“Energy-efficient house: economic, ecological and social justification in Ukrainian conditions”

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Energy-efficient house: economic, ecological and social justification in Ukrainian conditions

Abstract

The main goal of the article is the efficiency justification of energy-efficient house (EEH) from the different points of view: economic, ecological and social. In this case, the EEH under the green economy context was considered by the authors. In addition, according to the Ukrainian ongoing condition, the key preconditions of EEH implementation among the Ukrainian households were allocated. Besides, the main approaches to define EEH are analyzed and systematized by the authors. On this basis, the main bullet points and features of EEH were indicated. The authors determined the EEH opportunities for spreading among the Ukrainian households. It should be noted, that the lack of awareness among the civil society provokes the slow temp of the EEH enlarging in Ukraine. At the same time, the European experience showed that the huge part of their households can be characterized as energy-effective. With the purpose of understand the efficiency of EEH, the authors had estimated the economic benefits of installed solar collector in the household as one of the parts of EEH. According to the results, the authors allocate the restraining factors of the EEH spreading in Ukraine. Thus, the great payback period is one of them. In addition, the high level of the currency rate has negative impact on the payback period. From the other side the continuously increasing of the utility bills have been indicated as a negative stimulate factor. In order to increase the awareness of the EEH benefits under the Ukrainian civil society, the main economic, ecological and social benefits of EEH were systematized by the authors.

Keywords: benefit, ecological effect, economic effect, house, passive house, payback period, solar collector, utility bills.
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Introduction

The limitation of the fuel and energy resources, a lot of ecological problems, energy dependence from the other countries, the constant increasing of utility bills require development and enlarging the mechanisms of decreasing consumption of traditional fuel and energy resources, including among the private households. In this case, the spreading of the alternative energy is the ongoing problem in the world community.

It should be noted that the modern technologies ensure the possibility of great decreasing energy consumption by the consumers, including the civil society. However, generally the population use the ineffective methods what causes the continued energy consumption growth. In addition, the most of houses are characterized as inefficient envelope building, which has the high coefficient of heat transfer. All of these factors lead to not only energy excessive costs, they also increase volume released of harmful substances such as greenhouse gas and solid wastes which pollute the environment.

In addition, the Ukrainian residential sector can be characterized as non-energy effective with the highest level of energy costs. Thus, on average, the Ukrainian private households consume 31.1% of total final energy, at the same time, the share of the final energy consumption by production sector is 34.3% from its gross volume (Renewable, 2017).

In connection with the above, the development of appropriate tools to popularize the use of alternative energy sources by the households has been becoming actual in the current conditions. And as a result, it will provide the spread of EEH among the civil society.

1. Literature review

According to the results of research, it is possible to make a conclusion that in the world, the relative share of alternative energy consumption of the primary energy is stable (Fig. 1). But, compared to the traditional sources (coal, gas, oil, etc.), its relative share remains low. Thus, in comparison with 1997, the alternative energy consumption increased by more than 876.2 million tons of oil equivalent (Global Energy, 2017). In addition, according to the experts' forecasts, by the end of XXI century, in comparison to the beginning of the century, the world consumption of final energy will being increase approximately by 2.5 times, while the annual expenses for the world energy production – by 4-6 times.

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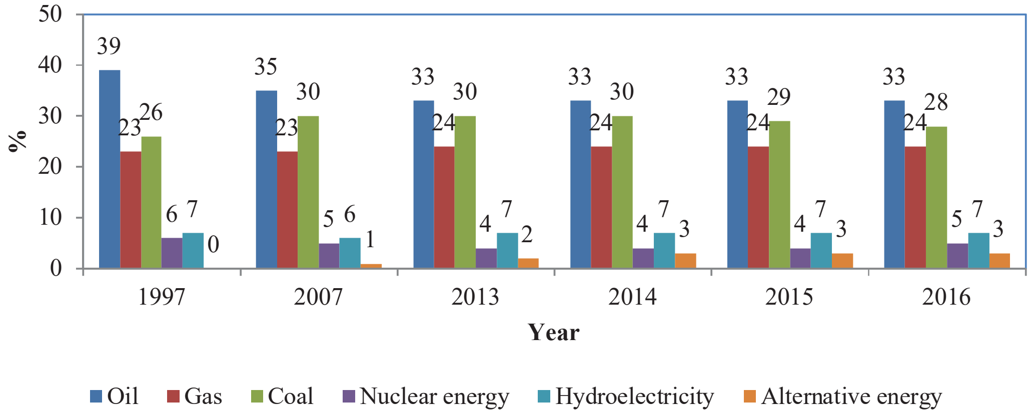

