Iosifov, Valeriy Victorovich; Almastyan, Nairuhi Akopovna; Figus, Alessandro et al.

Article

The problem of harmonizing the environmental priorities of electricity generating companies and regional socio-economic systems : DEA-based approach

International Journal of Energy Economics and Policy

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2017, 7(5), 159-165.

The Problem of Harmonizing the Environmental Priorities of Electricity Generating Companies and Regional Socio-economic Systems: DEA-based Approach

Valeriy Victorovich Iosifov[1], Nairuhi Akopovna Almastyan[2], Alessandro Figus[3], Yuri Alexandrovich Chepurko[4]*, Nguyễn Hoàng Hiển[5], Marina Alexandrovna Krotova[6]

[1]Department of Land Transportation and Mechanics, Kuban State Technological University, Krasnodar, Russia, [2]Analytical Center of Kuban State University, Krasnodar, Russia, [3]Department of International Relations, Università Degli Studi Link Campus University, Italy, [4]Department of Economics, Kuban State University, Krasnodar, Russia, [5]Faculty of State Management on Economic Affairs, National Academy of Public Administration, Vietnam, [6]Faculty of Economics, Kuban State University, Russia.
*E-mail: chepurko@yandex.ru

ABSTRACT

This paper suggests a two-step method of non-parametric optimization, in which the problem of increasing efficiency of energy companies on a set of ecologic and economic parameters is viewed as a sub-problem of increasing the overall ecologic and economic efficiency of the regional economic system. This task is based on the input-oriented ecological data envelopment analysis model with variant returns to scale. The method was tested by coordinating the ecologic priorities of one of the biggest Russian electric and heat generators "OGK-2" and the Krasnoyarsk Region.

Keywords: Ecologic and Economic Efficiency, Energy Companies, Interest Coordination, ISO 14001:2015 Standard, Non-parametric Optimization, Data Envelopment Analysis
JEL Classifications: O33, Q42, Q47, Q48

1. INTRODUCTION

The electric power industry is traditionally considered to have a significant negative impact on the environment. During the production of electricity and heat, large volumes of primary energy are processed, which leads to negative environmental effects such as emissions of various pollutants and greenhouse gases into the air, abstraction of natural waters, discharges of pollutants into water bodies, and solid waste generation.

The new version of the ISO 14001:2015 standard increases requirements towards the regional context of business activity for companies, which now need to look at the most important regional ecologic problems while developing their ecologic policies. Considering the fact that in Russia the penetration rate of ISO 14001 is the highest among energy companies, the scientific problem of developing methods for coordinating the ecological priorities of energy companies and regional socio-economic systems on their territory are becoming more relevant. The problem of reducing negative impact of the economy on the environment and the withdrawal of regional economic systems (RES) on the trajectory of sustainable development is not trivial: Not only from the investment and technological point of view, but also methodologically. In this framework is highly adopted environmental data envelopment analysis (EDEA) method. In general the interests of the regions and electric generating companies, represented as a set of optimal solutions of EDEA models, may not overlap. Therefore, in this paper, a two-step EDEA method is developed, for the purpose of coordination of the environmental priorities of power generating companies and regional socio-economic systems. It includes the consistent solution of two tasks of nonparametric optimization and the use of target parameters for reducing the primary negative effects of RES for choosing the highest-priority areas of the environmental policies of power generating companies.

2. LITERATURE REVIEW

Nowadays one of the most popular instruments of environmental management on the enterprises of various industries, including the electric power industry, are the international standards of the ISO 14000 family (Comoglio and Botta, 2012; Zobel, 2013; Testa et al., 2014). In Russia, the interest from the business environment in certification according to ISO 14001 "Environmental management systems - requirements with guidance for use" is still very weak, but the level of prevalence of the standard among Russian energy companies is much higher than in other industries, which can be explained by their export orientation. The share of Russian energy companies in the total number of ISO 14001 certificates in 2015 was 14%, while the similar share of energy companies in the world as a whole at the same time was only 3% (Ratner and Iosifov, 2017).

