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Application of the private-public partnership model in energy sector

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Abstract. The best international practices in implementing investment energy-efficient projects show that the most effective form of implementing industrial, infrastructure and socially important projects and programs is the public-private partnership (PPP). The purpose of the study is to analyze the current situation and prospects for using hydrogen fuel in the process of energy transition in order to solve environmental problems and overcome the energy crisis within the framework of public-private partnership (PPP). The study is novel in that the prospects for the development of hydrogen energy are predicted on the basis of the international and Russian practices; an approach to forming the Dynamic model of sustainable economic development: Smart Green Technology application within the framework of public-private partnership (PPP); considered the main provisions of the Development Concept Hydrogen technologies in the Republic of Tatarstan, approved by the order of the Cabinet of Ministers of the Republic of Tatarstan in 2023; an approach to the formation of matrix for energy efficiency management which is the goal of further research.The hypothesis about the effectiveness of public-private partnership as an instrument of green energy in Russia within the framework of developing direct conversion technologies and modernizing the energy sector when implementing national projects was confirmed in the course of the study.

1 Introduction

The International Energy Agency (IEA) estimates that the current energy efficiency potential is in the range of 38-42% of total energy consumption (The IEA has named energy efficiency the “first fuel” in a new Energy and Climate Change report. URL: http://www.energosovet.ru/news.php?zag=1435650827 (13.05.2022)). In order to realize this potential, the world is actively searching for optimal and effective mechanisms for interaction between the state and business at the national and international levels in order to improve energy security, the development of innovative measures to improve the energy efficiency of industrial production [1-12], buildings and structures, transport, as well as the implementation of the state energy strategy aimed at reducing the environmentally harmful impact through the use of new technologies and alternative energy sources [2; 7; 13].

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The theoretical and practical relevance of the study is based on the possibility of applying certain conclusions and generalizations when forming and adjusting the state program “Energy Efficiency and Energy Development” - in particular, when developing measures to improve the energy efficiency of projects and industries, public transport, in tax incentives for energy efficiency, providing state guarantees and benefits, etc. It should be noted that for the current period of time Russia has already adopted the Concept for the Development of Hydrogen Energy that envisages that our country becomes one of the world leaders in producing, exporting, and using hydrogen fuel, as well as in developing industrial hydrogen products and equipment. This determines the relevance of the chosen topic [14-19].

In some foreign countries the concept of a Smart city became widely spread which includes creation of basic and intellectual infrastructure. According to the United Nations, 67% of the world population will live in such cities by 2050. Experts believe that global investments in this sphere will grow from 36.8 B US dollars in 2016 to 88.7 B US dollars by 2025. The concept of Smart City is successfully implemented and is used by such countries as Singapore, the UAE, Japan, China, South Korea, France, Morocco, Finland, the Netherlands, the USA, Canada, Spain, and Kazakhstan.

In Singapore, 80% about 3.2 M humans of the population live in affordable apartments and construction of such apartments is initiated by authorities of the city-state. Smart technologies are widely used in the sphere of urban planning [20].

Basing on „Smart“ and „Green“ technologies, an experimental eco city, the Sino-Singapore Tianjin Eco City, is under construction in China that will continue during the next 10–15 years. The project is a product of bilateral cooperation of China and Singapore, it encompasses the area over 30 square kilometers and is designed for 350,000 dwellers [21].

Main example of implementing the Smart cities concept is Masdar project in Abu Dhabi, United Arab Emirates. The project is based on applying solar power and other renewable energy sources; it is designed for 50,000 dwellers, 40,000 passengers and 1,500 enterprises that primarily specialize in “clean technologies” [22].

2 Materials and methods

With the development of new technologies, there is no unified approach to the process of urban area efficient management. Implementation of the Smart City and „Green“ concept is related to improving the efficiency of functioning (power efficiency) of certain buildings, infrastructure items, some city districts, and the city as a whole. The Smart approach has parameters that are similar to so called “green” approach: power efficiency improvement, infrastructure development, improvement of residents’ living comfort, monitoring and verification of various systems (water supply, heating, and power supply), preliminary imitation power modeling using information technologies and software products, automated control of greenhouse gas emission level, humidity, and other characteristics of living comfort [18; 19]. For the purpose of assessing the quality of operation and functioning of a “green” development project, it is necessary to interview consumers on a regular basis that will allow detecting the level of their satisfaction using Smart systems without troubling the building users’ comfort.

Within the framework of implementing the concept of the sustainable economic development, the authors of this study developed a dynamic model of sustainable development using the Smart Technology (Figure 1).

