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ENVIRONMENTAL AND ECONOMIC BENEFITS OF THE RUSSIAN ALTERNATIVE ENERGY REGARDING RESOURCE INTENSITY

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Abstract

The article presents results of an analysis of resource intensity of the traditional and alternative electric power industry of the Russian Federation. The environmental and economic advantages of alternative energy were identified. The analysis was carried out using the indicator of total MI (Material Input) – numbers which sets specific resource intensity of various energy sources. The calculation made it possible to obtain totals for all federal districts using alternative energy sources, determine the share of alternative energy in the regional energy balance, the total amount of natural resources consumed, the specific value of alternative energy sources. Russian small hydropower plants and biofuel-powered power plants account for 53.5 % of the alternative energy production, solar energy plants – 26 %, geothermal plants – 11 %, and wind turbines – 9.5 %. The study determined the mass of natural resources used for producing traditional and alternative energy. The volume of substance transferred during the production of traditional energy is 2 billion tons, which is comparable with natural geological forces. Alternative energy can transport 0.42 million tons. The replacement of traditional energy capacities with alternative energy facilities can reduce the level of negative anthropogenic impacts on the environment. The real reduction level was predicted with a further increase in the share of alternative energy in the energy balance of Russia and its regions. The reported study was funded by RFBR, project number 18-010-00861.

Keywords: Resource intensity, environmental benefits, economic benefits, environment, natural resources.

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1. Introduction

The electric power industry has a very significant negative impact on the environment, causing various environmental problems. Traditionally, special attention is paid to emissions and discharges. However, they are only a consequence of transformation of material flows in the natural environment; their change decreases biomass volumes, reduces biodiversity, and decreases the area of natural territories. Production of goods and provision of services redirect biosphere material flows to the socio-economic system, which is the main problem of environmental problems (Lipenkov, 2012).

2. Problem Statement

It is impossible to reduce the negative impact without reducing resource consumption, material and energy flows operating in the technosphere. One of the first publications that has analyzed the resource consumption factor was the report by the Club of Rome created by D. Medouz's group – "Limits of Growth". This paper presents a mathematical model, where main directions of socio-ecological-economic system development are described in dynamics: industrialization, food production, demographic situation, environmental degradation, reduction of available natural resources. The general awareness of the existing problem, and the search for solutions created a concept of sustainable development. Attention is paid to the problem of resource intensity of economic sectors. To achieve the sustainable development goals formulated in 2015, the green economy model was developed. It is designed to become the basis for sustainable development, reduce the level of consumption of natural resources, material flows, the anthropogenic impact on the environment. The Rio de Janeiro Declaration, The Future We Want, adopted in 2012, says that "The green economy in the context of sustainable development and poverty reduction will strengthen our ability to rationally use natural resources, reduce negative environmental impacts, increase resource efficiency and reduce waste." It is the green economy that is called upon to ensure further economic growth while reducing material flows which can improve the environmental and economic efficiency of the basic economic sectors (Lipenkov & Davankov, 2005). A decrease in resource intensity in the electric power industry can be considered as the most important characteristic of the green economy. In recent years, the concept of anthropocene has been developed. The XXXVth session of the International Geological Congress held in 2016 suggested distinguishing the Anthropocene era. An important characteristic of this geological era is the movement of significant volumes of substances during economic activities. These values should be correlated with the volumes of material flows arising from the activities of various natural forces. To reduce the anthropogenic impact, increase the level of economic greening, it is necessary to reduce resource intensity, or resource intensity, of the basic sectors of the economy, such as energy production (Davankov et al., 2016; Schiller, 2009).

3. Research Questions

There is a certain lack of information on objective evaluation criteria (Giljum, 2011; Nikulin, 2008). Some researchers carry out a similar assessment for traditional energy production. They confirm that the scale of movement of substance in the energy production is comparable with geological forces. However, for alternative energy, there is a lack of information which can be used to assess material flows.

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4. Purpose of the Study

The problem of resource intensity is crucial for solving environmental management issues, assessing the impact of alternative energy which has relatively small "output" material flows associated with emissions. In fact, the environmental and economic advantages or disadvantages of the alternative electric power industry can be revealed only by comparing such data with data on the traditional energy industry. Only in this case, it is possible to draw a conclusion about the general level of its ecological and economic efficiency and impacts on the environment (Huppes, 2009; Suh, 2005).

