UDC 338.2+332.1

DEVELOPMENT OF A SOFTWARE PACKAGE FOR DECISION SUPPORT FOR ESTIMATING ENERGY EFFICIENCY OF MUNICIPALITIES

Bogachkova Lyudmila Yuryevna, Dr. Sc. (Econ.), Prof.
Sorokin Anton Vladimirovich, M. Sc.

Volgograd State University, Pr-kt Universitetsky, 100, Volgograd, Russia, 400062; e-mail: bogachkova@volsu.ru; loginant@yandex.ru

Purpose: development of a regional subsystem for monitoring energy efficiency of regions based on the elaboration and automation of the methods for integrated ranking estimation of municipalities in terms of rationality of energy consumption, waste management and environmental protection. The study draws on the case of the Volgograd region. *Discussion*: in October 2021, the Government of the Russian Federation approved the Strategy of socio-economic development of Russia with a low level of greenhouse gas emissions until 2050. This made urgent the problem of developing a system of accounting and analysis of the efficiency of energy supply, energy consumption and environmental protection of territories to ensure an increase in their energy efficiency. At the regional and subregional levels, there is a demand for new tools that would allow for the formation of an integrated ranking estimation of energy efficiency based on the available official data. *Results*: a software package that allows for the automation of ranking estimation and analysis of municipalities' energy efficiency has been developed and tested. It is based on sixteen indicators characterizing energy consumption, technical condition of power supply networks, waste management and environmental protection. An approach to the restoration of missing values of indicators based on scenario modeling has been proposed. A comparative analysis of the energy efficiency of the municipalities of the Volgograd region over the period of 2012-2019 has been carried out.

Keywords: energy efficiency of territories, ranking estimates, energy consumption, subregional economy, environmental protection.

DOI: 10.17308/meps.2021.12/2742

Introduction

In modern Russia as in other countries of the world, the measures aimed at improvement of energy efficiency have the status of a priority area of state economic policy. However, the Russian system of accounting and analysis of energy consumption is in its infancy and needs to be developed, which is especially important for its regional subsystem. The study of energy efficiency at the regional and subregional levels of the Russian Federation is carried out on the basis of limited data. Moreover, there is a lack of methods and tools for data analysis [4].

Various economic and managerial aspects of the energy efficiency of the regional economy, including the municipal level, are investigated in numerous works [1-3, 5-9, 11]. One of the sections of the monograph [7, c. 31-55] is devoted to a review of modern literature on this topic. This article represents a part of the research project devoted to the development of tools for decision support for estimating the energy efficiency of territories and enterprises of the Russian Federation [2, 3, 12]. We propose the methodology for integrated ranking estimates of the energy efficiency of municipalities, which differs from the «fundamental» one [2; 3] in accounting additional indicators that characterize technical condition of heating networks and housing stock, as well as environmental protection along with those taken into account in [2] indicators of specific energy consumption in the public sector and housing and utility sector. We have developed a software package that solves the problem of automation of the proposed methods application. The study has been carried out on the basis of official statistics data included in the passports of municipalities.

Research methodology

The data source is represented with the passports of municipalities formed by the Territorial Body of the Federal State Statistics Service in the Volgograd Region (Volgogradstat) over the period of 2012-2019. The complete list of indicators used for ranking analysis of municipalities includes 16 items:

– ten indicators of specific energy consumption for 1 year in apartment buildings and in municipal budgetary institutions (electricity (kWh per person); heat (Gcal per m^2); hot water (m^3 per person); cold water (m^3 per person); gas (m^3 per person));

– three indicators that directly or indirectly characterize the loss of energy in infrastructure networks and residential premises:

- share of the length of heating and steam networks that need to be replaced in the total length of heat and steam networks on the territory of a municipality;
- share of the area of residential premises in dilapidated and emergency residential buildings in the total area of residential premises on the territory of a municipality;
- share of expenditures on housing and utility sector in the total actually executed expenditures of the local budget;

– three indicators characterizing environmental protection:

- share of screened and neutralized pollutants in the total amount of pollutants emitted by stationary sources;

- solid household waste removed over a year (m^3/person);
- liquid household waste removed over a year (m^3/person).

The agreed notation: n – number of indicators; 1≤ i ≤ n – indicator number; 1≤ j ≤39 – municipality number; P_i – i-th indicator; P_{ij} – i-th indicator for j-th municipality; $P_{i,\max}$ – maximum value of the i-th indicator among all the municipalities.

