Power supply for educational institutions: efficiency and alternatives

Collective monograph edited by M. Sotnyk,
Doctor of Technical Sciences

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Proposed methodological approaches to modeling short-term forecasting and longterm planning of electrical consumption in educational institutions based on retrospective data. A logic-structural model and software of the circuit "object of monitoring of electric consumption — factors of influence — regulatory tools" of an automated system for controlling the efficiency of energy consumption in educational institutions have been developed. There are given practical recommendations of feasibility study of introduction of alternative power supply sources in educational institutions, in particular: solar generation, heat pumps, autonomous energy sources, etc.

Proposed scientific and methodological approaches to the introduction of an organizational and economic mechanism for managing the development of renewable energy in educational institutions and a motivation system for employees of the energy management service.

The monograph is a generalization of scientific research conducted by employees of Sumy State University during the state budget research work "Model of an efficiency management and forecasting system for the consumption of electric energy" (State Registration No. 0118U003583).

The monograph is intended for researchers and specialists in the implementation of energy management systems.

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CONTENTS

INTRODUCTION

Reduction of electricity consumption is possible due to the introduction of new energy-efficient equipment in technological processes and introduction of organizational and technical measures aimed at optimization of modes and regulation of electric and heat consumption.

In the monograph, at the system level, deals with these two aspects of optimizing energy consumption: it summarizes the results of scientific research on managing the efficiency of electric consumption in educational institutions. The specific features of educational institutions as an object of electricity supply were identified, which consist, first of all, in the mode and structure of electricity consumption. It is these features that are taken into account in the development of methodological approaches to modeling short-term forecasting and long-term planning of electricity consumption. The dynamics of internal (technical and economic, structural, regime) and external (meteorological, ecological, energy, macroeconomic) restrictions of electric consumption is investigated and included in the proposed models.

The improvement of the system for managing the consumption and saving of electricity by individual facilities (institutions) and sectors of the economy as a whole provides for the creation of a regional-sectoral organizational and economic model. The scientific and methodical approaches proposed in the monograph for the development of the energy saving management system in the education sector are aimed at forming the organizational foundations and algorithmic base for collecting, processing, analyzing information on the use of electricity, making management decisions and conducting an electrical energy audit, monitoring electricity consumption, improving the electricity limiting system, creation of electric power certificates of objects.

From a practical point of view, the development of analytical tools of an automated software complex for short-term forecasting and long-term planning of electricity consumption, including for educational facilities, consists in adapting the methodology, methodological principles for the generation and processing of incoming information, taking into account factors affecting the amount of electricity consumption contained in “International Performance Measurement & Verification Protocol. Concepts and Options for Determining Energy and Water Savings. Volume I”.

The adaptation procedure includes several interrelated steps:

- development of a concept of a management system for electricity consumption and electricity saving and for assessment of electric power efficiency of

educational facilities;

- development of a model of a system for managing efficiency and forecasting of electric energy use by consumers;

- development of an adapted model for predicting the electric energy consumption, based on a combination of elements of autoregressive integrated moving average (ARIMA), structural and cointegration (theory by R. Engle and K. Granger) models, etc.;

- development of a methodological support (toolkit) for the creation of a system for controlling the processes of efficient electricity consumption: universal economic and mathematical models of the electric consumption processes of objects in the education sector, methodological materials for the organization of an energy saving management system;

- development of an automated software package for short-term forecasting and long-term planning of electricity consumption based on retrospective data and taking into account the dynamics of external influences (technological, weather, organizational, regulatory);

- development of a recommendation on the implementation of a power consumption and saving management system and assessing the electric power efficiency of complex economic facilities (using the example of the education sector) on the basis of an automated software complex.

One of the main stages is the development of an automated software package for short-term forecasting and long-term planning of electricity consumption. It is the results of forecasting and planning electricity consumption that can be the basis for the development of energy conservation projects based on the principles of Enterprise Content Management (ECM).

At the same time, the choice of one or another model for forecasting the electric energy consumption by consumers depends on the organizational and managerial tasks for optimizing electric consumption that the analyst sets himself. The choice of models depends on both the technical capabilities and the cost-effectiveness of their implementation. In any case, you must follow the general recommendations set out in the Handbook (1997) American Society of Heating, Refrigerating and Air-Conditioning Engineers - (ASHRAE), in particular in section 30 - Energy Eatimating and Modeling Metods.