5. Research Methods

To evaluate the transported substance, or resource intensity, the MI (Material Input) -number was used (Ritthoff, 2002). This indicator was developed. MI numbers are determined by the following algorithm: the "input" flows of a substance required for producing a particular product or service are expressed in units of mass (tons or kilograms). They allow you to display the value of natural materials, or ecosystem components, required for the production. To assess resource intensity of the industry, a modernized indicator was used – total MI numbers (Dvinin, 2014). It determines the totality of the substance transported, while the calculation of certain categories of material input of the product is not carried out. This approach allows us to analyze activities of the electric power industry. If necessary, this indicator can be decomposed into separate categories at the final research stage. The traditional MI numbers are presented in the following categories of material input: atmospheric resources, abiotic and biotic, soil and water resources. The division of categories makes it possible to carry out a full analysis of the negative impact on the environment. Specific data on resource intensity of materials used for producing alternative energy sources are available on the website of the Wuppertal Institute for Climate and Environment (Germany) www.wupperinst.org. Information about Russian alternative energy facilities was retrieved from the statistical data, the energybase.ru information portal and author's research. The calculation was carried out as follows: an inventory analysis of the "input" and "output" flows of natural resources was carried out, these flows were transferred to the category of total MI numbers. For wind farms, the following specific indicators of resource intensity expressed in MI numbers were obtained: atmospheric resources, kg.kW.h – 0.008; abiotic resources, kg.kW.h – 0.09; water resources, kg.kW.h – 0.84; total MI numbers, kg.kW.h – 0.1. For solar power plants (SES), the following specific indicators of resource intensity expressed in MI numbers were obtained: atmospheric resources, kg/kWh – 0.0009; abiotic resources, kg.kW.h – 0.12; water resources, kg.kW.h – 4.93; total MI numbers, kg.kW.h – 0.12. Information on the volume of water consumed was used to identify the specific resource consumption of small hydroelectric power stations.

6. Findings

The traditional energy production sector of the Russian economy is very diverse. There are regions where coal energy is produced by large district power stations. Their negative impact is offset by regions that have energy systems consisting of hydroelectric power stations and nuclear power facilities. The use of natural gas has a significant positive impact on the environment. In this case, it is necessary to

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emphasize a significant increase in its share in the energy balance over the past twenty years. Based on the calculations presented in Table 1, the federal district with the most environmentally efficient traditional energy is the North-West. This situation is due to the high level of development of the nuclear power industry, and the presence of a large number of small hydropower facilities on the northern rivers. To produce thermal energy, natural gas is used. Significant resource intensity values for traditional energy have been established in The Ural, Central and Siberian regions. This problem is due to the presence of a large number of large coal-fired power plants. They create disturbances in the natural environment due to emissions into the atmosphere, discharges into water bodies, formation of slag dumps, and transformation of landscapes when extracting and enriching fossil fuels.

Table 01. The volume of consumed natural resources in total MI numbers for the traditional production of electricity in the regions of the Russian Federation

Federal districts	**Electricity generation per year million kWh**	**Resource intensity in total MI numbers, thousand tons**
Far Eastern Federal District	45952.36	71685.68
Volga Federal District	176734.4	134318.14
North-western Federal District	97969.32	61720.67
North Caucasus Federal District	26824.93	19313.95
Siberian Federal District	197337.8	309820.35
Ural federal district	129678	172471.74
Ural federal district	222487.6	169090.57
Southern Federal District	63125.76	42925.51
the Russian Federation	1923323.73	2000256.68

Table 2 shows the environmental and economic characteristics of Russian alternative energy. Small hydropower and bioenergy plants account for 58.1 %, solar energy plants account for 21.1 %, geothermal plants account for 11.3 %, wind turbines account for 9.5 %. The total value of the elements of ecosystems exposed to the greatest anthropogenic impact was determined; abiotic resources consume 126.2 thousand tons, atmospheric resources – 5.5 thousand tons, biotic and soil resources consume 129.3 thousand tons. A large biogas plant of Belgorod Region consumes more than 95 thousand tons of raw materials per year.

In the Far Eastern Federal District, the specific resource intensity of alternative energy production, and the level of negative anthropogenic impacts on the environment is 8.8 times less than that of the traditional energy production. At the same time, the level of specific water consumption is 2.9 times less. The Kamchatka Krai enters the Far Eastern Federal District, where there is a significant share of alternative energy – 36.35 %. It is due to the isolated energy system and availability of unique geothermal sources. In the Siberian Federal District, the level of negative impacts of alternative energy on the environment is 15.2 times less than that of traditional energy. The value of specific consumption of water resources is 3.7 times less. The specific resource intensity of alternative energy production in the Ural Federal District is 900 times less. In the Volga Federal District, the level of negative impacts is 7 times less, and the level of specific water consumption is 1.41 times less. In the North-western Federal District,

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the value is 256 times less. Alternative energy of the Central Federal District does not have large production facilities; the specific level of resource consumption does not differ significantly from that for the traditional energy production. In the North Caucasus Federal District, the resource intensity value for alternative energy production is 464 times less than for the traditional energy production. However, in this district the specific water consumption is 6.78 times more; this fact allows us to draw a conclusion about the relatively low environmental and economic efficiency of small hydropower plants. In the Southern Federal District, the specific resource intensity of the alternative energy production is 6.69 times less than that of the traditional energy production, and the specific water consumption is 1.34 times less.