In 2015, a new version of the ISO 14001 standard, corresponding to the innovative ISO format for the development of standards for management systems was published. Comparing to the old version it is implying a significant expansion of the requirements for the formulation of the company's environmental policy. The approval of the Russian national standard in accordance with the new version of ISO 14001:2015 has happened in 2016, which means that the transition to it should be carried out by enterprises within the next 3 years. One of the important differences between the version of the 2016 standard and the old one of 2007 is the introduction of the concepts of "stakeholders" and the "context" of the organization, so the enterprise in the new version of the standard is considered not as an isolated object, but as an agent of a certain socio-ecological and economic system (Ratner and Iosifov, 2017). When forming an environmental management system, a company must take the regional context of its activities and the interests of other agents of the socio-economic system into account. Hence, the issues of coordinating the environmental priorities of power generating companies with the optimal (from the ecological and economic point of view) trajectory of development of the RES are becoming especially topical.

When developing projects for the economic development of territories, decision makers need to take the multidimensional nature of social, environmental and economic effects into account, the connections between which are not always clear and obvious (Nizhegorodtsev and Ratner, 2016; Ratner and Ratner, 2016), which leads to the emergence of multi-criterion nonparametric optimization problems. In Ratner and Ratner, (2017) it was shown that such problems can be successfully solved by constructing models of EDEA. At present, EDEA is a developed methodology for assessing the comparative complex ecological and economical effectiveness of a set of homogeneous objects using various models of mathematical programming, both linear and nonlinear (Cook and Seiford, 2009; Korhonen and Luptacik, 2004; Bian and Yang, 2010). EDEA allows to identify objects whose activities can be recognized as effective, and find the best way to approach the efficiency boundary for inefficient objects.

In the process of development of environmental policies in case of a large energy company, some multi-criteria nonparametric optimization problems also arise and then can be solved by various EDEA-models (Ratner and Ratner, 2017).

For the first time, this problem was solved in (Ratner and Almastyan, 2016), however, in this paper the models with constant returns to scale were considered, whereas in the problems of estimating negative environmental effects it is better to use DEA-models with variable returns to scale in order to take the process of negative impact accumulation into account. So, in this paper we use an EDEA-model with variable returns to scale for evaluation of the scores of complex ecological and economical effectiveness of the regions of Russia and identification of targets for reduction of negative ecological effects.

3. DATA ANALYSIS AND ESTIMATION TECHNIQUES

3.1. DEA-based Problem for Evaluation of the Targets for Environmental Protection in Regional Social-economic Systems

Let's consider the task of evaluating the complex ecologic and economic efficiency of RES through a number of indicators, representing resources needed for economic activities (such as energy, raw materials, labor, capital, etc.), the positive value of production activities and their negative ecological effects. Using a basic input-oriented EDEA model (Färe and Grosskopf, 2004) we can consider resources as inputs, positive economic effects as desirable outputs and negative ecological effects as undesirable outputs in the model. It is worthy to remind that the main difference between EDEA and traditional DEA models lies in the presence of unwanted outputs. The desirable outputs of economic activities on the regional level can be measured with a variety of widely-used indicators, such as the gross regional product (GRP), regional gross value added, population's levels of income in the region, etc. Furthermore, each RES (considered in the model as decision making unit [DMU]) also produces some negative ecologic effects as an unavoidable result of economic activity (atmosphere pollution, solid waste, waste water, etc.). For each RES, we look for a way to reduce the inputs (use of resources) and undesirable outputs (negative ecologic effects) without reducing desirable outputs (economic results). DMUs that produce maximal results with minimal negative ecologic effects and resource consumption can be considered effective.

The mathematical formalization of the problem is as follows. Let there be K homogenous DMUs, each of which is defined with N inputs and M outputs. Outputs 1, 2,… p are desirable (useful economic and social results) and outputs p+1, p+2,…, M are undesirable (negative ecological effects).

