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Developing Renewable and Alternative Energy Sources to Improve the Efficiency of Housing Construction and Management

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ABSTRACT

Demographic, economic and cultural changes increase energy consumption in the housing sector and cause even higher levels of the related greenhouse gas emissions. The goal of this work is to identify opportunities for developing renewable energy sources (RES) in the housing sector to improve its energy efficiency. The results of the study show that the construction industry, and especially the housing sector, can save more energy as compared to other types of the energy use. RES are important in reducing CO_2 emissions in the housing sector and in improving the energy efficiency of buildings. In recent years, the production and consumption of energy from renewable sources in the housing sector have increased. However, the main volume of energy consumption in buildings is provided by fossil fuels. The main barriers to the introduction of renewable energy in the DNC housing system are financial ones, as well as logistical problems of biomass transportation and storage. To reduce these barriers, the authors offer a number of measures, including the governmental support for the use of renewable energy in the systems of heat supply and cooling of buildings, as well as the creation of storage facilities for renewable energy. The system of encouraging the use of RES applied in Denmark, which is the world leader according to the use of renewable energy in the housing construction, is considered as an example.

Keywords: Energy, Energy Consumption, Housing Sector, Buildings Sector, Renewable Energy Sources, DNC
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1. INTRODUCTION

Today, energy supply has become one of the main problems of the mankind. Needs in energy increase as technology develops. It is expected that by 2035 the world energy consumption will have increased threefold as compared to 1998. In response to these needs, fossil fuel reserves are being rapidly depleted. The widespread use of traditional energy sources in the housing, transportation and industrial sectors complicates the problem even more.

Buildings with the total area equivalent to Paris (105 sq. km) are built every five days in the world (UN Environment and International Energy Agency, 2017). At the same time, their energy efficiency in the housing sector is not given enough attention. The housing sector is one of the top priority areas in terms of energy efficiency because it consumes a large amount of energy (on average, 20-30% of the total final consumption (United Nations Economic Commission for Europe, 2009).

Now, the housing construction uses much more energy than it is necessary. The contribution of housing to carbon dioxide emissions is high, and continues growing (Venables, 2016). Many residents do not have available energy that is sufficient for life. The penetration of energy efficient technologies in the industry is low, and most of the associated potential is not used.

While the existing technologies provide a high potential for drastically reducing of the energy consumption in the housing sector, now the sector retains the outdated inefficient practice, and is one of the factors for high consumption. Even the developed countries that have advanced construction standards are very far from using the full potential of the sector.

A certain problem for these countries is to overcome the so-called energy inefficiency trap or a situation when countries with lower energy efficiency cannot change their relevant status because they do not have funds, experience, technology, motivation, and initiative.

At the same time, the state of the existing technologies shows very high potential for a sharp reduction in the energy consumption in the housing sector. These technologies are included in zero-energy homes or even buildings with the surplus energy produced by renewable sources, and surplus energy is delivered to the total energy network.

Many technological solutions are also cost-efficient: According to the estimations, depending on the country, it is possible to achieve 25-40% of direct energy savings (International Energy Agency, 2018) at the national level in the housing sector by using cost-efficient technologies. However, investments in energy efficiency are made on a limited scale. This is much lower than the rational.

This paradox is known as the energy efficiency gap. The most serious problems in the area of energy-efficient housing appear to be related not only to technologies: They are related to the need to create appropriate and functioning institutional structures that could trigger large-scale measures on improving the efficiency.

Rationalizing the energy use in housing can solve problems and thereby contribute to solving today's global problems of climate change, energy security, economic uncertainty and poverty.

To discover these opportunities, this study states the main benefits, problems, and prospects countries should consider when developing their energy efficiency policies in the housing sector.

2. LITERATURE REVIEW

A review of theoretical sources on the problems of creating affordable and energy efficient housing shows that there are many conceptual approaches to this theme.

Recently, the concept of "a green building" has become increasingly important in various countries (Farid and Wonorahardjo, 2018). The practice of sustainable construction can be crucial in achieving sustainability in the construction industry (Darko et al., 2017).

In a broad sense, "a green building" is defined as a building located, designed and exploited to reduce the negative impact on the environment, and has positive impact on the economy, health, performance and society throughout the life cycle (Jian et al., 2018).

