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# INFLUENCE OF RENEWABLE ENERGY ON SUSTAINABLE DEVELOPMENT OF THE RUSSIAN REGIONS

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## Abstract

The relationship between material and energy largely determines the development sustainability of the regional socio-ecological and economic system flows in the biosphere and industry-related flows arising as a result of economic activity. It is necessary to maintain specific proportions between the flows circulating in the biosphere and the regional economic activity. The resulting imbalances are primarily related to the activities of regional energy using fossil natural resources as fuel. In recent years, renewable energy has been widely developed; its peculiarity is that it uses energy already circulating in the biosphere, i.e., in contrast to traditional energy, it does not significantly affect natural material change energy flows. MI-numbers (material input indicator) were used to identify patterns between the level of development of traditional and renewable energy and regional development sustainability. This is a single criterion for evaluating the consumption of various natural resources and ecosystem elements' movement. The maximum permissible energy load estimated the assimilation potential of the regional natural environment. As a result of the research, the Russian Federation regions, where traditional energy activity leads to the formation of severe imbalances relative to the natural environment of the region, are identified. Regularities in the development of renewable energy have been identified that allow changing this situation and increasing sustainability in developing the regional socio-ecological and economic system.



*Keywords:* Balanced development, material and energy flow, regional socio-ecological and economic system, renewable energy, traditional energy

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## 1. Introduction

When assessing the sustainability of material and energy flows arising from economic activities, there are always questions about applying some special criteria. Energy activity in economic activity leads not only to emissions into the environment ("output" flows), which are paid close attention when solving environmental issues, but also creates "input" material and energy flows of consumed resources and energy, which is a more significant negative impact factor than conventional discharges and emissions. As a result, some significant functions disappear in ecosystems and lose their ability to maintain the conditions for life support (Gorshkov, 1995).

Thus, a scientifically based assessment of these flows allows determining the existing relationships between the two systems (Korhonen et al., 2018). This approach also makes it possible to assess the cost of renewable energy sufficiently. It should be noted that the concept of forming a "green economy" is currently gaining popularity, so the analysis of the material and energy input of the primary economic sectors not only is essential for environmental protection but also has significance for further improving the economic competitiveness of the industrial region (Grinberg & Savchenko, 2019).

## 2. Problem Statement

All evolving systems are open. As a particular case of an open self-developing system, the socio-ecological and economic system must obey arbitrary open systems' general development laws. Primitive systems cannot always maintain stability, increasing disintegration over time invariably leads to self-destruction (Lipenkov, 2012). Much more complex systems must have mechanisms for creating balanced material and energy flows. Thus, the regional socio-ecological and economic environment consists of three major subsystems: changes in matter, changes in energy, and a management subsystem responsible for the transformation of information flows (Sedov, 2016). It is necessary to influence the information flows, which should set the desired proportions of the distribution of energy and matter flows in the other two subsystems to manage the regional economic activity within the boundaries of biosphere stability (Pryakhin & Sedov, 2016). Accordingly, the management mechanism should be based on the use of sustainability indicators of the socio-ecological and economic system, where there is a common indicator of the regional assimilation potential (Davankov & Kocherov, 2016).

## 3. Research Questions

Research questions are as follows:

### 3.1. Determination of the material input of traditional and renewable energy in Russian regions.

It is necessary to apply a single criterion that allows evaluating the consumption of various natural resources, the movement of ecosystem elements, in some cases not having a market price to carry out such an analysis of the material input of energy.

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### 3.2. Identification of patterns between the level of development of traditional and renewable energy and the sustainability of regional development.

Changes in natural systems caused by nature-intensive sectors of the economy, including energy, are manifested in the form of significant material and energy flows (Davankov et al., 2017). The movement of ecosystem components and the extraction of natural resources lead to the degradation of the natural environment and put it in an unbalanced state (Padilla-Rivera et al., 2019). The sustainability assessment of energy biosphere flows and energy of regional economic activity should be based on the use of a general criterion of material input (Giljum, 2011).