Fig. 1. The dynamic of shares of world consumption of the primary energy, 1997–2016*

*Source: created by the authors on the basis of the literature sources (Global Energy, 2017).

Furthermore, in length of time, due to high price, using the natural gas will be economic unjustified. For that reason, in the paper (Antonenko, 2010) broad implementation of alternative energy sources was considered to be used with purpose to increase energy safety for each country and decrease the human impact on the environment

Jaunius (2016) in his paper analyzed the energy problems and main challenges of renewable energy sector. They approved that the effective legislative activity and energy sector management was a good incentive instruments to stimulate the production and consumption of electricity from renewable energy sources. And as a result, to decrease the energy dependence from the other country. In the paper by Ishchenko (2017), the renewable energy was analyzed from the point of view that alternative energy is an integral part of the way to achieve the sustainable development.

In this direction, it should be underlined that concept of the alternative energy using from the fundamental point of view had been already researched by Ukrainian and foreign scientists. In that case, Ukrainian community have already understood the ecological problems, have had a lot of green concepts and goals, definitions, methods, green technologies, etc. Unfortunately, the Ukrainian civil society doesn't know how to use and implement the abovementioned knowledge at the local level, in their households.

According to the actual of the issue studied, a huge number of Ukrainian and foreign academic papers are dedicated to the problems of energy efficiency, including EEH.

Thus, Klimchuk in the paper studied the main principles of the energy-efficient concept through the implementation of the passive house and the triple zero principle. In his work, the implementation of the triple zero principle was measured as a great progress and straight to resource's saving and diversification.

The scientists Sainitskiy, Poznyak and Maroyak analyzed the main problems of energy saving in the current housing. In the paper by Sainitskiy (2015) they justified the need to popularize the energy efficiency concept in civil engineering and consecrate their research on the technical aspects of the EEH.

Stepanenko and Dubrovska, on the basis of EU experience, approved the EEH efficiency. Furthermore, they indicated the main restriction to enlarge the EEH among civil society is design of the EEH (Stepanenko, 2014).

The researches in the paper by Sylvia (2017) justified the positive effects of solar water heating and the usage of innovative technology in residential homes. In addition, they noticed that word-of-mouth is an important vehicle to communicate the benefits of solar water heating and that positive social pressure can translate into higher implementation.

In spite of great research results in this direction, some features of purchasing, promoting and spreading of EEH at the local level should be researched according to the Ukrainian condition through the allocation of social, economic and ecological benefits.

In addition, in the abovementioned scientific works and manuscripts of other scientists, no proper attention is paid to EEH threats and opportunities according to the natural conditions and features in the different countries, particular in Ukraine.

According to the above mentioned above, the main purpose of this paper is to analyze the efficiency of EEH from the different points of view (social, economic and ecological), according to the ongoing Ukrainian condition.

2. Key research findings

According to the official statistic databases, in Ukraine, during the last four years, the utilities bills have been increasing from year to year. It is worth emphasized that in 2016, the share of cost for utilities bills for the majority of Ukrainians was approximately 33% from the average salary, whereas in 2012 – 16% (Fig. 2).

