Modeling the processes of substantiation of renewable energy development projects

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Abstract. The features of the assessment of the economic efficiency of energy saving projects based on the combination of traditional and renewable energy and material resources with an increasing degree of cogeneration of energy types and by-products are revealed. The object of the research is the formed energy-technology complex of objects or the industrial park, and the subject is the modeling of the processes of combining and cogeneration to determine the options for the best organizational and technical solutions in projects for the development of renewable energy. The variants of projects for the transformation and landfill reclamation of an industrial area with a critical level of environmental pollution are substantiated.

1. Introduction
The relevance of the economic justification for renewable energy development projects determines the need for new models and methods for project evaluation [1,2]. Such energy consumes renewable energy resources (RER). The global scale of the problem of their insufficient use is associated with the expected depletion of non-renewable energy resources and the increasing importance of environmental protection in the concept of sustainable development [3,4]. At the same time, the volumes of a new type of material resources with the energy potential of development - solid household waste (SHW) in the amount of about 0.5 billion tons or 500 kg/person - are added every year. The climatic and geographical conditions of most of the territory of Russia and the significant reserves of traditional resources do not contribute to an increase in the use of such long-known RERs as the energy of the sun, wind, tides, ocean currents. Therefore, it is advisable to refer to the experience of developed countries: in Germany, projections are well known that by 2025 energy facilities consuming nuclear and coal fuels should be closed, and by 2035 the share of RER should be 8%. This is aimed at improving the quality of life of the population and takes into account the rapid increase in the cost of traditional energy resources of a non-renewable type. The costs include the environmental component, since the norms of environmental activities must be strictly observed [5].

2. Modeling the processes of substantiating projects
The economic benefits of maximizing the quality management of energy saving are considered by us in assessing the reduction of losses due to underutilization of reserves and the variability of the level of efficiency with an imbalance with opposite goals of energy and environmental efficiency of projects. The following indicator of level (L) is proposed for evaluation (1):

\[ L = \frac{\sum R}{\sum C} \]
where $\sum R$ – cumulative results of reducing economic losses due to under-utilization of resources, types of energy and by-products; $\sum C$ – consumer costs for the purchase and use of such products [1] in the formed energy technology complex combining objects and polygeneration (ETC) of SHW-based products (in general, liquid for plasma-fire neutralization or biogas production) The result of the project may be the reduction of losses from the insufficient quality of energy-saving control processes, expressed in the under-utilization of the results: replacement of traditional energy resources; more types of energy products in terms of cogeneration, trigeneration and, in general, their polygeneration; diversification of energy production methods, increasing the reliability of energy supply in remote areas; increased processing of SHW to solve environmental problems; sale of waste to other countries.

Consequently, the following optimization task can be defined: to ensure the minimum of integral economic losses of the energy complex in the short and long terms by regulating the additional functions and structure of the functional subsystems of the Energy Saving Project Management Center in the ETC of a large city or region. The multifactor nature of the analyzed processes, the need to predict their behavior make it expedient to use methods of mathematical modeling and optimization according to the criteria for reducing the imbalance of goals. It is necessary to take into account the additional costs associated in this case with the missed opportunities of rational organization of the collection of various household waste.

The function of economic losses from poor quality of energy-saving management processes can be defined as the reciprocal of energy and environmental efficiency levels. This justifies the exponential form of the function of the relative level of economic losses ($EL$) for assessing the effects of mastering new energy-saving equipment and ETC technology based on the use of RER over time (2):

$$EL(t) = 1 - y(t) = a - b \cdot t$$

(2)

where $a \geq 0$ – parameter corresponding to the initial level of energy saving efficiency and determined by the costs and losses of the late response to changes in the environment of the previous stage of development based on RER; $b \geq 0$ – a parameter interpreting the regulation of the intensity of the use of special functions of managing energy-saving development and regulating impacts of the ETC Project Management Center on producing and consuming facilities of the complex. Thus, in the case of insufficient proactive investments in planned development management, the forced costs will be higher and the level of efficiency ($LE$) will be lower. This leads to an increase in the time to reach the normative level $y_n$ from $t_1$ till $t_2$ and an increase in losses from the under-utilization of reserves for improving the quality of energy-saving management. From the analysis of graphs in Fig.1 it is visible that at a numerical ratio in comparable units of measurement $b \leq y_n$ there are distinct function minima $LEx = f(y_0)$. Moreover, an unreasonable increase in the intensity of the use of control functions at minimum values $y_0$ leads to an increase in losses, if the necessary preliminary costs for the formation of the technical, technological and organizational structure of ETC facilities are not invested (to increase the initial level $LE_0$). When the ratio in relative units $b > y_n$ economic losses are constantly growing, which is explained by the excessive costs of this formation, that is, the inexpediency of applying only the managerial component in increasing the level of efficiency of separate activities of objects. This means that to ensure a compromise of the goals of economy and energy conservation, investments are needed in the tangible assets of ETC facilities or an industrial park. The additional use of the proposed special functions and control subfunctions causes (with an increase in $b$) a reduction in the effective compromise zone (due to excessive costs for its provision) to the interval $[0.1 < b < 0.5]$. This is justified in earlier studies [1,6].

