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PRINCIPLES OF RESOURCE-PROCESS MODELING OF TERRITORIAL COMMUNITIES COMBINED ENERGY SUPPLY IN THE CLIMATE CHANGE PREVENTION CONTEXT

Abstract. *The research is devoted to the theoretical and practical substantiation of the principles of formation of systems of combined energy supply with heterogeneous sources to increase the energy efficiency of territorial communities in the conditions of climate change resistance. New approaches and structural models for the formation of local microenergy systems are proposed, which will encourage territorial communities to a new type of activity related to their own energy generation based on the use of local types of fuels and renewable energy sources. The principles of building such local energy supply systems, in general, consist in the rational distribution of resources (renewable sources, sources of combined energy generation using biofuels, energy from external networks) and coordination of the processes of generation, transmission, accumulation, distribution and consumption of energy within the boundaries of a separate territorial community by creating its own high-tech infrastructure assets. The formation of the energy balance in the medium and long term is proposed to be carried out on the basis of a resource-process analysis of the operation of local networks by finding the optimal use of local types of biofuels and renewable sources in the combined generation of electricity and heat, taking into account their current value. The cost of energy for the end consumer is determined by differentiated tariffs of energy supply companies and the use of several heterogeneous sources that participate in the process of decentralized energy production. Mathematical relations are obtained for calculating the values of the time intervals of the execution of a set of parallel processes that arise during the interaction of competing sources of distributed generation with end consumers and establishing the regularities of the formation of the energy balance a micro energy system. The proposed method can be a tool for finding optimal energy efficiency management scenarios of facilities with local energy supply, using operational redistribution of energy flows in the system of combined energy generation and forecasting current costs for energy supply in calculation periods. Such a concept can be a theoretical basis for the formation of principles of energy independence of territorial communities.*

Keywords: territorial community, combined-heat-and-power-system, renewable energy sources, biofuel, energy balances.

1. Introduction

The modern experience of organizing structures of territorial communities in the context of the global "green" energy transition [1] and the decentralization of energy supply systems shows a return to collective ownership and management of resource assets related to own energy generation through the introduction of distributed generating capacities with renewable energy sources (RES) and energy generation systems based on local biofuels [2]. Due to the rational distribution of resources and coordination of the processes of generation, transmission, accumulation, distribution and consumption of energy, it becomes possible to create local high-tech infrastructure assets within a separate territorial community for the formation of independent (island) energy supply [3, 4].

Today's energy policy at the community level is implemented on the basis of the market for the services of corporate suppliers. This means that such companies don’t participate in filling local budgets, because of profits from their activities are directed to the shareholders of these companies, who, in the vast majority of cases, are outside the territorial community. This does not contribute to the inflow of investments in this area and the creation of additional jobs. Under such conditions, regional development is quite problematic, since the community does not receive economic benefits and constantly bears costs for energy consumption.

There is a well-known experience when newly created local cooperatives undertake to generate ecological energy in the region by establishing an independent supplier [5, 6]. In this case, the creation of a new local energy infrastructure provides consumers with an alternative to reorganizing energy supply technologies in a way that would correspond to the region's development strategy. Decentralized management of energy resources helps to achieve three main goals: implementation of energy generation facilities both at the individual level and at the community level; accumulation of financial resources in the community for the purpose of investing profits in regional sustainable development projects; strengthening the influence of end consumers on the economic model of energy supply of the territorial community.

The current increase in interest in solving the problems of energy supply of local communities, which could use local alternative fuels and renewable sources, as well as the development of "smart" networks, draws attention to project activities on the creation and improvement of local microenergy systems of combined energy generation of electricity and heat with heterogeneous sources (CHPS). Local communities (especially in developed countries) are transforming, trying to change their traditional identity as passive consumers. There is already experience in the formation of so-called active consumers who are both consumers and producers of energy [7, 8]. Local energy systems can potentially contribute to overall energy and climate goals by helping to reverse trends in energy consumption and greenhouse gas emissions.

Local micro-energy networks have wide opportunities for the integration of renewable energy sources by taking into account the peculiarities of their interaction in ensuring the demand of end consumers and coordinating the use of the external energy system and require new organizational approaches in solving their management tasks. New energy initiatives are aimed at using a different logic for structuring local energy supply. This is consistent with the concept of "mass innovation", which aims to replace existing socio-technical structures. The material manifestations of the new structure are facilities for local sustainable energy generation, such as solar and wind power plants, biomass and biofuel generation facilities. In addition, local cooperatives are experimenting with such innovations as energy storage and the creation of "smart" grids [7, 9].

