Factor analysis of household behaviours in saving energy

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Abstract. The relevance of the study is related to the role of household behavior in the field of energy saving in the context of the development of hydrocarbon energy, in the implementation of energy-saving technologies, the rational use of resources in energy generation, as well as in stabilizing the energy market. The research methodology is based on system and factor analyzes of the neoclassical direction and institutionalism of economic theory, which are ambiguously implemented in shaping the behavior of households in energy saving. The conclusions of the study include highlighting the specifics of the behavior of households in energy saving, the influence of external factors - institutional, infrastructural and others on the rational behavior of households in energy saving. It was stated that the imperfection of the regulatory framework for the provision of energy services and their constant changes limit the formation of rational behavior of households in energy saving. It is suggested that when drawing up an energy-saving policy in the short term, it is necessary to use the factorial theoretical and methodological provisions of neoclassicism, and in the long term to use the factorial approach of institutionalism. The paper analyzes and proposes four models of energy-saving behavior of households and identifies problems and difficulties in the process of their implementation in practice. A factor analysis of the influence of household behavior on the implementation of sustainable energy was also carried out. The transition to sustainable energy, as well as the solution of the problems that stand in its way, must be carried out taking into account the interests and capabilities of households.

1 Introduction or history

To solve problems in the adaptation of national economies to modern economic conditions and in improving the energy efficiency of GDP, it is necessary to pay attention to energy saving. Energy saving at all levels of energy consumption is the most important factor in economic development, as it contributes to saving energy resources and reducing the energy intensity of production. The need for a deeper study of the energy saving process is influenced by a number of factors, among which we can highlight the trend of the world economy towards the rational use of hydrocarbon energy, the global spread of energy-
saving technologies, the limited resources for generating energy of any kind, as well as rising prices for purchased energy resources. In the global energy sector, a Roadmap to achieve net zero by 2035 has been developed, which notes the importance of creating mechanisms to more effectively promote investments in clean energy in emerging market and developing countries [1].

Basically, all subjects of the economy of the national economy are interested in energy saving. However, in the field of view of state bodies responsible for reducing the energy intensity of production, there are the behavior of state institutions, sectors of the economy, and large economic units. And the problems in the formation of an energy-saving culture at the household level remain in the background. This is despite the fact that households consume about 20% of all electricity generated. In the world and in individual countries, there is an increase in energy consumption by households. In the structure of household consumer spending in Russia, housing services, water, electricity, gas and other fuels accounted for 10.8% in 2019, and 11.9% in 2020 [2]. At the same time, in these services, electricity accounted for 1.4% in 2019 and 1.5% in 2020.

The need to study the behavioral aspects of the behavior of households in energy conservation is a requirement of our time. Among the scientific works, the studies of Mahmoud Salari and Roxana J. Javid on modeling household energy expenditures in the United States [3], Boudet X. and others on clustering energy-saving behavior in the family [4], Ito and Koichiro on how consumers take into account the marginal or average price of electricity [5], Boogen Nina on the level of efficiency of electricity use by households in Switzerland [6]. In particular, it was noted that the average inefficiency in the use of electricity by Swiss households is around 20-25 percent. The Global Commission on Urgent Action on Energy Efficiency following a conference at the International Energy Agency (IEA) recommended the following: “Use behavioral insights for more effective policies. People are at the center of energy efficiency efforts, and an understanding of the behavioral sciences can help develop smarter policies” [7]. Bouktif, S. et al. [8] have re-viewed the accounting of household behavior in energy conservation.

## 2 Methods

When considering the features of modeling the behavior of households in energy conservation, various theoretical and methodological approaches can be used. Accordingly, the received scientific and practical recommendations and results in the field of energy saving may differ, or even be in conflicting provisions. In particular, the recommendations of representatives of institutionalism and neoclassicism can be implemented in different directions. Factors influencing energy saving can be classified according to different criteria, for example, into key (essential) and non-key (insignificant). Key (essential) variables predetermine the process of formation and development of household behavior in energy conservation (Table 1).

