Assessment of the consumer readiness to pay for investments in "green" electricity

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Abstract. The article is devoted to the analysis of the impact of the electroenergetics on the environment, as well as to the consideration of possible scenarios for minimizing the impact of electroenergetics on the ecosystem in the future, taking into account its investment prospects and benefits. The aim of the study was to develop the most likely scenario of the impact of the electric power industry on the ecosystem. The result of the study was the pessimistic, optimistic, and basic scenarios of the most likely impact of the electric power industry on the environment for the current situation in the world, the assessment of alternative sources of electricity as the main element of reducing the negative impact of electricity on the environment. The scenarios are considered by the consumer with pairwise comparisons. Understanding the relative environmental impacts of different sources of electricity is essential for developing sound energy policies and responsible investment.

1 Introduction

The ecology's problem is acute, since there are many forms of energy impact on the environment. Environmental entrepreneurship is a leading trend. Now there is a modern trend of abandoning "non-ecological" brands when consuming products. Based on this trend, ratings are compiled. Company ratings are based on environmental policy and resource use [1]. For example, Forbes has compiled a rating of the top-30 most environmentally friendly companies in Russia. There is State Corporation "Rosatom" in the fourth place. SIBUR (the largest integrated petrochemicals company in Russia) is in the seventh place and Rosseti (the operator of energy grids in Russia) is in the eighth place. There are many electric power companies, but only a few of them are listed in the environmental ratings.

Almost any type of activity requires the availability of electrical energy, which is used at most stages of the production processes of various economic entities [2]. The main disadvantage of electricity production is the large amounts of emissions and waste [3]. With the initiative of the UN, a concept for a "green" economy has been developed, which will

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ensure the improvement of people's well-being, avoiding increasing risks to the environment. The "green" economy corresponds to the principles of sustainable development [4, 5, 6]. The priority topics of the "green" economy are: renewable energy sources [7], energy efficiency [8], environmental impact assessment [9].

Significant attention is paid to alternative and renewable energy sources [10, 11, 12] in the scientific literature today, even despite the uncertainty of the technological future [13], since they have a significantly lower burden on the natural environment, having virtually no harmful emissions into the atmosphere and hydrosphere, while simultaneously changing the production base [14] and the mobility of people [15]. Their impact on the environment is local in scale [16].

Today the main problem of the world is:

- the stock of traditional fuel is extremely actively depleted, there is a situation of fuel shortage [17];
- an increasing number of environmental problems [18] related to the greenhouse effect of carbon dioxide emissions and the dangers of nuclear power [19];
- obtaining economic benefits from investing in the development of alternative energy [20].

So, the development and use of alternative energy sources are of particular relevance.

The subject of the study is scenarios of the impact of the electric power industry on the environment. The purpose of the study is to develop possible scenarios for the development of the impact of the electric power industry on the environment, to compare the result of the most likely scenario with the realities of practice in the electric power industry, to identify solutions to achieve the most environmentally friendly effect of the impact of the electric power industry on the environment.

2 Materials and methods

The methodological basis of the study is the method of Analytic hierarchy process (AHP) by T. Saaty [21], according to which the planning and forecasting of scenarios is carried out by modeling problems that are eventually systematized, evaluated and established in accordance with the priority in the overall model. The method involves performing the following actions sequentially:

- design a qualitative model of the problem in the form of a hierarchy that includes the goal, alternative options for achieving the goal and criteria for evaluating the quality of alternatives;
- evaluation of alternative projects according to the selected criteria and determination of local priorities (in particular, using paired comparisons);
- determination of criteria's priorities using the method of paired comparisons;
- synthesis of global priorities of alternatives by linear convolution of the priorities of elements in the hierarchy;
- error assessment, checking judgments for consistency;
- decision making based on the results obtained.

The scenario probability tree method was chosen as the method of economic feasibility probabilities. The requirement applies to this method: the sum of the probabilities on each branch must be equal to 100%. The authors also used modeling and data visualization techniques to present the results.

The author's research is based on data on the activities of large companies in various areas of the electric power industry. The authors used open data from the financial statements of companies presented on official websites as the basis of their calculations. The calculations given in the article are based on Gazprom corporation data. Gazprom is a global energy company focused on geological exploration, production, transportation,

storage, processing and sales of gas, gas condensate and oil, sales of gas as a vehicle fuel, as well as generation and marketing of heat and electric power.

3 Results

Today, the issues of the the electric power industry's impact on the environment are in the field of development tasks in Russia and are regulated at the state level. There are state programs that solve the problems of reducing the anthropogenic impact on the environment by increasing the environmental efficiency of the economy.

The conversion of natural resources that are capable of recovery into energy, with the aim of its subsequent use for human needs in everyday life and economic activities, is an alternative way of obtaining energy.

