Energy Services Market: Conceptual Framework and Mechanism of Forming

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Abstract– *The energy services market is the youngest, compared to other types of energy markets, but also the most actively expanding worldwide in two priority areas: energy efficiency and renewable energy sources. At the same time, the incompleteness of the theoretical foundations substantially slows down its development. This paper provides an overview of the legal and regulatory frameworks associated with energy services market formation, brings together conceptual ideas and innovation studies from developed countries, and offers a theoretical foundations (model) of the energy services market formation based on the synergetic combination of energy systems requirements analysis and set theory. A new organizational structure of the energy services market clients' interaction with energy-and-fuel markets, markets of energy efficiency and renewable energy technologies and markets of consumers, as well as a new organizational mechanism for supporting the effective functioning of the energy services market based on a system of corresponding equations are proposed. In general, the proposed framework allows the researchers and engineers to define in more depth and more clearly the system-coordinated pathways to improve the energy services market functioning.*

Keywords— energy services, market structure and mechanisms, set theory equations.

I. INTRODUCTION

Today's global economy is rapidly changing from manufacturing to a service economy that covers now all major business sectors, where fuel and energy resources are used intensively (IEA & IRENA, 2017; IEA, 2019; Novoseltsev et al., 2013). Largely, these are energy, industry, transport, housing and communal sectors, agriculture etc.

To keep abreast of current trends, global energy services (ESs) markets are developing in two priority areas: energy efficiency (EE) and renewable energy sources (RES), where EE is considered a 'specific type of fuel'. Other important areas of ESs markets development include increasing regulatory capacity, securing energy supply to meet demand, and facilitating private sector-led energy investment. Note that the cumulative investment in EE and RES in the world for 2016-2050 is estimated under different scenarios as US$ (29.0-37.0) trillion and US$ (13.0-27.0) trillion, respectively (IRENA, 2019).

The foremost system-integrating role in the ESs markets plays energy service companies (ESCOs), whose effectiveness has been proven in practice in both developed and developing countries. The size of global ESCO business was USD 28.6 billion in 2017 with annual growth rate of over 8 %. China ESCO market grew 11 % to USD 16.8 billion, the USA market – to USD 7.6 billion, EU – to USD 3.0 billion, and in the rest of the world – shrunk since 2015 by 8 % to USD 1.5 billion (Boza-Kiss, et. al., 2017; ECS, 2016; ECS, 2018; IEA, 2019; Stuart et al., 2016). ESCOs represent the commercial type of organizations (companies, enterprises) that operate on the basis of an ESs performance contracting, providing a range of turnkey energy services that covers the energy, economic, environmental, financial and legal aspects of the design, engineering, installation and commissioning of

ESs projects, long-term monitoring and verification of the projects' savings. In addition to Energy performance contracting format of ESs contracts, the next, most commonly used in the world, are Guaranteed savings, Shared savings, Chauffage, Energy supply, First out, Full management, Integrated energy etc. (Kovalko et al., 2013; Lefebvre et al., 2015; Kovalko et al., 2018).

Among other important ESs markets actors (participants), the manufacturers of energy-efficient and RES equipment and materials, primary energy-and-fuel resources providers, utility companies, investors, representatives of trading platforms, state and local governments and regulators should be taken into account when analyzing the ESs markets (Grazer Energy Agency, 2016; Szomolanyiova et al., 2018).

International and / or cross-border cooperation between the ESs markets participants creates a fundamentally new challenges in the field of EE and RES, aimed at carrying out upgrade and innovative technical and technological development of each enterprise and national economies of the countries which cooperate (Kovalko et al., 2013; Novoseltsev et al., 2013).