<table>
<thead>
<tr>
<th>Scientific basis</th>
<th>Key Behavior Factors</th>
<th>Non-Key Behavior Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neoclassical theory</td>
<td>Necessity (need) for energy. Benefits of energy consumption processes. Rationality of actions</td>
<td>Elasticity. Energy tariffs data</td>
</tr>
<tr>
<td>Institutional theory</td>
<td>Organizational, managerial and institutional conditions for energy consumption. The most important institution is a deal (contract)</td>
<td>Social and psychological factors. Emotional Factors</td>
</tr>
<tr>
<td>Keynesianism</td>
<td>Part of ensuring reproduction</td>
<td>Derivativeness from the real sector of the economy</td>
</tr>
</tbody>
</table>
In conditions of economic instability, there is a certain transformation in the energy-saving behavior of households. For example, one can compare the behavior of households in the 20th century and the 21st century. If in the 20th century, in the public consciousness of the population, saving resources was perceived as simple wishes, then in the 21st century, saving resources was perceived as an urgent need. As is known, households can simultaneously act as consumers and producers of energy. The behavior of households in the energy market can be defined as actions based on their ability and desire to acquire an energy resource (energy demand) and their willingness as a seller to provide this product for a certain fee (energy supply) [9].

It should be noted that the concept of "energy" has a broad understanding, and not only as electricity. It includes various types of used and produced energy (thermal, mechanical, etc.), including human. In all cases, the leitmotif of household behavior is the maximization of financial or other benefits, usually through savings in the use of energy of any kind. As a rule, the principle “the less energy is spent, the less the payment for it” is actively applied by the majority of the population.

At the same time, it is necessary to take into account the fact that many situations in modeling consumer behavior in energy saving are characterized by the simultaneous demand for many alternatives that can be substitutes or vice versa. The energy economy involves not only a reduction in the amount of energy used, but also a "shuffling" of its various types, in particular thermal and energy. In such cases, a simple and frugal econometric approach with multiple discrete continuous extreme values (MDCEV) can be applied for deep analysis. This approach was used in the work in the analysis of energy consumption in residential premises [10].

3 Results

3.1 First item

As you know, the neoclassical direction of economic theory has many scientific schools, concepts, and teachings. D. Colander notes that the concept of "neoclassicism" has expanded today. First, a wide variety of mathematical methods allow economists to work with complex systems, structural shifts: multiple equilibria, i.e. explore questions that were previously unanswered. Second, modern developments in theory, coupled with the latest developments in psychology, experimental economics, and evolutionary game theory, enable researchers of economic behavior to explore and test a variety of premises, rather than accepting the rather sterile rationality premise characteristic of neoclassical theory of the past [11]. When modeling the behavior of households in energy consumption from the perspective of neoclassicism, it is necessary to focus on the following features:

Firstly, the absence of obvious alternatives in the use of energy, in theory there is such an alternative, but in practice the conditions for choosing the types of energy used have not yet been created. It should be noted that some work in this direction is underway.

Second, there are different levels of elasticity of savings with respect to the main variables. For example, saving electricity is price elastic. Tariffs (prices) per kWh of energy are growing, and the amount of savings is increasing. And the demand for electricity itself is malelastic. Among the researchers, Salisu A.A. and Ayende T.O. [12]. However, when considering the consumption of other types of energy, the indicators of demand for them differ. Thus, the demand of households with district heating and without it differs. And the elasticity of demand is also different.