Alternative energy sources - renewable resources that replace traditional non-renewable energy sources that operate on oil, natural gas and coal, which, when burned, will release carbon dioxide into the atmosphere, contributing to the growth of the greenhouse effect and global warming. Prominent examples of alternative energy sources are wind, solar, thermal and other types of energy.

Each of the listed alternative energy sources has its own advantages and disadvantages, resulting from the characteristics of the energy source, the method of its conversion, the efficiency, the features of the equipment, etc. However, alternative energy has common advantages and disadvantages in general. Each of the methods of using alternative energy sources uses renewable resources, which is very important at the current rate of use of natural resources. In addition, it is worth noting the environmental friendliness of all processes, which is also very important given the global trend associated with the struggle for the ecology of the planet and the economy of traditional fuels.

Also, the advantages of using alternative energy sources include the availability and wide range of uses and the low cost of energy produced. The negative aspects of alternative energy are fairly high cost of equipment and the need for huge costs at the initial stage of installation and start-up of equipment, low efficiency, as well as a relatively small installed capacity of generating plants. In addition, the success of this energy industry depends heavily on external factors, such as weather conditions, wind strength, etc.

Implementing comprehensive measures to improve the environment will allow the introduction of innovations, that is, new technologies, as well as the transition to the best available technologies. Many documents have been developed on the topic of the best available technologies: the Clean Water Act, the Clean Air Act, the Air Framework Directive, and others. The introduction of innovations in the technological processes of the electric power industry will minimize the negative impact on the environment. The best available technologies should not only eliminate the negative effect of such an impact, but also be economically feasible, and should also be used at two or more facilities.

The production's modernization will allow us to achieve the desired state of the environment in the future. Mathematical and statistical methods, stochastic analysis (correlation analysis, variance analysis), optimization solution (probability calculation, research) can be used to build a model of the desired future and rational use of existing technologies. The optimization solution is one of the most convenient [22], since it allows us to consider the probabilities of different scenarios-that is why the authors use AHP.

Designing a qualitative model of the problem, namely the relationship of events and their impact on the environment, in the form of hierarchies involves the development of focus, actors, goals and possible scenarios. The focus is on the desired state of the environment in the future with minimal negative impact of the electric power industry on the ecosystem. The actors in this case will be: owners of electricity production companies, investors, suppliers of raw materials, consumers, and the environmental protection agency.

Each of the actors has goals: a) owners (small surplus of capacity, a high level of income), b) investors (minimum level of risk, the maximum level of income from investments), c) suppliers of raw materials (sales growth, the availability of contracts for the future), d) consumers (affordable prices for electricity, uninterrupted supply of electricity), e) the environmental protection agency (clean water, clean air, the introduction of innovations in technological processes that correspond to the level of permitted emissions and waste).

Based on these goals, actors and focus, there are three possible scenarios: 1) the first scenario is basic, namely, the business in the electric power industry has no changes in the implementation of technologies to minimize the impact on the environment,2) the second scenario is optimistic, that is, the support of the state to actively take measures to eliminate the negative impact of electric power enterprises on the environment, 3) the third scenario is the investment of funds in technologies to minimize the impact on the ecosystem by companies that produce electricity independently. The second and third scenarios may involve the introduction of legislation that will oblige electricity producers to develop and implement a set of measures in technological processes to eliminate or minimize the negative impact of production on the environment. These scenarios will affect shifts in the price of electricity, as well as the capital costs of electricity generation companies. Based on this, it is necessary to consider how the external and internal factors that make up the scenarios affect the price of electricity and capital expenditures.

The electric power industry unites a large number of industries: oil, coal, nuclear, gas and others. To develop and analyze possible scenarios for the future impact of the electric power industry on the environment, it is necessary to perform a number of calculations, considering the giant companies in each of the types of industries. When developing scenarios, factors affecting the price are taken into account, and the price is a key component for possible outcomes. The price increase will be caused by the need of companies to introduce new capacity due to the growing demand for electricity, as well as the growth will be caused by inflation, other external and internal factors affecting the activities of companies that produce electricity. In the basic scenario, inflation and rising commodity prices will have a significant impact on price growth, but in the pessimistic scenario, if electricity producers need to introduce new technologies that are less negative for the environment, without financial support from the state, the price increase will be due to the costs of introducing new, more environmentally friendly technologies. In an optimistic scenario, the price of electricity may become more expensive and cheaper. With sufficient government funding, the price of electricity can become more affordable for consumers, but if the funding is targeted, the price will increase due to the factors described above.

