
SOFYA V. KISELEVA¹, LENINA A. KORINEVICH², SERGEY A. LEBEDEV³,⁴,⁵

¹Lomonosov Moscow State University, Russia
²Department of Mineral Resources of the Southern Federal District, Geology and Licensing Department of the Republic of Adygeya, Russia
³Geophysics Center of the Russian Academy of Sciences, Russia
⁴Space Research Institute of the Russian Academy of Sciences, Russia
⁵Maykop State Technological University, Russia

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Abstract
The paper presents assessment of the renewable energy potential in the Republic of Adygeya. The territory of the Republic of Adygeya, thanks to its geographical location, natural characteristics, economic specialization, has significant gross and technical potentials of renewable energy resources. It is the most preferable region for the development of solar energy. The gross potential of solar energy for the territory of the Republic of Adygeya is 1.3 billion TOE (Tons of Oil Equivalent) and the technical potential is 6.4 million TOE for the production of heat and 0.5 billion TOE for electricity production. The gross potential of wind energy in the Republic of Adygeya is 1862 billion kWh/yr, or 633 million TOE per year. The gross potential of hydraulic energy of small rivers is 7–9.65 billion kWh and the technical potential is 2.2–3.15 billion kWh. The analysis of geothermal conditions on the territory close to Maykop confirmed the possibility of the usage of thermal water for the city’s public and industrial heat supply.

Key words: Republic of Adygeya, renewable energy resources, gross and technical potential, regional assessments.

Introduction
Renewable energy resources (RER) are sources of energy formed on the basis of existing or periodically occurring processes in nature, as well as in the life cycle of plant and animal life, and life activity of the human society. A characteristic feature of RER is their inexhaustibility or the ability to restore their potential in a short time - within the lifetime of one generation.

In accordance with the United Nations General Assembly Resolution No. 33/148 (1978), non-traditional and renewable resources of energy include solar, wind, geothermal, energy of sea waves, tides and temperature gradient of the ocean, energy of biomass, including wood, waste from agricultural production, charcoal, peat, shale, bituminous sandstones, as well as energy of large and small watercourses.

RER can be classified by energy types (Twidell & Weir 2015): mechanical energy (energy of wind and water flows); thermal and radiant energy (solar and geothermal energy); chemical energy (energy contained in the biomass).
THE REPUBLIC OF ADYGEYA RENEWABLE ENERGY POTENTIAL

For renewable energy resources, the following definitions of energy potentials are used:

The gross (theoretical) potential of renewable energy resources is the annual energy volume contained in a given type of renewable energy, with its complete conversion into useful energy.

The technical potential of renewable energy resources is a part of the gross potential, the conversion of which into useful energy is possible at the existing level of development of technical facilities and in compliance with the requirements for the protection of the environment. The technical potential ranges from a portion of a percent (solar energy) to tens of percent (hydropower) of the gross potential. It constantly increases as production develops and technology improves.

The economic potential of renewable energy resources is a part of the technical potential, the conversion of which into useful energy is economically feasible at a given level of prices for fossil fuels, thermal and electric energy, equipment, materials, transportation services, wages, etc. The economic potential ranges from portions of a percent to tens of percent of the technical potential and can vary in any direction, depending on the fluctuation in the price ratio of these components. For renewable energy resources, the general trend is an increase in the economic potential.

The Republic of Adygea, due to its physical and geographical position and socio-economic characteristics, has quite a high potential for the development of renewable energy. On the one hand, there are significant resources of various types of renewable energy; on the other hand, there are autonomous consumers of electric and thermal energy (tourism facilities, hard-to-reach consumers outside the zone of centralized energy supply, in particular, cellular retranslators, farms, etc.).

The main types of renewable energy for Adygea are: wind, solar, geothermal energy and biomass energy. They have a high potential and are already used in existing power supply facilities in neighboring areas of the Republic of Adygea: the Krasnodar and Stavropol Territories, the Rostov Region, etc. In these regions, solar facilities for electricity and heat supply are used both by large urban objects and small autonomous consumers (livestock farms, farms of distance pasture, tourism facilities, etc.).

Material and Methods

Implementation of projects on renewable energy makes it necessary to assess feasibility and effectiveness of renewable energy resources for energy supply. To do this, first we need extensive data sets on natural resources and economic characteristics of the region. This paper presents the assessment of renewable energy resources in the Republic of Adygea, based on meteorological and hydrological data, the results of mathematical modeling and statistical data on agricultural productivity in the region. Economic characteristics will remain out of the scope of this study, such as energy infrastructure, energy balances, power transmission lines, presence of forestry, wood processing, food and other industries; characteristics of agricultural production, etc. Detailed analysis of these components is necessary for determination of profitability of specific projects on renewable energy.