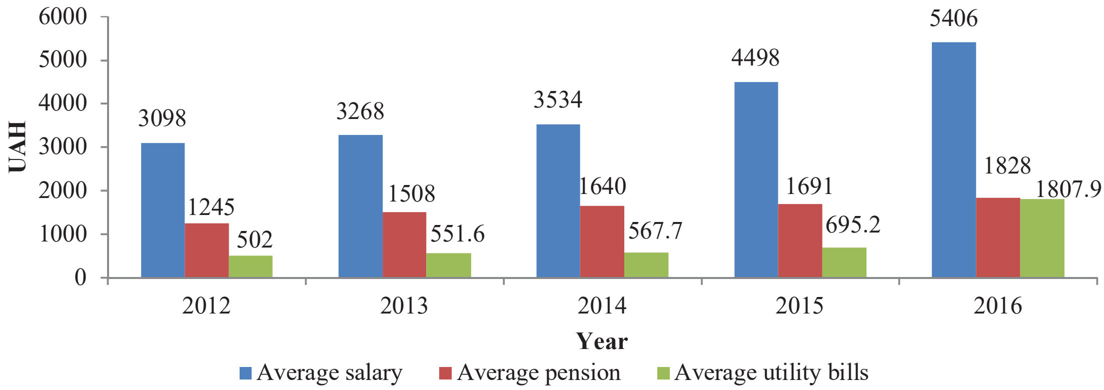

Fig. 2. The dynamic of income and expenses to utilities of Ukrainians*

*Source: created by the authors on the basis of the literature sources (Dynamic, 2017; How much, 2017).

Unfortunately, according to the European standards (Fig. 3), Ukrainians are beyond the energy poverty. In relation with above, it is important to implement the mechanisms of stimulation of green energy using at the local level, as well as development corresponding instruments to popularize the implementation of these mechanisms.

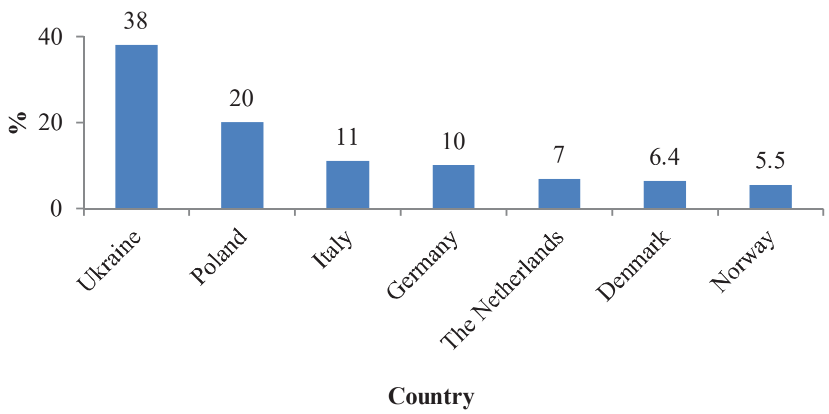

Fig. 3. The part of utility payments in income of EU countries in 2017

*Source: created by the authors on the basis of the literature sources (Cost of Living, 2017).

In turn, it would ensure spreading of EEH among the population, and as a result, decrease the relative weight of expenses to the utility bills. Thus, nowadays, the "net-zero house", "passive house", "climate's house" and "energy-efficient house" have the snowballing development and have become the mainstream in the modern world. We can find a lot of definitions and approaches to classify the building as an "eco-friendly house" (Pimonenko, 2017).

In accordance with the results of research, it is possible to make a conclusion that the scientists of different countries define and called EEH in different ways. The systemized results of the analysis are shown in Table 1.

Table 1. The systematization of the main approach to define the EEH*

Definition	Sense/Sources
Climate's house	The house is built from the environmental by friendly construction materials. Besides, this building is heated by renewable resources and consumes less than 50 kWh/m2 of heating energy per the year (South Tirol).
Energy-efficient house	Is an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy *(US Department of Energy)*
Passive house	The energy consumption of the house should be less, than – 15 kWh/m2 (*EU, Germany*)
Net-zero house	The house is built according to the standard MINERGIE–P is classified as energy-efficient house *(Switzerland)*
Net zero energy building	A building having a primary energy use lower or equal to zero kWh/(m2) *(Norway)*

Source: systematized by the authors on the basis of the literature sources (Pimonenko, 2017; Ecotown, 2016; Passive house, 2016).