In recent years, a number of fundamental and applied research works have been carried out, which touch on the structural-parametric synthesis of combined power supply systems of energy-efficient buildings based on smart technologies, management systems of micro-energy networks of local objects based on a conditional dynamic tariff, etc. [10]. The decarbonization policy requires a further increase in the share of RES energy in the balance of regional energy systems, which traditionally depended on fossil fuels. This leads to the need to find solutions for the optimal combination of the processes of generation, transmission and distribution of thermal and electrical energy. Traditionally, such energy networks were designed as separate independent systems, but their integration in load nodes means that a deeper study of heat-electric processes at the level of primary fuel conversion technologies and energy consumption management at the end consumer level is necessary [11, 12].

Theoretical studies of the processes of formation of dynamic tariffs for the formation of daily management scenarios at local energy facilities allowed to establish regularities in the development and implementation of combined energy supply systems [13–15]. The basic objects in Ukraine for their use at the initial stage of energy supply projects are solar power plants of households with a capacity up to 30 kW, the number of which reaches almost 40 thousand as of 2023. This circumstance can significantly affect the level of the current cost of electricity during the day and more long time intervals (month, year). Such systems in the summer period are characterized by the use of significant amounts of electricity in the structure of consumption for the generation of cold (air conditioning).

It is the formation of the overall energy balance of such a microenergy system in the absence of expensive electricity storage technologies that opens up opportunities for finding optimal energy efficiency management scenarios based on forecasting current energy supply costs. Such a concept can be the theoretical basis of our approaches to the formation of energy independence of territorial communities.

Several methods of modeling integrated energy systems are known. Such systems are often called differently, but the key principles of their construction are similar: for example, multi-component energy networks (MCEN) [16, 17], multi-flow energy systems (MEFS) [18], multi-vector energy networks and integrated energy systems (IES). [19]. Energy networks with several different energy carriers are able to meet demand and efficiently combine their use, including energy storage. Even in networks that do not have a clear coordination of the work of sources (like MCEN), there is a growing number of elements that create additional connections within local networks and between external networks. In principle, such networks cannot be considered as independent from each other [20].

The scientific idea of using a resource-process analysis of the operation of local networks as a tool for increasing the energy efficiency of objects with a separate formation of energy balances is increasingly receiving support from clients acting as long-term investors. The development of new principles for the construction of micro-energy systems became the main basis for the formation of energy independence of the selected objects. The idea is not simply to use energy effectively, but, first of all, to change the attitude of the end consumer towards the processes of own generation based on local fuels and renewable sources, taking into account its present cost. The cost of energy is determined not only by differentiated tariffs of energy supply companies, but also by the use of several heterogeneous sources that participate in the process of decentralized energy production.

2. Research methodology

The principles of forming the energy independence of territorial communities are a modern approach to the integration of several sources of distributed generation of small power to external power grids. The key feature of such CHPS is their ability to predictably change the structure of the energy balance by replacing the main component of energy consumption from external networks and, under certain conditions, to switch to an isolated (island) mode of operation without reducing the quality of energy supply. At the same time, synchronization with external networks makes it possible to maneuver distributed generation in a microenergy system with stochastic parameters of its own generation and to have operational flexibility when using sources of distributed generation.

The use of several sources of distributed generation, which form the CHPS structure and are integrated into existing networks, requires the following tasks to be solved:

- implementation of automatic switching between external networks and the micro-energy system, determination of the conditions for switching to the island mode of energy supply;
- development of principles of construction and algorithms of operation of network control systems of CHPS with several heterogeneous sources;
- development of the principles of building a system of intelligent control of energy consumption on the end consumer’s side and functioning algorithms to ensure the stability of the operation of the micro-energy system when exchanging energy with external networks and when operating in island mode.

It is advisable to analyze the behavior of CHPS with several energy sources in several stages:

1) determination of annual energy consumption/production by companies, assessing the main variables related to energy;

2) evaluation of the energy balance (demand/supply) for the calculation period (it is assumed that energy generation should cover only current energy needs. Surplus energy produced in previous periods cannot cover needs in future periods in which generation is insufficient);

3) determination of the short-term, medium-term and long-term energy profile for the generation of electricity and heat and the consumer;

4) modeling of the formation of the energy balance in the combined CHPS and analysis of cost indicators in the energy supply system to forecast future end consumer energy management scenarios.