In the coefficient form, the problem of evaluating the efficiency of the 0[th] DMU can be written down as:

$$\max_{u,v} \sum_{m=1}^{M} u_m y_{m0} \tag{1}$$

s.t.

$$\sum_{m=1}^{M} u_m y_{mk} - \sum_{n=1}^{N} v_n x_{nk} \leq 0 \quad k\ 1, 2, \cdots K,$$

$$\sum_{n=1}^{N} v_n x_{no} = 1$$

u_m, $V_n \geq 0$ m = 1,2, …m n = 1,2,…n

Where

$X = (x_{10}, \ldots x_{No}^{t}) \geq 0$ is a vector of inputs of size N,

$Y = (y_{l0}, \ldots y_{M0}) \geq 0$ is a vector of outputs of size M,

K is the number of DMUs,

- Unknown non-negative weights that need to be determined by solving the task.

For each DMU, we solve a rational linear programming task to maximize the following ratio of weighted sums:

$$h = \frac{\sum_{r=1}^{p} \mu_r y_{ro} - \sum_{s=p+1}^{N} \mu_s y_{s0}}{\sum_{i=1}^{M} v_i x_{i0}}, \quad (2)$$

s.t.

$$\frac{\sum_{r=1}^{p} \mu_r y_{rj} - \sum_{s=p+1}^{N} \mu_s y_{sj}}{\sum_{i=1}^{M} v_i x_{ij}} \leq 1$$

The ratio (2) is the complex efficiency measure for ecologic and economic efficiency of a DMU. DMUs that have this coefficient (efficiency score) equal to 1 are considered effective, and the others are not. A well-known study (Korhonen and Luptacik, 2004) proves that the undesirable outputs can simply be viewed as inputs, in this case, the efficiency measure (2) becomes:

$$h^* = \frac{\sum_{r=1}^{k} \mu_r y_{ro}}{\sum_{i=1}^{M} v_i x_{io} + \sum_{s=k+1}^{p} \mu_s y_{so}} \quad (3)$$

In some practical applications for ecology problems, undesirable outputs can be used as the only inputs for a model. This simplified version of the problem identifies the RESs, that produce the maximal social and economic results with the minimal negative ecological effects, as efficient. Inefficient DMUs (RES that have efficiency scores below 1) can have their inputs proportionally reduced to move closer to the efficiency frontier (Cook and Seiford, 2009) and this result has a lot of very important regional environmental policy application. Thus, in the paper (Ratner and Ratner, 2017) a new methodological approach for assessment of regional environmental efficiency with the use of CCR models was developed. It was shown that solving an EDEA model can give a reasonable target for each inefficient region to improve its ecological indicators in order to achieve complex economic and ecological efficiency.

These results can be achieved through the use of BCC model, that differs from the CCR only by adopting a variable scale effect. The BCC model allows to determine of the increasing or decreasing economies of scale for each DMU, and, thus, to divide their total efficiency into technical efficiency and efficiency, depending on the economies of scale, as shown in (Schefczyk, 1996) for agricultural enterprises. In the case of a constant scale effect, the output parameter varies in proportion to the input factor. Changing the input factor with a variable scale effect can lead to a disproportionate change in the output parameter. This assumption fully corresponds to the economic theory of diminishing marginal utility and has a significant effect on the values of the efficiency scores. From ecological point of view, it reflects the effect of accumulation of negative environmental impacts in a more adequate way.

So, let's consider as inputs of the EDEA model of assessing the environmental and economic efficiency of the regions, the following indicators characterizing the impact of RES on the environment:

- x_1 - the annual volume of emissions of pollutants into the atmosphere from stationary sources, kt (reflects predominantly the impact of the economy);
- x_2 - the annual volume of emissions of pollutants into the atmosphere from mobile sources, kt (reflects the impact of the economy and the population);
- x_3 - the annual volume of discharges of polluted sewage into surface water bodies, million cubic meters (reflects the impact of the economy and the population);
- x_4 - the annual volume of waste generation, million tons (reflects the impact of the economy and the population);
- x_5 - the annual volume of abstraction of fresh water, million cubic meters (reflects the impact both the economy and the population).

As outputs of the model, representing the socio-economic outcome of the RES activity, the following indicators were selected:

- y_1 -GRP, million rubles;
- y_2 - population, thousands people.