According to the experts, these are buildings where wastes are minimized at each stage of building construction and exploitation, which leads to low costs according to experts in technology (Kumar et al., 2018). A "green" building is evaluated by a holistic approach, where each component is viewed in the context of the entire building and its social and environmental impacts. An important component of the sustainable construction is energy (Soudan et al., 2018).

Urgent issues related to energy efficiency in the housing construction in developing countries are studied in the works of Makarov et al. (2018), Manganelli et al. (2019), Loudyi and El Harrouni (2018), D'Alpaos and Bragolusi (2018), Liu and Ren (2018), etc.

According to Ouf et al. (2018), the size and shape of the building, insulation, tightness, heating system and energy-saving solutions have impact on energy efficiency. A rather long period of consideration also makes it possible to take decisions in reconstruction projects economically reasonably.

Energy consumption in the housing sector depends, inter alia, on income, energy prices, location, characteristics of buildings and households, weather, efficiency and type of equipment, access to energy, availability of energy sources and energy-related policies. As a result, the type and amount of energy consumed by households can vary considerably depending on regions and countries.

Energy efficiency requires a system approach to the design and construction of a house. All elements of the building: The basement, frame, roof structure and windows are crucial in determining potential energy savings for the house. The use of energy inside the house is the second area of the study. Mechanical equipment designed for actual loads of the house, natural daylight, and ventilation have considerable impact on how much energy will be used to ensure comfort and convenience. Appliances and lighting also have an effect on the net energy efficiency. All this must be taken into account at the early stages of design in order to maintain cost-efficiency (Singh et al., 2017).

Better energy efficiency is considered as a result of applying technologies and/or knowledge, which, in its turn, is substantiated by the conditions conceptualized as five key words: "Investments, information, innovations, incentives, and initiative" (Atkins et al., 2018).

The government, landlords and the construction industry are a triangle of key stakeholders whose mutual relations determine the status of "5-INs" in ensuring a better energy efficiency (Killip et al., 2018).

Using this approach, it is possible to define a number of barriers and problems for energy efficient homes. The most common barriers to investing in energy efficiency in housing are the lack of incentives and the low priority given to energy issues as compared to alternative opportunities of households and economic entities (Ghimire and Kim, 2018).

The state policy should stimulate complex technological and institutional changes for increasing energy efficiency, and eliminating the inconsistency of microeconomic interests at the national and international levels (Arpan et al., 2018). Some progress has been made recently in this area, but in many countries that have different levels of economic development the current situation has many opportunities for improvement.

The increase in the utility rates and growing concerns about carbon emissions make more and more homeowners consider alternative and renewable energy sources (RES) to keep their homes (Nabielek et al., 2018). The RES sector remains one of the most dynamic, rapidly changing sectors of the global economy.

In the residential sector RES devices and systems are used in heating premises, water heating and electricity generation for lighting and power supply of household electrical appliances (Juntunen, 2014).

It is commonly agreed that renewable energy development should be encouraged, but there are different opinions on how to achieve this in practice best of all (Karasu, 2009). Despite the financial support from the governments of many countries to stimulate the introduction of renewable energy technologies in the housing sector, the consumption remains low (Balcombe et al., 2013).

This is due to the fact that, despite the fact that RES, such as hydropower, geothermal energy, solar energy or wind energy, provide the consumer with electricity at a much lower price, renewable energy projects are quite complex and are implemented within longer periods than traditional energy projects (Akcay et al., 2017).

It is necessary to note that in recent years there have been a considerable number of references on energy-efficient housing design. At the same time, it is necessary to further study the opportunities of RES to improve the efficiency of housing construction in developing countries.

3. METHODOLOGY

The purpose of this article is to study the opportunities of developing RES in the global housing sector. The study was performed by using qualitative and quantitative methods of analysis, methods of economic theory, including the method of comparing the dynamics of statistical indicators of the world energy for 5 years.

The sources of information are statistical databases and official publications of the International Energy Association (IEA), IRENA, the International Renewable Energy Agency, the World Bank, and OECD, the organization of international cooperation and development.

4. ANALYZING THE ENERGY EFFICIENCY IN THE GLOBAL HOUSING SECTOR

The global housing sector continues growing. In 2016 its area reached 235 billion m^2. According to the IEA, in 2016 the construction housing sector of buildings and structures accounted for 21.6% of the global final energy consumption.

