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ANALYSIS OF ECONOMIC EFFICIENCY OF USING DIFFERENT FUEL TYPES IN INDIVIDUAL HEATING SYSTEMS

Abstract. *The basis of traditional methods for comparing the efficiency of using different types of energy sources is normative coefficients of capital investments and payback period, which became non urgent in our time under unstable price policy. Therefore, the need for short-term forecasting of efficient use of energy sources is topical.*

At present, many individuals and legal persons, while solving the problem of choosing the energy source for heating social and industrial facilities, provide different types of heating equipment before building, that is, they install several boiler units with different types of fuel, or machines that allow using of several fuel types. The efficiency of using different types of energy sources depending on consumption volume and time of day, fuel price and transportation costs on the basis of a comparative analysis of the cost of using energy sources depending on their energy capacity was analyzed in the article.

Keywords*. Energy capacity, energy sources, fuel, cost equivalent, relative cost equivalent, coefficient of use.*

Код JEL Classification. C51 Побудова моделі та оцінка

Formulation of the problem. The main task set in the Energy Strategy of Ukraine for the period up to 2035 (ESU) is to increase Ukraine's energy security. Thus, it is planned to reduce energy import dependence of the country from 51.6% in 2015 to 33% in 2035 according to the ESU [1]. Moreover, import dependence of Ukraine in gas is 75%, in oil and oil products is 85% [2].

It should be noted that energy capacity of the gross domestic product in Ukraine is 3 times higher than in the developed countries in the world [2].

The situation in the housing-and-communal complex is quite complicated in terms of energy use efficiency. Households in general structure of energy consumption had a share of 34.1% in 2016 which is higher than the industry index - 29.0% [3]. In Ukraine, the average annual specific energy consumption of housing fund is 250-270 kW·h/m^2, which is almost twice as high as in European countries with similar climatic conditions [4]. Moreover, a large part of housing fund was built in Soviet times, and low purchasing ability of the population hinders its modernization.

The structure of energy sources used in households is shown in Table 1.

Table 1

Energy balance of Ukraine by types of energy sources in households, % *

Year	Coal and peat	Oil products	Natural gas	Biofuel and waste	Electricity	Heat energy	Total
2016	1,56	0,65	52,80	8,56	17,57	18,86	100,0
2015	1,83	0,08	54,87	6,63	19,23	17,36	100,0
2014	1,42	0,16	57,61	5,25	16,44	19,12	100,0
2013	3,11	0,13	57,51	4,24	15,15	19,86	100,0
2012	3,05	0,3	58,64	3,99	14,08	19,95	100,0

* *according to the State Statistics Service of Ukraine* [5].

Data in Table 1 show that the share of oil products in energy balance of households decreased, except 2016, the share of natural gas also gradually reduced. Thus, the use of natural gas in Ukraine decreased by 0.6 billion m3 (from 33.8 to 33.2 billion m3, - 2%) in 2016 compared with 2015 [6]. In turn, the share of biofuel and waste stably increases. But gas remains the main source of energy.

According to the ESU, it is planned to reduce energy consumption by households by “increasing thermal resistance of enclosing structures in buildings (thermal protection of walls, roofs and cellars, replacement of windows and doors), replacement and/or installation of energy efficient equipment (furnaces, boilers, heat recuperators, automatic control systems, etc.), carrying out the measures to provide regulation of heat energy consumption by the consumer (replacement of central thermal points to individual, reconstruction of in-house thermal systems, installation of general building and individual regulators of heat consumption)" [1], including through "formation of local heating systems based on economically justified consideration of the capacity of local fuel types, logistics of supply, regional and overall state energy infrastructure" [1].

In this regard, the right choice of energy source and heating equipment that directly affects the energy efficiency type of the buildings [7], influences on the general energy costs and, as a consequence, their market value. Also, it is necessary to take into account political, economic and ecological risks when choosing the energy resource [8] which are related, in particular, to current and long-term conditions of prices for energy resources, which, in particular, depend on the

development of technologies and unstable political situation, and this directly affects the cost of energy sources. Considerable influence on the choice of energy source in Ukraine also has grants that are not stimuli for their effective use.

