Finding the potential contribution of the fuel and energy sectors to increase the energy efficiency of the economy

DOI: 10.34130/2070-4992-2019-4-92-98
УДК 338.27:330.42

S. L. Sadov, *Institute of Socio-Economic and Energy Problems of the North of Komi Scientific Center, Ural Branch of the Russian Academy of Sciences (Syktyvkar, Russia)*

This article is devoted to the method of determining the potential contribution of the fuel and energy complex (FEC) sectors to improving the energy efficiency of the region or country's economy. Knowing them will help in developing the main directions and mechanisms for improving energy efficiency. Method is based on the analytical hierarchy process, which requires structuring the task – constructing in this case a full three-level hierarchy of the goal, factors influencing it and FEC branches. At the lower level of the hierarchy, the fuel and energy complex is represented by six enlarged sectors, the second is formed by the six most significant factors, and the first is the goal – improving the energy efficiency of the economy. Initial data is expert estimates of pairwise comparisons of both the significance of branches for each of the selected factors and the significance of factors for the main goal – improving energy efficiency.

The analytical hierarchy process makes relatively soft requirements for the initial data – the absence of transitivity violations for pairwise comparisons and compliance with restrictions on the values of consistency relations for such comparisons matrices. The article first proposed a procedure for generating initial data with good consistency and without violating transitivity. It ensures the reliability of the results obtained by the method of analysis of hierarchies, is quite simple and suitable for work as a single expert or the whole group.

Author's expert estimates for the Komi Republic economy are presented. Based on them, the expected contribution of the five integrated FEC sectors to the potential in energy efficiency increasing of the region's economy was obtained. It is interesting that the contribution of non-traditional energy sources has a potential almost equal to the contribution of some traditional sectors of the FEC – despite the fact that now their proportion in energy production is very small. The results can be useful in concretizing the main directions of the regional energy policy in order to determine ways to improve energy efficiency.

Keywords*: fuel and energy complex, energy efficiency of the economy, contribution of the energy sectors, analytical hierarchy process, consistency of input information.*

Introduction

The problem of improving energy efficiency for Russia is one of the most important. The energy intensity of Russia's GDP is significantly higher than the global average, and it is 3 times lower than in advanced countries in this indicator [1]. Stable GDP growth is impossible without reducing its resource intensity, including and energy intensity. This requires government bodies at the federal and regional levels to have balanced comprehensive programs to increase energy efficiency [2]. Nowadays, there is no such program at the federal level in Russia [1], the situation is different in the regions, but also it is far from the desired [3]. Including for these reasons, according to the Ministry of Economic Development of Russia[1], the seven-year results of the law No.261-FZ have shown that the goal set to reduce the energy intensity of the economy by 40% is not substantially achieved. Therefore, the problem of improving energy efficiency does not lose its severity and relevance, rather the opposite. And developments in this area are still in demand [4]. I believe that the previously proposed solution to the problem of finding a rational, optimal in its kind ratio of control actions of various types aimed at improving the energy efficiency of the economy [5] will be useful for the development and operational adjustment of energy efficiency programs. This article is devoted to the formulation and solution of the unsolved problem of determining the potential contribution of the sectors of the fuel and energy complex (FEC) to improving energy efficiency. Its solution will also find application in the development of the mentioned programs.

[1] Letter of the Ministry of Economic Development of the Russian Federation No. 29204-EE / D07 dated 09/27/2016. URL: http://economy.gov.ru/ minec / documents / vostrebdocs? Type_select = message & WCM_PI = 1 & WCM_Page.697cd88042f0ff329527b757f947fd1b = 2 (accessed 04.24.2019)

Research methodology

The most suitable way to solve the two problems described above to determine the degree of influence of various aspects on energy efficiency is the Analitical Hierarchy Process (AHP). It has established itself as an effective mathematical tool that uses economic and other indicators as initial information, which are not the result of accurate measurements, but are based on expert judgments and estimates [6]. This method has found application in many fields – economics, energy [7], including nuclear [8], engineering [9], information technology [10], etc. And since for many tasks of economics and management related to relationships between people, it is impossible to operate with clearly defined results of numerical measurements, then the AHP in this situation gives researchers the opportunity to obtain stable and relevant results, having comparative expert assessments of a qualitative nature as initial information [11], obtained, as a rule, by pairwise comparison of factors and indicators [12].