The research is based on the fundamental methodology proposed in [2, 3]. In the present article, this methodology which traditionally implies the account of indicators according to the principle "the less, the better", is modified by expanding the list of indicators and changing the principle of accounting for some additional indicators.

According to the fundamental methodology, in the absence of data on a certain indicator from any particular municipality, and taking into account the fact that other municipalities have data on this indicator, it is proposed to assume that the ranking estimate is equal to the number of analyzed indicators. This assumption allows for downgrading the ranking score of those municipalities that do not provide data on any indicators. It is proposed to consider such lack of data as insufficient information support for energy efficiency policy. It is also necessary to take into account the different nature of the indicators' values: for example, indicators 1-13 are assessed according to the principle «the less, the better», while indicators 14-16 – on the contrary: «the more, the better». Thus, the particular ranking estimate is calculated by using the formula:

$$\omega_{ij} = \begin{cases} \dfrac{P_{ij}}{P_{i,\max}}, & if \;\; i \le 13; \\ 1 - \dfrac{P_{ij}}{P_{i,\max}}, & if \;\; i \le 13 \\ \\ n, \;\; if \;\; no \; data \; is \; available. \end{cases}$$

The integrated ranking estimate of the j-th municipality for n particular indicators is calculated by using the formula:

$$R_j = \frac{\sum_{i=1}^{n} \omega_{ij}}{n}.$$

The number of particular indicators on which there was no data for the j-th municipality is determined by the integer part of the variable of an integrated ranking estimate:

$$m_j = \left[R_j \right].$$

To obtain an integrated ranking estimate without taking into account the missing indicators, it is sufficient to omit the whole part Rj:

$$\tilde{\omega}_j = R_j - \left[R_j \right].$$

Analysis of the data available in the passports of the Volgograd Region's municipalities showed that the calculation of the integrated ranking estimate according to the proposed methodology, taking into account all 16 indicators, is possible only for the period from 2012 to 2016. The year of 2019 is the last reporting period for which municipalities' passports were available, and they contained only values for the first ten indicators. We propose to use scenario modeling to restore the missing data with the aim to apply the methodology, taking into account all the available indicators.

The scenario approach is based on the formation of several most probable scenarios for the development of the process under study. The main purpose of the scenario approach is "to predict possible directions for the development of the processes under study, to identify control effects on their formation" [10]. In this work, data recovery was carried out according to dynamic and static scenarios (depending on the nature of the available retrospective data for the periods preceding those for which the data were absent). The static scenario was founded on the assumption that the values of indicators remained at the average level, while the dynamic scenario was based on the assumption that the growth rates of these indicators remained at the average level.

Discussion

The software package has been developed to automate the application of the proposed set of methods. The software implements the formal model described above. Automation of calculations simplifies data analysis, reduces error probability. The proposed implementation scheme is not limited to a fixed list of indicators and can be used to analyze the energy efficiency of municipalities in regions with any set of indicators that do not contradict the formal model.

The software package has been implemented as a web application with a multi-level architecture (Fig. 1). The main architectural components include the client side (frontend); server side (backend); database.

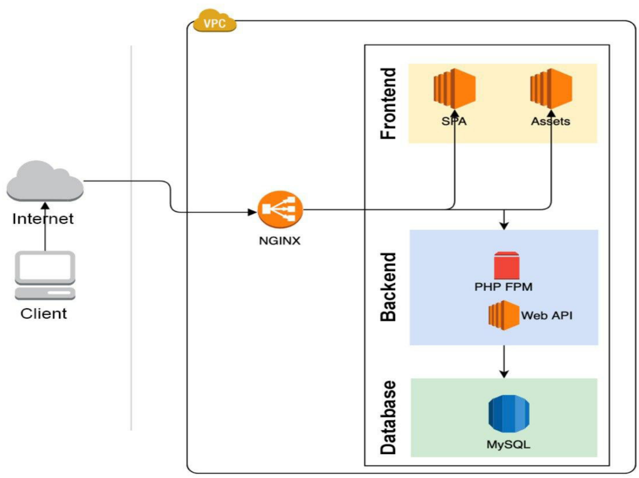

Fig. 1. Architecture of the proposed software package

The client side provides a user interface, interacts with the backend by sending requests and receiving data, and constructs graphs and tables to display data in a user-friendly form. The JavaScript programming language was used to implement the client side.

The server side receives requests from clients, on the basis of which it requests the necessary information from the database management system, performs calculations and sends a response to clients. This service has been implemented using the 8th version of the PHP programming language.

