Ecological and economical assessment of efficiency of application of alternative energy sources to achieve the goals of the Climate Strategy of St. Petersburg

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Abstract: The paper considers the procedure and methodology for assessing the environmental and economic efficiency of using alternative energy sources installed at industrial enterprises, which can significantly reduce climate risks by reducing greenhouse gas emissions in replaced sources. Based on the proposed methodology, the costs of introducing a hybrid solar installation at an electronic equipment manufacturing enterprise were determined, resource efficiency indicators of efficiency and environmental impact, as well as the cost of generated energy, were calculated. It is shown that the application of the methodology will contribute to the selection of the best available technologies for alternative energy and the achievement of the goals of the Climate Strategy of St. Petersburg.

1. Introduction

Assessing the effectiveness of possible impacts in order to reduce and prevent climate change is one of the most pressing problems on the agenda of the international community, the solution of which is provided for in the 2015 Paris Agreement and subsequent documents [1].

In the framework of this task, the need for Russia's participation in the global system of scientific and technological exchange of knowledge and cooperation is not only important for the import substitution of equipment, but also for the development of assessment methods and the selection of the most effective solutions, as these ensures timely response to the requirements of the international market, and therefore will increase the production of green energy from alternative sources in Russia by 2035.

In St. Petersburg, the Climate Strategy developed until 2030 aims to create conditions for assessing and mobilizing development potential in changing climate conditions through the timely implementation of adaptation measures aimed at reducing and (or) preventing climate risks in relation to urban sectors, as well as facilities of urban infrastructure, ecosystems and public health. Among possible measures, consideration should be given to replacing traditional sources of hydrocarbon fuel energy with alternative energy sources (AIE) [2].

The aim of this work is to develop a procedure and methodology for assessing the environmental and economic efficiency of using alternative energy sources installed at industrial enterprises, which can significantly reduce climate risks by reducing greenhouse gas emissions in replaced sources. The objectives of the work are: 1) to verify the feasibility of the technical implementation of the installation of a solar electric power generator and to reduce the environmental load when introducing
electronic equipment at one of the enterprises of St. Petersburg, and 2) to evaluate the investment and operating costs associated with the introduction of equipment in the equipment’s life cycle.

The relevance and timeliness of the research topic is confirmed by the need to solve the pressing problems of the energy sector development, to determine changes in economic parameters in accordance with the Energy Strategy of Russia for the period up to 2035, on the one hand, and the need to invest in the production of alternative energy, on the other.

Based on environmental and economic assessment, one can choose the most suitable alternative energy sources or combinations of these for the St. Petersburg region, and choose the best option for implementation in a particular cluster.

Such assessment is important for the implementation of relevant projects for the creation of wind farms, solar power plants, devices capable of receiving geothermal energy, hydropower and biomass energy. Its application will contribute to the achievement of the all-Russian strategic indicator for the development of renewable electricity by 2024 at the level of 4.5% of the total energy production [3].

2. Materials and methods
The research methodology was based on the methods of statistical analysis, the problem-target approach, reverse forecasting with the participation of stakeholders, resource efficiency analysis (ARE), environmental life cycle impact assessment (LCA) and life cycle cost assessment (LCA), which all together allowed developing a multi-step procedure for environmental and economic assessment of the choice of the best available technology for an alternative energy source [4].

A review of the main sources of greenhouse gas (GHG) emissions into the atmosphere of St. Petersburg shows that the largest mass of GHG emissions is characteristic of the areas where the heat power plant is located. Emissions from thermal power plants, namely soot and CO₂ emissions lead to the greenhouse effect, and nitrogen dioxide emissions to smog in the city and, consequently, affect climate change.

At the first stage, the climatic parameters of the region were assessed, which determine the effectiveness of using an alternative energy source: a solar battery.

The standard solar system for autonomous power supply consists of solar panels with a total capacity of 3.4 kW [5] and can reliably meet the electricity needs of most owners of private residential buildings. The use of alternative energy sources is currently being considered at a number of large industrial enterprises, ensuring the achievement of market leadership and sustainable development in the long term.

At the next stage, the main stakeholders were analyzed, as well as constraining and stimulating factors in the development of the alternative energy market.

Among the stakeholders with the greatest degree of influence, as shown in the authors' work [4], there are the authorities, shareholders, creditors, suppliers and employees of the company.

Among the factors hindering the development of alternative power sources, an abundance of traditional fuels and the lack of a regulatory framework to support green energy were highlighted. As a stimulating factor, one can note the rapid development of technologies and the widespread use of alternative energy sources abroad, which inevitably should lead to the development of the production of equipment and technologies for obtaining renewable and alternative energy in Russia, since in the future this will eliminate the dependence on foreign energy technologies.

Formulating a vision of the future and determining the necessary steps to achieve the desired goals (development scenario), called the method of reverse forecasting, were used in the early 2000s in relation to the development of energy efficiency at the state level [5,6] and later at the corporate management level [7,4].