We will assume that the mathematical model of a scalable distributed microgrid includes:

$n \geq 2$ – the number of sources participating in the territorial community's own energy production;

$C \geq 2$ – the number of final consumers of electricity (a building with a defined specific energy consumption);

$W \geq 2$ – the number of structured competing energy flows from sources of distributed generation, taking into account their specific present values (price ranges V);

$T = [t_{ij}]$, $i = \overline{1,n}$ $j = \overline{1,m}$ – the matrix of time intervals of energy transmission by the i-th source from the j-th price range;

$V = [v_{ij}]_{n \times m}$ – matrix of the cost of a reduced unit of energy from the j-th price range when generated by the i-th source;

$\xi > 0$ is a parameter characterizing the system time that is spent on the organization of parallel transmission of energy from n sources C to final consumers.

It is assumed that all sources of electrical energy are distributed, that is, energy flows are transmitted to various end consumers who are connected to the network infrastructure. We will call a distributed microgrid heterogeneous if the time intervals of energy transmission to end consumers are different for different sources. We will call a distributed microgrid homogeneous if each end consumer has the opportunity to receive energy from all selected sources of the micro energy system $t_{ij} = t_j, i = \overline{1,n}, j = \overline{1,m}$. A distributed microgrid will be called uniformly distributed if the times of energy transmission by each source to all final consumers coincide, that is, a fair sequence of equalities, $t_{i1} = t_{i2} = \cdots t_{im} = t_i$, for all $i = \overline{1,n}$.

The approach to the selection of a technological base for the generation of electricity and heat and the distribution of energy flows is proposed to be presented in the form of a local power node of the CHPS (Fig. 1, Fig.2), which includes:

- at the system level: heterogeneous sources (centralized power supply system (CPSS), local heating network (HG), solar power plant (SPP), wind power plant (WPP), thermal power plant (HPP), biofuel cogeneration plant (BCP);
- at the local resource level: primary fuels (firewood, wood chips, agricultural waste, bioenergy crops, peat, biogas);
- at the local consumer's level: elements of individual energy supply of the end consumers (gas boiler, solid fuel boiler, electric boiler, heat pump).