The database stores data, provides an interface for selecting data according to various conditions, and allows them to be added and modified. The database management system MySQL is used as a data storage.

The database diagram of the software package is shown in Fig. 2. It consists of the following tables:

1. Municipalities: the table contains an identifier and the name of a municipality.

2. Energy efficiency indicators: the table contains an identifier, name, designation, unit of measurement and the principle of indicator accounting.

3. Values of energy efficiency indicators: the table contains an identifier, indicator value, period and a link to the municipality to which the value refers.

The graphical interface of the developed software package consists of two main sections: ranking of municipalities and scenario modeling. The section «Ranking of municipalities» displays the ranking calculated according to the available data.

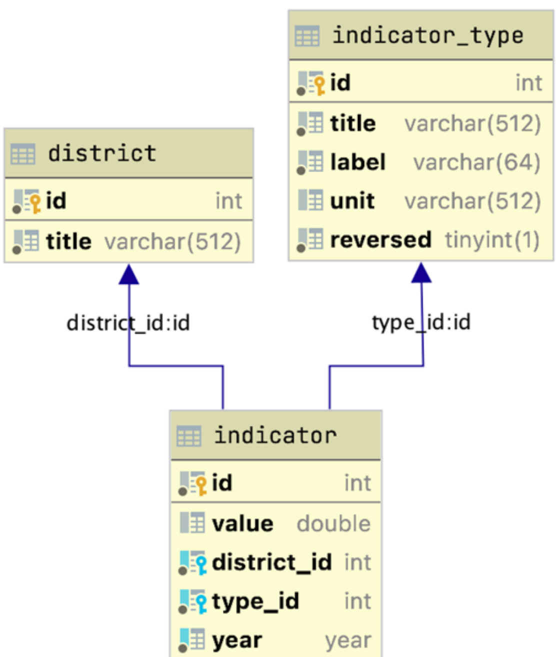

Fig. 2. Scheme of the database of the developed software package

The software implies the possibility of calculation using various sets of indicators, which allows for application of all variants of the previously described complex of methods. It is also possible to select several periods, and estimates for the selected periods get summarized and displayed as a single table or multi-colored lines in a graphical representation. A set of energy efficiency indicators on the basis of which the ranking will be built, as well as periods for comparison, can be selected in the settings block, which is displayed when clicking on the button Parameters. There is a possibility of interactive table search: table rows are filtered based on the phrase entered in the Table search field.

In the Scenario Modeling section, the ranking of municipalities is displayed. It is calculated using the restoration of missing values by the forecasting method based on scenario modeling. Forecasting is carried out according to dynamic and static scenarios. Forecasting parameters can be configured in the settings block. The user is asked to select periods and indicators, the missing data for which will be restored according to the selected scenario. For a dynamic scenario, the base period and comparison period should be specified (P_ (ij, base) and P_ijt, respectively).

In the absence of data necessary to predict the value of an indicator, the value remains blank, which leads to a decrease in the position of the municipality in the ranking.

Thus, the developed software package implements all the necessary aspects of the proposed set of methods for ranking estimation of the energy efficiency of municipalities.

Conclusion

Based on the application of the proposed software package, the developed methods for estimating the energy efficiency of the Volgograd Region municipalities were tested according to the available data for 2012-2019, as well as on the basis of the results of scenario modeling of the indicators' missing values for 2019. Formation of rankings allows for conducting a comparative analysis of the energy efficiency of municipalities and monitoring the dynamics of the relative levels of their energy efficiency.

It was revealed that the amount of data collected and provided to Volgogradstat by the municipalities of the Volgograd region is increasing, which indicates an improvement in information support for the state energy efficiency policy. This allowed some of the previously low-performing municipalities to rank high in 2019.

Information on the identified most successful and low-performing municipalities can be used to evaluate the performance of local energy efficiency policies and to make management decisions to improve the measures taken in the field of energy saving and environmental protection.

References

1. Andreev A.V. Tseli i pokazateli sistemy upravleniya energosberezheniem v sfere obrazovaniya [Goals and indicators of the system of energy saving management in the sphere of education]. *Fundamentalnye issledovaniya*, 2016, no. 3 (part 1), pp. 108-112. (In Russ.)

2. Bogachkova L.Yu., Zaytseva Yu.V., Usacheva N.Yu. Tools for Monitoring Energy Efficiency of Municipalities' Housing and Utilities Sector and Budget Sector (the Case of the Volgograd Region). *Advances in Economics, Business and Management Research (AEBMR)*, 2018, vol. 39, pp. 429-432.