The results of the calculation of efficiency scores for 79 regions of Russia completed in the MaxDEA using the BCC-input-oriented model on the data taken from the statistical collections "Regions of Russia. Socio-economic indicators, 2010-2014," are presented in Section 2. The target parameters that need to be achieved for inefficient regions in order to become more efficient are also presented in Section 2. When solving the problem of reconciling the interests of RES and electricity generating companies, these indicators of the potential for reducing negative environmental effects calculated are the main result, since they determine the priority directions of the environmental activity of the electric power industry enterprises.

3.2. DEA Problem for Evaluation the Scores of Complex Economic and Ecological Effectiveness for Electric Generating Companies

Here we formulate the second EDEA problem for DMUs, that now represent electricity generation companies of Russia.

Let the following parameters indicate the inputs of the EDEA model:

- x_1- the annual volume of emissions to the atmosphere (thousand tons);
- x_2 - the annual volume of solid waste generation (thousand tons);
- x_3 - the volume of fresh water consumption for the company's production and domestic needs (million cubic meters).

As one can see these parameters partly match the inputs of EDEA model for regional socio-economy systems, in other words, they deal with the same negative ecological effects. Since these two models are input-oriented, their solution will give us the understanding of how the inputs of inefficient DMUs (negative ecological effects) need to be reduced. When the generating company is located in an inefficient region, the reduction of its inputs (negative ecological impact) will simultaneously reduce the inputs of the regional socio-economic system. Thus, this results in harmonization of environmental management goals of the company and the region.

As one can notice, the introduction of the fourth indicator - the annual volume of discharges of insufficiently treated sewage - would completely solve the problem of reconciling the interests of electricity generating companies and regions, but it is not technically possible in view of the lack of statistical data on this indicator in the reports of energy companies.

As the outputs of the model, we consider the annual production of electric energy (million kWh) and thermal energy (thousand Gcal). The presence of two outputs responsible for power generation and thermal generation allows us to take the positive impact of cogeneration technologies on the overall environmental and economic efficiency of the company into account. We will solve the CCR problem with a constant scale effect for the primary players in the wholesale electricity market: Five biggest wholesale electricity market generating companies and several territorial generating companies (a total of 24 companies). It will allow us to find efficient companies that produce the biggest amount of energy (both electric and heat) with the lowest impact on environment. For inefficient companies, which have efficiency scores below 1, we can also calculate the target parameters of each input and use it for goal-setting in environmental policies.

It is worth noting that each of the companies under consideration is a large holding, the production divisions of which are located in different regions. But the solution of the task of efficiency evaluation at a more detailed level (the level of individual power plants), from our point of view, seems inappropriate, since a decision-making process takes place on the integrated level. It is the integrated structures that develop ecology policy, innovation policy, the design of environmental management systems, take company through the process of ISO 14001 certification and elaborate the projects for reduction of negative impact on the environment. At the same time, if the company is considered inefficient, a third EDEA problem can be solved for the evaluation of comparative ecological and economic effectiveness of each utility in the holding. Then each inefficient utility can determine the goals of environmental policy taking into account target parameters, obtained by solving the EDEA problem.

In practice, a simultaneous achievement of reduction of all negative environmental effects is usually difficult due to the lack of financial resources for complete modernization of the production process, sometimes it is simply impossible at the current level of technology development. In this case, the choice of particular measures to reduce the negative environmental impact can be made by determining the fastest path to the efficiency frontier.

Let us denote h_{nj}^{if} as the conditional score of the efficiency of the j^{th} production object, which is calculated under the assumption that the n^{th} input of the model takes its target value $x_{nj} = x_{nj}^{tar}$, and all other inputs of the model stay the same as their real values. In this case, since the approximation to the efficiency boundary occurs in one direction, obviously, the condition $h_j \le h_{nj}^{if}$ is satisfied, i.e., the score of efficiency increases. Obviously, the number of conditional scores is equal to the number of inputs of the model. Knowing all conditional scores can help us to choose the way to move to efficiency frontier.