Thirdly, the dependence of the rational behavior of households in energy saving on external factors - institutional, infrastructural, etc., which can be divided into main and
secondary ones. These factors are often variable. Of particular importance in the analysis of modeling the energy-saving behavior of households in the framework of neoclassicism is the theory of rational expectations. Ideally, a household should have complete information and possess the tools of energy competence and, based on them, make decisions that maximize their benefits and, accordingly, minimize the degree of risk in energy saving. Such behavior of households is called rational. On this basis, models of supply and demand in the energy market are built. The irrational side of the behavior of households includes examples that arise as a result of improper operation of energy receiving devices; ignoring periods of energy use, not taking into account factors that affect energy demand, such as emotional highs as a result of waiting and holding family events, etc. But, the theory of rational expectations is idealized and serves as a tool for substantiating the behavior of an economic subject in the chosen field of activity. We can single out a work that studies the optimization of energy demand in the framework of the operation of a smart apartment [13].

Household behavior can be affected by technical and technological failures in energy consumption. For example, sometimes electrical networks cannot withstand the simultaneous switching on of several loads (heaters, electric kettles, washing machines), and safety devices are triggered, the network is turned off. Then the choice arises: which of the tasks have the highest priority and what needs to be connected first. In solving this issue, you can use the modern method - an automatic device that is given the task: to control the order of switching on and off electrical appliances. One has only to set the current consumption threshold in the circuit, which is defined as a priority, with a potentiometer on the relay panel. If it is exceeded, the relay turns off the non-priority electrical circuit. Reducing the current consumption in the priority circuit below the set value leads to the automatic connection of a non-priority circuit. Unfortunately, this approach to electricity consumption is owned by a minimum number of households.

In addition, the total energy consumption of a household depends on the consumption of all family members, respectively, on the individual behavior of each of them. Some aspects of the importance of individual energy consumption for human development and well-being are considered in the work of Giovanni Frigo [14].

Energy-saving behavior of households from the point of view of game theory is characterized by uncertainty. The content of game theory is deeply considered in the work of Samerer C. [15]. Households can take certain proactive energy saving steps. In particular, when buying energy-receiving devices, reconstructing premises, building a house. However, this does not fit the essence of game theory. There must be interaction between the energy consumer and the energy supplier. But energy suppliers, taking advantage of their monopoly position, rarely negotiate with consumers. An integrated element for their coordination is the price (tariff) of the types of energy supplied in the future.

The lack of energy resources, as well as their cost and price, can predetermine the behavior of households aimed at creating conditions for household-based energy generation. If there is a certain potential for energy generation, opportunities are created for its further distribution for a certain fee. In this direction, a number of measures have been taken in Russia to support the generation of electricity by small economic entities, including households. That is, households can create alternative energy sources themselves. But, the question arises about the accumulation of energy in special devices (household batteries) and their legal support. Formation of the infrastructure for the generation and consumption of all types of energy, including human energy, is the task of today.

In the arsenal of the state and the business structure of the energy sector, there are many tools to motivate the energy-saving behavior of households, but this process takes quite a long time. It should also be noted the factors hindering the formation of rational behavior of
households, in particular, the constant change in the regulatory framework for the development of the energy sector.

When modeling state programs in the field of energy saving, it is necessary to take into account the presence of a large number of theoretical and methodological provisions that consider the features of the mechanism for using different types of energy, among which neoclassical (market) provisions occupy a special place, since they directly affect the formation of household energy saving behavior in the short term plan.

3.2 Second item

At the same time, in the long term, it is necessary to take into account the foundations of institutional theory, since a change in the functioning of energy institutions takes a long time lag. Depending on the selected factors in the field of energy consumption, one can distinguish technological, moral, market, regulatory and wasteful models. The functioning of each model depends on external and internal factors, and their implementation in practice is accompanied by the need to solve numerous problems.

For example, the technological model includes energy saving through optimization or application of new technologies and power receivers. For example, a study showed the usefulness of energy distribution and the efficiency of excess energy in multi-family buildings in Australia [16]. It is worth paying attention to the lighting factor, incandescent lamps and fluorescent lamps should be replaced with LED lighting sources, since their consumption with the same luminous flux is much lower. Unsustainable use refers to the background standby power consumption of, for example, computers, etc. Heat energy can be saved by installing reflective panels near the radiators along the wall, as they prevent the wall from heating up and reflect infrared radiation into the room. Also, do not forget about the installation of thermostats on radiators, which allow you to adjust the room temperature depending on weather conditions.