The development and implementation of the system proposed in the monograph allows us to establish a forecast of electric energy consumption in educational institutions by the types (elements) of their activities: educational process, maintenance of the educational process, scientific research, experimental design, etc. Such a forecast and a system of current monitoring of actual energy consumption should become the basis for the further formation of levers of

influence on the encouragement of staff and managers of educational institutions and other institutions to effectively implement energy saving. At the same time, it should be considered as a basic element of the general system for forecasting electricity consumption for a particular region, and, therefore, the formation of energy consumption and generation balances at the regional and state levels. That is, it should become the basic element on which the regional and state system of short-term forecasting of electrical energy consumption, optimization of energy balances, rational consumption of electrical energy and its generation is based and developed. This approach allows, on the one hand, to establish effective control over the electricity consumption, and on the other, to minimize its generation, which should reduce the environmental burden on the environment.

The monograph proposes and justifies the logical-structural model and software of the circuit “object of monitoring electric consumption - factors of influence - regulatory tools” of the system for controlling efficiency and predicting the electric energy consumption for educational institutions. Both the scientific and methodological foundations for the organization and construction of an automated system for short-term forecasting and monitoring of electricity consumption by educational institutions, as well as hardware and software, have been developed. The monograph contains important practical recommendations. In particular, a structural diagram of information blocks of the algorithm for calculating the forecast volumes of electricity consumption was thoroughly developed, the “spectrum” of electric consumption in the educational process was analyzed and the method of analyzing its components was proposed.

Considerable attention is paid to the feasibility study for the introduction of alternative sources of power supply: generation of electric energy with the location of solar panels on the enclosing structures of educational institutions, etc.

The materials presented in the monograph can be useful for specialists in public administration in the formation and implementation of an effective organizational and economic mechanism for managing electricity consumption in educational institutions, built on the principles of renewable energy.

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improving the quality of forecasts is a combination of various modeling approaches (autoregressive, structural modeling, neural network forecasting, artificial intelligence methods), as well as the use of hybrid models. Based on the selected theoretical models, it is planned to develop scientific and methodological support (tools) to create a multi-level control system for the processes of efficient electricity consumption. Assessment of the dynamics of demand for electricity and possible cause-and-effect relationships for various objects and levels, extrapolation and scenario analysis of the results obtained will allow developing the main mechanisms of energy efficiency policy and the principles of their practical implementation.

1.4. Incorporation of Environmental Factors in the Developing Energy-Saving Strategies

The problems of rational use of fuel and energy resources are relevant for many countries of the world that lack their own energy resources. As a rule, in most economies, along with industry (for industrialized countries) and agriculture (for agricultural ones), the household sector is one of the most important energy consumers.

Thermal energy for heating residential buildings can be obtained using various technologies that involve the use of natural gas, coal, peat, electricity (including from renewable energy sources), and alternative heat sources, such as heat pumps, geothermal energy, etc. In this regard, the governments of the Nordic countries are developing and implementing their own national strategies to maximize the use of local energy resources and to increase the energy efficiency of the heating process, to optimize household spending on them. The implementation of such strategies is supported by a system of state incentives and regulation of the use of various energy carriers by households, directing these economic entities to use the most promising energy resources from the point of view of national energy security. Moreover, in recent decades, special attention in the development of energy strategies in developed countries has been paid to environmental issues; thereby the strategies envisage the development and use of renewable energy sources, along with traditional ones. Examples of the most popular instruments for regulating the structure and volume of energy consumption of households in these countries, with the aim of greening the processes of production and consumption of energy, are the introduction of “green” pricing and certificates, quotas for energy consumption and production from renewable sources, the introduction of state and local programs to support the development of local objects of “green” energy generation, compensation to households for a part of the installing energy

efficient equipment cost from the state and local budgets, etc. [28].

This section explores the possibilities of optimizing the heating costs of an economic entity using various opportunities provided by the government as a part of economic incentives for increasing energy efficiency and developing renewable energy sources in the country, as well as using traditional exhaustible energy sources available within the existing power supply systems on the example of a typical Ukrainian household.

A feature of this study is that using combinations of various types of available energy resources, both renewable and non-renewable, taking into account current prices for them, existing benefits for the use of energy and its production by households, investments in energy equipment, the most effective consumption strategy for the household is being built, and on this basis, the effectiveness of the state incentive policy as a whole is being assessed, outlining its future results. Furthermore, recommendations for further stimulating the development and use of renewable energy sources are being developed on the basis of the calculations. The main contribution of this study to the existing theory and practice of energy regulation is that on this ground, in the future, it is possible to create a methodology for constructing an energy strategy for any household and to determine what will be the structure of energy consumption in the household sector with a given set of instruments for the state economic stimulation of energy processes, that is, what results should be expected from the current state energy policy in the household sector. The obtained research results and proposals can become a serious assistance for state and local authorities in the field of reforming the country's energy system in the direction of increasing the energy security of the territories and achieving sustainable development.

