's economy.

For example, in the "smart" regions of Russia, RFID has proven to be the most universal technology for sustainable and environmentally friendly development of the energy economy. The advantages of electronic sales have proven to be reduced, and ERP systems have been contradictory. This requires more flexible management of "smart" technologies in the energy sector at the regional level compared to the level of energy companies. The practical significance of the results obtained is that the applied case experience of the "smart" regions of Russia, considered in the article, can be useful for the rest of the Russian regions and regions of other countries of the world in terms of sustainable and environmental development of the energy economy.

Research limitations are connected to the fact that despite this paper's substantiating the expedience and providing successful examples from Russia's leading experience, it does not cover the perspectives of the full-scale transition to a smart regional economy. As the performed case study showed, even in such progressive digital economy with the developed oil and energy complex, the sustainable and environmental development of the energy economy has been achieved only in separate smart regions. Future studied should form the scientific and methodological framework for the systemic sustainable and environmental development of the energy economy in smart regions at the scale of the regional economy on the whole.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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