3. Bogachkova L.Yu., Zaytseva Yu.V., Usacheva I., Zaytseva E. Razvitie regionalnoy podsistemy monitoringa energoeffektivnosti na osnove sravnitelnogo analiza energopotrebleniya munitsipalitetov (na primere Volgogradskoy oblasti) [Development of a regional subsystem for monitoring energy efficiency based on a comparative analysis of energy consumption of municipalities (on the example of the Volgograd region)]. *Sovremennaya ekonomika: problemy i resheniya*, 2019, no. 8, pp. 121-138. (In Russ.)

4. Bogachkova L.Yu. Problemy analiza energoeffektivnosti na muni-tsipalnom urovne v RF i nekotorye resheniya na primere Volgogradskoy oblasti [Problems of energy efficiency analysis at the municipal level in the Russian Federation and some solutions on the example of the Volgograd region]. *Sistemnoe modelirovanie sotsialno-ekonomicheskikh protsessov. Trudy 42-oy Mezhdunarodnoy nauchnoy shkoly-seminara [System modeling of socio-economic processes. Proceedings of the 42nd International Scientific School-Seminar]*. Voronezh, 2019, pp. 189-194. (In Russ.)

5. Davydyants D.E. et al. *Energosberezhenie i energoeffektivnost na obyektakh zhilishchno-kommunalnogo khozyaystva gorodskikh i selskikh munitsipalnykh obrazovaniy* [Energy saving and energy efficiency at the objects of housing and communal services of urban and rural municipalities]. Stavropol, Agrus Publ., 2015. 212 p. (In Russ.)

6. Gasho E.G., Stepanova M.V. Razvitie regionov cherez povyshenie energoeffektivnosti [Regional development through increasing energy efficiency]. *Energeticheskaya politika*, 2015, iss. 3, pp. 59-65. (In Russ.)

7. Khurshudyan Sh.G. *Instrumenty analiza energoeffektivnosti regionov RF: razrabotka i primenenie* [Tools for analyzing energy efficiency of the regions of the Russian Federation: Development and application]. Moscow, RUSCIENCE Publ., 2018. (In Russ.)

8. Marchenko E.M., Belova T.D. Klasterizatsiya regionov s uchetom pokazateley energoeffektivnosti [Clustering of regions taking into account energy efficiency indicators]. *Regionalnaya ekonomika: teoriya i praktika*, 2016, no. 1, pp. 51-60. (In Russ.)

9. Mokhov V.P. Faktory differentsiatsii elektropotrebleniya v gorodskikh domashnikh khozyaystvakh v munitsipalnykh obrazovaniyakh Permskogo kraya [Factors of differentiation of electricity consumption in urban households in the municipalities of the Perm Territory]. *Energetika. Innovatsionnye napravleniya v energetike. CALS-tekhnologii v energetike*, 2020, vol. 1, pp. 5-13. (In Russ.)

10. Naumov I.V. Teoretiko-metodologicheskie osnovy stsenarnogo podkhoda k modelirovaniyu matritsy finansovykh potokov v regionalnoy sisteme [Theoretical and methodological foundations of the scenario approach to modeling the matrix of financial flows in the regional system]. *Upravlenets*, 2017, no. 3(67), pp. 8-17. (In Russ.)

11. Nikitaeva A.Yu., Maslyukova E.V., Podgaynov D.V. Modelno-analiticheskiy instrumentariy otsenki faktorov energoeffektivnosti v regionakh Yuga Rossii [Model and analytical tools for assessing energy efficiency factors in the regions of the South of Russia]. *Regionalnaya ekonomika. Yug Rossii*, 2018, no. 4, pp. 150-160. (In Russ.)

12. Sorokin A.V. Informatsionnye sistemy upravleniya energoeffektivnostyu na mikrourovne: mirovoy opyt i rossiyskaya praktika [Information management systems for energy efficiency at the micro level: World experience and Russian practice]. *Molodoy uchenyy*, 2019, no. 51 (289), pp. 429-431. (In Russ.)

РАЗРАБОТКА ПРОГРАММНОГО КОМПЛЕКСА ДЛЯ ПОДДЕРЖКИ ПРИНЯТИЯ РЕШЕНИЙ ПО ОЦЕНКЕ ЭНЕРГОЭФФЕКТИВНОСТИ МУНИЦИПАЛИТЕТОВ

Богачкова Людмила Юрьевна, Full Prof., Dr. Sc. (Econ.)
Сорокин Антон Владимирович, M.Sc.