According to the analysis, results the European countries identify the "eco-friendly house" like the "energy-efficient house". Besides, the own standards of the energy-efficient house were accepted by the leader countries.

In Switzerland, the house, which is built according to the standard MINERGIE–P is classified as energy-efficient house. According to the US Department of Energy, the net-zero building is an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy (US Department of Energy, 2015).

In South Tirol, the "eco-friendly house" is named like a "climate's house". This house is built from the environmental friendly construction materials. Besides, this building is heated by renewable resources and consumes less than 50 kWh/m2 of heating energy per the year (Ecotown, 2016; Pimonenko, 2017).

In Norway, a net zero energy building (ZEB) is defined as a building having a primary energy use lower or equal to zero kWh/(m2) (Kurnitski, 2013; Pimonenko, 2017). In Germany, the energy-efficient building is built according to the following standards: KfW-55 and KfW-70. The numbers indicate the maximum percentage of the annual primary energy consumption and heat's loss from the minimum indicators which were accepted by the Germany government in the energy-savings' documents. Thus, the primary energy consumption according to the KfW-55 standard is less than 40 kWh/m2, and to the KfW-70 standard – 60 kWh/m2 (Ecotown, 2016; Pimonenko, 2017).

The analysis of EU experience is shown that only energy-efficient house is built according to the standard of passive house is similar standard in the all EU. This standard was accepted in Darmstadt (Germany) by Institute of passive house. Thus, the energy consumption of the passive house should be less, than – 15 kWh/m2. The passive house also should be built according to the following requirements: Space Cooling Demand; Primary Energy Demand; Airtightness; Thermal Comfort (Passive House, 2016; Pimonenko, 2017).

In this research, EEH means a building where the energy resource savings is gained through the use of the innovative, technically perfect and economic justified decisions, acceptable in ecological and social regard, which don't change the accustomed lifestyle.

It should be underlined that the solar collectors are the first step to the archived the EEH. In addition, according to the results in the previous works (Pimonenko, 2017), the solar collectors is the most popular part of the EEH.

It should be underlined that Ukraine has already had some progresses in this direction. For instance, a quantity of private households which have already installed the solar stations has been increasing from year to year. By 2015, the total number of registered private solar stations was 214 units, while by the third quarter of 2017 – 2323 units (Fig. 4).

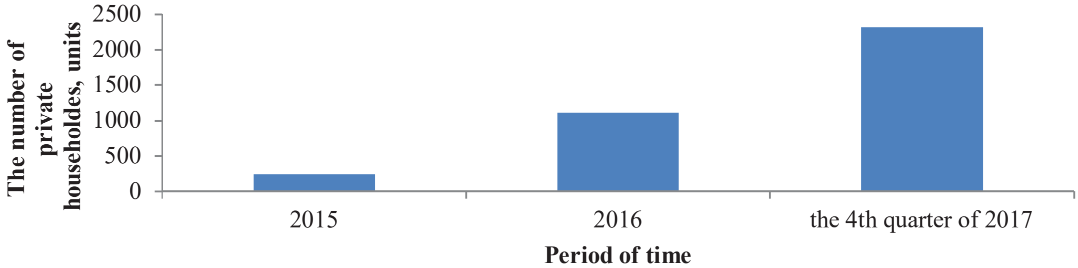

Fig. 4. The dynamic of the number of private households where the solar station is installed*

*Source: created by the authors on the basis of the literature sources (Renewable, 2017; Fedosenko, 2017).

With the purpose of justifying the EEH economic efficiency, we propose to estimate the economics effect from the installed solar collector efficiency. For our calculation, we took the cottage with 160 m2 in the village. According to the Official Database in Sumy region, on average, three persons live in such house. For our calculation, we take the solar installation with power 12 kWh and 24 kWh which was installed in the January 2017.