For 2012-2016 the energy consumption in the global housing sector has increased by 70,904 thousand toe, or by 3.6% (Figure 1).

The demand for energy in the global housing sector continues growing due to the improved access to energy in developing countries, increased use of energy-consuming devices, as well as rapid growth of the buildings area in the world.

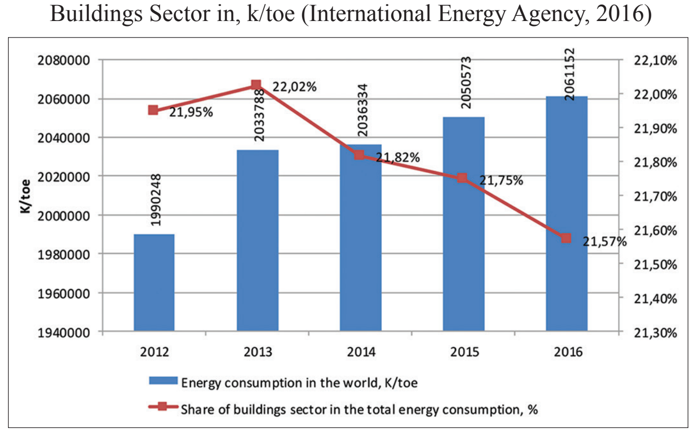
The energy demand per capita at the level of 3.3 MW per person per year, where the average global energy consumption in buildings per person has remained almost unchanged since 1990, is more indicative.

The energy intensity of the buildings sector in terms of energy consumption per 1 m^2 continues improving, with an average annual rate of about 1.5%. However, the global area continues growing at about 2.3% per year, and compensates for these improvements of the energy intensity.

Buildings account for 28% of global energy-related CO_2 emissions (Figure 2).

For 2012-2016, the CO_2 emissions from buildings and structures have annually increased by almost 1%. During this period, the total emissions amounted to about 76 gigatons (Gt) CO_2. At the same time, it is necessary to note that the global annual carbon emissions associated with buildings seem to have peaked in 2013 when their volume was about 9.5 Gt of CO_2, and then decreased down to 9.0 Gt of CO_2 in 2016. On the contrary, CO_2 emissions from the building construction had steadily increased: From 3.1 Gt of CO_2 in 2010 up to about 3.7 Gt of CO_2 in 2016.

Figure 1: Dynamics of the Global Energy Consumption in the Buildings Sector in, k/toe (International Energy Agency, 2016)



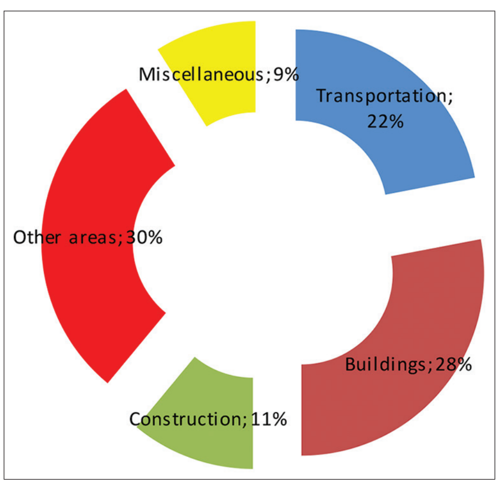
Almost two-thirds of the world's energy consumption in the buildings sector is provided by fossil fuels (coal, refined products and natural gas) for direct use or electricity generation. Globally, direct use of fossil fuels in buildings decreased during the period under consideration. In 2016 it amounted to 34.6% of the total final energy consumption. It is necessary to note that the use of coal in buildings decreased by 6.2%. At the same time, the consumption of refined products and natural gas in buildings increased by 6% and 7%, respectively. The global use of electricity in buildings had increased by an average of 2.2% per year since 2012, while electricity accounted for almost 23.7% of the total energy consumption in buildings in 2016 (Table 1).

The modern renewable energy provides about 37% of the final energy consumption for heating and cooling buildings, mainly due to biomass energy and only to a small extent from solar thermal and geothermal energy.

Developing countries still rely on the traditional use of solid biomass (for example, for cooking). In 2016 their share was one third of the total demand for final energy in buildings of these countries. The main type of alternative energy sources in the housing sector is solid bio fuel: Its share in the overall structure of RES is 95%. For 2012-2016, the total global consumption of the energy produced from renewable sources in the housing and construction sector remained virtually unchanged.