One of the ways to reduce energy dependence is to optimize energy consumption, including using local energy resources. For example, the authors affirm in the study [9] that "... the total amount of received natural gas will be 10.9 billion m3 after annual volume of straw combustion in the amount of 30 million tons. In these conditions, additional investments for preparation and combustion of straw will be 14.6 billion UAH, and the payback period will be from 1.2 to 1.3 years.".

Therefore, reasonable consumption of energy resources in this segment of energy consumers is a topical issue under uneven growth of prices and tariffs for energy sources.

Analysis of recent research and publications. Scientific works of V. Andriichuk, I. Karpa, H. Panchenko, V. Rozen, B. Syzonenko, Sh. Shydlovskyi and other prominent scientists are dedicated to the problems of energy security, forecasting the structure of energy supply and increasing the efficiency of energy resources use in Ukraine.

M. Hnidyi, G. Golub, S. Denysiuk, H. Dziana, V. Dubrovin, V. Zhovtianskyi, M. Kovalko, M. Kulyk, S. Kukharets, S. Lukianets, M. Melnychuk, M. Mitrakhovych, O. Novoseltsev, Yu. Poliakova, M. Raptsun, O. Sukhodolia, Yu. Shulha and others among domestic scientists are engaged in research and improvement the theory and practice of energy efficiency issues and mechanisms for its achievement. Mechanisms for achieving energy efficiency of the economy need further research despite a large number of theoretical and practical works. The choice of the topic of our study was specified by the lack of explanation at the theoretical and empirical levels, the importance and urgency of the issue on energy efficiency in the economy and mechanisms for its achievement.

In our opinion, the tendency of consumption of energy resources per capita needs to be explained taking into account the efficiency of energy resources use by the household sector. For this purpose, it can be used offered ACE indicator - average

consumption of electricity by the households per capita [10].

According to S. Yermilov, V. Heyets and others, energy resources did not become a stimulus for energy efficiency in Ukraine under transition to market conditions of economy despite the significant increase in prices and tariffs for energy resources [11]. Directive but not economically proved price formation combined with imperfection of consumption recording of energy resources led to cross-subsidization of consumers and to energy wastefulness. There was also a tendency for uncontrolled cutting of trees for firewood.

A large number of households, while solving the problem of choosing the energy source for heating social and industrial facilities, provide different types of heating equipment before building, that is, they install several boiler units with different types of fuel, or machines that allow using of several fuel types. Therefore, taking into account that prices for energy sources constantly change, there is a need to choose the energy source for heating based on its cost and the cost of its transportation for the present time. Figures 1 and 2 show diagrams of the dynamics of tariff changes for electricity and gas for heating purposes for the population. Prices for other fuels vary significantly depending on the region of output or production of fuel and its seller making it difficult to obtain reliable data on its cost and dynamics of price changes [12]. But it is necessary for comparative analysis to take into account the current prices and tariffs for the period that is modeled for the territory where the household is located.

The basis of traditional methods for comparing the efficiency of using different types of energy sources is normative coefficients of capital investments and payback period, which became non urgent in our time under unstable price policy. Therefore, the need for short-term forecasting of efficient use of energy sources is topical.