The typical household under study is a two-storey private house with a heated area of 200 m^2, located in the north-east of Ukraine, in the city of Sumy. The house has a solar power plant with an installed capacity of 10 kW; the power usage limit is 10 kW. Solar panels are installed permanently on the roof of the house and they generate electricity, which enters the general power grid and it is paid for to the household at a "green" tariff [29; 30]. The solar power plant was commissioned in June 2017; household income from the sale of generated electricity at the current "green" tariff [31] net of taxes is UAH 4,76 per lkWh at the end of June 2018.

Under the terms of the agreement with the local energy company, the surplus of generated "green" electricity consumed by the household goes to the general grid and it is paid to the household at the "green" tariff. In the event of a shortage of self-produced electricity, the household buys electricity from the local energy company at the established two-zone tariffs: from 11:00 p.m. to 7:00 a.m.- a

reduction factor of 0.5 is applied to the cost of electricity, and from 7:00 a.m. to 11:00 p.m.- the payment is made at the full tariff [32].

A gas boiler with a thermal power of 15kW is used to heat the house in the cold season. The heating period lasts 187 days.

With the existing gas tariff for the population in the amount of UAH/m^3 6,9579 [33], the household expenses for heating only for the season are (with a gas consumption of 2,317m^3) UAH 16121,45. Average gas consumption for other household needs is 27m^3/month, that is, 27 m^3 x 12 months = 324 m^3 per year or 324 m^3 x UAH/m^3 6,9579 = UAH 2,254.36 in value terms. Taking into account the income received from the sale of generated electricity under the "green" pricing, the household has the opportunity to cover all its costs of using gas and electricity per year, while the net income remaining at its disposal is UAH 35542,73 - UAH 16121,45 - UAH 2254,36 = UAH 17166,92 or 48.3% of the income from the sale of electricity under the "green" pricing.

In the northeast of Ukraine, the most affordable options for heating a house involve the use of such energy resources, such as: 1) natural gas, 2) electricity (including that generated by the household); 3) low-potential energy of the environment using a heat pump; 4) solid wood fuels, as well as combinations of these resources.

Natural gas is used as a basic home heating strategy. The following are accepted as other options for home heating strategies: heating using only electric energy (electric boiler); combined heating with gas and electricity; combined heating with gas and a heat pump; heating with solid fuel (wood pellets).

The most possible and affordable organization of home heating is the use of a solid-fuel boiler, in which firewood, wood pellets, and briquettes are used as a fuel. The market value of 1 ton of wood pellets is in the range of UAH 2800-3000.

When operating a solid-fuel boiler, electrical energy and pellets are used. The standard service life of the boiler is 20 years.

With the installed power of the boiler electrical equipment of 260 W, the daily electricity consumption is 0,26 kW x 24 hours = 6,24 kWh, the monthly consumption: 187,2 kWh, the consumption for the heating season: 1166,88kWh. Since for a solid-fuel boiler the limit of 3000 kWh is not assumed within the framework of the current regulatory framework, the household daily costs for electricity associated with the operation of the boiler, taking into account the two-zone tariff, will be: from 11:00 p.m. to 7:00 a.m.-0,26 kW x 8 hours x x UAH/kWh (1,68 x 0.5) = UAH 1,75; from 7:00 a.m. to 11:00 p.m.-0,26kW x x 16 hours x UAH/kWh 1,68 = UAH 6,99, i.e. 1.75 + 6,99 = UAH/day 8.74.

Monthly costs are UAH/day 8,74 x 30 days = UAH 262,08, for the heating season: UAH/day 8,74 x 187 days = UAH 1633,63.

The specific heat of combustion for pellets is 17,17 MJ/kg, for natural gas-33,5 MJ. Thus, the amount of pellets equivalent to burning lm^3 of gas, taking into account the efficiency of a solid-fuel boiler, is 33,5 MJ / 17,17MJ / 0,9 = =2,17 kg. Considering that the volume of natural gas used during the heating season reaches 2317 m^3, the required amount of pellets will be 2,17 kg/m^3 x x 2317m^3 = 5022,94 kg, and in value terms-5022,94 kg x UAH/t 3000 = UAH 15068.82 for the heating season, excluding transport costs.