Depending on the choice of the production object in EDEA problem, the conditional scores of effectiveness can be calculated for individual utilities, for electric generating holdings and, finally, for regional social-economic systems. This approach allows one to determine the preferred way for achieving efficiency for individual utilities, electric generating holdings and regional social-economic systems, which, in general, can mismatch. The environmental priorities of individual company, selected on the criterion of reducing various types of production and non-production costs (including the costs of environmental payment and emissions) generally do not coincide with the priorities for the sustainable development of regional economies. The incentive for the individual companies for implementation of environmental protection measures which help regions to become effective can be the possibility of successful certification under the new requirements of ISO 14001: 2015, which focuses on the regional component of the activities of enterprises.

4. RESULTS OF COMPUTATIONS

The results of calculations of effectiveness scores for RESs, presented in Table 1, show that only 18 regions out of 78 can be considered effective: The Kaluga Region, the Moscow Region, the Republic of Kalmykia, the Krasnodar Territory, the Republic of Dagestan, the Republic of Ingushetia, the Kabardino-Balkarian Republic, The Republic of Chechnya, the Republic of Bashkortostan, the Republic of Mordovia, the Republic of Chuvashia, the Saratov Region, the Tyumen Region, the Republic of Altai, the Republic of Tyva, the Altai Territory, the Jewish Autonomous Region and the Chukotsky Autonomous District. For all other regions the reduction of negative ecological impacts (considered as inputs of the EDEA model) is needed.

The results of calculation of efficiency scores and targets for reducing negative environmental effects for inefficient electricity generating companies, are presented in Table 2. They were

Table 1: The efficiency scores of Russian regions

Regions of Russia	2010	2011	2012	2013	2014
Belgorod	0.68	0.57	0.97	0.96	0.94
Bryansk	1	1	0.99	0.96	1
Vladimir	1	0.97	1	1	1
Voronezh	0.76	0.76	1	1	1
Ivanov	0.70	0.70	0.78	0.76	0.77
Kaluga	1	1	1	1	1
Kostroma	0.62	0.57	0.67	0.67	0.55
Kursk	0.66	0.66	0.80	0.82	0.98
Lipezk	0.63	0.60	0.72	0.66	0.81
Moscow (not including Moscow City)	1	1	1	1	1
Orel	0.89	0.86	1	0.81	0.99
Ryazan	0.59	0.57	0.63	0.62	0.69
Smolensk	0.64	0.58	0.69	0.63	0.81
Tambov	1	1	1	0.93	0.97
Tver	0.57	0.65	0.65	0.67	0.91
Tula	0.55	0.52	0.68	0.58	0.58
Yaroslavl	0.55	0.53	0.71	0.77	0.86
Kareliya Republic	0.47	0.45	0.61	0.49	0.49
Komi Republic	0.49	0.49	0.84	0.91	1
Archangelsk	0.59	0.57	0.76	0.63	0.62
Vologda	0.48	0.48	0.66	0.74	0.60
Kaliningrad	0.87	0.93	1	1	1
Leningrad	0.53	0.52	0.74	0.77	0.72
Murmask	0.72	0.61	1	0.77	0.80
Novgorod	0.61	0.56	0.97	0.66	0.80
Pskov	0.59	0.48	1	0.48	0.53
Adygea Republic	0.81	0.65	1	0.96	1
Kalmyikiya Republic	1	1	1	1	1
Krasnodar	1	1	1	1	1
Astrachan’	0.52	0.43	0.78	0.75	1
Volgograd	0.56	1	0.99	0.96	0.90
Rostov	0.77	0.79	1	1	0.85
Dagestan Republic	1	1	1	1	1
Ingushetia Republic	1	1	1	1	1
Kabardino-Balkarskaya Republic	1	1	1	1	1
Karachaevo-Cherkesskaya Republic	0.76	0.61	0.63	0.63	0.45
Northern Osetiya Republic	0.70	0.65	0.82	0.91	0.81
Chechenskaya Republic	1	1	1	1	1
Stavropol	0.97	0.86	1	1	1
Bashkortostan Republic	1	1	1	1	1
Mariy El Republic	0.83	0.76	0.87	0.88	0.87
Mordoviya Republic	1	1	1	1	1
Tatarstan Republic	0.92	1	1	1	1
Udmurtskaya Republic	1	1	0.91	1	1
Chuvashskaya Republic	1	1	1	1	1
Perm	0.56	0.57	0.88	0.73	0.69
Kirov	0.68	0.60	0.80	0.65	0.70
Nizhniy Novgorod	0.66	0.63	1	1	1
Orenburg	0.46	0.44	0.76	0.64	0.66
Penza	0.95	0.74	1	0.96	0.93
Samara	0.50	0.48	0.81	0.83	0.82
Saratov	1	1	1	1	1
Ul’yanovsk	0.94	0.82	0.93	0.89	0.86
Kurgansk	1	1	0.93	0.95	1
Sverdlovsk	0.99	1	1	1	1
Tyumen’	1	1	1	1	1
Chelyabinsk	0.55	0.53	0.89	1	0.96
Altay Republic	1	1	1	1	1
Buryatia Republic	0.60	0.65	0.66	0.50	0.55
Tyva Republic	1	1	1	1	1