## 4. Purpose of the Study

The purpose of the study is to identify the existing patterns between the level of material input of traditional and renewable energy and the development sustainability of the regional socio-ecological and economic system.

## 5. Research Methods

The main method of research is the indicator of the specific material consumption of a product or service obtained from the Material Input Per Service (MIPS) method. This method is aimed at analyzing the "input" material flows as a result of production activities; its basis is the criterion of MI-numbers. This criterion allows evaluating the total material input of products per unit of product or service received (Schiller, 2009). Most often, they express the total amount of natural resources used (in kilograms or tons) required to produce one kilogram of the main product. MI-numbers are calculated using the following algorithm: the initial material input of natural resources that are necessary for the production of the evaluated product or service (including the use, repair, and disposal of waste at the landfill) is expressed in the selected mass units (kilograms or tons) of conventional natural resources and summed up. MI-numbers calculated for all major raw materials and semi-finished products are available on the website of the Wuppertal Institute for Climate and Environment (Germany) www.wupperinst.org. Using the data obtained by the Institute, the MI-numbers of any other complex products and services can be calculated. In this case, first, it is required to get information about the composition of a complex product, about the energy resources spent on its production, and the amount of waste generated in the production process. If necessary for project analysis, the division of incoming natural resources with five categories of material input is used: abiotic resources, biotic resources, soil movement, atmospheric and water resources. Partial use of the specified categories of material input is also allowed. The use of different categories of material input has a basis in the design of products and services. However, when evaluating and analyzing individual economy sectors, such a division significantly complicates the process of making managerial decisions; in this case, it is necessary to reduce these indicators to a single value.

It is proposed to use the criterion of total MI-numbers, without the need to allocate separate categories of material input to assess the balance of energy biosphere flows and energy of regional economic activity. All consumed natural resources are reduced to a single value, which allows for further effective environmental and economic assessment. Since the total MI-numbers express the total material input, they can also be used in the analysis of the material input of regional economic activity. In the process of analyzing the total MI-numbers of regional energy economic activity, it is possible to identify the relationship existing between the level of consumption of natural resources and the emission of greenhouse gases, which in the future makes it possible to plan for reducing their emissions through the implementation of resource-saving mechanisms (Davankov et al., 2016).

## 6. Findings

By the example of electricity production, a study was conducted that revealed that significant values of specific material input are present in industrial regions with large power plants using brown coal: the Primorye Territory, Trans-Baikal Territory, Krasnoyarsk Territory, the Republic of Buryatia, Omsk Region, Chelyabinsk Region, Ryazan Region, and several others. Their activities also have a significant negative impact on the environment, which is confirmed by the high level of greenhouse gas emissions in these regions. The exception is the Krasnoyarsk Territory, which has powerful hydropower facilities. The widespread use of brown coal leads to an impact on atmospheric, soil, abiotic and biotic resources, and the traditional electric power industry in these regions has a very significant negative anthropogenic impact.

Table 1 shows regions with traditional energy with the highest material input (more than 1 kg/kWh).

**Table 1.** Regions of the Russian Federation with the largest specific material flows arising in the course of traditional energy activities

| Regions | Total MI-numbers of the traditional electric power industry, kg/kWh | Specific greenhouse gas emissions, kg/kWh |
|---|---|---|
| | **Central Federal District** | |
| Bryansk Region | 1.35 | 0.72 |
| Ivanovo Region | 1.01 | 0.54 |
| Kaluga Region | 1.03 | 0.55 |
| Moscow Region | 1.2 | 0.55 |
| Ryazan Region | 2.73 | 1.29 |
| Tambov Region | 1.05 | 0.56 |