The main factorial problems of implementing the technological model into practice are:

1) Low income of the population, poverty;
2) The high cost of acquiring new energy-saving technologies and equipment;
3) There is no appropriate infrastructure;
4) Low level of personnel readiness. For example, in world practice there is a biogas production technology that is not widely used in the Russian Federation, one of the reasons is the lack of highly qualified personnel necessary for the safe and efficient use of this technological process;
5) Lack of certified domestic equipment. The use of homemade equipment carries a great risk to the prosperity of the economy and the lives of workers. Ordering imported equipment incurs colossal costs that domestic economies cannot afford;
6) Cheapness and availability of natural gas. This means that the economic effect is not so high and the payback period becomes longer, these factors cannot afford new and only growing economies.

The main problematic factors hindering the introduction of a moral model into energy-saving practices in the national economy are:

1) People lack understanding of the role of personal consumption in its impact on the environment;
2) An established way of life that has social and environmental costs. Further research is needed on "consumerism" to determine its impact on the environment;
3) Fear that energy-saving behavior will not be socially approved and shared by others and thus will not affect the general background of inaction. To remove this barrier, it is necessary to introduce the understanding that the coordinated actions of people who independently do the same thing can lead to the desired effect;
4) Low susceptibility of the population to innovations;
5) Transformation of education in the field of energy saving from childhood to adulthood;
6) Low level of energy literacy of the population in households.

The main factors influencing the implementation of the market model in practice include:
1) The market in the energy sector is imperfect, for example, the generation of electricity is monopolized by energy companies, the transmission of electricity from the place of generation to consumers is also far from using market principles of management.
2) Households are not involved in the choice of energy suppliers;
3) Conditions for market trade in the energy sector have not been created;
4) Imperfection of normative-legal documents. It should be noted that Russia recently adopted the Law on Microgeneration of Electricity. This direction allows to stimulate the growth of the share of electricity generation by alternative energy sources, allowing to save the environment in the world. Thanks to incentives from the state, an ordinary citizen has the opportunity to significantly reduce electricity costs. In Russia, this method of saving has not yet become widespread, the main problems are the high price of equipment and the lack of sufficient incentives from the state.

In the normative model of energy saving, the following factors for the implementation of energy savings can be distinguished:
1) Constant changes in regulatory documents on energy saving, including tariff policy, execution of necessary settlement documents. Electricity consumers cannot adapt to these changes. It can be recommended to the responsible institutions of the energy market to introduce a moratorium for about 2-3 years on changes in laws and by-laws (instructions) in the field of energy saving;
2) The absence of strict standards from the state for produced and sold energy-consuming devices;
3) Inadequate legal policy in the field of energy and the environment, expressed in fuel subsidies, transport planning, building codes, etc.

To the wasteful model, energy saving factors include:
1) Irrational use of electrical energy, for example, when lighting a room, using an overly powerful light source, or too many light sources that create a strong luminous flux. This leads to energy costs and is also harmful to health. The solution to this problem is to determine the required luminous flux for a given room and the selection of luminaires that provide this luminous flux for work areas.
2) Lighting of unused rooms, for example, a person came from the hall to the kitchen, drank a glass of water, and went back, leaving the light in the kitchen on, or in another case, he remains in the kitchen with the light on in the corridor. To solve these problems, it is necessary to turn off the light when you leave the room, and use walk-through switches in the corridors to turn off the light from any exit to the corridor.
3) Increasing the level of energy literacy of the population.