In recent years, the consumption of solar thermal (+67%) and geothermal energy (+13.4%) has increased in the global buildings sector (Table 2).

Figure 2: Share of global energy CO2 emissions by sectors, 2016



Despite the increase in the energy production from renewable sources, their share in the final consumption in the housing sector of many countries remains low. The final energy consumption for heating and cooling buildings is provided mainly by the energy of biomass and only to a small extent by solar thermal and geothermal energy.

5. DISCUSSION

According to the IEA experts, the potential for energy savings in buildings is enormous. For example, in case of the outer containment (enclosure structures): The construction of high-performance buildings and a deep energy reconstruction of the existing ones can save about 330 EJ by 2060 – more than the annual energy consumption of all G20 countries in 2015. The transfer to highly efficient heating and cooling technologies will save another 660 EJ of energy until 2060 - the equivalent of all final energy consumed in China over the past decade (International Energy Agency, 2017).

In November 2016, the European Commission published the *Clean Energy for All Europeans* policy package, which states the plans of the European Union's energy policy for the period until 2030 and later. It contains a wide range of offers on energy efficiency, energy markets, RES and climate, including the plans to revise the Energy Performance of Buildings Directive.

One of the ways to improve the energy efficiency of buildings is to increase the role of renewable energy. IRENA experts note that in order to increase the share of RES in the global energy consumption, it is necessary to accelerate their implementation not only in the end-use sectors, including housing, but also in transformative sectors, such as power generation and centralized heating and cooling (DHC). While the production of renewable energy has made clear progress and been given considerable attention, the role of renewable centralized heating and cooling systems (DHCs) remains uncertain.

Studying the availability of renewable resources for DHC generation up to 2030 shows that most countries have considerable amounts of under-used raw materials for biomass. They are potentially available for central heating boilers or cogeneration plants (International Renewable Energy Agency, 2017). For example, Denmark is already actively using biomass for centralized heating, especially for converted coal-fired power plants. However, most of this fuel is imported from neighboring countries, because domestic resources are limited. However, both

Table 1: Consumption of energy sources in the global buildings sector in 2012-2016 (International Energy Agency, 2016)

Energy sources	2012	2013	2014	2015	2016	Change 2016/2012
						Ktoe (%)
Coal	77,504	75,384	74,935	73,651	72,729	−4,775 (−6.2)
Refined products	197,386	202,316	200,357	206,385	209,304	11,918 (6.0)
Natural gas	403,134	429,020	421,898	419,322	431,242	28,108 (7.0)
Geothermal and solar energy	19,927	25,889	27,722	30,030	31,640	11,713 (58.8)
Bio fuel and wastes	738,349	737,921	731,865	728,533	728,600	−9,749 (−1.3)
Electricity	439,852	454,250	461,446	471,176	488,440	48,588 (11.0)
Heating energy	110,622	105,865	105,173	102,369	99,197	−11,425 (−10.3)

Table 2: RES consumption in the global housing sector in 2012-2016, GWh

RES	2012	2013	2014	2015	2016	Change 2016/2012 ± *GWh* (%)
Municipal wastes	539	655	590	0	0	−539 (−100.0)
Primary solid bio fuel	29,127,474	29,097,147	28,831,170	28,666,176	28,724,660	−402,814 (−1.4)
Biogases	337,346	343,160	337,932	325,736	317,813	−19,533 (−5.8)
Liquid bio fuel	589	601	577	619	605	16 (2.7)
Geothermal energy	188,966	211,710	232,916	266,148	290,041	101,075 (53.5)
Solar thermal	645,348	872,224	927,751	991,139	1,034,673	389,325 (60.3)
Total,	30,300,262	30,525,497	30,330,936	30,249,818	30,367,792	67,530 (0.2)

Japan and Switzerland benefit from large forest resources, and it is likely that these residues will be under-used. In general, the potential for increasing the use of biomass in thermal generation is considerable.

The case studies conducted by IRENA showed that one of the main barriers to the introduction of renewable energy in the system of heat supply and cooling of buildings were the financial barriers associated with high initial investment costs in renewable centralized heating projects, as well as the risks perceived by potential customers and investors.