Table 02. Ecological and economic characteristics of alternative electricity in the federal districts of the Russian Federation

Federal districts	**Electricity generation per year million kWh**	**Alternative energy share in electricity produced, %**	**Resource intensity in total MI numbers, thousand tons**	**SPP/PEP/GTP/Small HPP and BioPP,**	**Greenhouse gas emissions**	**The difference between specific resource intensity values for alternative and traditional energy industries**
Far Eastern Federal District	628291.66	1.37	47.8	98/0/0/2	30663.07/0	8.8
Volga Federal District	221.31	0.12	22.58	52/39/0/9	65391.73/0	7
North-western Federal District	204.05	0.21	0.51	0/2,5/0/97.5	26451.72/0	256
North Caucasus Federal District	621.6	2.32	1.08	1/0/0/99	10193.47/0	464
Siberian Federal District	1357.52	0.79	160.78	97/1/0/2	91388.28/0	15,2
Ural federal district	35.8	0.027	0.05	0/1,5/0/98.5	73916.46/0	900
Ural federal district	147.84	0.066	132.43	0/0/0/100	68971.15/0	1
Southern Federal District	547.9	0.87	56.63	82/8/0/10	19568.9/0	6,69
the Russian Federation	2763.49	0.14	421.39	26/9,5/11/53.5	788562.73/110	7

The most significant share of alternative energy is typical of the regions isolated from the existing energy system. Alternative energy is not used as a real tool to reduce the negative impact on the environment, it is perceived only as a means of providing electricity to isolated territories.

It was found that the amount of substance transported due to the activities of traditional energy plants is 2 billion tons. A comparative analysis presented in Table 3 allows us to conclude that the these volumes are correlated in scale. The share of the alternative electric power industry in Russia is

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insignificant – only 0.14 %; therefore, the mass of transported substance is relatively small – 421 thousand tons.

Table 03. Volumes of substance transferred by geological and technogenic processes

Geological or technogenic process	Substance transfer, billion tons / year
Solid stock	14.1
Denudation in the areas of cover glaciation	2.2–2.3
Traditional electric power industry of the Russian Federation	2.0
Eolian masses	2.0–4.0
Volcanogenic accumulation	1.8
Marine abrasion	0.7–1.1
Biogenic accumulation	1.0
Accumulation of outer substance	0.02
Alternative power industry of the Russian Federation	0.0004

At present, in Russia, the traditional energy industry transfers volumes of substance comparable to such geological processes as glacier and wind transportation, and surpasses activity of volcanoes, marine abrasion, and biogenic accumulation. The volume of substance transported by the alternative energy industry is insignificant, it is 7,700 times less than the volume transported by the traditional energy industry. The data obtained allowed us to confirm that the greening of the energy industry is possible provided that the alternative energy sector is expanded. Assuming a hypothetical scenario of the complete replacement of traditional energy with alternative energy, the volume of transported substance will be 7 times less. This allows us to conclude that an increase in alternative energy can increase the level of greening of the energy sector.

7. Conclusion

1. The total resource intensity (resource intensity) of the traditional electric power industry in Russia is 2 billion tons (in MI numbers), the resource intensity of the alternative electric power industry is 0.4 million tons (in MI numbers). The total volume of the substance transported by the alternative electric power industry is 4700 times less than by the traditional one.

2. Small hydropower plants and biofuel facilities account for 53.5 % of energy production, solar energy plants account for 26 %, geothermal plants account for 11 %, and wind turbines account for 9.5 %.

3. The value of the elements of ecosystems subject to the greatest anthropogenic impact is as follows: abiotic resources – 126.2 thousand tons, atmospheric resources – 5.5 thousand tons, biotic and soil resources – 129.3 thousand tons.

4. Under the further development of alternative energy, which involves the replacement of traditional energy facilities, the value of resource intensity will be 7 times lower. This allows us to conclude that an increase in alternative sources can reduce the negative anthropogenic impact on the environment in all regions of the Russian Federation.

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