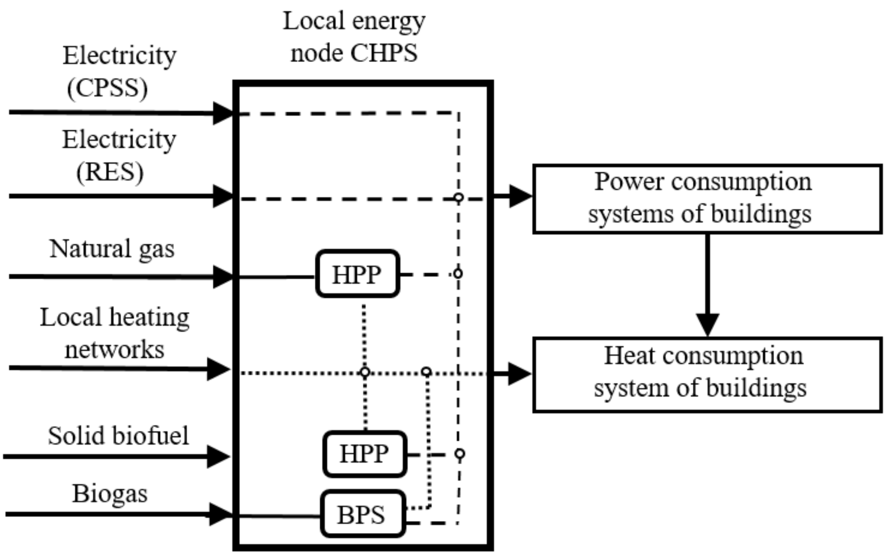

Fig. 1. The structure of energy flows of a local node CHPS

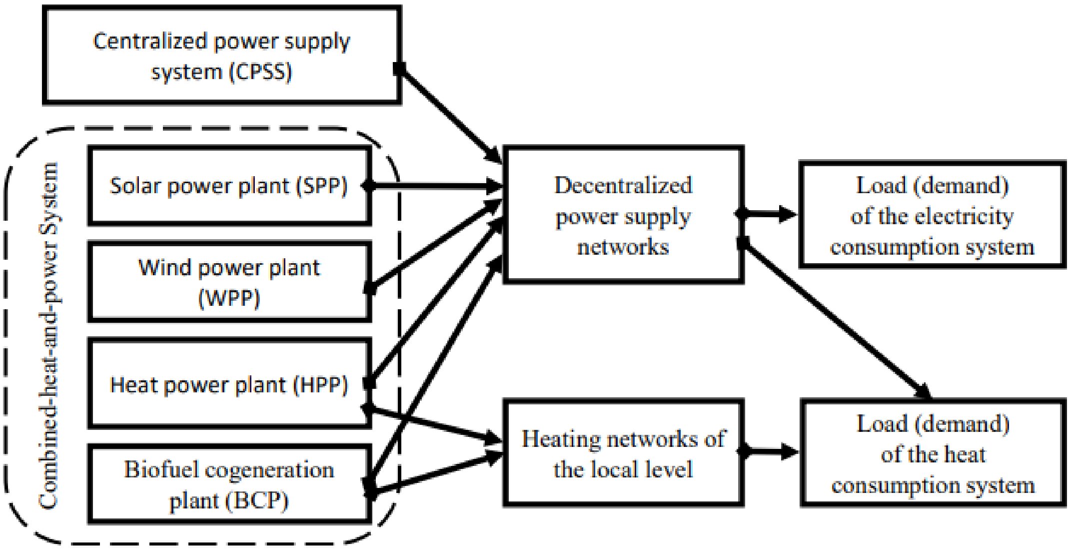

Fig. 2. Structure of combined energy supply with heterogeneous sources

In general, the following criteria can be chosen to evaluate the effectiveness of CHPS of this class:
- economic and financial efficiency;
- ecological neutrality;
- social orientation and increase of jobs in the community;
- priority use of local fuels with a competitive cost;
- minimal use of material and energy resources (implementation of energy management);
- energy quality indicators;
- indicators of reliability of energy supply;
- indicator of energy independence (indicator of the ratio of network and local components of energy in the balance of CHPS).

All the criteria listed above have a complex hierarchical structure and are described by a set of partial criteria that reflect their different specificities. The transition from general goals to partial ones is accompanied by competition in the system of main priorities, which often leads to their mutual contradictions.

At the beginning of the analysis of the micropower system (Fig. 1, Fig. 2), let us denote the vector of parameters of external factors (traditional energy sources) of the formation of the energy balance $D(t)$, the vector of structuring parameters $R(t)$ (this includes primarily the structural implementations of CHPS with heterogeneous sources, including RES with a stochastic nature of generation), the vector of control influences $Y(t)$ and the criterion vector functional F_T.

The vector criterion (objective) functional is integral, since in multicomponent systems, optimal solutions are usually determined not by the instantaneous response of the system, but by a certain calculation period T:

$$F_T = \int_0^T F_i\big(D(t), R(t), Y(t)\big)dt, \quad i = \overline{1, n}. \qquad (1)$$

With this representation (1), the value of the vector functional is a function of the input parameters, and ultimately in the form of a function of the controlling influences $Y(t)$.

The parameters $D(t)$, $R(t)$, $Y(t)$ are usually variables and are specified by an expression of type

$$D_{min} \leq D \leq D_{max}.$$

The change of these parameters is also mutually dependent

$$\Delta_t\big(D(t), R(t), Y(t)\big) \geq 0.$$

We believe that for the system shown in fig. 3, there is some information about the internal connections between its elements, which allows the parameters of the system to be presented in the form of internal (endogenous) $D_{end}(t)$ and external (exogenous) $D_{ex}(t)$ connections. The production of control influences by the control system, the reaction of which occurs through feedback. The values acquired by the endogenous variables depend on the values of the exogenous and control variables

$$D_{end}(t) = \Delta\big(D_{ex}(t), R(t), Y(t)\big) \geq 0.$$

For the case of probabilistic conditions, parameter D can take different values $X_1, X_2 \dots X_n$ with known probabilities of occurrence of these parameters $p_1, p_2 \dots p_n$,

$$\sum_{j=1}^{n} p_j = 1. \qquad (2)$$

From the logic of building microenergy systems building and their control systems, we consider endogenous and control parameters to be dependent, and exogenous parameters to be independent. In addition, the conditions for the formation of the system structure can be deterministic (defined), probabilistic and uncertain. In the case of deterministically given parameters, the optimal solution search function can be written in the form $F(Y) \to min$. The parameters of internal and external influences in this case do not affect to the search for the optimal solution, as they are set prescriptively.

