

Prospects for Renewable Energy at the Regional Level (in the Example of the Kemerovo Region) in the Context of Decarbonization and Decentralized Generation

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Abstract. The Kemerovo region is one of the largest regions for coal mining. The region's economy is growing every year, but residents of remote communities still use diesel generators (which negatively affects the environment and essentially means poor use of it) or do not have access to centralized electricity. The Advanced Development Programme for Electricity Systems in the region has a limited budget and does not cover all regions. Most of the existing infrastructure has been in use for more than 25 years, which increases the relevance of decentralized generation. Renewable energy not only reduces emissions significantly, but also addresses the challenge of providing energy to rural people. The authors studied the feasibility of installations of solar panels, wind and hydro installations of low capacity in the Kemerovo region. As a result of the study, it was concluded that the use of hydropower plants will provide 6% of rural Residents of Tisul and Tashtagol municipal districts with electricity. Solar panels and collectors can be used in almost any area, but it is economically justified to link their installation with tourism development programs in the region. As far as wind farms are concerned, they are under-powered for objective reasons, and decisions about their use require further research.

1 Introduction

Many remote communities in northern Russia do not have a central power supply, so they generate expensive diesel power plants. Sometimes, because of the economy in such settlements, there is no electricity for most of the day. To solve this problem, perhaps through distributed generation based on renewable energy sources (RES), which produce energy more environmentally friendly and cheaper.

G.I. Davydov in the article «Hybrid energy in a decentralized zone» [1] explores the potential of renewable energy to provide energy to settlements in the Far East and Arctic

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regions far from centralized electricity supply. In his opinion, hybrid solutions - a combination of renewable energy and diesel generator - are optimal - to ensure the reliability of the system and energy generation on the one hand, when renewable energy produces it in insufficient volume, but on the other hand to reduce the cost of electricity generation and reduce emissions from the burning of diesel fuel. An additional solution is the use of modern energy storage with intelligent control systems (MicroGrid), which allow you to respond quickly to changes in demand.

F.L. Byk, L.S. Myshkina in the article «Distributed Energy and Improving the Reliability of Electricity» [2] consider the distributed generation object as an isolated system. The MicroGrid intelligent system provides reliable support for the region, but the whole system as a whole, i.e. renewable energy can be used exclusively to supply a particular region, city, village.

A.N. Asaul, M.A. Asaul, I.A. Levin, A.M. Platonov in the work «Energy supply of isolated areas in the context of attracting investment and development of the region's economy» [3] considered the possibility of decentralized generation in the Republic of Tyva, which is surrounded by other regions with large industrial consumers. The Republic of Tyva has the potential to experience a shortage of electricity due to insufficient generation capacity.

Among the possible solutions for renewable generation are solar power plants, wind farms, mini-power plants, etc. In the process of preparing the author's article, the experience of using a solar power plant in the village of Nikulkino of the Khanty-Mansiysk Autonomous Okrug and a hydraulic turbine with a built-in hydraulic pump, which was installed in North Ossetia-Alania, was studied. These regions have similar climatic conditions with the Kemerovo region, for which different options for distributed generation on the basis of renewable energy were considered in this article.

2 Materials and Methods

Kuzbass is one of the largest reserves of coal and its production basin of Russia and the main, and according to some estimates, the only supplier of technological raw materials for the Russian industry.

The conditional reserves of coal in Kuzbass exceed all the world's reserves of oil and natural gas by more than 7 times (in terms of conventional fuel) and amount to 693 billion tons, of which 207 billion tons - coking coal. This is 73 per cent of the country's total coal reserves. The volume of these reserves can provide the whole of Russia with raw materials for coke production. For comparison: coking coal reserves in Donbass - 25 billion tons, Pechora coal basin - 9 billion tons, Karaganda - 13 billion tons [4].

The remaining stone coals are unique in the sense that, having the ability to bake, can, depending on the direction of their enrichment, serve as both coking and energy raw materials. There are other types of fossil fuels in the Kemerovo region. This is peat (more than 20 deposits), reserves of oil and natural gas.

The Kemerovo region's fuel and energy complex is one of the largest in Russia. In 2018, the 10 largest subjects of the Russian Federation accounted for 38.8% of all energy resources consumed in the country in terms of absolute consumption of fuel and energy resources. Among the regions with the highest consumption of TER are the Khanty-Mansi Autonomous Region - Yugra (6.3%), Moscow (4.5%), Kemerovo Region (4.2%) and the Chelyabinsk Region (4.1%). Moscow region (3.8%) (Figure 1).