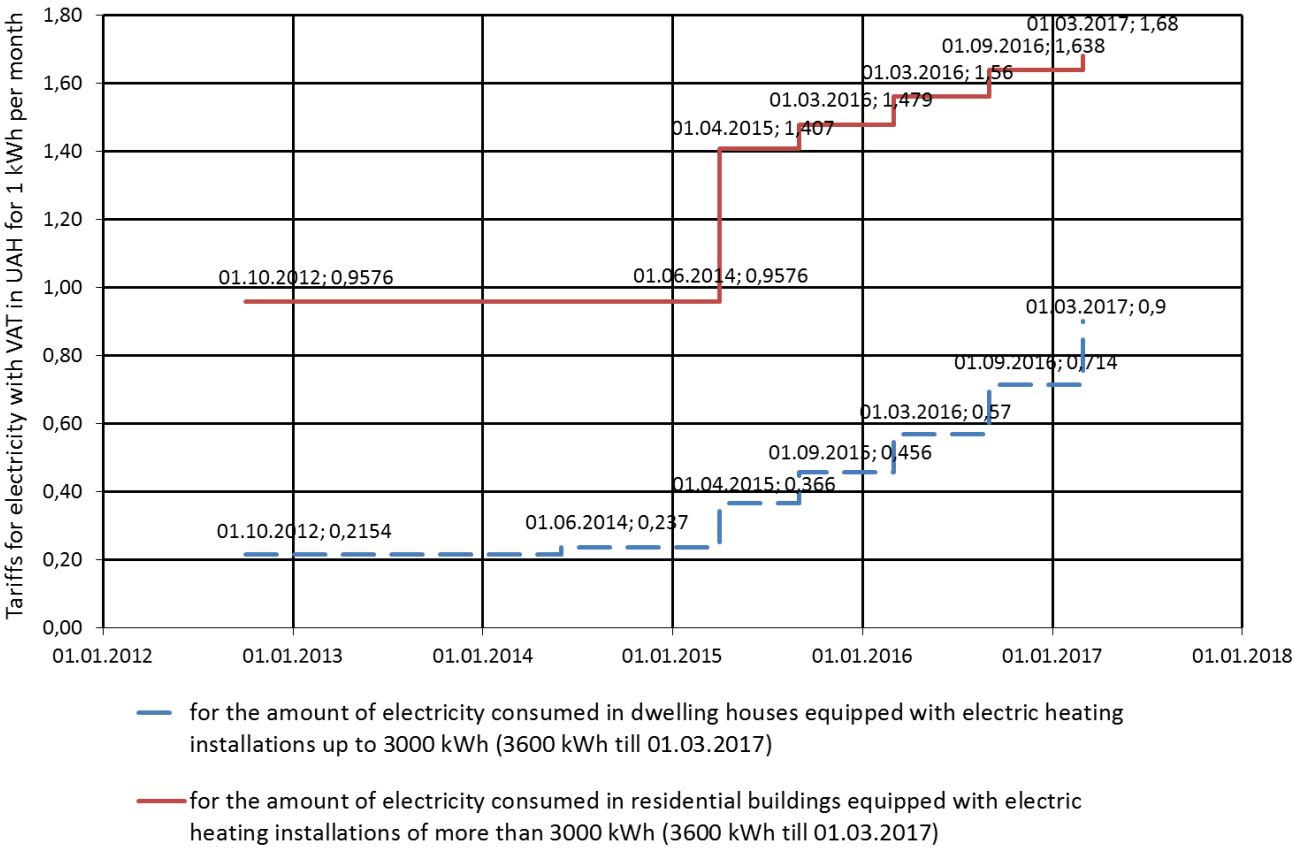

Fig. 1. Dynamics of tariff changes for electricity for heating purposes for the population (according to [13, 14])