The maximum economic efficiency of the project of reclamion of unorganized storages such as dumps of accumulated household waste in terms of energy and environmental performance is achieved for a certain period. In the process of modeling, the parameters of time were identified, the intensity of application of additional project management functions corresponding to the zone of minimum economic losses, taking into account the costs of their development and implementation.
Figure 1. Dynamics of economic losses of the project $LE_{0}$ depending on the initial level of efficiency $y_0$ 

The organization of the development and implementation of projects is often carried out in the context of a shortage of energy resources in the industrial consumption sector. Considering that the demand for electricity will grow during the upcoming period, a decentralized commissioning of new generating capacities of distributed energy is necessary. As a result, the load on the available capacity of the power systems of industrial regions increases [1,7]. In them, enterprises are experiencing a constant shortage of electrical capacity, and supplying additional capacity is associated with significant costs and is technologically impossible in the next 2-3 years [8]. Modeling of this type and analysis of experience led to the conclusion that gas-piston type cogeneration plants are cost-effective at an installed capacity of approximately 1,000 kW for SHW cities with a storage capacity of at least 1 million residents and waste storage period of 25-30 years. Therefore, the construction of a mini combined heat and power plant (HPP) of experimental designation based on the cogeneration of thermal and electrical energy using the above-mentioned renewable resources will create additional capacity. The gas utilization system of this type of renewable sources will allow to regulate the production of thermal energy over a wide range. To do this, it is necessary to vary the gas supply using the storage of the appropriate type. This scheme allows you to provide simultaneously independent electrical and heat schedules of the station load can cover them without significant losses to transfer even heat, so many industrial and residential consumers are located within a radius of 1–5 kilometers from the waste storage facility in Chelyabinsk. With a greater installed capacity, a transition to gas turbine installations of HPP plants as part of ETC for the complete processing of SHW with the observance of environmental standards is necessary.

In the course of experimentation, it is necessary to identify the ranges of changes in the heat of combustion of a mixture of gases from an unconventional source such as a repository of waste of various
types. It is known that the majority of such domestic RER sources are characterized by excessive differences and uncertainties in the fractional composition of the stored components due to the SHW collection practices that are inappropriate to modern requirements. Therefore, it is necessary to introduce additional technical means of automation and temperature stability control over a larger range of changes in fuel consumption. It should be noted that gas-piston units are able to work for a long time at partial loads (from 50% to 100% of nominal capacity) [9,10] without detriment to their resource indicators that meet existing environmental standards. This makes them reliable in the conditions under consideration. The optimal operating mode at the maximum power level (100%) is achievable provided the organization of the SHW separate collection system, their storage and processing in specially designed and constructed facilities according to the principles of combination and cogeneration or polygeneration. It is practically established that in the conditions of trigeneration, maximum results are achieved when the useful use of the RER of the specified type reaches 80-85%. In such a complex, standard conditions for the safety of personnel and the public and environmental standards can be better ensured. This follows from taking into account the location of many objects of the considered types of renewable waste.

3. Model of bifurcation development
Quantitative assessments of the results of project implementation were obtained by examining the above-mentioned dynamics of the ETC system, which assesses the quality of process management by the criterion of reducing the imbalance of efficiency objectives and environmental and energy efficiency [1,2]. The processes under study in terms of energy saving options under conditions of uncertainty of the trajectories of bifurcation development can be described by a significantly nonlinear second-order differential equation [2]. Heaviside functions in the mathematical model, and the dotted line, using the analytical approximation. The thick line corresponds to a periodic decision on the choice of educational methods to improve the quality of management of an energy saving project. The presence of two closed loops displays possible activity options (minimum and maximum with the creation of an ETC or an industrial park) as limit cycles of increasing the energy and environmental efficiency of using SHW as RER. They correspond to the implementation of innovative methods of energy saving, different target attractors and level of innovativeness of the method of energy saving. This defines a set of parameters for the choice of evolutionary or breakthrough energy-saving development projects. Obviously, the presence of a zone of attraction of attractors, which determines the action of factors of formation of a dynamic compromise region according to the criterion of reducing the imbalance of goals. This means that in projects of minimal modernization of facilities without using their combination of resources and polygeneration of products, the development trajectory is characterized by great predictability in the implementation of well-known and simple technical solutions. On the external contour, the profitability of development decreases, which corresponds to the transition to the development of uniquely innovative energy saving methods.

Evolutionary transitions are shown that correspond to development plans within the framework of the existing phase portrait for five variants of technical solutions or management methods with different levels of innovativeness of options for increasing the energy and environmental efficiency of using RER. The synergistic effect of switching between these attractors characterizes the possibility of a controlled transition of the system formed by ETC from low-innovation, but cost-effective energy saving methods to more costly. This made it possible to identify a set of quantitative control indicators for improving the quality of project management. Consequently, the reduction of negative synergy results is justified subject to the use of highly innovative energy-saving technologies. In any case, in a situation of economic crisis and economic sanctions, this will avoid the effect of the economic dynamics of the system. Variation of coefficients in the model will allow interpreting the trend of expanding the scale of application of highly innovative energy-saving technologies. Other coefficients determined the oscillatory component of the trend caused by the use of individual indicators of the quality of project management.
4. Scientific novelty
For the first time in the energy industry, econometrics methods are applied. These methods in this scientific research, reflecting the use of management methods combining traditional and renewable resources according to the criteria of reducing the imbalance of the goals of efficiency and environmental-economic efficiency, are presented.

5. Practical significance
The object of the research is the formed energy-technology complex of objects or the industrial park, and the subject is the modeling of the processes of combining and cogeneration to determine the options for the best organizational and technical solutions in projects for the development of renewable energy. The variants of projects for the transformation and landfill reclamation of an industrial area with a critical level of environmental pollution are substantiated.

6. Conclusion
Thus, the models and methods developed in the study provided the following results.

The results of scientific research, reflecting the use of management methods combining traditional and renewable resources according to the criteria of reducing the imbalance of the goals of efficiency and environmental-economic efficiency, are presented. This provides a focus on improving the manageability of the processes of development and implementation of projects. The developed toolkit provides enhanced opportunities for quantitative assessment of the results of the transformation of a complex of objects based on mathematical modeling of evolutionary and abrupt processes of transition to methods of energy-saving development.

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