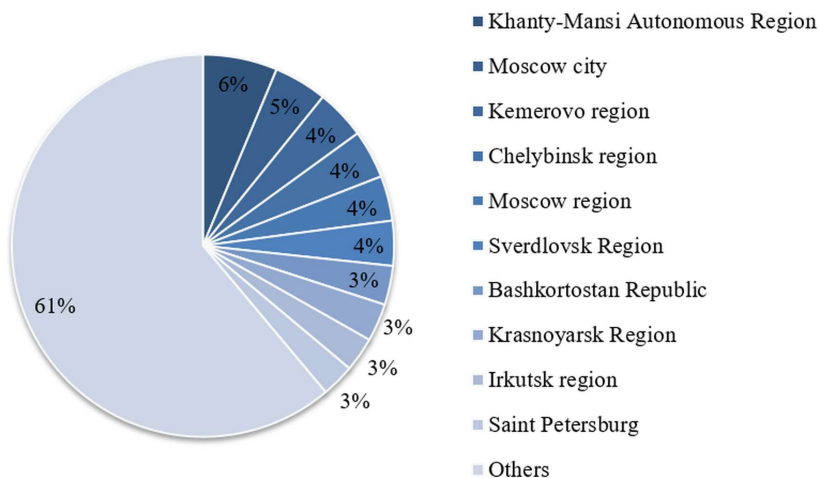


Fig. 1 Distribution of energy consumption in the Russian Federation in 2018. Source: composed by [5].

According to the ratio of fuel and energy sources to GRP, the best subject of the Russian Federation was the city of Moscow - 37.04 kg.tce. per 10,000 rubles (in 2012 prices). The lowest energy intensity rate among all regions in 2018 in the Lipetsk region is 553.2 kg.tce. per 10,000 rubles (in 2012 prices). Also among the worst energy intensity of the regional economy are Vologda region, Kemerovo region, Hakasia Republic and Chechen Republic (Figure 2).

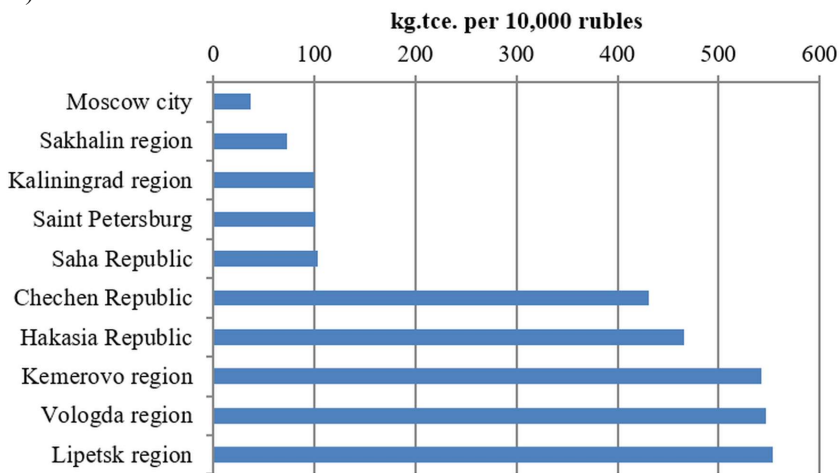


Fig. 2. The regions with the largest GRP energy intensity in 2018. Source: composed by the authors.

Since 2012, these regions have been able to improve their energy efficiency results (Figure 3). But in one region - Vologda region - during this period there is a negative dynamics (an increase in energy intensity by 2%).

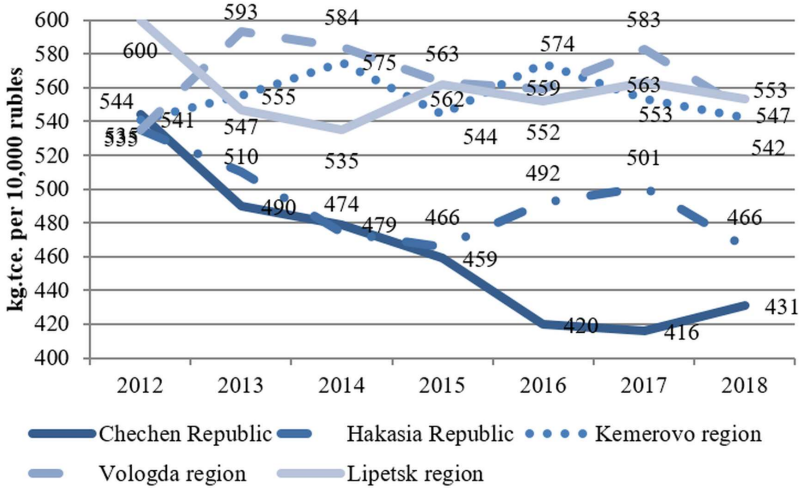


Fig. 3. Energy intensity dynamics in the regions with the highest values in Russia in 2012-2018 (source: composed by the authors).