(Contd...)

Table 1: ***(Continued)***

Regions of Russia	2010	2011	2012	2013	2014
Khakassia Republic	0.61	0.63	0.76	0.72	0.80
Altay Kray	1	1	1	1	1
Zabaykalskiy Kray	0.71	0.54	0.67	0.86	0.81
Krasnoyarsk	0.44	0.43	0.86	0.75	0.91
Irkutsk	0.44	0.41	0.64	0.60	0.90
Kemerovo	0.62	0.58	0.93	0.89	0.98
Novosibirsk	0.68	0.67	1	1	1
Omsk	0.77	0.76	1	1	1
Tomsk	0.65	0.58	0.96	0.98	1
Sacha Republic	0.62	0.59	0.79	0.88	1
Kamchatka	0.62	0.83	0.76	0.70	0.97
Primorskiy Kray	0.54	0.53	0.84	0.86	0.81
Chabarovsk	0.58	0.53	0.80	0.86	0.71
Amursk	0.74	0.77	0.94	0.92	0.86
Magadan	0.59	0.55	0.62	0.61	0.62
Sakhalin	0.60	0.59	1	1	1
Jewish Autonomous Region	1	1	1	1	1
Chukotsky AutonomSous Region	1	1	1	1	1

Source: Authors calculation

calculated by MaxDEA software for the last year in the observation period.

The worst indicators of environmental and economic efficiency are exhibited by “Kuzbassenergo,” “Enel OGK-5,” “Enisseyskaya TGK,” OGK-3 and OGK-2. Increasing the environmental and economic efficiency of these production facilities is possible when moving to the efficiency frontier in different directions. The choice of the best direction can be carried out with the help of technical and economic analysis, in which existing technological capabilities (the best available technologies) are taken into account, and their economic indicators, such as the required investment volume, payback period (due to lower costs for environmental payments and penalties), etc. But when the task of increasing the efficiency of the power generating company is subordinate to the task of increasing the environmental and economic efficiency of the RES as a whole, the environmental priorities of the company should be determined not only on the basis of corporate interests, but also on the basis of harmonization with the priorities of sustainable development of the regions in which they are located.

Consider the algorithm for solving the subordinate task by the example of choosing the way to improve the efficiency of OGK-2. OGK-2 is a large corporation that unites several production facilities located in different regions of Russia. The structure of OGK-2 includes such generating facilities as Adlerskaya CHP (Krasnodar Krai), Kirishskaya CHP (Leningradskaya Oblast), Krasnoyarskaya CHP (Krasnoyarsk Territory), Novocherkasskaya CHP (Rostov Region), Pskovskaya CHP (Pskov Oblast), Ryazan CHP (Ryazan Oblast), Serovskaya CHP (Sverdlovsk Region), Stavropolskaya CHP (Stavropol Territory), Surgutskaya CHP (Tyumen Region), Troitskaya CHP (Chelyabinskaya Oblast) and Cherepovetskaya CHP (Vologda Region).