Note that the solar radiation differs between the cities of Ukraine and depends on time of the year. Thus, in southern Ukraine, the effective use of solar collector is possible during 9 months (from March to November), and 7 months (from April to October) in northern Ukraine. In winter time, the efficiency of solar collector decreases, but does not disappear. In this way, for our climate conditions the solar collector's work is possible during whole year but with exchangeable efficiency.

According to the results of research and potential of Sumy region to generate energy by the solar collector, there is defined that 12 kWh solar collector in Sumy can generate from 7 to 67 kWh per day. For the calculation, the annual average of generation was taken 37 kWh per day.

Table 2. Initial data for calculation*

Parameter	Amount
Predictable of energy production per month, kWh	1100
Predictable of energy production per year, kWh	13320
The square of house, m^2	160
A number of people who live in the house	3
Date bought of the solar collector	January 2017
Predictable minimal level of energy consumption per month, kWh	450
Predictable maximum level of energy consumption per month, kWh	600
Predictable minimal level of energy consumption per year, kWh	5400
Predictable maximum level of energy consumption per year, kWh	7200

*Source: compiled by the authors.

According to the current electricity tariff, if consumer doesn't install solar collector, he will pay 0.9 UAH per 1 kWh from March, 2017 and 0.714 UAH per 1 kWh before March 2017 in condition of energy consumption less than 100 kWh, if he consumes more than 100 kWh the electricity tariff will be 1.68 UAH from March 2017 and 1.29 before March 2017 (Green tariff, 2017).

Therefore, the payment of energy consumption per year can be calculated:

$$Payment = M \times \left[100 \times t_1 + \left(CEC - 100\right) \times t_2\right], \quad (1)$$

where M – number of months; t_1 – tariff for 100 kWh, UAH; t_2 – tariff for more than 100 kWh, UAH; CEC – current energy consumption per month, kWh.

Thus:

- the payment of energy consumption per year with consumption 450 kWh per month

$$2 \times \left(100 \times 0,714 + 350 \times 1,29\right) + 10 \times \left(100 \times 0,9 + 350 \times 1,68\right) = 7825,8\, UAH \text{ per year}$$

- the payment of energy consumption per year with consumption 600 kWh per month

$$2 \times \left(100 \times 0,714 + 500 \times 1,29\right) + 10 \times \left(100 \times 0,9 + 500 \times 1,68\right) = 10732,8\, UAH \text{ per year}$$

In order to determine the annual amount of economics effect (EE), we propose to calculate the difference between the payments to the energy company (payment for energy consumption) and from the energy company (revenue from the sales of produced energy won't be consumed by consumer) by the formula 2.

$$EE = Payment + \left(CEP - CEC\right) \times Gt - Ps, \quad (2)$$

where G_t – feed in tariff, UAH; CEP – current energy production by the solar collector, kWh; Ps – payments to the energy company if we install the solar collector.

According to the results, without solar collectors, the electricity fees would be 7825.8 UAH per year with consumption 450 kWh per month and 10732.8 UAH per year with consumption 600 kWh per month.

If the consumer installs the solar collector, the predictable annual energy generation will be 11980 kWh, where the predictable consumption – 7200 kWh per year.

In order to determine the amount of annual savings on the electricity bills and income from selling energy, it should be calculated the amount of "green" money which will be obtained after selling generated, but not consumed energy.

Thus, according to the results, electricity will be produced by solar collector will be missed (if we consume 600 kWh) for four months (January, February, November and December). The sum of the additional payment will be 1311.6 UAH per year.

If the consumption is 450 kWh, electricity will be produced by solar installation will be missed for 3 months (January, November and December). On average, the additional payment will be 549.90 UAH per year.

The rest of the year the consumer will get money by feed-in tariff from selling generated electricity by the solar collector, but not consumed.

According to the decisions of the National Commission on the regulation of the energy sector and utilities from September 29, 2016 No. 1678 (The National, 2016) feed-in tariff from 1 January 2017 to 1 January 2019 is 498,17 kop/ kWh (without VAT). With VAT the feed in tariff is 597,80 kop/ kWh.