3. Results

Obtaining mathematical ratios for calculating the exact values of the total execution time of a set of parallel processes that occur during the interaction of competing sources of distributed generation with end consumers will allow in real time to optimally control any segments of the microgrid, plan the connection of new objects, quickly redistribute energy flows, manage the efficiency of the use of primary fuels.

If $T^{\xi} = \left[t_{ij}^{\xi}\right]$, and $n \times m$ is matrix of time intervals of energy transmission by the i-th source from the i-th price range, taking into account the parameter ξ. Then, if we establish a mutual and unambiguous correspondence between the sources and the requirements for the formation of the energy balance based on seasonal schedules of energy consumption, then the matrix of time intervals of energy transfer $\left[t_{ij}^{\xi}\right]$, $i = \overline{1, n}$, $j = \overline{1, m}$ will coincide with the matrix of time intervals for the formation of the energy balance structure from selected sources n with characteristics m as a single-route Bellman-Johnson task [21]. Therefore, to calculate the minimum total time $T_{\sum}(C, n, m, \xi)$ of energy transfer by $n \geq 2$ heterogeneous distributed competing sources that use $m \geq 2$ structured flows in a microenergy system with $C \geq 2$ final consumers, taking into account the parameter $\xi > 0$, then for our case the Bellman-Johnson functional can be written:

$$T_{\sum}(C, n, m, \xi) = max_{(1 \leq u_1 \leq u_2 \leq \dots \leq u_{m-1} \leq n)} \left[\sum_{i=1}^{u_1} t_{i_1}^{\xi} + \sum_{i=u_1}^{u_2} t_{i_2}^{\xi} + \dots + \sum_{i=u_{m-1}}^{n} t_{i_m}^{\xi}\right], \qquad (3)$$

where $t_{ij}^{\xi} = t_{ij} + \xi$, $= \overline{1, n}$, $j = \overline{1, m}$, a $u_1, u_2, \dots, u_{m-1}$ are positive integers.

For micro-energy systems with combined energy supply, it is advisable to use a method that allows you to solve the problem of determining the minimum total time $T_{\sum}(C, n, m, \xi)$ of transmission of heterogeneous distributed competing energy flows in the form of an $n \times m$ transmission matrix from the j-th price range i-th source $T^{\xi} = \left[t_{ij}^{\xi}\right]$, $i = \overline{1, n}$, $j = \overline{1, m}$. To do this, we build a network vertex-weighted graph G_1, which contains

nm vertices located at the nodes of a rectangular $n \times m -$ lattice (Fig. 3), the formation of which consists in a tabular record of the time intervals for servicing applications (demand for energy), which consist of n rows and m columns. The minimum element is defined in the table. If it belongs to the first column, its row number is written in the first free position on the left of the prepared row. If this minimum belongs to another column, its row number is written in the first free position from the right. In any case, the row where there was a minimum is deleted from the table of the service interval. This sequence is repeated until all the empty positions of the prepared line are filled.

This determines the optimal schedule, which sets the priority for the participation of sources in the formation of the energy balance of the CHPS. If you need to select several identical minimums, you can select any of them. When choosing a different minimum, a different optimal set of components of the energy balance can be obtained.

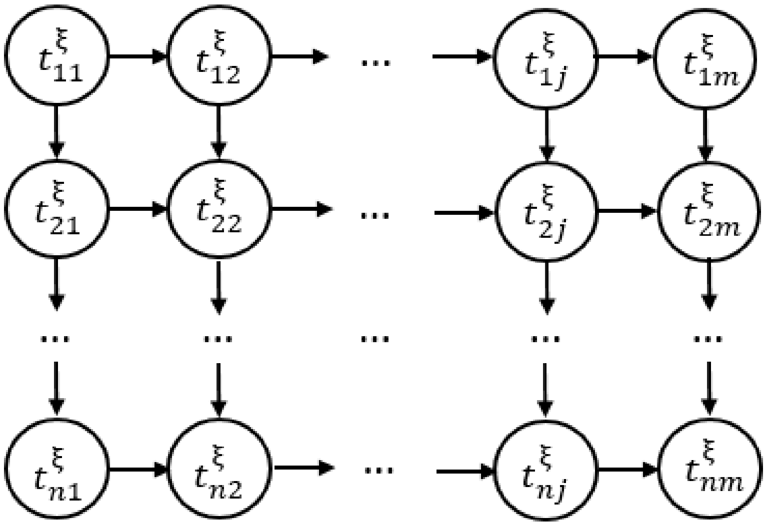

Fig. 3. Network vertex-weighted graph for determining the minimum total time $T_{\sum}(C, n, m, \xi)$ for the transfer of heterogeneous distributed competing energy flows