Two generating facilities (Kirishskaya CHP and Krasnoyarskaya CHP) are located in the regions which are recognized as the

Table 2: The results of solving the EDEA CCR problem for power generating companies of Russia

Название	Score of efficiency	Target for air pollution, Kt	Target for waste, Kt	Target for water consumption, mln. m^3
OGK-1	0.37	91.5	224.66	886.87
OGK-2	0.17	377.9	927.84	3662.84
OGK-3	0.14	186.1	456.92	1803.79
OGK-4 "E.ON Russia"	0.61	91.5	240.94	676
"Enel OGK-5"	0.13	330.3	917.29	1825
TGK-1	0.40	54.59	98.1	526.6
TGK-2	0.27	82.98	237.7	364.7
Moscow Energy Company	1.00	51.4	126.2	498.2
TGK-4 "Kvadra"	0.97	20.94	35.6	201.8
TGK-5	0.94	26.04	80.5	107.8
TGK-6	0.59	26.3	30.5	282.17
"Volga TGK" (TGK-7)	1.00	34.2	39.1	328.3
TGK-9	0.49	122.2	350.37	532.7
"Fortum" (TGK-10)	0.48	51.3	141.87	291.2
TGK-11	1.00	131.8	1658.4	73.2
"Kuzbassenergo" (TGK-12)	0.11	173.6	456.03	1296.9
"Enisseyskaya TGK" (ТГК-13)	0.14	127.3	352.20	720.6
TGK-14	0.72	36.56	105.20	154.3
Generating companies of "Lucoil" group	1.00	19.2	18.6	356.2
"Dalnevostochnaya GK"	0.26	245.7	1981.86	555.6
"Irkutsk Energo"	0.53	119.34	343.43	503.7
"Tatenergo"	1.00	17.2	49.5	72.6
"Bashkirenergo"	0.84	30.03058	79.3	219
"SIBECO"	0.22	82.5	230.54	437.4

Source: Author's calculations based on data of Russian Ministry of Energy, EDEA: Environmental data envelopment analysis

regions with the worst indicators of environmental and economic efficiency. Therefore, the priority areas of OGK-2's activities to improve the efficiency of its activities should be the environmental aspects, according to which these regions need the greatest development of eco-innovations: A decrease in wastewater discharge in the Leningrad region (the location of Kirishskaya CHP) and a reduction in fresh water consumption in Krasnoyarsk Territory (the location of Krasnoyarsk CHP).

5. CONCLUDING REMARKS

The two-step algorithm of harmonization of the priorities of the environmental policy of power generating companies and the regions in which they are located developed in this paper allows us to choose the most preferable directions for technological modernization of energy companies from the point of view of the region. However, for the company itself, the chosen path may not be the most preferable from the point of view of its corporate interests and the goals of innovative development. The required modernization can be financially costly (Sinyak and Kolpakov, 2014), not fit existing state support programs for innovative development in electricity generating companies (Ratner and Nizhegorodtsev, 2017), or assume introduction of yet not fully mature (in Russia) technologies such as wind energy generation (Fortov and Popel, 2014; Ratner and Klochkov, 2017; Tarasenko and Popel 2015) or geothermal energy generation (Alkhasov and Alkhasova, 2014). In such cases, the incentives resulting from certification according to ISO 14001 may not be sufficient for the companies to launch the process of negative environmental impact reduction. Considering the fact that the most significant effects from the implementation of innovation projects of power generating companies will be obtained at the regional level, it seems appropriate to envisage the introduction at the regional level of additional economic stimulus measures aimed at externalizing the positive externalities of the environmental activities of energy companies. For example, it may be additional opportunities to use the resources, infrastructure and intellectual potential of regional innovation systems (Ratner and Ratner, 2016).

The problems of coordinating the priorities of innovative development of power generating companies with the goals of reducing the negative impact on the environment and keeping up the economic feasibility are multi-criterial and complex. The traditional methods of their solution such as technical and economic analysis do not always allow to find an optimal way of development. That's why the elaboration of special methods is needed. New methods should allow to find optimal trajectories for development of complex production systems in a multidimensional ecological and economic space. One of such methods is ecological DEA, the application of which can be used as a basis for the algorithm for reconciling environmental and innovation-investment priorities.