For calculations using the AHP method by T. Saaty identifies the giant companies for each type of industry in the electric power industry. Next, authors select key indicators and track the trend of changes in indicators over the years. The original author's calculations are based on Gazprom corporation data (table 1). For all calculations, four key indicators are used: price, capital expenditures, production volume, and cost. The determination of the price change is based on the trend of inflation over ten years, as well as on possible independent financial investments of the company in eco-friendly technologies, on state targeted financing. The remaining key indicators are taken from the reports of the companies used in the calculations. Changes in production volume and capital expenditures are based on the probability of future growth or decline scenarios based on past trends, as well as on assumptions about external factors affecting the electric power industry in terms of political, economic and social factors.

Table 1. Basic data for calculations.

Indicators	Year				
	2015	2016	2017	2018	2019
Production volume, million barrels	3170.97	3201.91	3550.45	3720.63	3741.16
Capital expenditures (CAPEX), in USD millions	26761.64	20485.5	24108.72	26064.76	26444.67
Cost of production per 1 barrel, USD	8.44	6.40	6.79	7.01	7.07
Average exchange rate RUB/USD	61.32	66.83	58.31	62.9	64.64

When determining the importance of forces relative to the overall goal, it is recommended to use a special scale with 2-9 alternatives and criteria, and evaluate the priorities of the criteria in paired comparisons in the range from 1 to 9, where "1" means equal importance of the criteria,"9" means very strong superiority of one criterion over another. The higher the quantification, the higher the priority of the criterion and the effectiveness of the alternative project.

Next, an inversely symmetric matrix of pairwise comparisons is compiled. In the force importance matrix, the sum of relative importance is calculated by columns, the geometric mean is calculated by rows, the total sum of all geometric averages is calculated, and the importance for each row is calculated as the ratio of the geometric mean of each row of the matrix to the total calculated sum of the geometric mean. Then the matrix of alternatives by criteria (table 2) is calculated based on the scenario tree: each factor that affects the price change is considered. In this case, a matrix is compiled for each of the individual criteria, and the importance of the forces is determined.

Table 2. Evaluating alternatives by criteria.

Lack of funding	Oil price				
Oil price	62.8826	60.59596	51.449	Geometric mean	Importance
62.8826	1	4	6	2.88	0.69
60.59596	0.25	1	3	0.90	0.22
51.4494	0.16	0.33	1	0.38	0.09
Sum	1.42	5.33	10	4.17	1

When constructing matrices for each factor, it is necessary to calculate the super matrix, which is a general composition of priorities (table 3).

Table 3. Super Matrix.

Oil price	1	2	3	Probability
62,8826	0.69	0.19	0.62	0.55
60,59596	0.22	0.10	0.06	0.16
51.4494	0.09	0.75	0.31	0.29
Importance	0.65	0.28	0.07	1

After the tree of expected changes in indicators for calculation is constructed, the basic values of indicators for calculation are determined, the importance of alternatives and the

super matrix are calculated, it is necessary to calculate the economic efficiency based on the scenario tree. The net present value (NPV) is calculated for each outcome option (table 4).

Table 4. NPV calculation for at the 62.8826 USD oil price.

t	Production volume	CAPEX	Cost of production	Cash Flow	Discount rate	NPV	Cumulative total NPV
1	3710.03	32113.97	8.44	169871.54	1.00	169871.54	169871.54
2	3746.23	24582.7	6.40	187022.13	0.91	170020.12	339891.66
3	4154.03	28930.48	6.79	204078.3	0.83	168659.75	508551.41
4	4353.14	31277.72	7.00	211963.07	0.75	159250.99	667802.41
5	4377.16	31733.61	7.07	212573.14	0.68	145190.31	812992.72

After NPV calculating, a table is compiled with calculations of the probabilities of outcomes(Pbi), net present value (NPV), probabilities of reaching the maximum possible values of net present value (NPV,%). Calculations of the net present value for all possible outcomes (table 5), and then a probability curve of the effectiveness of financing is constructed (fig. 1).

Table 5. Calculations of NPV probability for all possible outcomes.

Pbi	NPV	%
0.045962	441215.43	100.00
0.047838	482397.19	95.40
0.09849	557884.45	90.62
0.183478116	587052.66	80.77
0.10251	599066.21	62.42
0.022638	620811.88	52.17
0.190967019	628234.42	49.91
0.023562	661993.64	30.81
0.04851	774555.54	28.46
0.090369818	812992.72	23.60
0.05049	815737.30	14.57
0.094058382	854174.48	9.52

Thus, there are three possible solutions. The first variant is a solution based on the maximum probability, the second variant is a solution based on the mathematical expectation, the third variant is based on the constructed probability curve.

On the example of Gazprom, we can see that the oil industry is likely to see a drop in prices, a drop in production and an increase in capital expenditures, which indicates the modernization of the production process, the company's investments in new technologies that are more environmentally friendly, and the state support. Using a similar algorithm, authors perform calculations for giant companies from the remaining types of industry.