Each vertex of the graph G_1 corresponds to the value $t_{ij}^{\xi} = t_j$, $i = \overline{1, n}$, $j = \overline{1, m}$, and t_{11}^{ξ} is the initial vertex, t_{nm}^{ξ} is the final vertex. The arcs in graph G_1 reflect the linear order of transmission of structured competing energy flows by each source of distributed generation, as well as the linear order of reception of the same flows by different end consumers.

The basic configuration of a local microgrid with inputs from a centralized power system, wind-solar power plants, autonomous generators with internal combustion engines, heat energy and cogeneration plants (on biogas, biodiesel, biofuel), static power sources, a system for monitoring and managing the energy consumption of end consumers will allow the formation of adaptive energy balances of the community, taking into account the costs of primary fuel, transmission and distribution of electric and thermal energy among end consumers.

For a conditional optimal solution selected from a set of solutions, $Y_i\,(*)$ and the value $F_i(*))$ will be reached with the same probability as the parameter D_i will be formed. Therefore, the value of the functional can be written in the form of a formula for finding the mathematical expectation:

$$MF(Y_*) = min_{\overline{i=1,m}} \sum_{j=1}^{n} p_i F_{ij}\,(D_j Y_i). \qquad (4)$$

In this case, the order of calculations can be carried out in the sequence outlined in Table 1.

Table 1. The order of calculations when searching for the optimal solution in the conditions of probabilistic-deterministic determination of the initial data

D / Y	X_1	X_2	…	X_j	MF
	p_1	p_2	…	p_j	
Y_1	$\boldsymbol{F_{11}}$	$\boldsymbol{F_{12}}$	…	$\boldsymbol{F_{1j}}$	$MF_1 = \sum_{j=1}^{n} p_j F_{1j}$
Y_2	$\boldsymbol{F_{21}}$	$\boldsymbol{F_{22}}$	…	$\boldsymbol{F_{2j}}$	$MF_2 = \sum_{j=1}^{n} p_j F_{2j}$
…	…	…	…	…	…
Y_i	$\boldsymbol{F_{i1}}$	$\boldsymbol{F_{i2}}$	…	$\boldsymbol{F_{ij}}$	$MF_i = \sum_{j=1}^{n} p_j F_{ij}$
…	…	…	…	…	…
Yj	$\boldsymbol{F_{m1}}$	$\boldsymbol{F_{m2}}$	…	$\boldsymbol{F_{mj}}$	$MF_m = \sum_{j=1}^{n} p_j F_{mj}$
					$min_{\overline{i=1,m}} MF_i$

It is clear that the task of optimization based on the resource-process approach in probabilistic deterministic should be based on the demand of the energy supply system $D_j, j = \overline{1,n}$ and the probabilities p_j with which these values are realized. If $Y_j, j = \overline{1,m}$ are options for forming the energy balance of a microenergy system based on generation by several sources, and F_{ij} is an integrated reduced cost indicator that takes into account the specific cost of electricity and heat energy. The optimal solution will be the one in which the structure of the sources of the micro-energy system will provide the minimum integral indicator of costs in the long term (from one calendar year).

The values of the functional $F,$ obtained with comparable variants of alternative Y_i and various external conditions X form the so-called payment matrix (highlighted in bold letters in Table 1). The value of the function $F,$ in this case can be rightfully interpreted as resource costs that we seek to minimize. Recommendations or rules for choosing the best solution in such a situation are the subject of further research.

Based on the concept of creating a CHPS justified in this study and determining its functional capabilities in relation to the insular character of replacing the share of electric and thermal energy in the energy balance of the territorial community in Fig. 4 proposed a generalized structure from heterogeneous sources of the network level (centralized power supply system (CPSS), local heating network (HG), solar power plant (SPP), wind power plant (WPP), thermal power plant (HPP), biofuel cogeneration plant (BCP) and equipment for the end consumers energy supply (gas boiler, solid fuel boiler, electric boiler, heat pump).

Electricity generation technologies are based on the use of solar photovoltaic installations, wind power plants and installations of combined energy generation on solid biofuel and biogas, allowing to maneuver capacities to cover demand. Consumers united in energy communities independently consume the produced energy and thus become collective end consumers of energy. Any additional electricity generation from such sources can be exported to the main (centralized) grid, sold to third parties or accumulated.