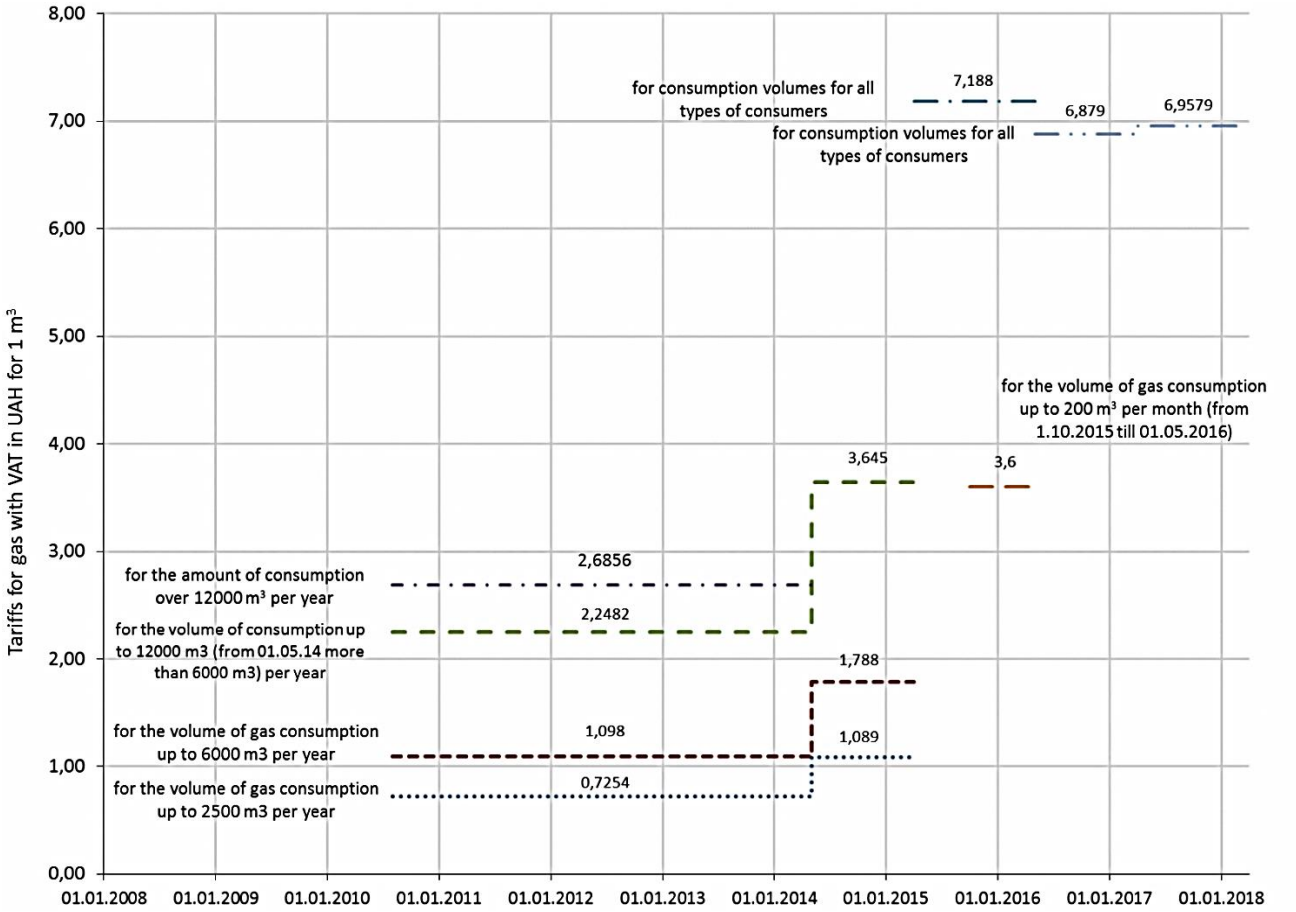

Fig. 2. Dynamics of tariff changes for gas for population (according to [13, 14])

Analysis of the cost of 1 MJ of heat under changes of prices and tariffs for energy shows not only an increase in its value, but also an uneven growth in various types of energy (Fig. 3).

Thus, on 01.12.2013 the lowest cost of 1 MJ of heat was in the case of using gas at the rate of consumption up to 2500 m3 during the heating season, then electricity at night rate (Fig. 3). These indicators were leveled out on 01.12.2014. The cheapest source was heating by firewood on 01.12.2015. This tendency remains further.

The issue of energy efficiency while heating the premises using methods for use estimation of various fuels in particular is presented in the work [15, 16, 17, 18, 19].