II. LITERATURE SURVEY

The implementation of EE and RES are one of the main strategic objectives of the low-carbon development of national economies, as well as the global economy as a whole. Great example – the USA: a network of federal and local energy-saving agencies were established, programs for financing and promoting energy-efficient and RES technologies were implemented, and a special fund for investing in ESs activities was created in accordance with the Federal Energy Policy Act of 1992. The necessary financial resources for the implementation of these programs, set the tasks for increasing the internal production of traditional energy resources, the paces of gradual reduction of the country's dependence on import of oil, measures to ensure national energy security were allocated among others under the Energy Policy Act of 2005. The Energy Independence and Security Act of 2007 aims to: increase the production of clean renewable fuels, protect consumers, increase the efficiency of products, buildings, and vehicles, facilitate exploration and deployment of greenhouse gas collection and storage options, improve the energy performance of the Government, and increase the US energy security, stimulate the production of renewable fuels, and improve vehicle fuel economy. Under the US legal framework, a 30 % tax benefit applies to equipment manufacturers using the latest state-of-the-art technologies. The National Action Plan for Energy Efficiency of 2005 represents a private-public initiative to create a sustainable, aggressive national commitment to EE through the collaborative efforts of gas and electric utilities, utility regulators, and other partner organizations. The National Action Plan Vision for 2025: A Framework for Change establishes a goal of achieving all cost-effective ESs measures by 2025. The American Recovery and Reinvestment Act, designed for 10 years, regulates a number of preferential mechanisms for economic incentives to save energy and increase EE. The program of its implementation provides US$787 billion to implement ESs projects. In total, 34 new or updated standards concerning EE and RES have been introduced in the USA since 2009.

EE and RES services are the key driver in attracting investment in the EU energy infrastructure in order to achieve the Union's headline targets on EE of at least 32.5 %. For this, a package of ESs measures that include policy, energy savings obligation, obligation schemes, methods and principles for calculating their impact, rules for metering gas, electricity, heating and cooling, domestic hot water parameters were developed. In this context, measures, encompassing policies and individual actions that provide verifiable end-user energy savings, enfold responsibilities of each participating party, including public authority, and ensure monitoring of the results, were stipulated. It was pointed out that their economic analysis must take into account all relevant costs and energy savings due to increased flexibility in the supply, transportation and use of energy resources, including the optimization of operation, avoided costs and saving from reduced investment in infrastructure. In total, EU framework in regulating ESs sphere covers Directives that are binding on EU Member States and over 340 standards of International Electrotechnical Commission (IEC), 110 standards of International Organization for Standardization (ISO) and 300 European Standards EN (EU, 2018; EU, 2019).

A deeper analysis of legal and regulatory frameworks in developed countries aimed at stimulating ESs improvement can be found in (Callon, 1998; Grazer Energy Agency, 2016; Szomolanyiova et al., 2018). It is noted that the growth of the ESs market provides a number of significant benefits for the sustainable economic growth of countries, reducing dependence on energy imports, increasing incomes and employment, improving the profitability and competitiveness of produced goods and services, developing the knowledge-intensive industries. Among the tools are actively used multi-level structures of ESs management, national, local and sectoral target-oriented programs, national standards and certification

programs, as well as government subsidies and grants, tax benefits and preferential lending.

With regard to the development of the ESs markets in developing countries, Ukraine is a typical example. The Energy Saving Law of 1994 can be identified as a key starting point. As separate clauses of this Law, topics of the ESs contract, sources of ESs financing, including the State Energy Saving Fund, clients' own and borrowed funds, state and local budgets, Energy Efficiency Fund are considered. Instruments for stimulation of energy saving have been identified by giving tax privileges, priority crediting of ESs measures, setting of high rates of depreciation of energy saving fixed assets, targeted state and other subsidies and irrevocable allocation, standardization, establishing a set of mandatory norms, rules and requirements. The main practical steps in the formation of the ESs market in Ukraine are the creation of 10 small private ESCOs under the US technical assistance, as well as creation of Ukrainian ESCO (UkrESCO) under the EBRD credit of US$20 million in 1998.

The next decisive points are the Law of Ukraine “On Introduction of New Investment Opportunities, Guaranteeing the Rights and Legal Interests of Entrepreneurs for Large-Scale Energy Modernization” of 2015 and the “Energy Strategy of Ukraine till 2035: Safety, Energy Efficiency, Competitiveness” of 2017. The Law of 2015 defines the concept of energy services and energy service agreement, basic conditions to regulate the relationship between the clients and ESCOs, as well as mechanisms for tendering and securing payments for investors. Among the main objectives of the Energy Strategy in the EE sphere are the elimination of cost-based methodology of tariff formation, improving the framework for regulating energy markets, enhancing their competitiveness, marking household goods by energy indicators, conducting energy audits at enterprises and in buildings, expanding energy efficient transport, using the ESCOs contracts in the public and housing sectors, creating instruments of state financial and technical support (with foreign partners) to implement ESs measures. With regard to RES, a steady expansion of the use of all types of renewable energy is envisaged. Thus, by 2025, the Strategy plans to increase their share to 12% of total primary energy supply and to at least 25% by 2035.