3.3 Third item

In addition, a factor analysis of the behavior of households in energy conservation makes it possible to assess its role in the development of sustainable energy. At the heart of the definition of sustainable energy is the lack of energy depletion and the possibility of its continuous use. Sustainable energy ensures the development of the economy and society. And sustainable energy is mainly associated with energy sources that will not be exhausted during the existence of all mankind. Unlike sustainable energy, sustainable energy involves the formation of various energy systems and is important for balancing the development of
the economy. According to the definition of the International Energy Agency (IEA), sustainable energy is energy that takes into account the balance between energy security, economic development and environmental protection [17].

Some of the society's actors are in "hibernation" in the creation and implementation of sustainable energy and in the decarbonization of energy supply, in particular households, while the share of households in the final products sector in electricity consumption in 2017 in Russia amounted to 20.9%, and the share in consumption their fuel and energy resources - 34.1% [18].

Accordingly, the formation and development of sustainable energy may depend on the rational and irrational energy-saving behavior of households.

The contribution of households to the provision of sustainable energy will be determined by the following areas:

1. Participation of the households themselves in the generation of energy and the provision of renewable energy at home. In particular, this refers to the generation of solar energy. This also includes the accumulation of previously used energy and the creation of conditions for its reuse.

2. Primary and secondary (repeated) energy consumption based on the use of energy-efficient and energy-saving technologies and energy-receiving devices and technical devices.

3. Infrastructural conditions for the generation and consumption of energy. Conditions must be created for equal and safe access of households to energy resources and the decarbonization of energy conservation.

4. Resource support for the quality of life of household members.

Each type of behavior depends on many factors, which are divided into external and internal. External factors are associated with the consideration and analysis of the relationship between behavior and the environment of the life of the household, internal factors are behavioral motives based on the individual needs of each member of the household (Table 2).

### Table 2. Behavioral Factors of Households in Ensuring Sustainable Energy.

<table>
<thead>
<tr>
<th>Behaviors</th>
<th>Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>External</td>
</tr>
<tr>
<td></td>
<td>Main</td>
</tr>
<tr>
<td>Energy generation and storage for reuse</td>
<td>The need for energy supply and equipment with technical devices and devices that allow generating and accumulating energy</td>
</tr>
<tr>
<td>Primary and secondary (re) energy consumption</td>
<td>Status and amount of energy consumed</td>
</tr>
<tr>
<td>Infrastructural bases of energy generation and consumption</td>
<td>Equipped with energy-saving technologies and devices to ensure comfortable living conditions</td>
</tr>
<tr>
<td>Resource support for the quality of life</td>
<td>Desire to satisfy needs</td>
</tr>
</tbody>
</table>

Within the framework of the UN, 17 goals have been developed that are aimed at achieving sustainable development throughout the world [19]. Each factor in the be-havior...
of households contributes to the implementation of the principles of the Sustainable Development Goals and has its own level rating.

In reality, in the analysis of the formation of household behavior in sustainable energy, it is especially necessary to pay attention to the condition of residential buildings, the improvement of which will primarily affect the behavior of households in energy saving and reducing carbon dioxide emissions.

The physical and mental well-being of household members depends on the condition of housing and the environment. Thermal discomfort, asthma symptoms and non-asthmatic symptoms affect the quality of life and work productivity, respectively, to reduce poverty. According to some estimates, ill health caused by poor housing costs $1.4 billion a year, of which $145 million and up to 35,000 excess winter deaths are due to cold houses alone [20].

Reuse of waste energy and heat is essential for stabilizing the level of energy consumption. An example is the process of cooking in the kitchen, in which a certain amount of heat is released, which in turn warms the room in winter. There are many such examples in human life. We need technologies for the accumulation of thermal energy in the household. It should be noted that insufficient attention is paid to the reuse of waste heat in business projects for building a house.

To achieve the goals of analyzing the impact of households on the state of sustainable energy, various measures of the factors of their command can be used (Table 3).

Table 3. Measures of household participation in sustainable energy.