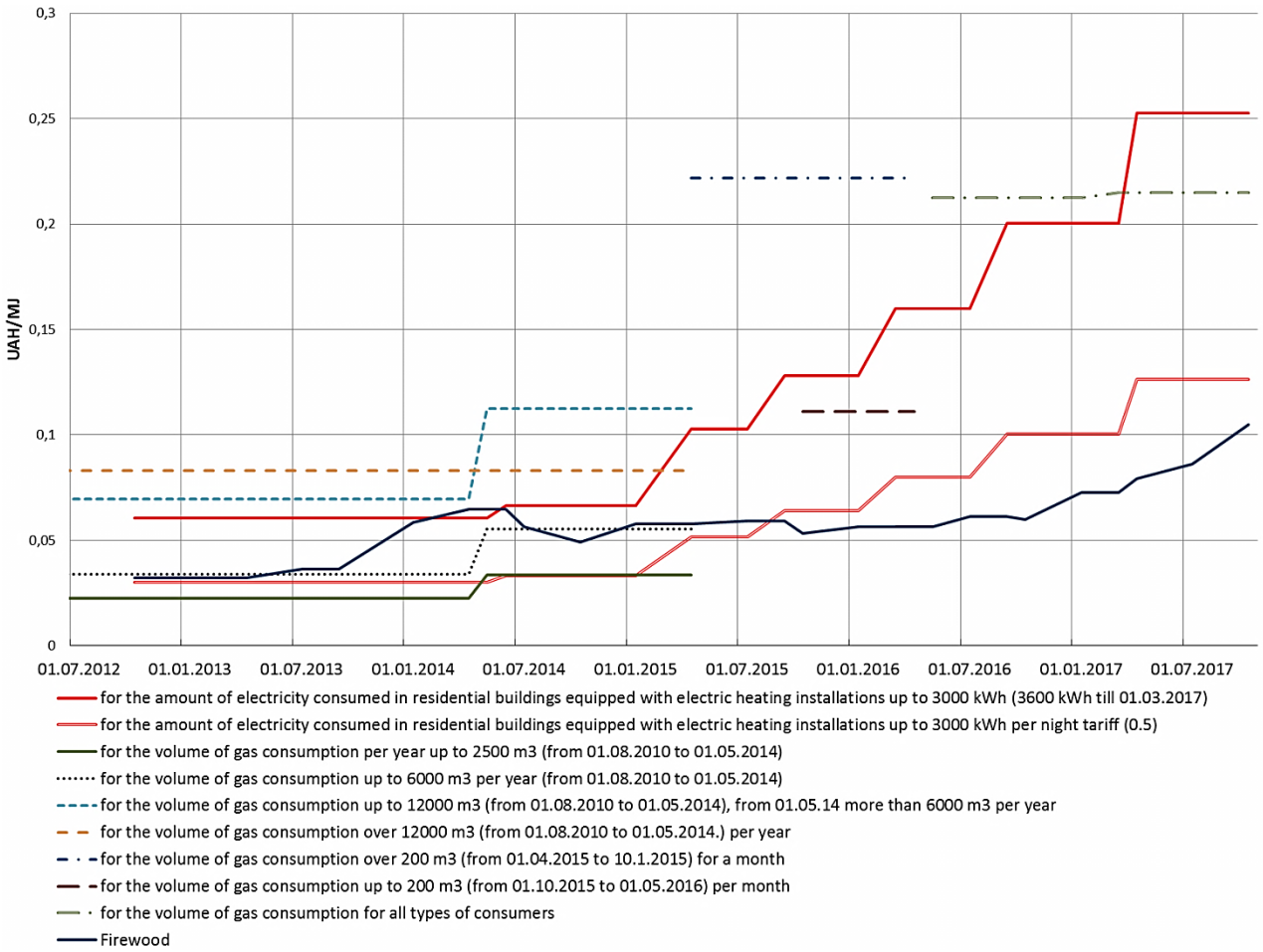

Fig. 3. Dynamics of the cost of 1 MJ of heat for the population

Thus, it is stated in the work [15] that "Methods of risks estimation should be

based on a small number of factors in order to ensure operability, accessibility and sufficient objectivity under existing conditions. They should relate to the characteristic and determining factors for the given sphere of activity, as well as objectively assimilate risks by related directions."

The authors of the work [15] propose the cost equivalent of energy source S, in conventional monetary units (c.m.u.):

$$S = \frac{N \cdot m \cdot T \cdot F}{h} = \frac{s}{h}, \quad (1)$$

where N - power of the heat source, kW; T - duration of the heating period, hour/year; C - expected average annual price of energy source, c.m.u./kW·hour; h - coefficient of fuel consumption (c.f.c.) of the system which is calculated; s - cost equivalent of fuel consumption, c.m.u., without taking into account c.f.c.

Value S is a part of brought cost P, c.m.u./year and characterizes fuel costs. Other items, components of P - cost (without price of fuel) of annual maintenance of the system and capital investments, including equipment cost, search, design-and-construction, building-and-installing, start-up and other works К.P = S + K. Efficiency parameter П is calculated as the ratio of P1 to P2 of the compared variants.

But this method is oriented to the consideration of variants while designing new systems of heat supply, since it includes the cost of capital investments.

The purpose of research. The purpose is to analyze the efficiency of using different types of energy sources in a case that a consumer has different heating equipment depending on the volume of energy source consuming and time of day, fuel prices and transportation costs, excluding capital investments.