Results

Wind Energy

The underlying surface and the circulation of air masses determine the wind regime on the territory of the Republic of Adygea. In the northern plain area, winds of the eastern, northeastern, western, and southwestern directions in general prevail throughout the year. In January, the frequency of eastern and northeastern winds is the highest. This is due to the transfer of air from the east, from areas under the influence of the Asian Maximum of atmospheric pressure, towards the region of low pressure formed over the Black Sea. In July, over plains western and southwestern winds prevail as a result of the formation of a high pressure area over the Black Sea, and in the eastern regions – as a result of the South Asian Minimum of atmospheric pressure. In the foothills, winds of southern directions prevail, the frequency of eastern winds is higher, which is connected to the meridional orientation of the river valleys of the northern slope of the Greater Caucasus. The average wind speed in the Republic is 2.9 m/s, but it varies from north-west to south-east (Fig. 1). On the plain, it reaches 3.3 m/s, and in the mountain valleys - about 1.5 m/s. In the annual course of wind speed, there are two maximums – the main one in March, and an additional one on the plain
in November and December, in the mountain area - in October and November. Minimum wind speeds are observed in summer in August, and in winter in January.

Assessment of wind energy resources is a difficult task due to the temporal and spatial wind unevenness, and, consequently, the need to have a sufficient factual basis for calculations. Below we shall examine approaches currently used to determine the gross (natural) potential of wind energy in the region.

A large number of wind parameters, including up to two dozen characteristics, are used for a comprehensive description of the gross potential of wind energy and the possible production of electricity by wind power plants (Nikolaev et al., 2007). Such characteristics include:

1) Climatic characteristics, which help assess the regional gross wind energy potential;
2) Parameters that determine operating characteristics of wind power plants and selection of optimum operating modes;
3) Wind parameters used in designing and calculating the strength and stability of the operation of wind power plants.

Figure 1. Distribution of the average annual wind speed (m/s) at the height of meteorological measurements on the territory of the Republic of Adygeya (Atlas…, 2005).

According to the (Guide… 2007) and long-term meteorological observations, the gross potential of wind energy in the Republic of Adygeya is 1862 billion kWh/yr, or 633·million TOE (Tons of Oil Equivalent) per year. Calculated by the NASA Surface meteorology and Solar Energy (SSE) (release 6.0) (Stackhouse et al. 2016), the wind energy gross potential at different heights is shown in Fig. 2. According to estimates made on the basis of long-term meteorological observations, the technical potential of wind energy in the Republic of Adygeya is 4.7 billion kWh/yr, or 1.6 TOE/yr (Guide… 2007).

Deviations in the results, obtained in the two above-mentioned studies, are due to the difference in the used sources of primary wind characteristics, the height of wind speed measurements, as well as due to methodological approaches (Kiseleva & Rafikova 2010). At the same time, taking into account the
difference in the heights for the determination of the potentials, the gross and technical potentials of wind energy on the territories are very close, which suggests reliability of the obtained estimates.

Figure 2. Assessment of the wind energy gross and technical potential on the territory of the Republic of Adygeya based on NASA SSE data (Stackhouse et al. 2016).

The significant potential of wind energy in the Republic of Adygeya allows for possible implementation of projects in this branch of renewable energy. For example, since 2011, a project on construction of three wind farms in Shovgenovsky, Giaginsky and Koshekhabsky districts with a total capacity of 441 MW is being implemented. The most prepared is the site of a wind park in Shovgenovsky district with a total capacity of 150 MW (75 units with a capacity of two MW each are envisaged). By now, wind monitoring has been carried out and the necessary data for designing have been obtained. Observations that were conducted for 1.5 years confirmed the availability of a commercially acceptable wind. Its strength at an altitude of 80 m was 6 m/s with an allowable speed of 3 m/s. The first phase of the 30 MW wind farm will be launched in 2018.

Solar Energy
The Republic of Adygeya is located in the south-west of Russia (within 44-45° N). A large number of sunny and clear days per year (up to 200-250) provide a significant influx of solar energy onto the underlying surface (more than 1200 kWh/m² per year), which indicates the high potential of solar energy in the region (Fig. 3).