The dynamics of this indicator require the identification of the reasons that led to it, since the region in 2012 adopted the Energy Saving Program, which in particular provided for the use of renewable energy to improve the energy security of the region, measures to improve energy efficiency, but the program was later in 2013 was abolished [6]. Currently, there is a program of prospective development of the electricity industry of the Kemerovo region for 2021-2024, the research of which is devoted to this work, namely, explores the possibilities and plans for the introduction of renewable generation.

As of 01.03.2020, the total installed capacity of power plants in the Kemerovo region with a single capacity of 5 MW and above was 5,525.34 MW. All generating capacity of the power grid of the Kemerovo region are represented by thermal power plants (Figure 4).

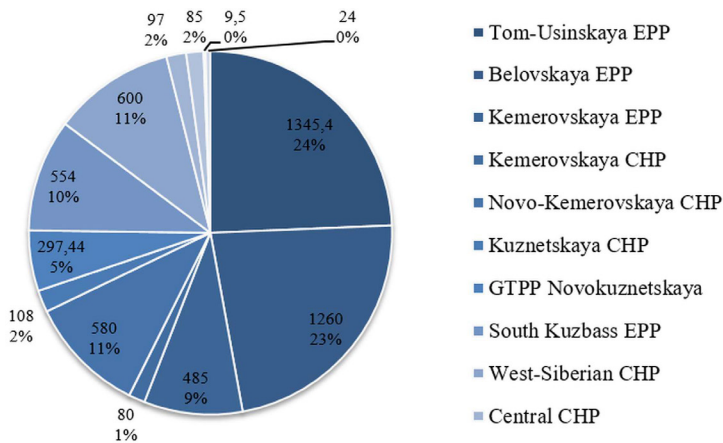


Fig. 4. The structure of capacity in the Kemerovo region 01.03.2020 Source: composed by [7]

In 2018, they generated 22,680 million kWh of electricity [7]. Electricity consumption in the Kemerovo region in 2018 amounted to 32,009 million kWh, the maximum load - 4554 MW. Thus, the Kemerovo region is an energy-deficient region in terms of electricity and power surplus, the deficit is filled by flows from the adjacent power grids of Khakasia,

Krasnoyarsk and Altai region, Tomsk and Novosibirsk regions. As of 2020, industry (including mining) is leading the structure of electricity consumption in the region, with 10.4%.

The largest consumers of electricity in the region are RUSAL Novokuznetsk (primary aluminium production), EVRAZ SSMC (coking, steel), Kuznetsk Ferroalloys (ferrosilicia and microcremnes). Kuzbassenergossit serves as a guarantee supplier of electricity [8]. Problems of the current state of electricity in the Kemerovo region - Kuzbass are related to:

- A lack of capacity of electrical networks - 110 kV and above to ensure the transfer of power in the required volumes, indicating limiting elements.
- There is not the ability to provide acceptable voltage levels (including insufficient voltage control capacity).
- Insufficient branching of power lines and high share (50-80%) (transformers, RS 10, 220, 500 kV), used for more than 35 years.

These problems, despite the measures taken, have not yet been solved, but it is impossible to achieve the strategic goal of the socio-economic development of the Kemerovo region - ensuring the faster pace of development and competitiveness of the economy and social sphere, as well as achieving a leading position in the quality of life of the population and the level of development of human capital, without it. Economic growth will lead to an increase in demand for electricity, and the level of maximum daily capacity will increase (Figure 5). Most of the increase will be in the coal-mining enterprises of the region, but a significant reduction in the electricity consumption of the coal company «Kuzbassrazrezugol» is projected - by more than 80 million kWh compared to 2019 (by 12%).