Such approaches show a conceptual way of finding the best solution, which allows you to build several chains of logical trends regarding the justification of the choice. This is precisely the principles of resource and process optimization.

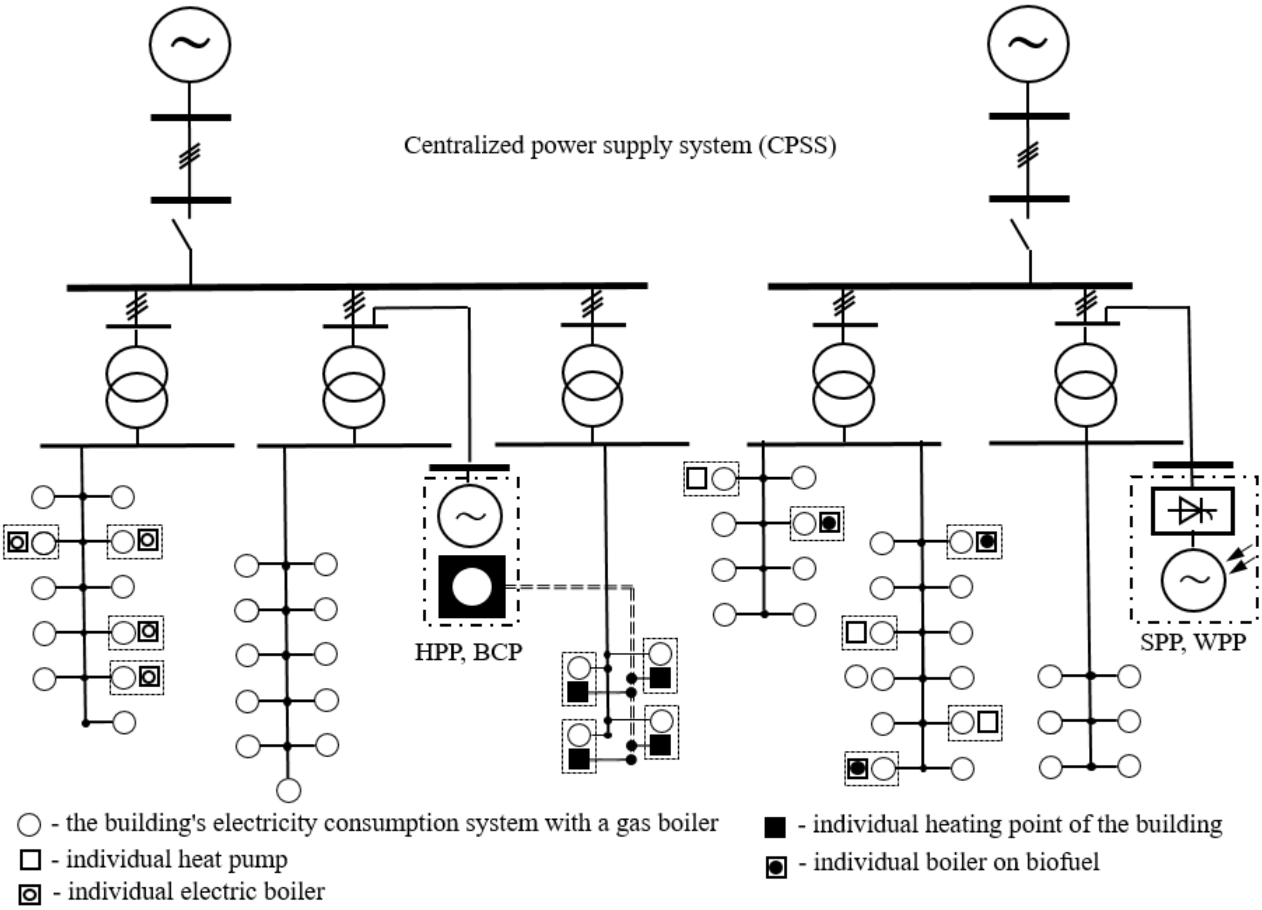

Fig. 4. Generalized system of combined energy supply of the territorial community

Measures to increase the energy efficiency of territorial communities (as main or auxiliary) should motivate community members to reduce energy consumption and invest in the modernization of buildings (for the population) and production technologies (for businesses). An important factor is the further implementation of the dynamic energy management system, which will allow for parity formation of tariff plans within the territorial community and show investment-attractive directions for further energy efficiency improvement and reduction of greenhouse gas emissions.