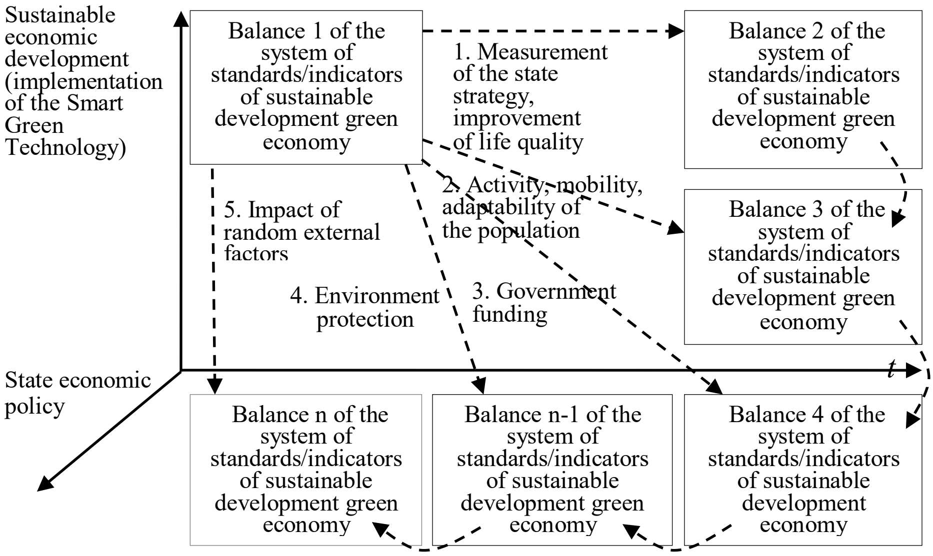

Fig. 1. Dynamic model of sustainable economic development: Smart Green Technology application within the framework of public-private partnership (PPP)

Basing on this dynamic model, an economic and mathematical model of sustainable development model with the Smart Technology applied was developed and successfully tested. Shift of the balance of system n of indicators/standards of sustainable economic development using the Smart Technology moves to the state economic policy with the lapse of time.

In order to adopt optimal innovative solutions within the framework of the Smart City concept and the Plan of Measures on "Development of Hydrogen Energy in the Russian Federation until 2024" (Decree of the Government of the Russian Federation of October 12, 2020 No. 2634-r "On Approving the Plan of Measures on "Development of Hydrogen Energy in the Russian Federation until 2024". (15.05.2022)), a theoretical and complex analysis of the external environment and internal components is also needed, based on the knowledge, experience, logic and intuition of Smart management system. Estimation of economic and energy efficiency of the considered innovative projects of Smart Ural Region makes it possible to obtain a dependence of the profitability on the indicator of specific energy savings (Figure 2).

The inclination angle between the approximated straight line and the abscissa axis is 40^0 [17].

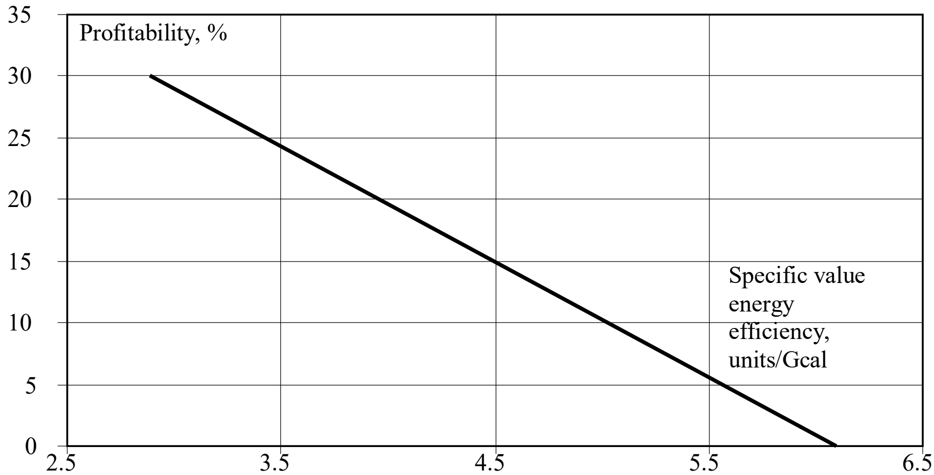

Fig. 2. Diagram of capital investments profitability versus specific value of energy efficiency, I_{ee} (forecast for 2018)

Using the method of least squares, an approximate straight line was obtained. The continuation of this straight line crosses the abscissa axis at the point of 0.17. The continuation of this straight line crosses the abscissa axis at the point of 5.8, if the cost of the investment project per each saved Gcal of energy, taking into account all available alternatives, is more than 5.8, then the profitability of the project is below 0.

For the range in question, from 2.5 to 6.0, the diagram is described by the following formula

$$Y = 58 - 10X, \quad (1)$$

where Y is the return on investments in the innovative project;
X – unit cost of energy savings.