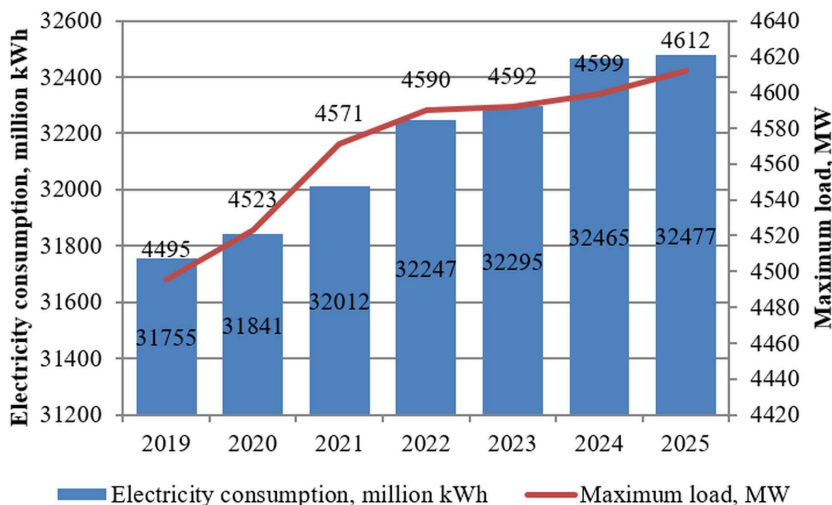


Fig. 5. Planned energy development indicators for the Kemerovo region up to 2025. Source: composed by [8].

The development of the generating capacity of the Kemerovo region's power grid for the period up to 2025 is based on the data presented in the draft Scheme and development program of the United Energy System of Russia for 2020-2026 and the Kemerovo Region Electric Power Development Program - Kuzbass for the period 2021-2025 [8]. At the same time, these measures of modernization and reconstruction apply to individual substations and do not solve the problem of providing 100% of residents with electricity, including during peak periods.

This problem can be solved by distributed generation, and in view of the difficult environmental situation in the region and the global climate agenda, energy production should minimize or even reduce greenhouse gas emissions to zero. Renewable energy sources can provide such an effect: solar, tidal, wind, geothermal, etc.

3 Results and Discussion

Renewable energy has many positive effects:

- Minimize emissions from energy production, which reduces the impact on the biosphere and further normalizes the environmental situation.
- Energy supply to remote areas from centralized networks.
- Reducing energy costs the possibility of developing previously unprofitable deposits, etc.

The Kemerovo region has historically developed as a coal-producing region, which has a negative impact both on the region's economy in terms of its lack of diversification, and on the health of workers and residents of the region, who are constantly experiencing the consequences of man-made influence («black» snow, dust storms, etc.) [9]. However, as has already been noted, the introduction of renewable energy in this region is appropriate for two reasons: 1) the supply of settlements in the mountains and small towns with energy; 2) Slowing emissions growth when burning coal.

The first aspect of the introduction of renewable energy has already begun to be implemented, but so far in Kuzbass there is only one solar power plant (SPP) in only one settlement. SPP with a project capacity of more than 70 kilowatts under the agreement of the regional administration with the Ministry of Energy of the Russian Federation more than three years ago put into operation in Elbez Tashtagol district of the region. The construction of power lines from centralized power grids would take 60-80 million budget rubles [10]. The owners of the farms are responsible for the maintenance of 84 lithium-ion solar cells of Russian production. Exploitation is limited to clearing snow in winter [11].

The head of the Tashtagol district, Igor Idigoshev, notes: «There are four dozen taiga villages in the Mountain Shhoria, located away from the main power grids, gas pipelines and delivery routes of the most common fuel in Kuzbass - coal. The project on Elbez was a pilot project in the Tashtagol district. In the future, it is proposed to install not low-power, and modern solar modules with a lifespan not twelve, but 25 years, and for each house. In the near future, it is planned to electrify Ust-Anzas and if you do not have a permanent power line, we will stop on the solar panels» [12].

Boris Berlin, Acting Deputy Director General of the Kuzbassenergo- branch of MRSK Siberia, notes that «in the implementation of such projects, the issues of subsidizing and compensating for the falling revenues of resource-providing organizations, which provide energy in the decentralized zone, need to be resolved at the regional level» [6].

This special attention to the energy supply of the area is due to the fact that within its borders is the Shore Nature Reserve (Figure 6). At the same time, the installation of SPP or more precisely collectors (the purpose of it - heat supply) in the area is justified [13].