4. Conclusions

The current state of implementation of renewable energy facilities and the development of the latest technical and technological solutions for biofuel conversions for the combined generation of electricity and heat creates opportunities for managing the efficiency of energy supply of territorial communities in the context of greening the energy sector. The obtained results give an idea of further directions of research related to the justification of economically achievable levels of energy independence of territorial communities based on the development of their own generation and network infrastructure.

The work formulates theoretical and applied principles of structural implementations of combined energy generation systems for energy supply of territorial communities with heterogeneous sources. The formal presentation of results is related to the variability of competing resources and processes in CHPS when forming energy balances on the basis of the reduced integral indicator of costs, which takes into account the specific cost of electricity and thermal energy. The search for the optimal solution aims to consider the model series of the structure of the sources of the micro-energy system to ensure the demand for electricity and heat in the medium and long term at the minimum integral indicator of costs.

RES electricity generation and energy generation based on local biofuels are the basis of the structure of energy flows of the local node as a basic element of the energy supply system of the territorial community, a generalized structure of CHPS sources integrated into centralized networks is proposed. It is obvious that in this form CHPS constitute a new type of economic entities with a special organizational structure in the conditions of the functioning of the new energy market and the decarbonization of the economy.

The method of determining the integral indicator of costs for the energy supply of selected CHPS structures can be used to develop a system of dynamic energy management, which will allow the formation of tariff plans within the territorial community on a parity basis, taking into account the supply of energy from external networks, the possibility of accumulation, and show investment-attractive directions for further increasing energy efficiency and reducing greenhouse gas emissions gases This can play an important role in starting a new cycle of sustainable regional development.

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ПРИНЦИПИ РЕСУРСНО-ПРОЦЕСНОГО МОДЕЛЮВАННЯ КОМБІНОВАНОГО ЕНЕРГОЗАБЕЗПЕЧЕННЯ ТЕРИТОРІАЛЬНИХ ГРОМАД В КОНТЕКСТІ ПРОТИДІЇ ЗМІНИ КЛІМАТУ

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Анотація. *Дослідження присвячене теоретичному та практичному обґрунтуванню принципів формування систем комбінованого енергозабезпечення з різнорідними джерелами для підвищення енергоефективності територіальних громад в умовах протидії зміни клімату. Запропоновані нові підходи і структурні моделі формування локальних мікроенергетичних систем, які спонукатимуть територіальні громади до нового виду діяльності, пов'язаного з власним енерговиробництвом на основі використання місцевих видів палив та відновлюваних джерел енергії. Принципи побудови таких систем локального енергозабезпечення у загальному випадку полягають у раціональному розподілі ресурсів (відновлюваних джерел, джерел комбінованого енерговиробництва на біопаливі, енергії зовнішніх мереж) та узгодженні процесів генерації, передачі, акумулювання, розподілу та споживання енергії у межах окремої територіальної громади шляхом створення власних високотехнологічних інфраструктурних активів. Формування енергетичного балансу у середньо- та довгостроковій перспективі запропоновано здійснювати на основі ресурсно-процесного аналізу функціонування локальних мереж шляхом пошуку оптимального використання місцевих видів біопалива та відновлюваних джерел у комбінованому виробництві електроенергії і тепла з урахуванням їх приведеної вартості. Вартість енергії для кінцевого споживача обумовлюється диференційованими тарифами енергопостачальних компаній та використанням декількох різнорідних джерел, які беруть участь у процесі децентралізованого енерговиробництва. Отримані математичні співвідношення для обчислення значень часових проміжків виконання множини паралельних процесів, що виникають при взаємодії конкуруючих джерел розподіленої генерації з кінцевими споживачами, і встановлення закономірностей формування енергетичного балансу такої мікроенергосистеми. Запропонований метод може бути інструментом для пошуку оптимальних сценаріїв управління енергоефективністю об'єктів з локальним енергозабезпеченням при використанні оперативного перерозподілу потоків енергії у системі комбінованого енерговиробництва та прогнозуванні поточних витрат на енергозабезпечення у розрахункових періодах. Така концепція може бути теоретичною основою для формування принципів енергонезалежності територіальних громад.*
Ключові слова: територіальна громада, комбіноване виробництво електроенергії і тепла, відновлювані джерела енергії, біопаливо, енергетичні баланси.

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