The problem of increasing energy efficiency is multifaceted, and many of its aspects require attention. Moreover, it is in a zone of high uncertainty, which negatively affects the reliability of evaluations of the effectiveness of projects and activities aimed at improving energy efficiency, and makes it difficult to develop appropriate programs [13].

The fuel and energy complex (FEC) of any region or country as a whole is developing, transforming in cooperation with other industries and sectors of the economy, with external suppliers and consumers. The fuel and energy complex must fulfill its tasks in the current situation by increasing its energy efficiency, with a lower consumption of primary energy resources. The question naturally arises – how much can the contribution of one or another industry sector to the energy efficiency of the regional economy be different? The Analitical Hierarchy Process allows you to answer this question on the basis of expert estimates. To work on this method, the first step is to build a hierarchy of the problem, preferably complete [6]. The hierarchy allows us to represent the original intractable task as a composition of simple subproblems, and to obtain a solution as a kind of convolution of qualitative estimates obtained in pairwise comparisons on a 9-point scale (we will talk about it later). Mathematically, this is achieved by multiplying the inverse symmetric matrices of pairwise estimates.

The lower level of the hierarchy is formed by the energy sector (Fig. 1). In an enlarged, aggregated form, there are six such sectors – electricity, oil and gas, coal, hydropower, heat supply and the industry, which represents the electricity production and heat from non-traditional renewable sources or energy resources that previously went were wasted. The first four industries, along with the production of energy products, also include its main transport (overflows along power lines, pumping along major oil and gas pipelines, coal transportation by rail and water – without taking into account further distribution to end consumers). Oil and gas processing are included in the industry.

There are the factors at the second level of the hierarchy, whose influence on the fuel and energy sector in terms of energy efficiency is the most significant and can be expertly evaluated. Consider them. The industry's contribution to the overall increase in energy efficiency, of course, depends on its "specific gravity" in the economy or (which is identical in this case) in the fuel and energy sector of the region. This is the first. Secondly, differences in the sectoral efficiency of investing in projects aimed at reducing energy intensity, which also need to be reflected in the hierarchical model, are natural. If projects for the use of renewable or previously considered waste energy resources can be considered operational to increase energy efficiency, then the potential of traditional energy resources is already largely used.

Thirdly, industry differences are manifested in the ways and forms of financing projects, and this fact should be taken into account when solving the problem. Projects involving increased energy efficiency in different sectors differ in both scale and mass. It is one thing to finance the modernization of equipment at a power plant or boiler room; another is to equip residential buildings and premises with appliances that allow consumers to get the desired result with less energy consumption. This implies different sources, schemes and volumes of financing, fragmentation of financial flows. All of the above should be taken into account by an expert when working with such a generalizing factor as "the availability of project financing".

Next are regional factors. In general, they characterize the technical level of the energy sectors, the level of economic development of the region, as well as the degree of sophistication and quality of implementation of the regional energy policy.