National policymakers should provide support to promote and encourage the introduction of RES in DHC. This involves the implementation of a set of measures, such as:

- Creating equal conditions between traditional and renewable heating and cooling options: Broad support for competing fuels such as natural gas and electricity creates considerable barriers to the widespread use of RES in the housing sector. Reducing this support can be the first serious step towards changing energy systems.
- Setting certain target indicators for renewable heat and centralized energy: According to the data, the national target indicators for renewable energy supply in areas are efficient when combined with other support measures.
- Supporting and encouraging the use of RES in DHC.

The world practice shows that there is a wide range of national strategies to contribute to the implementation of DHC schemes. For example, the DHC support policy in Denmark, where the share of RES in the total energy consumption of the housing sector is the highest in the world and in 2015 it was about one third of the total heat and cooling energy for buildings.

The Danish legislation establishes market incentives such as price premiums, a fixed settlement price, a contract for difference, a base amount of support, or net support of private energy producers.

- The price premium is a fixed premium in addition to the market price. This type of addition can be provided on a limited and unlimited basis, where the value added will decrease if the market price reaches the set level. Upon reaching the marginal price, the surcharge is completely canceled (Danish Energy Agency, 2017).
- A fixed settlement price indicates a changing support cost in proportion to the market price. The estimated price is calculated by deducting the market price of electricity from the fixed estimated price.
- Contract for difference is a support scheme covering the purchase of wind turbines. It means that companies are responsible for the distribution of electricity in the market, and the subsidy is provided as the difference between the spot market price and the selling price.
- Basic support is a subsidy provided as a fixed annual amount.

The enterprise support usually covers some of its costs.

The below tables summarize the support schemes used by various RES and technologies, including the current subsidy rates, regulation and expiration of subsidies along with their legal basis.

- Net settlement with private electricity producers.

A private producer is a consumer of electricity that produces electricity or heat and electricity to fully or partially cover its own energy consumption.

As a rule, the consumer is exempt from paying taxes for the electricity produced and used in a particular mode. If, on the other hand, the consumer sells the generated electricity to the network and later buys electricity for its own consumption, it must pay taxes on all the purchased electricity. Upon request, the private producer may be allowed to deduct the electricity sold and purchased for a certain time, which means that only the net purchase of electricity during this time will be taxed. If the electricity production during this time has exceeded the consumption, a surcharge to the price for the production of excess electricity may be assigned, depending on the types of installation and fuel.

Larger private producers are additionally exempt from paying for environmentally friendly power generation for their own consumption, but they must pay a special fee for security of supply.

The condition for obtaining a net settlement account is that the power generation plant is 100% privately owned by the consumer and that it is connected to the public utility power network.

In addition to financial aspects, an important barrier to using RES in DHC systems is the problems associated with the logistics of biomass transportation. To eliminate this problem, it is necessary to properly plan and optimize supply systems, and to optimize the interaction with the relevant entities.

Taking into account the fact that some RES are not supplied on a permanent basis, it is necessary to create storage capacities. Consultants of the VYGON Consulting Company are sure that the creation of energy storage systems will be crucial in the growth of the share of generation facilities based on RES (Zhiharev and Posypanko, 2017). Heat storage allows using renewable thermal energy to better meet the needs within various time scales. Examples of implementing such projects are the introduction of energy storage systems with a capacity of 100 MW in the territory of the Hornsdale power plant (Australia), heat storage systems in Brest-Metropol (France) (Argouarch, 2018), Tesla solar system in Puerto Rico, etc.

There is no doubt that the realization of these opportunities will allow countries to expand the share of renewable sources in centralized heating and cooling systems of buildings.

6. CONCLUSION

The results of the study presented in this paper make it possible to draw a number of conclusions on the prospects for the development of renewable and alternative energy sources in the housing sector. The housing construction is the largest consumer of energy: It accounts for more than 21% of the global energy consumption.

Despite the progress in the development of renewable energy achieved in recent years, the main consumption in the buildings sector is provided by fossil fuels. Bioenergy accounts for the largest share of the renewable energy potential in the housing sector. The shares of other RES (solar and geothermal energy, liquid bio fuels and biogas) remain rather low.

The main barriers to the introduction of renewable energy in the system of heat supply and cooling of buildings are the problems of financing and logistics of transporting biomass. To reduce these barriers, national authorities need to develop a set of measures aimed at promoting and encouraging the use of renewable energy in the housing sector, as well as creating a renewable energy storage infrastructure to sustainably supply heat to buildings.

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