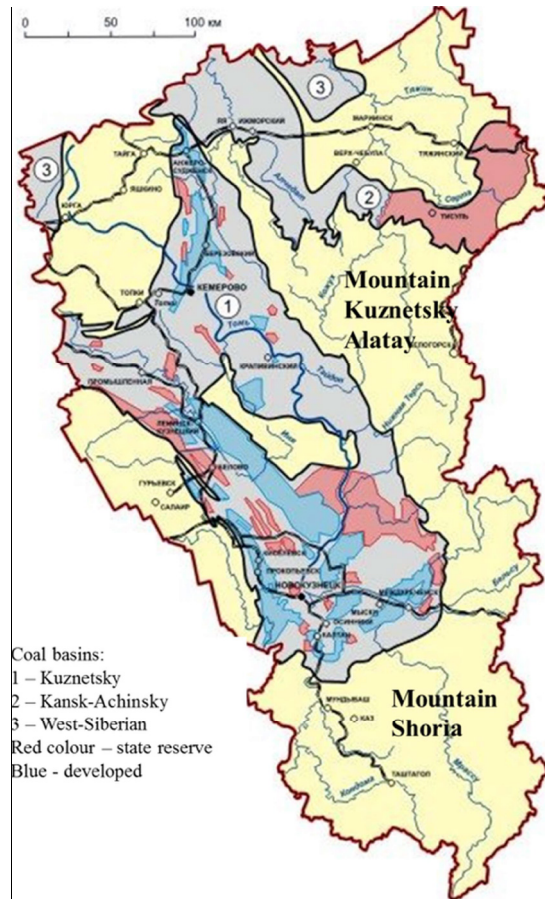


Fig. 6. Map of coal reserves in the Kemerovo region. Source: composed by the authors.

Assessment of the prospects for the use of different types of renewable energy in the region, based on the authors' own calculations and analysis of literary sources, sites of equipment suppliers, made it possible to draw the following conclusions regarding their use in the Kemerovo region.

Anushenko S.Yu in his article [14] considers it acceptable and economically viable in low-density areas to use micro-hydropower plants with a capacity of up to 100 kW and to build autonomous power systems based on them. The main factors in energy production are the presence of thresholds (level difference) and the volume of runoff. In this region, it makes sense to install only in the mountainous areas of Kuznetska Alatau and Mountain Shoria. And even here the maximum capacity of the rivers is not high: Kiya River (Kuznetsky Alatau, Tisul Municipal District) - 115 kWh/h (2760 kWh/day or 82.8 MWh/month with an average consumption of 694 kWh/month [11] 119 people will be able to provide energy), the Mars-Su River (Mountain Shoria, Tashtagol Municipal District) - 67.7 kWh (taking into account the efficiency of existing hydro installations 60%). [15], and the capacity is 3 GW, which provides 841 people with energy, i.e. only 6% of the rural population of these municipalities. Moreover, in 2015, hydroelectric power generation in Siberia decreased by almost 20%. The reason for this was abnormally low water level. That is why in the difficultly predicted natural conditions of Siberia and the Far East, the orientation only to hydro generation is erroneous.

Other sources of renewable generation are wind and solar power. A study of the wind pressure map showed that the average wind speed in the region is 4-5 m/s, which allows the

windmill to produce 76.9 Wt/m² [16], i.e. the diameter of the wind turbine blade is 1.14 m. The larger the diameter of the turbine, the more energy is generated by wind energy. At the same time, the wind speed for stable and efficient operation according to the documentation of manufacturers 9-12.5 m/s. Wind, which has such a speed, exerts high pressure, which increases the requirements for reliability of equipment (masts, gondolas, etc.). In addition, the work of the wind farm is accompanied by a high level of noise, which adversely affects the health of the population and animals. The effect is achieved from the installation of a wind farm on a flat terrain. According to studies, the south of Tashtagol and Novokuznetsk districts (along with the Tyazhinsky, Mariinsky and Yai districts of the north of the region) are most favorable for the development of wind generation. However, in this area, as in most areas of the Russian Federation, windmills will not be able to provide the need for energy due to insufficient wind speed.

Solar insolation of the region provides 3-3.5 kWh/m² per day, the duration of solar aurora is 1700-2000 h/year, i.e. to meet the annual electricity needs of the region will require to place solar panels on an area of 5.9 km² [17] i.e. 826 football fields. However, the area of the Kemerovo region itself is 95,500 km², in addition, the panels placed on the roofs of the buildings allow to save space. The panels can work even in cloudy weather.

The next step was to conduct an economic assessment of renewable energy projects, on the basis that all work on the supply of energy to the municipalities is carried out in contact with the district administration, which determines the prospects for the development of tourism, including ecological, settlements [18].