III. PROBLEM DEFINITION

Conducted literature survey confirms that ESs markets are starting to play a key role in the low-carbon transition of the global economy. At the same time, among theoretical studies, we can only see verbal models, – there are no publications aimed at substantiating the theoretical provisions of ESs markets, even the basics of their formation and functioning remain vague and uncertain, except for the general knowledge that they are related to the monetary exchanges of goods, services and information (Callon, 1998; Jackson, 2007). And this situation adversely affects the capacity of ESs markets adequate research and impedes their further sustainable development (Nolden et al., 2016; Deshko et al., 2018).

To correct this, we first need to develop a framework based on appropriate regulatory, financial and organizational support mechanisms. And herewith, we should take into account the differences between core energy services and energy-related services (WTO, 1998; Energy Charter, 2016; Eutukhova et al, 2020), when developing a generalized model (structural-functional scheme) of the ESs markets formation, workable in a competitive energy-technological environment, as well as to formalize adequate basic equations. These requirements are the goal of our study, which consists of the following tasks to be solved:

1. To conduct a legal-based analysis comparing appropriate approaches to regulatory, financial and organizational support.

2. To develop a multi-level organizational structure of energy services market aimed at improving the efficiency of its operation by building a causal chain of energy use from production to end consumption.

3. To generate a multi-level system of basic equations formalizing the proposed organizational structure that correlates with the efficiency (energy, technology, economic, etc.) of converting sets of input variables into sets of output variables for any level of the proposed structure.

4. To develop the process flow diagram of the engineering level mechanism for supporting the functioning of the energy services market.

IV. RESULTS AND DISCUSSION

To implement the tasks and achieve the goal, we used the provisions of systems requirements analysis and set theory, exploring ES markets as an integral part of a multi-level organizational structure aimed at improving the efficiency of operation of the cause-and-effect chain of energy use from its production to end consumption. Organizational structure of the proposed model is represented in Fig.1.