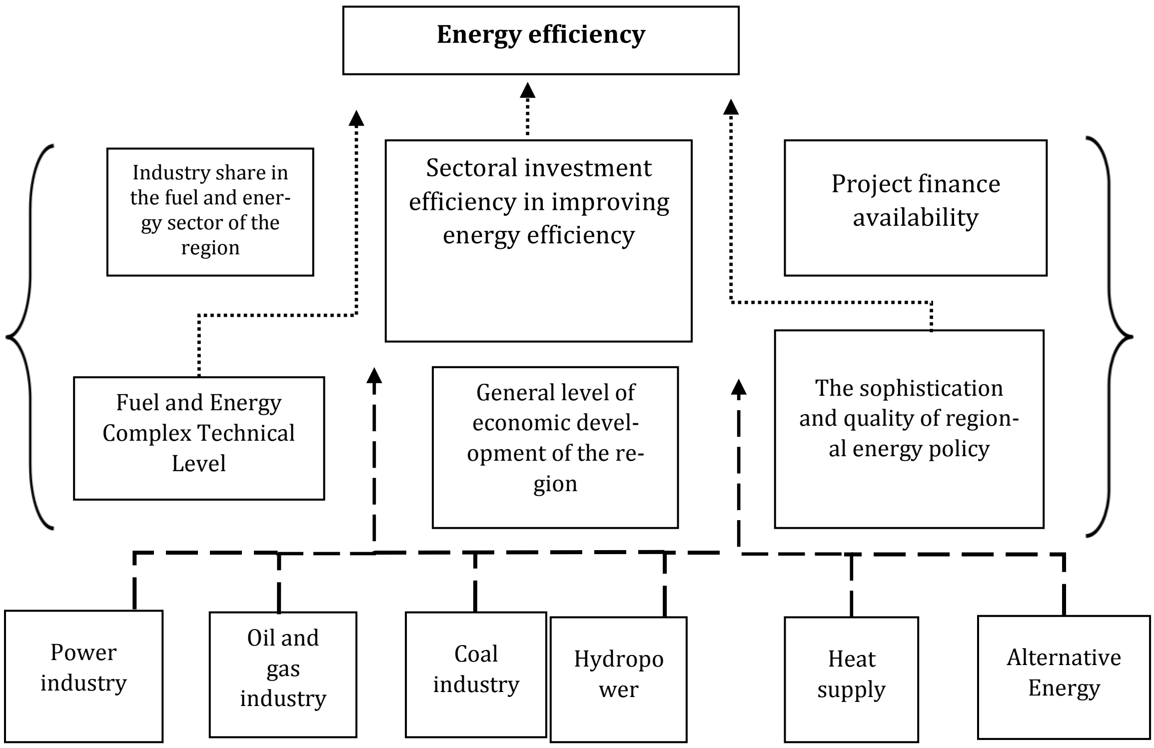

Fig. 1. A complete hierarchy to solve the problem of determining the contribution of the fuel and energy sectors to increase the energy efficiency of the economy

After building the hierarchy, it is required to make a pairwise assessment of the factors and branches of the fuel and energy complex and record the obtained estimates in the form of inverse symmetric matrices. To fill these matrices, a 9-point comparison scale is used [6]. For example, for factors A and B:

9 points means that factor A in importance absolutely exceeds factor B;

7 – that A is clearly more important than B;

5 – A is much more important than B;

3 – A is slightly more important than B;

1 – A and B are equally important.

Even points 8, 6, 4 and 2 express intermediate gradations of grades.

In the case when several experts are involved in the preparation of pairwise comparison matrices, often due to the difference in their preferences, methodological approaches, and experience, undesirable phenomena such as transient disturbance and poor initial data consistency indicators arise. In this case, you can use the techniques described in the works of T. Saati in the development of the Analitical Hierarchy Process [14; 15]. But regardless of whether one person or a group of experts is engaged in the preparation of the initial data, it is possible, by carrying out a simple procedure, to avoid transitivity and to keep the mismatch of the matrices of pairwise comparisons within the limits required by the AHP. To do this, when filling out the inverse symmetric matrix of pairwise estimates, it is necessary:

step 1 – pre-rank the compared values (indicators) from the most important to the least significant and determine for yourself how many gradations of the 9-point scale you can evaluate the difference between neighboring indicators (in some cases, when any neighboring indicators are recognized by the expert as equivalent, these estimates may be equal); further adhere to the derived ratios;

step 2 – the main diagonal of the inverse-symmetric matrix is filled with units, since it contains estimates of comparing each indicator with itself; to fill the first row of the upper triangular part of the inverse-symmetric matrix, you need to compare the first indicator with all the others and put in the matrix cells pairwise significance estimates on a 9-point scale, which are put in accordance with the ranked row; you should be careful about the difference between neighboring estimates in this series – the elements of subsequent lines will largely depend on it;

step 3 – further shorter rows of the upper triangular matrix are filled in (the elements of the lower triangular matrix automatically acquire values equal to the inverse of the symmetric element from the upper triangular part – this is why the matrix is called inverse symmetric); at this step, it is important to adhere to the difference between the neighboring indicators of the ranked series, which was outlined in the first step.

So, the initial data for solving with the help of the Analitical Hierarchy Process the task of determining the potential contribution of the fuel and energy sectors to improving the energy efficiency of the economy of the northern region will be the inverse symmetric 6 × 6 matrix for energy efficiency and six similar 6 × 6 matrices for the fuel and energy sector filled with pairwise estimates.

The results of the research

We will solve the problem for the Komi Republic. Since hydropower is practically absent in the republic, it is reasonable to exclude it from the list of sectors of the fuel and energy sector and from the lower level of the hierarchy (Fig. 1). Thus, five branches of the fuel and energy sector will remain under consideration. The estimates are based on author's judgments and, if available, statistical and other information. To prepare the initial data, we will use statistical information on the production of fuel and energy resources in the Komi Republic according to the results of 2018 – it amounted to (in tons of standard fuel)[1]:

- crude oil, including gas condensate – 20622;
- natural and associated gas – 3999;
- fuel wood – 50,6;
- electric power – 3433;
- coal – 5289.