According to the (Guide… 2007) and long-term ground actinometric observations, the gross potential of solar energy for the territory of the Republic of Adygeya is 1.3 billion TOE and the technical potential is 6.4 million TOE for the production of heat and 0.5 billion TOE for electricity production. According to SSE data (Stackhouse et al. 2016), the gross potential of solar energy is 1.42 billion TOE and the technical potential is 3.38 million TOE (27525 million KWh) to produce heat and 68.65 million GCal to produce electricity.

Deviations of the obtained results are due to the difference in the initial data on solar radiation, as well as due to calculation methods. At the same time, estimates of solar energy potentials for the territory of the Republic of Adygeya have one order of magnitude, which suggests reliability of the obtained estimates.

Construction of large solar power plants is preceded by calculations of economic return. The analysis shows that solar energy units on the territory of the Republic of Adygeya with a unit cost of up to 15000 rubles per square meter (in 2012 prices) and year-round operation with replacement of the energy of the cost of 2 rubles per kWh have acceptable pay-off periods (up to 7 years) (Butuzov et al. 2012).

Among the currently operating facilities on the territory of Adygeya, there is a solar unit of the “Seventh Heaven” Hotel, located on Lagonaki Plateau. It was launched in April 2016 and consists of 18 Exmork solar panels with a total capacity of 4.8 kWh (under ideal conditions). In practice, on average, the solar power plant produces 3.3-3.6 kWh, which ensures operation of the whole electrical equipment of the hotel for 7-8 hours.
Organic waste
Assessment of the gross and technical potential of organic waste in the Republic of Adygeya is based on the method suggested in the (Guide... 2007) and tried out in a number of studies on recent statistical material (Andreenko et al. 2012, 2014).

The general approach was as follows: data on average productivity per year (harvesting of crops, livestock, urban and rural population, etc.) were collected for each branch of agriculture, communal services, industries that formed organic waste (food, forestry, wood processing). Based on the known correlation values, evaluation of organic waste formation for each industry was carried out, as well as assessment of the energy content of this waste. The total energy of the waste from production and consumption in the region was taken as the gross energy potential of organic waste.

Thus, the basis for calculating the gross energy potential of organic waste was: volume of organic waste from each of the mentioned industries; waste density (for the transition from volume to mass); coefficients of specific energy content of waste (calorific value).

In this paper, we present the results of the assessments for the Republic of Adygeya, previously made with the use of statistical data of the early 2000s (Guide... 2007), as well as the results of our calculations made on the basis of the All-Russia Population Census of 2010, Rosstat data on productivity of agricultural sectors and industries of Russia for 2008–2013 (Fig. 4). It can be seen that the estimates of the gross and technical energy potentials of organic waste in the region are very close, that which suggests reliability of the obtained results.
In April—y2, conservative estimates, almost 50% of the territory of Adygea Republic of water, quite strong and regionally sustained permeable rocks. Temperatures of 100°C are 1900.

It suffices to note that a complex of different thermal conductivity, predetermined the high development of the West Kuban region.

In any case, the higher Russian Federation, made in the (Research report... 2014), hydraulic power of small rivers (Fig. 5) were performed assessments of the gross and technical potentials of hydraulic power of small rivers for the territory of the Republic.

Among the currently operating facilities on the territory of Adygea there is a mini-hydropower station on the Molchepa River, which provides electricity to the village Guzeripl. It was reconstructed in the framework of a joint project between the World Wildlife Fund and the Caucasus Nature Reserve. In April 2005, an old wooden dam was destroyed, and in June 2006, a mini-hydropower station of the capacity of 50 kW power was put into operation.

Geothermal Energy

The values of heat flows from the Earth’s interior in the Republic of Adygea range from 40 to 85 mW/m². In the large central part of the territory, which belongs to the platform part of the West Pre-Caucasian Region, these values reach 60–85 mW/m². Only in the western part of the Republic, which is located within the West Kuban trough, the values decrease to their minimum (Cheredeev & Maksimenko 1987).

Increased values of deep heat flows induced by the specifics of the geological structure and development of the Republic of Adygea, combined with changes in the capacities of lithologic-stratigraphic complexes of different thermal conductivity, predetermined the high-temperature character of the subsurface of this territory. The temperature at a depth of 1000 m varies from 40 to 60°C, at 2000 m – from 70 to 100°C (Fig. 5), at 3000 m – from 100 to 140°C, and at 5000 m – from 140 to 175°C. On the West Kuban trough territory and in the western regions of the Republic, there is a temperature decrease of 20-40°C in comparison with the central part of Adygea.