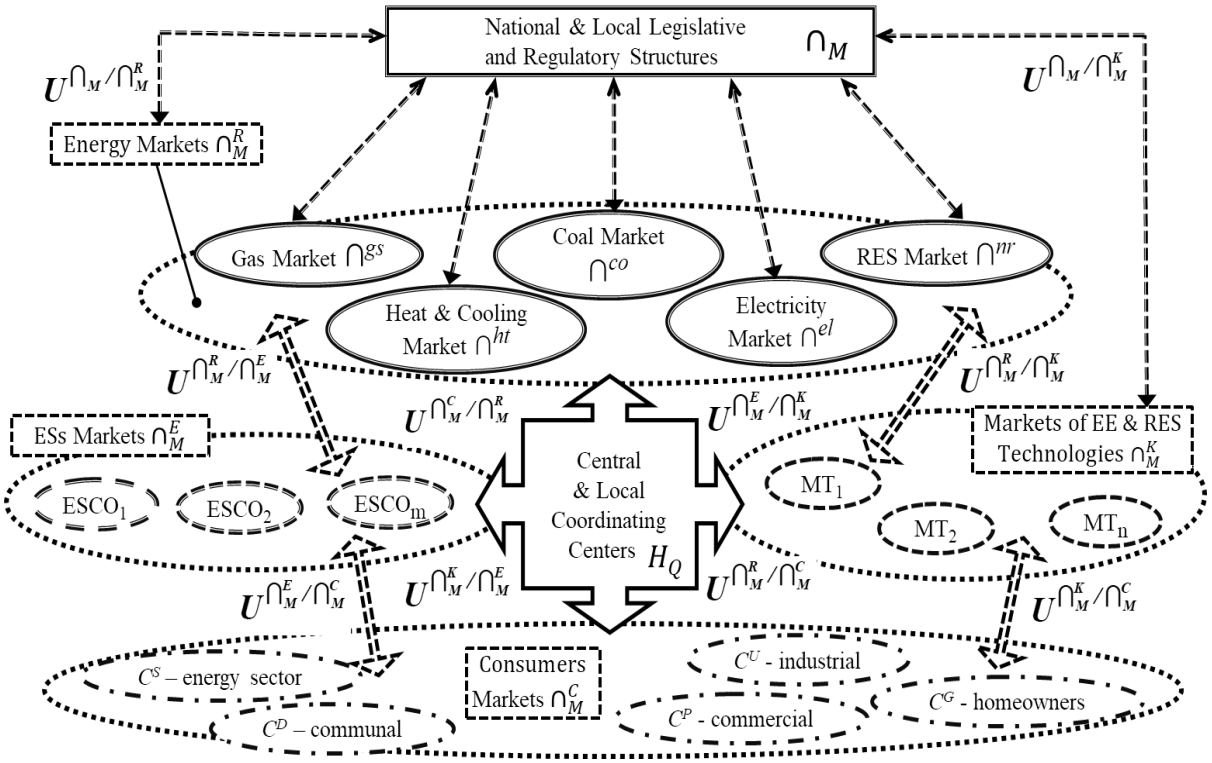

Fig.1: Object-oriented model of ESs market organization

As we can see, the focus position in the proposed organizational structure of the ESs market is occupied by national and local coordinating centers. The main task of these centers is to coordinate the activities of ES markets actors (participants) in the conditions of their legal and economic independence. Among the preferential mechanisms (instruments) of such coordination are the ESs contracts, as well as national and local target-oriented programs for economic stimulation to EE, energy saving and RES using.

The upper level of the proposed organizational structure is formed by the markets of energy resources (gas, oil, coal, renewables, heating and cooling, electricity). The next level integrated with others, constitutes by markets of EE and RES technological equipment and materials, where their manufacturers (also intermediaries) sell EE and RES goods, services and information to the end consumers (ESs clients). Among the latter, you can see representatives of the energy markets (they usually simultaneously carry out the functions of energy resources suppliers and energy services consumers), industry, trade, urban communities, homeowners, etc. (Deshko et al., 2019; Eutukhova et al., 2020). To reflect in the modeling process the complexity of the interactions between ESs market actors, the mathematical sign (∩) of intersection of sets in families is used in Fig. 1.

As follows from the consideration of the arrows in Fig.1, the interactions of the ESs markets actors are reflected in the proposed model by an ordered set of an organizational-and-technological modules that have diamond-shaped structure (Eutukhova et al., 2020). Their formalization in the model is represented in Fig.1 by a combination of mathematical signs of intersection of sets in families, for example, between energy and ESs markets, like $U^{\cap_M^R/\cap_M^E}$. In a more visual way, this interaction is displayed in the form of a Venn diagram (see Fig. 2), in which the interaction areas are highlighted in a darker color.

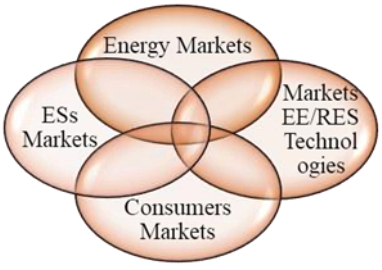

Fig.2: Venn diagram

It is also necessary to add that, when modeling the ESs markets, all four interacting level (modules) of the considered organizational structure should be regarded as

'immersed' in the environment of national and local legal and regulatory frameworks. This implies that the functioning of ESs markets, as a part of integrated system, must strictly meet the requirements of these frameworks.

Formatting the basic equations of the ESs model, the organizational structure of which, shown in Fig.1, is based on the set-theoretical approach, we will be carried out in the form of mappings (for example, this is $U^{\cap_M^R/\cap_M^E}$) of ordered sets of input variables (in our example this is $\cap_M^R$) into sets of output variables (in our example this is $\cap_M^E$) for each level of the model structure (these are R, E, K, C levels), with incorporating the impacts on these variables of managerial influences (H_Q) and feedback (F_i^j) from i to j level. It is important that the formalized in this way mappings will have a strict correlation with the efficiency (energy, technology, economic, ecological, social, etc.) of converting sets of input variables into sets of output variables for any level of the model.