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| | | |
|---|---|---|
| Tula Region | 1.9 | 0.99 |
| **Northwestern Federal District** | | |
| Arkhangelsk Region | 1.23 | 0.66 |
| Vologda Region | 1.49 | 0.74 |
| Komi Republic | 1.29 | 0.67 |
| Nenets Autonomous Area | 1.36 | 0.93 |
| Novgorod Region | 1.29 | 0.63 |
| Pskov Region | 1.02 | 0.54 |
| **Southern Federal District** | | |
| Astrakhan Region | 1.13 | 0.61 |
| Sevastopol | 1.18 | 0.63 |
| **North Caucasus Federal District** | | |
| Stavropol Territory | 1.01 | 0.54 |
| **Volga Federal District** | | |
| Orenburg Region | 1.0 | 0.53 |
| Republic of Bashkortostan | 1.05 | 0.52 |
| Republic of Mordovia | 1.01 | 0.54 |
| **Ural Federal District** | | |
| Kurgan Region | 1.32 | 0.58 |

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| | | |
|---|---|---|
| Sverdlovsk Region | 1.64 | 0.76 |
| Tyumen Region | 1.22 | 0.49 |
| Khanty-Mansi Autonomous District | 1.18 | 0.49 |
| Chelyabinsk Region | 1.81 | 0.87 |
| **Siberian Federal District** | | |
| Altai Territory | 3.14 | 1.26 |
| Trans-Baikal Territory | 4.90 | 1.08 |
| Kemerovo Region | 2.05 | 1.05 |
| Krasnoyarsk Territory | 1.99 | 0.47 |
| Novosibirsk Region | 1.38 | 0.71 |
| Omsk Region | 2.24 | 0.89 |
| Republic of Buryatia | 4.49 | 1.09 |
| Republic of Tuva | 1.29 | 0.5 |
| Tomsk Region | 1.71 | 0.77 |
| **Far Eastern Federal District** | | |
| Primorye Territory | 4.02 | 1.10 |
| Sakhalin Region | 1.54 | 0.75 |
| Khabarovsk Territory with Jewish Autonomous Region | 1.98 | 0.79 |
| Chukotka Autonomous Area | 2.28 | 0.82 |

| | | |
|---|---|---|
| Republic of Sakha (Yakutia) | 1.03 | 0.55 |
| **Russian Federation** | **1.04** | **0.41** |

Significant specific volumes of natural resources consumed by traditional electric power are established in three federal districts: Central, Siberian, and Ural. Mainly due to the presence of large coal-fired power plants, they form such environmental problems as emissions and discharges to the atmosphere, hydrosphere, create slag dumps, indirectly transform remote ecosystems during the extraction and enrichment of fossil fuels. This is also evidenced by the high level of specific greenhouse gas emissions in these regions, as shown in Table 1.

Thus, the functioning of traditional energy based on fossil fuels creates significant imbalances in material and energy flows (Nikulin, 2008). The high level of imbalance between natural and anthropogenic processes is largely due to the activities of traditional energy using fossil natural resources as fuel (Belik et al., 2017).

In recent years, renewable energy has been widely developed; its peculiarity is that it uses energy already circulating in the biosphere, i.e., in contrast to traditional energy, it does not significantly affect the change in natural material and energy flows. This makes it possible to assume that its activity allows identifying new patterns associated with an increase in the level of balanced development of economic activities and assimilation potential of the region with an increase in the share of renewable energy in its energy balance (Dvinin & Nikolaeva, 2020). As the share of renewable energy in the energy balance increases, the level of the economic balance of the regional socio-ecological and economic system will also change (Keiko et al., 2016).

Currently, the share of renewable energy in the total energy balance of Russia is 0.14%. The structure of Russian renewable energy is as follows: small hydroelectric power plants and biofuel power plants account for 53.5% of the Russian renewable energy generation, solar power – 26%, geothermal power plants – 11%, and wind power plants – 9.5%. At the same time, it should be noted that the situation differs significantly for different regions of the country.