More recently, residents of the village of Parlagol Tashtagol district used the energy generated by a diesel generator. According to the energy supply company of the region, today in 16 remote villages there are stationary diesel generators that generate electricity for three hours a day - an hour in the morning and two hours in the evening [19]. They require constant repairs, subsidies for the purchase of lubricants and fuel and so on. In 2019, the village implemented an investment project worth about 17 million rubles, which included the installation of 4 transformer substations, the construction of an intra-village power line with a capacity of 0.4 kilowatts and a length of 2.6 km with the construction of 200 reinforced concrete supports in the rocky ground and two steel crossings through Mrassa. This allowed to provide 800 residents of the village with energy [20].

The possibility of building power lines between the villages of Orton and Ust-Anzas, where the road to Hakasia is to pass by 2025, is being discussed. So far, Ust-Anzas also uses a diesel generator. The cost of a kilowatt is 60 rubles. Meanwhile, the cost of kWh produced by microhees is 17 rubles, on centralized networks 70 rubles, solar panels - 53 rubles. Solar panels costing 2 million rubles, providing 16 MW of energy per year (supply of 2 houses) pay off for 20 years, the internal rate of profitability is 1.8%. Microhees worth 3 million rubles of the same capacity pay off for 15 years, the internal rate of profitability is 12%.

The calculation did not take into account the measures of support from the federal budget, other types of benefits that allow to reduce installation costs [21-23]. The purchase of plants was also taken into account, but the Siberian Federal District has a number of leasing companies that can provide equipment for leasing, which will also reduce the load and allow to start installation in more villages. Among the measures to support renewable energy projects for decentralized supply are:

- Create a geo-information system (GIS) on renewable energy sources and the potential of using local energy resources, which will allow monitoring of projects, take corrective measures, more fully realize the potential of the region.
- The Kuzbass parliament proposed to establish tax incentives for coal seam methane projects. The methane is powered by modular power plants, and the electricity generated goes to the needs of the enterprise. Methane resources in Kuzbass are estimated at 13.1 trillion.

m³. The authorities reported that between 2013 and 2020, Kuzbass increased the volume of methane production from coal seams to 1 billion m³ per year.

- Implementation of electricity projects on the principle of «alternative boiler room».

Among the main problems of renewable energy is reliability issues. Electricity is a specific product that is not stored in a warehouse. As of 2016, the installed capacity of energy storage systems (including batteries) was only 3% (150 GW) of the world's generating capacity, with 95% accounting for the share of HAEP [25].

To address this problem, it is proposed to maintain reserve capacity. It can be a backup diesel generator (DG) as offered by S.J. Anushenko [13], G.A. Ryabov [19], and A.O. Mamintheva [26] or a peak power plant. The latter is a power plant with a capacity of up to 90 MW from Wartsila [27]. Natural gas and air are used as fuel, electricity and heat without combustion products are used at the exit. Of course, these facilities need to be maintained, protected, monitored for the provision of their raw materials. However, a lack of attention to renewable energy in the future will not improve the environmental situation.

4 Conclusion

Achieving high rates of economic growth should not be at the expense of the environment. At the same time, renewable energy sources play a significant role in ensuring that residents are provided with affordable and clean energy. The authors studied the possibility and feasibility of placing renewable energy facilities in the Kemerovo region in order to supply energy to the residents.

Decentralized renewable energy can completely replace the burning of hydrocarbon fuels, but to improve reliability, renewable energy should be used in conjunction with diesel generators or peak power plants.

For the municipal districts of Kuzbass, the following system of application of different types of renewable energy was obtained:

- for the Tisul and Tashtagol municipal districts, the use of low-power hydropower plants, which cover 6% of the rural population's electricity needs;
- south of the Tashtagol and Novokuznetsk districts (along with the Tyazinsky, Mariinsky and Yai districts of the northern region) can be used for the installation of wind farms, but the authors do not recommend their installation in view of the insufficient power provided by the wind and the noise generated;
- the installation of SPP and/or collectors (as has been proven by the example of the Tashtagol region) is applicable and economically justified for all other areas. However, given the limited funding, the installation of SPP should be linked to local tourism development programmes. This will reduce the payback period.

In conclusion, the use of renewable energy will save diesel fuel and improve the reliability of the existing electricity supply system in order to power insulated power grids and hard-to-reach areas.

Acknowledgement

The study was supported by Plekhanov Russian University of Economics.

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