3 Results and discussion

In large economically developed countries, several approaches to decarbonization and reduction of negative impact of human activities on the environment are currently being considered, in particular:

1) energy transition to a hydrogen economy (use of hydrogen in various sectors of the economy);
2) technologies for capturing carbon dioxide, storing it, placing it in geological formations and utilizing it;
3) development of electricity generation from renewables;
4) development of electric transport and electrification of production processes;
5) reducing losses in technological processes and increasing the efficiency of filtration systems;
6) use of nuclear energy and disposal of spent nuclear fuel.

Further development of hydrogen energy involves the development, implementation and modernization of technologies for the production, storage and transportation of hydrogen fuel, as well as the generation of electrical and thermal energy using fuel cells [4; 7].

This is an intermediate market product, where the chemical energy of the fuel is converted into electrical energy via the electrochemical method (Federal State Unitary Enterprise "Krylov State Research Center", Yekaterinburg. Ship electrical engineering and technology, fuel cells and hydrogen energy. URL: https://krylov-centre.ru/activities/ship-electrical-engineering-and-technology/ (18.08.2022)). The most popular in the near future will be eco-friendly trams and trains running on hydrogen fuel cells. Hydrogen is stored in special containers placed on the roof of a tram car or train. Today, two technologies for storing hydrogen fuel have been developed:

1) intermetallic - hydrogen fuel is stored inside refillable metal cartridges under low pressure, which meets the highest safety standards [1]. Hydrogen fuel storage tanks are filled with a calibrated mixture of metals (powders) capable of absorbing hydrogen with hybrid transformation, and, if necessary, releasing gas [12; 14];

2) balloon - a method of hydrogen storage, in which fuel is pumped into cylinders under high pressure; however, this method does not allow reaching a high volume content of gas [5].

Fuel cell power plants that can be installed on marine and river vessels will have similar expected characteristics. Of particular economic and technological interest is the process of providing fuel cell-based transport power units (FCPU). FCPU is a complex set of technological systems where an electrochemical generator is the energy source [5]. Hydrogen fueling stations based on the conversion of natural fuels have the following obvious advantages in comparison with the conventional stations: reduced cost of electricity; reducing the physical volume of the system from 36 to 7 m^3; increasing the system reliability and lifetime of equipment.

Figure 3 shows the graphical representation of a methodical approach to formation of the necessary matrix of energy efficiency management [6; 15].

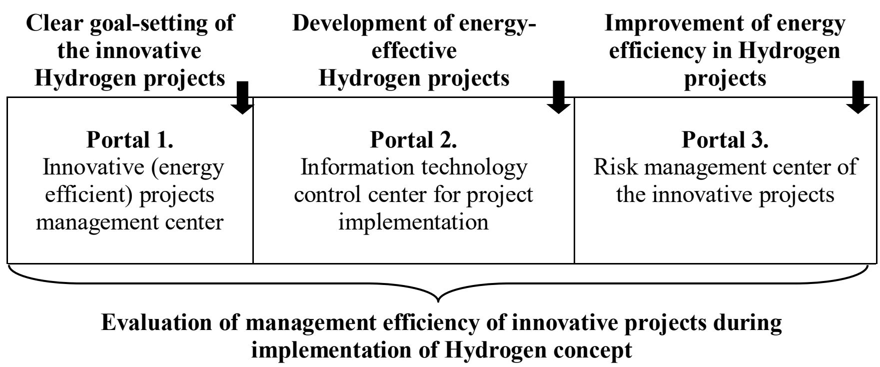

Fig. 3. Approach to the formation of matrix for energy efficiency management

The following refer to main principles of Hydrogen projects energy efficiency management matrix formation:

1) clear goal-setting for the development of innovative Hydrogen projects is the solution for the problem of increasing the energy efficiency of innovative projects;

2) formation of 3 portals for Hydrogen project management: 1 – Energy-efficient projects management center; 2 – Information technology management center; 3 – Innovative projects risk management center;

3) accounting for innovative component in assessing the energy efficiency of Hydrogen projects.

This approach takes into account the requirements for energy efficiency of capital construction facilities being built and operated in the context of the Smart City concept, as well as the need for applying the new innovative technologies [16].

Decarbonization of the Russian economy is considered primarily within the framework of fulfilling international obligations to reduce greenhouse gas emissions and as a necessary condition for maintaining product competitiveness.

Decarbonization and energy transition in potential sales markets will form certain requirements for hydrogen export from the Russian Federation. For this purpose, it is advisable to produce hydrogen on the basis of low-carbon electricity and traditional energy carriers in combination with technologies of carbon dioxide capture, utilization and storage. The development of hydrogen energy to meet domestic demand can be aimed at solving two groups of problems: first, it is an opportunity to reduce emissions of pollutants into the atmosphere, primarily from transportation; second, it is to ensure energy supply to isolated and hard-to-reach areas. In this regard, partial replacement of energy capacities (diesel power plants) by energy facilities based on renewable energy sources and small-scale nuclear power may be a solution. Hydrogen also has a high potential for application as a means of energy storage and accumulation in nuclear and renewable energy, as well as load balancing of power grids.