Acting like this, we generated system-level core equations (1), describing the procedures of the actor's interaction in the ESs markets, and a complementary system (2) of the two subsystems of mappings of output variables into managerial and feedbacks variables, where μ and η (with the matching indexes) reflect the efficiencies of corresponding mappings.

$$\begin{cases} U^{\cap_M^R/\cap_M^E}:\left(\cap_M^R\times H_Q^R\times F_E^R\right)\to\cap_M^E; \\ U^{\cap_M^R/\cap_M^C}:\left(\cap_M^R\times H_Q^R\times F_C^R\right)\to\cap_M^C; \\ U^{\cap_M^R/\cap_M^K}:\left(\cap_M^R\times H_Q^R\times F_K^R\right)\to\cap_M^K; \\ U^{\cap_M^E/\cap_M^R}:\left(\cap_M^E\times H_Q^E\times F_R^E\right)\to\cap_M^R; \\ U^{\cap_M^E/\cap_M^C}:\left(\cap_M^E\times H_Q^E\times F_C^E\right)\to\cap_M^C; \\ U^{\cap_M^E/\cap_M^K}:\left(\cap_M^E\times H_Q^E\times F_K^E\right)\to\cap_M^K; \\ U^{\cap_M^K/\cap_M^R}:\left(\cap_M^K\times H_Q^K\times F_R^K\right)\to\cap_M^R; \\ U^{\cap_M^K/\cap_M^E}:\left(\cap_M^K\times H_Q^K\times F_E^K\right)\to\cap_M^E; \\ U^{\cap_M^K/\cap_M^C}:\left(\cap_M^K\times H_Q^K\times F_C^K\right)\to\cap_M^C; \\ U^{\cap_M^C/\cap_M^R}:\left(\cap_M^C\times H_Q^C\times F_R^C\right)\to\cap_M^R; \\ U^{\cap_M^C/\cap_M^E}:\left(\cap_M^C\times H_Q^C\times F_E^C\right)\to\cap_M^E; \\ U^{\cap_M^C/\cap_M^K}:\left(\cap_M^C\times H_Q^C\times F_K^C\right)\to\cap_M^K. \end{cases} \quad (1)$$

$$\begin{cases} \mu_M^{ER}:\cap_M^E\to H_Q^R; \\ \mu_M^{CR}:\cap_M^C\to H_Q^R; \\ \mu_M^{KR}:\cap_M^K\to H_Q^R; \\ \mu_M^{RE}:\cap_M^R\to H_Q^E; \\ \mu_M^{CE}:\cap_M^C\to H_Q^E; \\ \mu_M^{KE}:\cap_M^K\to H_Q^E; \\ \mu_M^{RK}:\cap_M^R\to H_Q^K; \\ \mu_M^{EK}:\cap_M^E\to H_Q^K; \\ \mu_M^{CK}:\cap_M^C\to H_Q^K; \\ \mu_M^{RC}:\cap_M^R\to H_Q^C; \\ \mu_M^{EC}:\cap_M^E\to H_Q^C; \\ \mu_M^{KC}:\cap_M^K\to H_Q^C; \end{cases} \quad \begin{cases} \eta_M^{ER}:\cap_M^E\to F_E^R \\ \eta_M^{CR}:\cap_M^C\to F_C^R \\ \eta_M^{KR}:\cap_M^K\to F_K^R \\ \eta_M^{RE}:\cap_M^R\to F_R^E; \\ \eta_M^{CE}:\cap_M^C\to F_C^E; \\ \eta_M^{KE}:\cap_M^K\to F_K^E; \\ \eta_M^{RK}:\cap_M^R\to F_R^K; \\ \eta_M^{EK}:\cap_M^E\to F_E^K; \\ \eta_M^{CK}:\cap_M^C\to F_C^K; \\ \eta_M^{RC}:\cap_M^R\to F_R^C; \\ \eta_M^{EC}:\cap_M^E\to F_E^C; \\ \eta_M^{KC}:\cap_M^K\to F_K^C. \end{cases} \quad (2)$$