The total costs for solid fuel and electricity for the operation of the boiler (excluding transport costs) will be for the season: UAH 1633,63 + UAH 15068.82 = UAH 16702,45. The cost of transport expenses (at least 2 deliveries per season) will be 2 x UAH 800 = UAH 1600. Thus, the total costs for using the solid-fuel boiler will amount to UAH 16702,45 + UAH 1600 = UAH 18302,45. If we compare these costs with the basic version of gas heating, then the cost of heating a house with pellets exceeds the cost of gas heating by UAH 18302,45 - UAH 16121,45 = UAH 2181 or by 13,53%.

Lets calculate the purchase price for pellets, at which the current heating costs using a solid-fuel boiler will be equivalent to the costs of gas heating: UAH (16121,45-1633,63-1600) / 5022,94 kg = UAH/t 2565,79. If we take into account the capital costs for the purchase and installation of the solid-fuel boiler, as well as the period of its normative service, then the indicated price should be adjusted taking into account these costs: UAH (16121,45-1633,63-1600-55224/20) / 5,02294t = UAH/t 2016,07, that is, at least 28-33% lower than the existing one. Taking into account the discounting of cash flows, the price for pellets should be 7-8 times lower than the existing ones.

Thus, the use of wood pellets for heating a house with the purchase and installation of the solid-fuel boiler, if compared with the basic option at current prices for pellets (with a calorific value of at least 17,17 MJ/kg), the boiler equipment for pallets becomes unprofitable.

The peculiarity of the calculations was that the household uses a two-zone tariff for electricity consumed. Moreover, a solar power plant, which generates electricity sold by the owner to the local energy company at a “green” tariff, is installed on the roof of the house.

Comparison of the results of the performed calculations shows that when equipping the heating system of an individual house in the climatic conditions of northeastern Ukraine with gas and electric boilers, using a two-rate electricity tariff by the household, it is advisable to use combined heating: from 11:00 p.m. to 7:00 a.m.- the operation of an electric boiler and a gas boiler. In this case, the total heating costs for the season are reduced by 28.18% compared to the base case of using only the gas heating. The electric boiler can be used during the entire heating

season.

In order to maintain positive trends in the development of the use of alternative heating sources, it is advisable to recommend to the public authorities:

- to create favorable conditions for the development of the domestic market of electric boiler equipment for households, stimulating the emergence of the most energy efficient models of electric boilers, and to support the development of service networks for electrical equipment;
- to continue supporting the development of solar and wind power plants in households with the use of a "green" tariff, to pursue a stimulating credit policy in order to ensure public investment in renewable energy facilities;
- to stimulate the encourage of the public to the use of solid fuel for heating with the installation of solid-fuel boilers in households, it is necessary to reduce market prices for solid wood fuel, along with a reduction in the cost of solid-fuel boilers themselves, to develop a network of suppliers of wood pellets, to stimulate manufacturers of solid-fuel boilers to develop and to offer the market more energy efficient, economic, and inexpensive models of the boiler equipment, using economic regulators;
- to stimulate research and development in this area with the creation of new equipment samples adapted to the climatic conditions of Ukraine, given the high cost of heat pumps.

At the household level, it is necessary to constantly implement energy-saving measures, namely: to insulate building envelopes, minimizing heat loss; to economically use the available energy resources based on the development of optimal temperature regimes of premises and heating schedules; to attract as much as possible renewable energy sources, for example, energy of the sun, wind, heat of the earth, etc.

The practical implementation of these recommendations at the micro- and macroeconomic levels will ensure further energy transformations in the housing sector of Ukraine on the principles of energy efficiency and economic feasibility, increasing the level of energy security of the country, diversifying the energy resources used, and stimulating the development of renewable energy sources.

It should be noted that, in addition to the economic aspects of choosing energy-saving strategies, it is necessary to take into account environmental aspects, as well as that with the corresponding strict national environmental legislation, the decision of households to choose a specific energy resource or their combination can change significantly, since the environmental impact of heating processes in buildings is significant for the Nordic countries. Taking into account the existing international obligations on environmental protection and the development of renewable energy in Ukraine, achieving sustainable development,

researching the environmental aspects of the formation of energy strategies for households should become an integral part of substantiating the effectiveness of the instruments of the state economic policy in this area.

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