One of the problems that complicates the choice of the most appropriate energy source is a non-constant value of the coefficient of fuel use or coefficient of efficiency of a boiler, as well as different calorific ability of the same type of fuel (except electricity) which depends on the fuel field, manufacturer and other factors. Coefficient of efficiency of a boiler given in the technical documentation for the equipment is given for the nominal operating mode, which introduces some error into the method of estimation which is difficult to take into account. It is desirable for this

purpose to install the equipment at the entrance to the heating system which would automatically determine real coefficient of efficiency of the system with a particular boiler connected to it.

Results of the research. Method of determining the cost equivalent of energy source was used for comparative estimation [16]. Cost equivalent is the cost for purchasing and transporting of the energy source which is similar with a base energy source that is chosen by the desire of a researcher.

Comparison of the efficiency of use of energy sources available for the population is presented in Table 2 where gas is taken as the base energy source. The basis for comparative calculation is the cost of 1 MJ of heat taking into account the coefficient of fuel use. The index of estimation is the cost equivalent of fuel (energy source) which was calculated by the formula (2).

$$E = R^{б}/n = \left(\left(T^{б} + r_T^{б}\right) \cdot Q \cdot k\right)/(Q^{б} \cdot k^{б}), \quad (2)$$

where: $n = 1/Q_{пр}$ - amount of energy source for receiving one MJ of heat; $T_{б}$ - tariff (price) of the basic energy source; Q - energy capacity of fuel; K - coefficient of use or coefficient of efficiency; r_m - brought costs for transportation and storage of fuel; $Q^{б}$ - energy intensity of fuel by basic variant; $k^{б}$ - coefficients of use by basic variant.

According to Table 2, it can be seen that costs for heating by gas and, for example, by coal would be equal if the cost of coal with transport costs would be 3.46 UAH/kg. If coal had such price, then the owner would spend the same amount for obtaining the same amount of thermal energy from coal and gas. As of 01 December 2017, the cost of coal is about 5500 UAH/tone which is higher than cost equivalent, so its use is less profitable in comparison with gas.

Use of relative cost equivalent of energy sources calculated by the formula (3) gives more visible results. The results should be presented as a diagram (Figures 3a or 3b). Base variant is taken as zero for these diagrams, and other results are distributed on both sides by the principle “negative result to the negative side”, “positive result to the positive side” (sign σE indicates it).

$$\sigma E = \left(\left(T^{б} + r_T^{б}\right) \cdot Q \cdot k\right) / \left(Q^{б} \cdot k^{б} \cdot (T + r_T)\right) - 1 \qquad (3)$$

Using such energy sources as peat briquettes, fuel briquettes and fuel pellets become increasingly popular in the private residential sector and among small business in recent years [20, 21]. Moreover, there is an opportunity for their combustion to use existing equipment for combustion of coal or firewood. Diagram (Fig. 4) shows that σE for these types of fuel except fuel briquettes is higher than for gas.