The high-temperature subsurface conditions of a substantial part of the territory of the Republic are an important argument for the positive assessment of the prospects of the usage of the deep heat of the Earth. It suffices to note that, within the greater part of Adygea, the depths of occurrence of rocks with a temperature of 100°C are 1900-2400 m with a total thickness of the sedimentary cover from 4-5 to 8 km and temperatures of 140-220°C in the lower part of it. It is also important that in this temperature range there are quite strong and regionally sustained permeable rocks.

The results of the research on the characteristics and geothermal conditions of the subsurface of the Republic of Adygea show that it has significant potential resources of thermal water. The fields of thermal water discovered to date and occurrence of thermal water in drilled areas show that, according to the most conservative estimates, almost 50% of the territory of Adygea appears to be promising for extraction and

**Figure 4.** Estimation of the gross and technical potential of biomass energy in the Republic of Adygea (a) – from (Guide… 2007) and (b) – According to the Laboratory of Renewable Energy of Lomonosov Moscow State University.
use of geothermal water. As a rule, hot water can be obtained here by self-pumping and with sufficient flow rates for practical use.

Figure 5. Distribution of temperatures of geothermal water (°C) at a depth of 2000 m in the Republic of Adygeya (Butuzov et al. 2009).

On the basis of systematic and generalized information about the subsurface geothermal regime, hydrogeological conditions, characteristics and occurrence of thermal water on the territory, four promising thermal water areas were identified (Fig. 6).

In the Republic of Adygeya, the State balance of mineral resources of the Russian Federation includes two fields of geothermal water: Maykop and Khodzevskoye.

The Maykop field of thermal water is located 10 km to the south of Maykop (Fig. 6). When conducting exploration work, aquifer complexes with the lowest mineralization and aggressiveness of geothermal water, as well as those with the greatest thermal potential, were taken for exploitation. The operational reserves of thermal water are taken as 4.75 thousand m³/day. The average annual production of thermal water in the field is 750000-850000 m³/year.

The Khodzevskoye field of thermal water covers the southern part of Koshekhabs district near the aul (village) of Khodz (Fig. 6). The field was discovered in 1980. By exploratory work until 1988, it had been proved that the reserves of thermal water in category B were equal to 1500 m³/day for year-round selection.

The limiting factor in the usage of geothermal water reserves in the Republic of Adygeya is the use of outdated heating technology facilities and utilization of waste groundwater containing phenol and other harmful components. Underground water with high mineralization is not subject to discharge into surface water bodies after treatment, and fresh underground water with a high temperature factor has very limited distribution.
For wide industrial use of geothermal water, one of the necessary conditions is reverse injection of wastewater into production layers. This will ensure reliable protection of the environment, since the disposal of used mineralized water excludes contamination of surface water bodies and soil cover.

The analysis of geothermal conditions on the territory close to Maykop confirmed the possibility of the usage of thermal water for the city’s public and industrial heat supply.

According to preliminary calculations, the prospective scheme of thermal water use consists of 10 geothermal cells in the area of Maykop. Each cell consists of two inclined wells – for water intake and water pumping. Expected flow rates are 1500–2000 m³/day. Each cell provides thermal energy in the amount of 82–110 Gcal/day.

![Map of the Geothermal Waters Spread](image)

**Figure 6.** Distribution of thermal water in the Republic of Adygeya according to ROSNIPITERMNEFT.

**Discussion**

The territory of the Republic of Adygeya, thanks to its geographical location, natural characteristics, economic specialization, has significant gross and technical potentials of renewable energy resources. It is the most preferable region for the development of solar energy, like the whole territory of the Southern Federal District of Russia. The terrain and the developed hydrographic network provide a substantial hydropower potential. The leading place in the economy of the Republic belongs to agricultural production and processing industries. This leads to a considerable amount of organic waste and, consequently, raw materials for processing with production of energy products (primarily biogas and heat energy). The great potential of geothermal water on the territory of the Republic makes it possible to use it both for industrial purposes and for heating of residential houses.

Further research and preliminary design require analysis of the factors that could influence the development of renewable energy (geological conditions, terrain, land use restrictions, environmental...
aspects). It also necessitates assessment of potential consumers of renewable energy in the Republic of Adygeya.

References