Волгоградский государственный университет, пр-т Университетский, 100, Волгоград, Россия, 400062; e-mail: bogachkova@volsu.ru; loginant@yandex.ru

Цель: развитие региональной подсистемы мониторинга энергоэффективности региона на основе разработки и автоматизации методик для интегральной рейтинговой оценки муниципалитетов по рациональности энергопотребления, обращения с отходами и охраны окружающей среды (на примере Волгоградской области). *Обсуждение*: в октябре 2021 года Правительство РФ утвердило Стратегию социально-экономического развития РФ с низким уровнем выбросов парниковых газов до 2050 года. В связи с этим актуализируется проблема развития системы учета и анализа эффективности энергоснабжения, энергопотребления и охраны окружающей среды территорий для обеспечения повышения их энергоэффективности. На региональном и субрегиональном уровнях востребована разработка инструментальных средств, позволяющих выполнять формирование интегральной рейтинговой оценки энергоэффективности на основе доступных официальных данных. *Результаты*: разработан и апробирован программный комплекс, решающий задачу автоматизации рейтинговой оценки и анализа энергоэффективности муниципалитетов на основе шестнадцати показателей, характеризующих энергопотребление, техническое состояние сетей энергоснабжения, переработку отходов и охрану окружающей среды. Предложен подход к восстановлению отсутствующих значений показателей на основе сценарного моделирования. Выполнен сравнительный анализ энергоэффективности муниципалитетов Волгоградской области за 2012-2019 годы.

Ключевые слова: энергоэффективность территорий, рейтинговые оценки, энергопотребление, субрегиональная экономика, окружающая среда.

Список источников

1. Андреев А.В. Цели и показатели системы управления энергосбережением в сфере образования // *Фундаментальные исследования*, 2016, no. 3 (ч. 1), с. 108-112.

2. Bogachkova L.Yu., Zaytseva Yu.V., Usacheva N.Yu. Tools for Monitoring Energy Efficiency of Municipalities' Housing and Utilities Sector and Budget Sector (the Case of the Volgograd Region // *Advances*

in Economics, Business and Management Research (AEBMR), 2018, vol. 39, pp. 429-432.

3. Богачкова Л., Зайцева Ю., Усачева И., Зайцева Е. Развитие региональной подсистемы мониторинга энергоэффективности на основе сравнительного анализа энергопотребления муниципалитетов (на примере Волгоградской области) // *Современная экономика: проблемы и решения*, 2019, no. 8, с. 121-138.

4. Богачкова Л.Ю. Проблемы анализа энергоэффективности на муниципальном уровне в РФ и некоторые решения на примере Волгоградской области // *Системное моделирование социально-экономических процессов. Труды 42-й Международной научной школы-семинара*. Воронеж, 2019, с. 189-194.

5. Гашо Е.Г., Степанова М.В. Развитие регионов через повышение энергоэффективности // *Энергетическая политика*, 2015, вып. 3, с. 59-65.

6. Давыдянц Д.Е. и др. *Энергосбережение и энергоэффективность на объектах жилищно-коммунального хозяйства городских и сельских муниципальных образований*. Ставрополь, Агрус, 2015.

7. Марченко Е.М., Белова Т.Д. Кластеризация регионов с учетом показателей энергоэффективности // *Региональная экономика: теория и практика*, 2016, no. 1, с. 51-60.

8. Мохов В.П. Факторы дифференциации электропотребления в городских домашних хозяйствах в муниципальных образованиях Пермского края // *Энергетика. Инновационные направления в энергетике. CALS-технологии в энергетике*, 2020, Т. 1, с. 5-13.

9. Наумов И.В. Теоретико-методологические основы сценарного подхода к моделированию матрицы финансовых потоков в региональной системе // *Управленец*, 2017, no. 3(67), с. 8-17.

10. Никитаева А.Ю., Маслюкова Е.В., Подгайнов Д.В. Модельно-аналитический инструментарий оценки факторов энергоэффективности в регионах Юга России // *Региональная экономика. Юг России*, 2018, no. 4, с. 150-160.

11. Сорокин А. В. Информационные системы управления энергоэффективностью на микроуровне: мировой опыт и российская практика // *Молодой ученый*, 2019, no. 51 (289), с. 429-431.

12. Хуршудян Ш.Г. *Инструменты анализа энергоэффективности регионов РФ: разработка и применение*. Москва, РУСАЙНС, 2018.