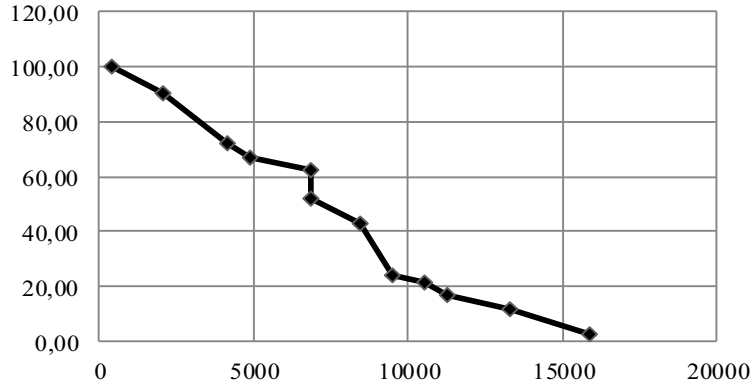

Fig. 1. Probability curve for evaluating performance.

4 Discussion

The study identified three scenarios: pessimistic, optimistic, and basic. The scenarios are considered by the consumer. In the basic scenario, the price will increase by the amount of inflation, raw materials, while in the pessimistic scenario, for example, with the introduction of a number of new standards, the price will also increase by the amount of the cost of introducing technologies, innovations in technological processes. In a pessimistic scenario, the electricity consumer will have to pay for the environment. In an optimistic scenario, the state will need to support electricity production companies to ensure that the price is not high. The most desirable scenario is an optimistic one, however, the state may not always be able to financially support the business in full. In this case, the question arises: is the consumer ready to pay for clean energy?

In the course of the study, AHP-method by T. Saaty's was studied and applied, which consists in decomposing the problem into simpler parts and step-by-step prioritization of the evaluated components using pairwise comparisons. The entire process is subject to review and reassessment until it is determined that the process covers all the important characteristics necessary to present and solve the problem. The process can be executed in a sequence of hierarchies. In this case, the results obtained in one of them are used as initial data in the study of the following ones. Thus, enterprises will inevitably incur an increase in capital expenditures due to the fact that modern legislation through the standards of permissible environmental impacts requires the modernization of equipment in order to comply with the maximum permissible concentrations. Capital expenditures should be aimed at diversifying the structure of energy resources by increasing the production and use of energy from renewable sources.

5 Conclusions

Thus, the study showed that the development of alternative energy sources is necessary. The placement of alternative power plants should be carried out in accordance with natural conditions. All alternative power plants should be combined into a single network to compensate for the non-periodicity of individual types of energy. Energy is essential to modern life as we know it, and any use of energy implies an impact on the environment up

to the point at which the work is done. Environmental impacts are an integral part of energy production and use at the local, regional and global levels. Like any other human activity, activities related to the production, transmission and distribution of electricity have a certain impact on the environment, which is controlled to minimize through the adoption of preventive and corrective measures.

Electricity generation entails the consumption of natural resources (mainly fuels), emissions that directly or indirectly cause a number of local and global impacts, water consumption (an increasingly scarce resource), the generation of conventional and nuclear waste, and finally the installation of infrastructure that affects certain natural spaces, as well as the flora and fauna of a given area.

Electricity generated from renewable energy sources has a lower impact on the environment than energy from fossil energy sources, which is perhaps the main incentive for the transition from fossil fuels to renewable energy sources. The types and extent of environmental impacts vary significantly from fossil fuel sources and from one renewable source to another, and the use of renewable energy sources does not completely avoid the impact. Understanding the relative environmental impacts of different sources of electricity is essential for developing sound energy policies.

More efficient production and use of electricity reduces both the amount of fuel needed to generate electricity and the amount of greenhouse gases and other air pollutants released as a result. New and existing power plants can reduce their environmental impact by improving production efficiency, installing pollution controls, and using cleaner energy sources. Electricity generated from renewable sources, such as solar, geothermal, and wind, generally does not contribute to climate change or local air pollution, as the fuel is not burned.

In the future, there are three main scenarios for the impact of the electric power industry on the environment. Reduction of emissions is possible in case of modernization of production, introduction of the latest technologies in technological processes. For the implementation, modernization and optimization of production, it is necessary to invest. When implementing legislation with tightened emission standards, companies will have to comply with them. Production support can be provided by the state. In this case, electricity prices will increase only by the value of inflation and the rise in the price of raw materials. Otherwise, companies that produce electricity need to independently invest in the modernization of technological processes. In the absence of the introduction of new legislation, the environmental situation may deteriorate. The impact of the electric power industry on the environment will not change or will entail large negative consequences, which is definitely undesirable.

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