<table>
<thead>
<tr>
<th>Behaviors</th>
<th>Estimated indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy generation and storage for reuse</td>
<td>The amount of generated energy in the household</td>
</tr>
<tr>
<td></td>
<td>The amount of accumulated energy in the household</td>
</tr>
<tr>
<td>Primary and secondary (re) energy consumption</td>
<td>Volume of primary energy consumption</td>
</tr>
<tr>
<td></td>
<td>Volume of secondary (re) consumption of generated energy</td>
</tr>
<tr>
<td></td>
<td>Share of consumption in the volume of accumulated energy</td>
</tr>
<tr>
<td>Infrastructural conditions for energy generation and consumption</td>
<td>Energy efficiency and decarbonization indicators</td>
</tr>
<tr>
<td></td>
<td>- residential buildings (houses);</td>
</tr>
<tr>
<td></td>
<td>- ventilation systems;</td>
</tr>
<tr>
<td></td>
<td>- furniture;</td>
</tr>
<tr>
<td></td>
<td>- technical devices and instruments, etc.;</td>
</tr>
<tr>
<td></td>
<td>The level of provision of households with technical devices and devices that allow generating and accumulating energy and assessing the state of decarbonization</td>
</tr>
<tr>
<td>Resource support for the quality of life</td>
<td>Indicators of the use of various resources</td>
</tr>
<tr>
<td></td>
<td>- household chemicals;</td>
</tr>
<tr>
<td></td>
<td>- perfumery;</td>
</tr>
<tr>
<td></td>
<td>- food ingredients;</td>
</tr>
<tr>
<td></td>
<td>- in the absence of a centralized supply of heat and electricity, indicators of the use of gas, coal, wood; etc.</td>
</tr>
</tbody>
</table>

The measures of types of household participation in sustainable energy provided in Table 3 represent, in a generalized form, only a part of all calculated indicators.

4 Conclusion

Thus, the behavior of households in energy conservation is based on various theoretical and methodological teachings, among which the concepts of institutionalism and neo-classicism are basic. A special role in shaping the energy-saving behavior of households is played by the theory of rational expectations and game theory. In the short term, it is necessary to focus on the teachings of the representatives of the neoclassical direction, and in the long term, the concepts of institutional theory, which mainly depend on the time lag, are valuable. An analysis of the technological, moral, market, regulatory and wasteful behavior patterns of households in energy consumption made it possible to identify their factors,
problems of implementation on a practical plane. In particular, the main factors for the
implementation of the technological model are the low level of income of the population,
the high cost of new technologies and equipment; lack of an effective energy saving
infrastructure, etc. The problems of the moral model of energy saving include an
established way of life, low susceptibility of the population to innovations; transformation
of education in the field of energy saving from childhood to adulthood; low level of energy
literacy of the population. The main problems of putting the market model into practice are
the imperfection of the energy market, the lack of conditions for market trade in the energy
sector, and the imperfection of legal documents. In the regulatory model, important factors
are constant changes in regulatory and legal documents on energy saving, the absence of
strict standards from the state for produced and sold energy-consuming devices; imperfect
legal policy in the field of energy and environment, etc. The wasteful model includes the
problems of irrational use of all types of energy, lack of awareness of the importance of
energy conservation for the country. The energy consumption behavior of households can
have a significant impact on the implementation of sustainable energy. This is due not only
to the behavior of households themselves, but to the fact that the economy ensures that their
needs for sustainable energy, energy-saving and decarbonized resources are met through
the development of all sectors and areas of the country's activities within the framework of
sustainable energy. When drawing up state programs and national projects in the field of
sustainable energy implementation, it is necessary to take into account the needs of
households. The transition to sustainable energy, as well as the solution of the problems
that stand in its way, must be carried out taking into account the interests and capabilities of
households.

At the same time, it is necessary to take into account the fact that any model is a kind of
ideal project, which is formed on the basis of essential and key properties and cannot but
take into account numerous additional and auxiliary factors of its existence, which may
even contradict each other. But, clearly, without the adoption of specific and sufficient
incentive measures by the state, effective energy-saving behavior of households is not formed.

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