With installation, the owner of EEH should pay 549.90 UAH per year instead of 7825.8 UAH and receive 33341.92 UAH subtract the taxes provided that consumption is 450 kWh. And the amount of economy and income from energy sales per year will be:

EE_{450kWh} = 7825.8 + 33341.92 – 549.9 = = 40617.82 UAH.

If the owner will consume 600 kWh, he needs to pay 1311.6 UAH per year instead of 10732.8 UAH and receive 27391.38 UAH subtract the taxes. Then the amount of economy and income from energy sales for the year will be:

EE_{600kWh} = 10732.8 + 27391.38 – 1311.6 = = 36812.58 UAH.

The summary of the results of calculation are presented in Table 3

Table 3. Summary of the data consumption and the electricity generation, solar installation 12 and 24 kWh at consumption of 450 and 600 kWh (own calculation)

Indicators	Annual		Monthly	
	12 kWh	24 kWh	24 kWh	12 kWh
Payment for 450 kWh of energy consumption, UAH	7825,8	7825,8	652,15	652,15
Payment for 600 kWh of energy consumption, UAH	10732,8	10732,8	894,4	894,4
Energy production by solar installation, kWh	11980	21790	1815,8	998,3
Difference between production and consumption for 450 kWh of energy consumption, kWh	4780	14590	1215,8	398,3
Difference between production and consumption for 600 kWh of energy consumption, kWh	4759,84	14570	1214,2	396,7
Payment for energy consumption with solar installation, UAH, for 450 kWh of energy consumption	549,90	6433,84	536,20	183,30
Payment for energy consumption with solar installation, UAH, for 600 kWh of energy consumption	1311,66	474,00	237,00	397,92
Revenue from the sales produced energy will be used, tariff 5,978 UAH, for 450 kWh of energy consumption	42204,96	97173,04	10797,00	4689,44
Revenue from the sales produced energy will be used, tariff 5,978 UAH, for 600 kWh of energy consumption	34672,63	86771,25	10846,41	4334,08
Revenue from the sales produced energy will be used subtract tax (21%) UAH, for 450 kWh of energy consumption	33341,92	76766,70	8529,63	3704,66
Revenue from the sales produced energy will be used subtract tax (21%) UAH, for 600 kWh of energy consumption	27391,38	68549,29	8568,66	3423,92
Economic effect, UAH, for 450 kWh of energy consumption	40617,82	85673,18	7139,43	3384,82
Economic effect, UAH, for 600 kWh of energy consumption	36812,52	80933,28	6744,44	3067,71

*Source: calculated by the authors.

According to the results of the analysis the market prices of the solar collectors in Ukraine the installation's price per 1 kWh is $ 2150, while the montage is $ 400. So the price of 12 kWh is $ 30600; the price of 24 kWh is $ 61200. According to the National Bank of Ukraine, exchange rate byJanuary 01, 2017 1 UAH = $ 0.04. Then

$$40617.82 \times 0,04 UAH\ per\ year \approx \$1624.71,$$
$$36812.58 \times 0,04 UAH\ per\ year \approx \$1472.5.$$

In the simple way, the formula of calculation the payback period is (3):

$$PP = \frac{Initial\ Investment}{Cash\ Inflow\ per\ Period}. \quad (3)$$

Under the conditions of excluding the time factor, other service expenses of the solar collector, losing coefficient of efficiency in course of time and the possible expenses for repairing, the payback period is approximately:

- for c450 kWh

$$PP = \frac{30600}{1624,71} = 18,8\,years$$

- for 600 kWh

$$PP = \frac{30600}{1472,5} = 20,8\,years$$

If solar collector with power 12 kWh will exchange for 24 kWH, then using the same approach, the payback period is:

- for 450 kWh

$$PP = \frac{61200}{3424,93} = 17,9\,years$$

- for 600 kWh

$$PP = \frac{61200}{3237,33} = 18,9\,years.$$

According to the received results, the changes in solar collector's power and the amount of energy consumption greatly influence on the payback period. Thus, in terms of the current electricity tariff, the minimal payback period of 12 kWH solar collector is with consumption 450 kWh and 600 kWh are 18.8 and 20.8 years, respectively. In the case of using 24 kWh solar collector, the payback period is 17.9 years if consumpting 450 kWh per month, and 18.9 years if consumpting 600 kWh per month.