Further (more deeper) detailing the variables in equations (1) and (2) to the level of energy (technology, economic, ecological, social, etc.) processes of the actors activities in ESs markets needs to take into account the actors capabilities to:

- realize the ESs management system based on a continuous quality improvement model known as Deming or PDSA cycle, which consists of a logical sequence of four stages: plan, do, check, and act. In turn, this management system should include the complex of procedures such as: conducting the preliminary and investment level audits, analysis of energy saving measures potential, design validation of the ESs projects (due diligence), evaluating the scope of funding and selecting the potential investors, concluding a package of ESs contracts, purchase of goods and services from third parties, implementation of the ESs projects, loans repayment, etc.;
- increase clients cost-effectiveness through the implementation of a turnkey package of ESs services that include EE, RES, distributed generation, heating, cooling, lighting, ventilation, building, etc., and by avoiding of the clients upfront costs through long-term third-party financing or on-bill repayment schemes;
- arrange payment by results allowing transfer of technical risk from clients to ESCOs by using the specialized financial support mechanisms (FSMs) to increase the scales of private funding and operating in coordination with local and international financing organizations;
- guarantee that the energy and/or money savings resulting from the ESs projects implementation will be sufficient to cover the costs of projects financing throughout the consensual period of their exploitation;
- make the ESs projects more attractive for state and local governments by ensuring that the main assets and services of these projects were recorded off governments balance sheets to restrict the impact on the

budget deficit and allowing them to realize much more investment ESs projects.

In order to be mutually effective in the realization of these tasks, each of the ES market clients should have appropriate organizational and financing support mechanisms. Recall that among these clients there are central and local (municipal) authorities, ESCOs, commercial banks, private investors, international technical assistance programs, EE equipment manufacturers, primary energy suppliers, etc. Developed on the basis of international experience, the process flow diagram of the organizational mechanism for supporting the effective functioning of the ESs market is shown in Fig. 2.

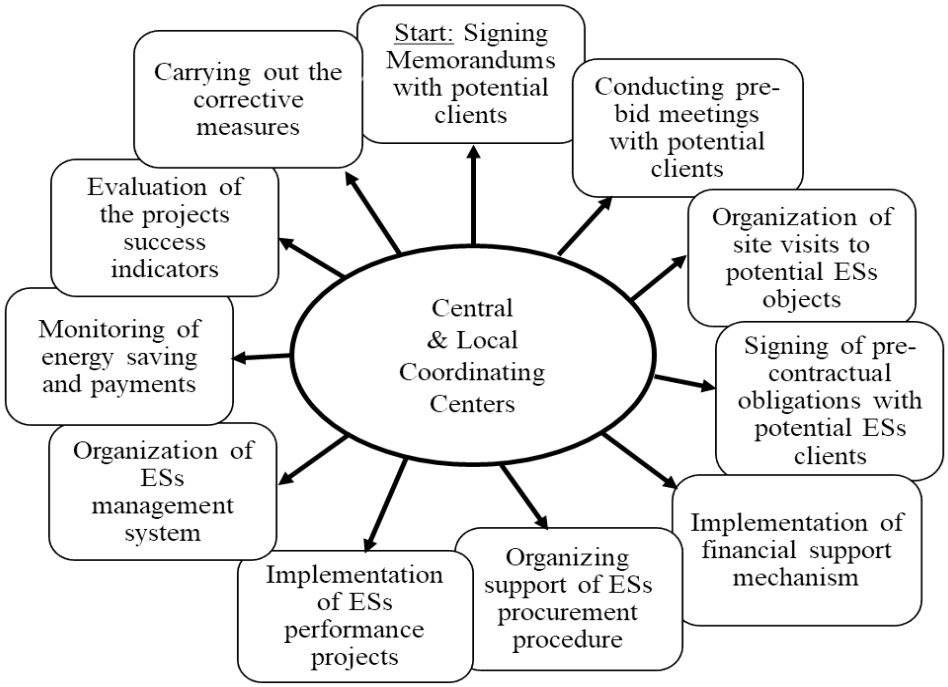

Fig.2: The stages of organizational mechanism for supporting the functioning of the ESs market