At the company level, independent scenarios for the implementation of AES can be carried out based on an analysis of the current situation in the technology market, setting specific goals to increase energy efficiency and reduce the carbon footprint, and creating an “ideal” picture of the company’s development in the future.
During the next stage of “Scenario Analysis”, the main indicators of environmental assessment of selected alternative energy sources in their life cycle are determined: environmental impact indicators of output flows (emissions, discharges and waste generation) by categories of impacts and input flows of consumed resources (abiotic, biotic, water and air).

“Scenario analysis” was carried out according to the method proposed by the authors for assessing the environmental and economic efficiency of alternative energy sources, which was tested by the example of a solar power plant [8] at an electronic equipment manufacturing enterprise in St. Petersburg.

The main steps of the methodology include: assessing technical feasibility based on available technologies, performing a resource efficiency analysis (ARE), a life cycle assessment (LCA) and costs of life cycle (LCC).

3. Results and discussion

The suggested methodology was applied to assess the cost-efficiency and environmental results of implementation of solar power plant at the electronic equipment manufacturing enterprise.

The main components of a photovoltaic solar power plant are: photovoltaic modules, a controller, a battery, and an inverter. However, to achieve reliable and efficient operation of any solar system, it is necessary to connect a diesel generator (DG).

The boundaries of the production system are determined by the following stages of the life cycle: transportation of the solar battery to assembly at the consumer, transportation of batteries to assembly at the consumer, transportation of the controller to assembly at the consumer, transportation of the inverter to assembly at the consumer, transportation of the diesel generator to assembly at the consumer, temporary storage of components of the solar battery in the organization’s warehouse, the process of assembling the solar battery at the consumer, the operation stage, the transportation process to the place of disposal in the end of life.

Based on the initial data and the performed calculations, material inputs or MI indicators were determined by the types of resources consumed. Analysis of resource efficiency (ARE) showed that the maximum impact is exerted by the operation stage - 86%; transportation by rail from China to St. Petersburg - 12% and by road to the organization – the assembler of an inverter - 2%. The remaining stages, the contribution of which is less than 1%, can be neglected.

At the stage of production of the solar battery, the biggest share of resources is consumed such as water - 88% and abiotic resources - 12%. The only material input at the operation stage is diesel fuel, which contributes to the consumption of abiotic resources and water. At the stage of transportation of solar modules, controller, battery and diesel engine by railway, the largest consumption share is water - 88% and abiotic resources - 12% due to the use of diesel fuel.

The calculation of the environmental impact of the output flows of the solar battery in the life cycle was performed based on the SimaPro software [9]. For a solar battery, by categories of impact, indicators such as global warming potential, g-eq. CO₂ / g, photochemical smog formation potential, g-equethen / g, eutrophication potential, g-equiv O₂ / g were determined.

To realize the goals of the Climate Policy, the analysis of the carbon footprint within the boundaries of the production system is of the greatest interest. The carbon footprint of the solar installation within the production system was 0.504 t-equ CO₂.

Costs in the life cycle were determined according to the methodology [10] and amounted to 4,481.35 thousand rubles. The annual duration of sunshine is an average of 1800 h/year in St. Petersburg and the Leningrad Region. With a solar battery power of 3 kW and a DG power of 10 kW, the electricity generated by the solar installation will average 75,000 kWh/year.

4. Conclusion

According to the calculated data, the cost of the entire life cycle of the solar battery is 4,481.35 thousand rubles, and to obtain 1 kWh of energy it is necessary to spend 3.98 rubles, which is comparable to the tariff for electricity from utility networks – 4.58 rubles per one kWh.
However, with a decrease in diesel consumption at the operational stage, as well as a reduction in the cost of acquiring AIE, it is possible to obtain much cheaper electricity and ensure sufficient autonomy from the electric grid energy and a significant reduction in the carbon footprint. According to the analysis of the technical potential of solar energy in St. Petersburg, it can be concluded that part of the energy received at industrial enterprises from traditional CHP plants can be replaced by energy received from solar panels, which will reduce emissions into the atmosphere from the burning of fossil fuels, affecting climate change in St. Petersburg.

The proposed methodology of environmental and economic assessment of the choice of an alternative energy source can be used to identify the best available technology from those available on the market that have minimal negative impact on the environment and minimize greenhouse gas emissions in the installation’s life cycle.

Such assessment ensures the implementation of the goals of the Climate Strategy of St. Petersburg until 2030 and the Energy Strategy of Russia for the period until 2035 to diversify the fuel and energy sector, and to increase the energy efficiency of enterprises. The cost of electricity in the life cycle can be used as an important indicator for further economic justification of investment projects for the implementation of AEI.

The practical significance of the proposed method lies in the fact that decision makers can use it to select the most environmentally friendly energy sources, both at individual enterprises and in the region as a whole.

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