Therefore, in the case of installation of solar collector in 2017, the owner will get income by selling not consumed electricity during 14 years. According to received calculations, the minimal payback period is 18.8 years for the solar collector with power 12 kWh.

Thus, the authors calculated the owner's savings after the cancelation of feed-in tariff, which act to 2030. In addition, the coefficient of efficiency of solar collector was taken into account. On average, the rate of collector degradation is 0.7% per year. According to it, by 2030, solar collector's power capacity will be 90.2%. The dollar rate is the same.

Taking into account losing of coefficient of efficiency and the cancelation of feed-in tariff, annual savings is 85673,18 UAH with 450 kWh consumption and 80933,28 UAH with 600 kWh consumption (Table 4).

Table 4. The summary data of annual savings depending on installation power and level of consumption of electricity by consumer, UAH*

The installation power/The level of consumption of electricity	Annual savings			
	2017		2030	
	450	600	450	600
12 kWh	40617,82	36812,52	28266,52	42219,44
24 kWh	85673,18	80933,28	30600,11	46686,24

*Source: calculated by the authors.

Thus, the earlier the solar collector will be installed, the less is payback period and the owner will be able to get income by selling not consumed electricity. Moreover, after the cancelation of feed-in tariff the solar collector is economic efficient too.

It should be noted that the features of EEH occupy an important place as in economic as in ecological and social components of "green" economy concept. The main features of EEH in the context of green economy are given in Table 5.

Table 5. The main features of EEH in the context of "green" economy

The concept components	The features
Economic	- the additional cost will become the profitable investment; - the value in reselling increase; - the low exploitation costs; - decreasing of the heat consumption more than in 10 times in accordance with the standard building; - savings on costs of installation conditioning and heating system.
Ecological	- the minimization of production process impact on the environment; - the ecological construction is favorable to its residents.
Social	- the qualities of EEH are comfort and convenience; - due to the special engineering systems fresh air, pleasant microclimate an even distribution of heat are in the rooms; - a well-being of hygiene and sanitation conditions in the rooms in all year round without using of active heat system or climatic installation.

*Source: reated by the authors based on the work by Klimchuk (2015).

It should be noted, that implementation of energy efficiency means has not only the positive ecological affect (reduction of use of energy resources, decreasing of greenhouse gas emissions, decline in negative impact on healthy, etc.) and also ensure a number of economic effects (energy savings, reduction of utility bills, solving of issues of electricity unreliability, etc.). At the same time, the ecological and economic effect is ensured in the different directions: the civil society will be able to feel the great reduction of utility bills; from the ecological side, the positive is the limiting of greenhouse gas emissions; the energy companies will be able to decrease the fuel expenses and avoid unjustified cost for building; resource savings, increase of production productivity leads to growing of country competitive.

Conclusion

It should be noted, that received payback periods, unfortunately, for Ukraine, economic situation is huge. From the other side, the continuously increasing of the utility bills tariff, dependence of the gas consumption from Russia are required to search the ways to solve abovementioned problem.

The results of research show that solar collectors' developing in Ukraine is retarded by following factors: the highest price and the lack of information about such system and its benefits. That is why it is necessary to launch information about solar collectors through civil society. Moreover, it is necessary to enlarge the information about existing possibilities and benefits of using solar collectors and developing the EEH.

Thus, in Ukraine, the special efficiency program has been operating since 2014 – "the preferential tariff for electric heating". The households which use the appliances to heat are eligible for a reduced tariff for electricity during the heating season (from October to April). Also, people need to see the understandable mechanism to install and register solar collectors.

In conclusion, it is necessary to redirect the people's mind to the green mind direction. But it is impossible without the huge government support and spreading information among civil society about advantages of the EEH, economics, social and ecological efficiency. And the most important part to show people the mechanism how to receive and use the abovementioned advantages.

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