At present, the development of large-scale production and consumption of hydrogen fuel in Russia and abroad is considered as a key tool to improve the sustainability of economic development and the sustainability of integrated energy systems, decarbonize industry, reduce greenhouse gas emissions and generally ensure “carbon neutrality”.
Hydrogen can be widely used as an environmentally friendly energy carrier or a chemical reagent in industry, the construction industry (the “Smart City” concept), transport, etc.

The Russian Government has made fundamental strategic decisions on the necessity and feasibility of developing hydrogen energy technologies, developed and approved fundamental documents defining general guidelines, specific goals and objectives, strategic initiatives, pilot projects and key activities for the development of hydrogen energy in Russia for the period up to 2035 and in the perspective up to 2050.
For example, in the Republic of Tatarstan an interdepartmental working group on climate policy and plans for decarbonization of the Republic of Tatarstan was established. As part of the functioning of this Working Group, a decision was made to form the Program for Implementing a Pilot Experimental Project to achieve carbon neutrality in the Republic of Tatarstan, and a Concept for Developing Hydrogen Technologies in the Republic of Tatarstan was developed. The above project will be implemented raising funds from a private player within the framework of public-private partnership and will not entail raising additional funds from the budget of the Republic of Tatarstan.

The strategic goal of hydrogen technology development in Russia is to realize the production and scientific potential as regards technologies and equipment for producing and using hydrogen with a low carbon footprint.

By 2035, the development of hydrogen technologies is associated with strengthening the competitive advantages of industrial enterprises in Russian regions and increasing the investment attractiveness of regions through the implementation of new projects by public-private partnerships, while reducing the negative impact on the environment.
In particular, in order to achieve the strategic goal of hydrogen technology development in the Republic of Tatarstan, a number of tasks should be solved:

1. Development and implementation of state support programs for projects to test technologies for reducing the carbon footprint in industry and energy, projects for capturing, storing and (or) placing in geological formations, transporting and using carbon dioxide, creating infrastructure and industries for the use of hydrogen.

2. Enhancement of the laws and regulations for producing and using hydrogen and energy mixtures based on it, industrial products for hydrogen energy.
3. Developing low carbon footprint hydrogen production technologies.
4. Increasing the scale of production of low-carbon hydrogen and energy mixtures based on it.
5. Developing production of equipment and its components for hydrogen energy, hydrogen transport, hydrogen production with a low carbon footprint.
6. Development of engineering in hydrogen technologies.
7. Development of infrastructure for transportation and consumption of hydrogen in Russia, in particular, the Republic of Tatarstan [21].
8. Intensification of interregional and international cooperation in the development of hydrogen energy and entry into foreign markets.

4 Conclusion

The relevance of the above conclusions for Russia is confirmed by the “road map” for the development of hydrogen energy and the Concept for the Development of Hydrogen Energy in the Russian Federation. Similar Concepts were adopted at the end of the 20th century in the US, the EU, China, etc. In this Concept, implementing eco-friendly transport under the public-private partnership is defined as one of the promising areas for the use of hydrogen technologies. To achieve this, it is planned to develop hydrogen power plants for electric transport, fueling stations, as well as storage and transportation systems for hydrogen fuel [11; 13].

We emphasize that within the framework of this Concept hydrogen is considered not as a fuel, but as an energy carrier.

This Concept will be implemented by interested entities within the framework of the state energy policy of the Russian Federation, the Concept for the Development of Hydrogen Energy in the Russian Federation and the “Roadmap for the Development of the High-Tech Area “Development of Hydrogen Energy” for the period up to 2030.

Public-private monitoring and implementation of the Concept is carried out by establishing the Interdepartmental Working Group for the development of hydrogen technologies in the Republic of Tatarstan. The members of the interdepartmental working group will include representatives of industrial enterprises, scientific and educational institutions, ministries and departments of the Republic of Tatarstan and other stakeholders.

Among the functions of the body monitoring and implementing the Hydrogen Concept are the following:

1. Developing “roadmaps” on hydrogen technology development and application in various sectors.
2. Attracting state support measures and other sources of financing (financial institutions, funds, investors, etc.) for implementing hydrogen technology projects.
3. Developing and substantiating proposals to eliminate regulatory barriers and stimulate government support for the formation of the hydrogen market in the Russian Federation.
4. Defining scientific and technological priorities of research and development in hydrogen technologies.
5. Promoting cooperation in hydrogen technologies with Russian and international corporations, consortia, companies, initiatives and working groups in this field, in particular, within the framework of PPP models.

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