The new structural elements in this flowchart, which distinguish it from the known verbally described procedures of ESs markets functioning, are: conducting pre-bid meetings with potential clients; organizing site visits at potential ESs objects, which in the future are planned to be put up for open bidding; formation and signing the mutual pre-contractual obligations between potential executors of ESs projects. In a generalized form, the proposed organizational structure of the ESs market consists of three main components (modules of the model): a market of pre-contractual obligations, trading platform (auctions) and a market of post-contractual obligations. Taken together, these modules represent a powerful mechanism for improving the functioning of ESs markets by creating a primary market for pre-contract ESs obligations, which ultimately allows the coordinated centers to enhance the multiplier effect by combining the efforts of several clients to implement the ESs projects pool.

Inclusion in this mechanism the support functions of international technical assistance programs and grants (national and international) play a crucial role in the formation of the ESs market worldwide. By analyzing the allocation of ESs projects funding in developed and developing countries, we propose to use a special form of grants – an energy performance grant (EPG), which is up to 25-30 % of the total ESs project cost. The EPG payments should be made only if and after the grant recipient took over the commercial funding and signed the ES contract awarded through the public procurement. EPG payment amounts should be dependent on energy savings achieved by grant recipient for the periods stipulated by ESs contract. Among the directions of using the EPG grants, first of all we propose to consider the development of ESs markets in small and medium-sized cities, conducting energy audits and preparation of bidding documents, offering free of payment ESs management systems for municipalities that undertake ESs contracts on co-finance basis with the private sector, mitigation of lending conditions by using the FSM, implementation of

the economically unattractive but socially significant ESs measures.

Among the tools of FSM, we propose to consider first the leasing mechanism, demand side regulation by suppliers of primary energy-and-fuel resources, financing (lending) from the state and local budgets on a return basis, municipal ESCOs (MESCOs) mechanism, public-private partnership, revolving (multifold) use of cost savings, and local EE funds. MESCOs should be the official representatives of local authorities and budget institutions in ESs markets, assuming control and management functions as well as executing projects in cases requiring community input. This gives the community a number of benefits through targeting the interests of the city community, creating competition for private ESCOs, ensuring the return of savings to the community budget, expanding community lending through local guarantees and enhancing the institutional capacity of the community in the EE and RES fields.

With regard to the structure of ESs markets funding, the results of comparative analysis of EU and Ukraine ESs markets shows that, on average, financing the ESs projects in EU is carried out at the expense of ESs client's funds mostly (52 %) and bank credits (26 %), the share of ESCO's own funds is only 5 %. The public sector remains the most important client sector of ESs markets. The practically same picture is in Ukraine, where to the main ESs markets development problems are added the instability of national currency exchange rate, high level of inflation, lack of long-term credit resources, high interest rates on loans in local banks, lack of international ESs credit lines.

V. CONCLUSIONS

1. Energy services (ESs) markets worldwide are now in their infancy and requires fundamentally new approaches for the development of methodological, organizational, financial and technological support for its evolution and sustainable functioning. Particular attention should be paid to improving the legal and regulatory framework, implementation of energy management systems, increasing the share of RES and cogeneration, as well as use of waste energy potential and attracting international technical assistance to switch to cheaper mix of fuels.

2. Synergistic combination of conceptual ideas of systems requirements analysis and set theory for the first time allowed to generate a system of equations, describing the interaction of ESs providers with participants of energy markets, markets of EE, RES technologies and final consumers of fuel and energy resources. This allowed creating a theoretical framework for further detailing the variables of these equations to the level of parameters of concrete energy-consuming equipment for optimization them by the criteria of energy, economic and environmental efficiency.

3. In general, the proposed structural-functional framework, as well as the organizational mechanism to support the efficient functioning of ESs markets, allow the researchers and engineers to define in more depth and more clearly the system-coordinated pathways of improving these markets functioning, as well as to expand the scope of energy services.

FUTURE SCOPE

In the future, we want to expand our study and analyze in detail the structure and functions of the ESs markets components so that they can be conveniently used in engineering practice.

CONFLICT OF INTEREST STATEMENT

The authors received no specific funding for this study.

The authors declare that they have no conflicts of interest to report regarding the present study.

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