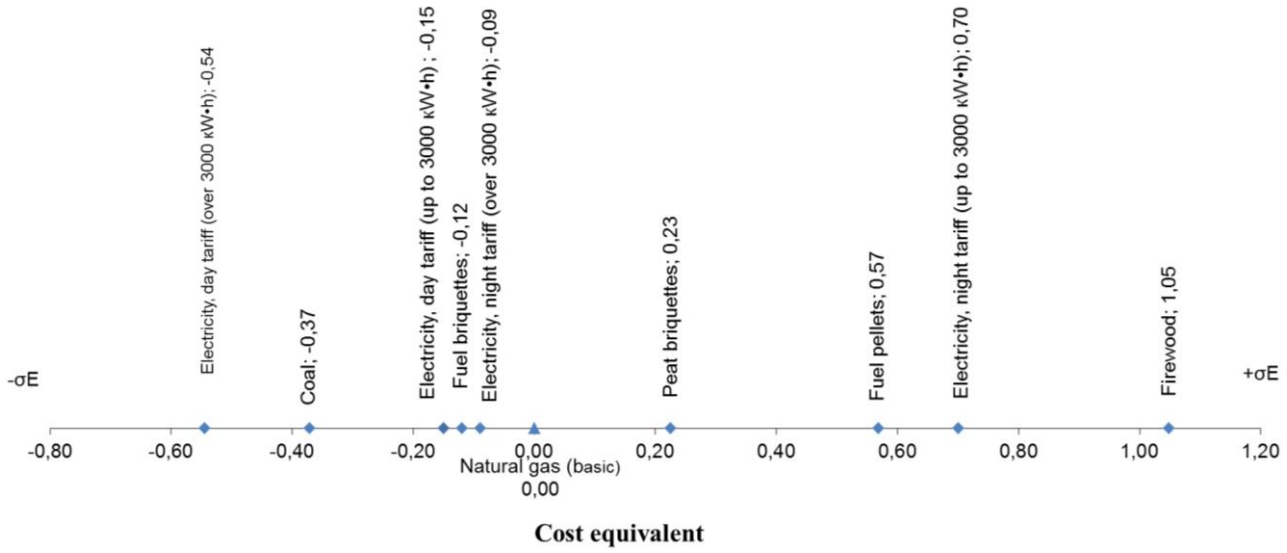

Fig. 4. Relative cost equivalents of sources of heat energy under tariff for gas – 6.9579 UAH/m^3

Electricity is the alternative to gas if it is impossible to use solid fuels, for example in city conditions. It is seen in the diagram that heating by gas is more advantageous than electric heating under gas prices of 6.9579 UAH/m3, except using of electric boiler at night under electricity consumption up to 3000 kW·hour per month in the condition of use of a two- or three-tariff plan and permission for electric heating.

Table 2

Cost equivalents of energy sources for heating production and domestic premises
(prices as of 01 December 2017)

Energy source	Energy capacity, Q	Coefficient of efficiency, k	Brought energy capacity, $Q_{пр}$	Amount of fuel for 1 MJ, n	Cost of 1 MJ of heat, UAH. R	Price (tariff) of energy source, T	E	σE
							Basic gas	
Electricity, day tariff (up to 3000 кW·h)	3,6 MJ/kW·hour	0,99	3,6 J/кW·h	0,281 kW·h/MJ	0,25	0,9 UAH/kW·h	0,77 UAH/kW·h	-0,15
Electricity, night tariff (up to 3000 кW·h)	3,6 MJ/kW·hour	0,99	3,6 MJ/kW·h	0,281 kW·h/MJ	0,13	0,45 UAH/kW·h	0,77 UAH/kW·h	0,70
Electricity, day tariff (over 3000 кW·h)	3,6 MJ/kW·hour	0,99	3,6 J/kW·h	0,281 kW·h/MJ	0,47	1,68 UAH/kW·h	0,77 UAH/kW·h	-0,54
Electricity, night tariff (over 3000 кW·h)	3,6 MJ/kW·hour	0,99	3,6 J/kW·h	0,281 kW·h/MJ	0,24	0,84 UAH/kW·h	0,77 UAH/kW·h	-0,09
Natural gas	36 MJ/м³	0,9	32,4 MJ/м³	0,031 м³/MJ	0,21	6,9579 UAH/м³	Basic	0,00
Coal	23 MJ/kg	0,7	16,1 MJ/kg	0,062 kg/MJ	0,34	5,5 UAH/kg	3,46 UAH/kg	-0,37
Firewood	15 MJ/kg	0,7	10,5 MJ/kg	0,095 kg/MJ	0,10	1,10 UAH/kg	2,25 UAH/kg	1,05
Peat briquettes	16,3 MJ/kg	0,7	11,4 MJ/kg	0,088 kg/MJ	0,18	2,00 UAH/kg	2,45 UAH/kg	0,23
Fuel briquettes	20,5 MJ/kg	0,7	14,4 MJ/kg	0,070 kg/MJ	0,24	3,50 UAH/kg	3,08 UAH/kg	-0,12
Fuel pellets	16,7 MJ/kg	0,7	11,7 MJ/kg	0,086 kg/MJ	0,14	1,60 UAH/kg	2,51 UAH/kg	0,57

Conclusions. We can make the following conclusions based on the above information:

1. Short-term forecasting of efficient use of energy sources allows the owner of the household to save on heating depending on the cost of fuel and the cost of its transporting at the moment.
2. Energy conservation can be implemented organizationally under the condition of direct interest of a consumer in efficient use of energy resources. Such interest becomes best apparent when the consumer of energy can influence on the energy-saving elements, in particular the choice of energy source that is currently the most advantageous.
3. Expand of a target system of crediting the measures to improve energy efficiency is necessary because of the fact that population does not have sufficient financial resources to increase energy efficiency of households.

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