In accordance with these indicators, the relative weight of the sectors will be evaluated on a 9-point scale used in the Analitical Hierarchy Process. According to the natural indicators of the production of fuel and energy resources, one can judge both the ranking order of industries by this factor and the difference in scores of industries.

Sectoral efficiency of investments in improving energy efficiency is a general concept that cannot be judged by individual projects. We use the above procedure for preparing the source data. We rank the industries by efficiency, and then establish the correspondence of each industry to any gradation of the 9-point scale used in the Analitical Hierarchy Process. The fifth sector is the leader in this factor – the implementation of any of its projects leads to the replacement of traditional fuel resources. Next, it is reasonable to put the power system in place – it has a large supply of unrealized opportunities for more economical delivery and conservation of heat, and there is the potential for expanding the decentralization of heat supply [7]. A lot has already been done in the electric power industry in terms of increasing energy efficiency, but there are still opportunities – for example, expanding the cogeneration of heat and electricity. Opportunities for the fuel industries are modest compared to others.

The availability of financing – the third factor – depends on a whole range of reasons. Here, the expected profitability of the projects, and the acuteness of the problem to be solved, and the difficulties in the presence of a large number of potential participants, and involvement in regional energy sector development programs, and many other difficult formalized circumstances.

Among the three factors listed, the first two can be evaluated with reference to expert assessments and quantitative indicators, and the latter only expertly. The remaining three factors are also evaluated expertly.

To fill in the matrix of pairwise comparisons of the significance of factors for energy efficiency, a ranked series of six indicated in Fig. 1 of the factors of the second level of the hierarchy (step 1 of the initial data preparation procedure) is as follows: the share of the fuel and energy sector – the technical level of the fuel and energy sector – the investment efficiency of the industry – the general level of the region’s economy – regional energy policy – financing opportunities. Then, following the above procedure, the matrix of pairwise comparisons takes on the form (the rows and columns are the factors in the order in Fig. 1):

1	6	4	3	4	6
1/6	1	2	1/4	1/2	4
1/4	1/2	1	1/5	1/3	3
1/3	4	5	1	2	6
1/4	2	3	1/2	1	5
1/6	1/4	1/3	1/6	1/5	1

[1] Use of fuel and energy resources in the Komi Republic / Statistical Bulletin No. 02-76-82 / 1. Syktyvkar: Komistat, 2019. 12 p.

The normalized eigenvector of this matrix, corresponding to its largest eigenvalue, is $[0.415, 0.089, 0.065, 0.249, 0.149, 0.033]$, the consistency ratio (OS) is 0.06, which is significantly less than 0.1 – the permissible upper limit of the OS values [6].

The dependence of factors and sectors of the fuel and energy complex is expressed as matrices (in all matrices, rows and columns correspond to industries):

. for the first factor — the industry's share in the region's fuel and energy sector — the ranked series looks like this: electric power — oil and gas — coal — heat supply — unconventional, and the matrix is –

1	1/6	1/2	1/2	5
6	1	4	3	8
2	1/4	1	1	6
2	1/3	1	1	7
1/5	1/8	1/6	1/7	1

This matrix has its own vector corresponding to the largest eigenvalue $[0.103, 0.500, 0.175, 0.191, 0.032]$, there is a consistency relation for it OS=0,041;

. for industry-wide investment efficiency in improving energy efficiency, the ranked series are as follows: non-traditional – heat power – electric power – oil and gas and coal; the matrix has the form

1	3	3	1/3	1/5
1/3	1	1	1/4	1/7
1/3	1	1	1/4	1/7
3	4	4	1	1/4
5	7	7	4	1

with normalized eigenvector $[0.123, 0.056, 0.056, 0.224, 0.540]$, OS=0,042;

. for the availability of project financing, a ranked series: non-traditional – electric power – heat power – oil and gas – coal, and the matrix –

1	5	7	2	1/3
1/5	1	3	1/3	1/7
1/7	1/3	1	1/5	1/8
1/2	3	5	1	1/5
3	7	8	5	1

with normalized eigenvector $[0.248, 0.065, 0.034, 0.143, 0.509]$, OS=0,049;

. д for the technical level of the fuel and energy complex, the ranked series looks like: electric power and oil and gas – coal – power – non-traditional; matrix –