ACKNOWLEDGEMENT

This research is partly supported financially by the Russian Foundation for Basic Research (RFBR), project No. 16-06-00147. Development of data envelopment analysis models for optimizing development of regional economic systems based on ecologic parameters" and completed with the use of scientific equipment of Ecology and Analytical Center of Kuban State University (Krasnodar, Russia), project No. RFMEFI59317X0008.

REFERENCES

Alkhasov, A.B., Alkhasova, D.A. (2014), Up-to-date state and prospects for the development of geothermal resources of the North Caucasus region. Thermal Engineering, 61(6), 411-416.

Bian, Y., Yang, F. (2010), Resource and environment efficiency analysis of provinces in China: A DEA approach based on Shannon's entropy. Energy Policy, 38, 1909-1917.

Comoglio, C., Botta, S. (2012), The use of indicators and the role of environmental management systems for environmental performances improvement: A survey on ISO 14001 certified companies in the automotive sector. Journal of Cleaner Production, 20, 92-102.

Cook, W.D., Seiford, L.M. (2009), Data Envelopment Analysis (DEA) - Thirty years on. European Journal of Operational Research, 192, 1-17.

Färe, R., Grosskopf, S. (2004), Modelling undesirable factors in efficiency evaluation: Comment. European Journal of Operational Research, 157, 242-245.

Fortov, V.E., Popel', O.S. (2014), The current status of the development of renewable energy sources worldwide and in Russia. Thermal Engineering, 61(6), 389-398.

Korhonen, P.J., Luptacik, M. (2004), Eco-efficiency analysis of power plants: An extension of data envelopment analysis. European Journal of Operational Research, 154, 437-446.

Nizhegorodtsev, R.M., Ratner, S.V. (2016), Trends in the development of industrially assimilated renewable energy: The problem of resource restrictions. Thermal Engineering, 63(3), 197-207.

Ratner, S., Iosifov, V. (2017), Eco-management and eco-standardization in Russia: The perspectives and barriers for development. Journal of Environmental Management and Tourism, 1(17), 247-258.

Ratner, S., Ratner, P. (2017), DEA-based dynamic assessment of regional environmental efficiency. Applied Computer Science, 13(2), 48-60.

Ratner, S.V., Almastyan, N.A. (2016), The method of harmonizing the environmental priorities of electricity generating companies and regional socio-economic systems. Innovations, 9, 40-47.

Ratner, S.V., Klochkov, V.V. (2017), Scenario forecast for wind turbine manufacturing in Russia. International Journal of Energy Economics and Policy, 7(2), 144-151.

Ratner, S.V., Nizhegorodtsev, R.M. (2017), Analysis of renewable energy projects' implementation in Russia. Thermal Engineering, 64(6), 429-436.

Ratner, S.V., Ratner, P.D. (2016), Regional energy efficiency programs in Russia: The factors of success. Region, 3(1), 68-85.

Schefczyk, M. (1996), Data envelopment analysis. Eine methode zur effizienz-und erfolgsschätzung von unternehmen und öffentlichen organisationen. Die Betriebswirtschaft, 56, 167-183.

Sinyak, Y.U.V., Kolpakov, A.Y.U. (2014), Analysis of the dynamics and structure of expenses in Russia's oil and gas complex over the 2000-2011 period and forecasts until 2020. Studies on Russian Economic Development, 25(5), 439-455.

Tarasenko, A.B., Popel', O.S. (2015), Manufacturing technologies for photovoltaics and possible means of their development in Russia (Review). Part 1: General approach to the development of photoelectric converters and basic silicon technologies. Thermal Engineering, 62(11), 825-832.

Testa, F., Rizzi, F., Daddi, T., Gusmerotti, N.M., Frey, M., Iraldo, F. (2014), EMAS and ISO 14001: The differences in effectively improving environmental performance. Journal of Cleaner Production, 68, 65-173.

Zobel, T. (2013), ISO 14001 certification in manufacturing firms: A tool for those in need or an indication of greenness? Journal of Cleaner Production, 43, 37-44.