In 2016, the National Research University Higher School of Economics implemented the project "Research on global challenges and long-term trends in innovative development", which presented scenarios for the development of renewable energy in Russia for the period up to 2030. The considered scenarios allowed drawing the following conclusion: the macroeconomic indicators of economic growth will remain relatively small for the foreseeable period, which does not allow making an optimistic forecast about the rapid development of renewable energy. The most likely scenarios are those where the share of renewable sources will reach 3–5% by 2030.

As a result of the study, it was determined what ecological and economic effect was expected when developing promising renewable energy sources in regions with the largest specific material flows of traditional energy. To do this, it was initially necessary to evaluate the material flows of renewable

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power facilities. The average specific value of material input for renewable energy in the Russian Federation is 0.15 kg/kWh (in total MI-numbers). This is the basis for comparison with traditional energy.

The value showing by how many times the specific material input will decrease under the condition of complete replacement of traditional energy with renewable energy is presented in Table 2.

**Table 2.** Regions of the Russian Federation where the development of renewable energy can significantly affect the balance of material and energy flows

| Regions | By how many times will the specific material input increase if traditional energy is completely replaced with renewable energy |
|---|---|
| **Central Federal District** | |
| Bryansk Region | 9 |
| Ivanovo Region | 6.73 |
| Kaluga Region | 6.87 |
| Moscow Region | 8 |
| Ryazan Region | 18.2 |
| Tambov Region | 7 |
| Tula Region | 12.67 |
| **Northwestern Federal District** | |
| Arkhangelsk Region | 8.2 |
| Vologda Region | 9.93 |
| Komi Republic | 8.6 |
| Nenets Autonomous Area | 9.07 |
| Novgorod Region | 8.6 |
| Pskov Region | 6.8 |

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| | |
|---|---|
| **Southern Federal District** | |
| Astrakhan Region | 7.53 |
| Sevastopol | 7.87 |
| **North Caucasus Federal District** | |
| Stavropol Territory | 6.73 |
| **Volga Federal District** | |
| Orenburg Region | 6.67 |
| Republic of Bashkortostan | 7 |
| Republic of Mordovia | 6.73 |
| **Ural Federal District** | |
| Kurgan Region | 8.8 |
| Sverdlovsk Region | 10.93 |
| Tyumen Region | 8.13 |
| Khanty-Mansi Autonomous District | 7.87 |
| Chelyabinsk Region | 12.07 |
| **Siberian Federal District** | |
| Altai Territory | 20.93 |
| Trans-Baikal Territory | 32.67 |
| Kemerovo Region | 13.67 |

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| | |
|---|---|
| Krasnoyarsk Territory | 13.27 |
| Novosibirsk Region | 9.2 |
| Omsk Region | 14.93 |
| Republic of Buryatia | 29.93 |
| Republic of Tuva | 8.6 |
| Tomsk Region | 11.4 |
| **Far Eastern Federal District** | |
| Primorye Territory | 26.8 |
| Sakhalin Region | 10.27 |
| Khabarovsk Territory with Jewish Autonomous Region | 13.2 |
| Chukotka Autonomous Area | 15.2 |
| Republic of Sakha (Yakutia) | 6.87 |
| **Russian Federation** | **6.93** |

In 15 regions of the Russian Federation, the theoretical scenario of replacing traditional energy with renewable energy can reduce the material input of the industry, which means that it can reduce the negative anthropogenic impact by more than 10 times. Greenhouse gas emissions from renewable power generation facilities in the Russian Federation are minimal. Their specific value is 0.03 kg/kWh, which is 13.6 times less than traditional energy and is due exclusively to the activities of biofuel plants.

## 7. Conclusion

As a result of the study, the following conclusions were drawn:

- If there is a high level of imbalance in the regional socio-ecological and economic system, then there are also significant material flows in the traditional energy sector; there is a high emission of greenhouse gases.

- Promising renewable energy sources that reduce the anthropogenic impact on nature have small indicators of specific material input, primarily wind and solar energy sources. Thus, when replacing energy with fossil fuels, it is possible to significantly increase the sustainability of material and energy flows arising from economic activities in the territories of industrially developed regions.

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