1	1	3	4	6
1	1	3	4	6
1/3	1/3	1	3	5
1/4	1/4	1/3	1	3
1/6	1/6	1/5	1/3	1

with normalized eigenvector $[0.353, 0.353, 0.166, 0.086, 0.043]$, OS=0,039;

. for the general level of economic development of the region, ranking will be given by a number of electric power industry – oil and gas – coal – heat power industry – unconventional, and the matrix will take

1	3	4	6	7
1/3	1	3	5	6
1/4	1/3	1	3	5
1/6	1/5	1/3	1	3
1/7	1/6	1/5	1/3	1

with normalized eigenvector $[0.477, 0.271, 0.144, 0.070, 0.038]$, OS=0,066;

• and for the elaboration and quality of the regional energy policy, the ranked series looks like this: unconventional – heat power – coal – electric power – oil and gas, which gives a matrix –

1	3	1/3	1/4	1/6
1/3	1	1/4	1/6	1/7
3	4	1	1/3	1/4
4	6	3	1	1/3
6	7	4	3	1

with normalized eigenvector $[0.074, 0.040, 0.139, 0.263, 0.484]$, OS=0,058.

Once again, I note that these initial data were obtained for the Komi Republic – for other regions, they can differ, sometimes very significantly. As for the quality of the initial information, the transitivity requirement is met for all six matrices, and the consistency ratio indicator is in a good range from 0.03 to 0.07, which indicates a rather high quality of the initial data. After we multiply the 5 × 6 matrix on the right, consisting of columns of normalized eigenvectors of all six factor matrices, by the normalized eigenvector of the energy efficiency matrix, we obtain a vector whose components are the weights (numerical indicators of relative importance) of the five main sectors of the fuel and energy complex, which form the lower level of the hierarchy (Fig. 1) – $[0.231, 0.346, 0.147, 0.149, 0.127]$.

Conclusion

The main result of the work is a developed method for determining the potential contribution of the fuel and energy sectors to improving the energy efficiency of the economy. It is useful in developing project plans and activities for programs aimed at improving the energy efficiency of regional economies and beyond.

In addition, undertaking this study, the author set one of the main goals to find out the prospects of alternative energy for the Komi Republic. So, the oil and gas industry turned out to be the most significant (34.6%) in terms of improving energy efficiency – this is not surprising given its contribution to the production of energy resources in the Komi Republic. Electricity is in the second place is (23.1%). Then, with approximately the same significance, the coal industry (14.7%) and the heat industry (14.9%) are. A combination of new, unconventional energy sources with a result of 12.7% is in last place. It is important to note here that they are only slightly inferior to the traditional coal industry and thermal power industry – and this is contrary to the fact that at present their contribution to the fuel and energy balance of the republic is very small. Here their great potential manifested itself precisely in terms of improving energy efficiency, and therefore work in this direction needs to be developed and strengthened. This conclusion – about the high potential of non-traditional energy sources – can be considered one of the main results of the work. Another significant result is the first developed rule for the preparation of initial data for the Analitical Hierarchy Process, which minimizes such undesirable properties as violation of transitivity and inconsistency. Its simplicity, which does not require mathematical training that goes beyond the framework of the Analitical Hierarchy Process, makes it promising for practical use.

References

1. Shhelokov Ja. M. *Energetika Rossii: voprosy jenergojeffektivnosti i politiki* [Russian Energy: Energy Efficiency and Policy Issues]. *Energosberezhenie* [Energy saving], 2017, no. 1, pp. 28–33 (In Russian).

2. Lebedev Ju. A., Pel'chenkov M. V. *Analiz programm stimulirovanija i normirovanija jenergojeffektivnosti: rossijskij i zarubezhnyj opyt* [Analysis of incentive programs and rationing energy efficiency: Russian and foreign experience]. *Mezhdunarodnyj nauchno-issledovatel'skij zhurnal* [International Research Journal], 2017, no. 11(65), pp. 171–176.

3. Zhigalov V. M., Pahomova N. V. *Sovremennaja sistema strategicheskogo planirovanija jenergosberezhenija i povyshenija jenergojeffektivnosti v Rossii v kontekste novoj klimaticheskoj politiki* [The modern system of strategic planning for energy conservation and energy efficiency in Russia in the context of the new climate policy]. *Problemy sovremennoj ekonomiki* [Problems of the modern economy], 2015, no. 3, pp. 62–72.

4. *Energetika dlja zavtrashnego mira. Dejstvovat' sejchas (Zakljuchenie Vsemirnogo jenergeticheskogo Soveta 2000 g.)* [Energy for tomorrow's world. Act now (World Energy Council 2000)]. *Elektricheskie stancii* [Power stations], 2005, no. 2, pp. 67–70.

5. Sadov S. L. *Opredelenie znachimosti vidov regulirovanija dlja povyshenija jenergojeffektivnosti v severnyh regionah* [Determination of the importance of regulation to improve energy efficiency in the northern regions]. Corporate Governance and Innovative Development of the North Economy: Bulletin of the Research Center for Corporate Law, Management and Venture Investment of Syktyvkar State University, 2018, no. 4, pp. 47–52.

6. Saati T. *Prinjatie reshenij. Metod analiza ierarhij. Per. s angl. R.G. Vachnadze* [Making decisions. Analytical Hierarchy Process. Trans. from English by R.G. Vachnadze]. Moscow: *Radio i svjaz'* [Radio and communication]. 1993. 278 pp.

7. Zajchenko I. M., Gutman S. S. *Primenenie metoda analiza ierarhij dlja vybora strategicheskogo prioriteta jenergeticheskogo razvitija rajonov Krajnego Severa* [Application of the Analitical Hierarchy Process to select the strategic priority of energy development in the Far North]. *Vestnik Zabajkal'skogo gosudarstvennogo universiteta* [Bulletin of the Transbaikal State University], 2017, vol. 23, no. 7, pp. 114–123.

8. Locatelli, Giorgio; Mancini, Mauro, 2012. A framework for the selection of the right nuclear power plant. International Journal of Production Research. 50 (17): pp. 4753–4766. DOI:10.1080/00207543.2012.657965.

9. Saracoglu, B.O., 2013. Selecting industrial investment locations in master plans of countries. European Journal of Industrial Engineering. 7 (4): pp. 416–441. DOI:10.1504/EJIE.2013.055016.

10. Kuz'kin A.A. *Metodika obespechenija ustojchivosti strategii razvitija informacionnyh tehnologij v organizacii* [Methodology for the sustainability ensuring of the development strategy of information technology in the organization]. *Trudy SPIIRAN* [Proceedings of SPIIRAS], 2014, Issue 6(37), pp. 95–115.

11. Thomas L. Saaty and L.G. Vargas, 2001. Models, Methods, Concepts & Applications of the Analytic Hierarchy Process. Boston: Kluwer Academic, pp. 345. DOI: 10.1007/978-1-4614-3597-6.

12. Saaty, Thomas L, 2008. "Relative Measurement and its Generalization in Decision Making: Why Pairwise Comparisons are Central in Mathematics for the Measurement of Intangible Factors – The Analytic Hierarchy/Network Process". Review of the Royal Academy of Exact, Physical and Natural Sciences, Series A: Mathematics (RACSAM). 102 (2), pp. 251–318. DOI:10.1007/bf03191825.

13. Zaharov V.P. *Energosberezhenie kak faktor razvitija regionov* [Energy saving as a factor in the development of regions]. *Upravlencheskoe konsul'tirovanie* [Management consulting], 2015, no. 9, pp. 130–139.

14. Saaty, Thomas L., 2009. Mathematical Principles of Decision Making: Comprehensive coverage of the AHP, its successor the ANP, and further developments of their underlying concepts. Pittsburgh, Pennsylvania: RWS Publications.

15. Saaty, Thomas L., 2013. On the Measurement of Intangibles. A Principal Eigenvector Approach to Relative Measurement Derived from Paired Comparisons. Notices of the American Mathematical Society, 60(2): pp. 192–208. DOI: 10.1090/noti944.

Для цитирования: Sadov S. L. Finding the potential contribution of the fuel and energy sectors to increase the energy efficiency of the economy // Корпоративное управление и инновационное развитие экономики Севера: Вестник Научно-исследовательского центра корпоративного права, управления и венчурного инвестирования Сыктывкарского государственного университета. 2019. № 4. С. 92–98. DOI: 10.34130/2070-4992-2019-4-92-98.

For citation: Sadov S. L. Finding the potential contribution of the fuel and energy sectors to increase the energy efficiency of the economy // Corporate governance and innovative economic development of the North: Bulletin of the Research Center of Corporate Law, Management and Venture Capital of Syktyvkar State University. 2019. No. 4. Pp. 92–98. DOI: 10.34130/2070-4992-2019-4-92-98.