Technical potential of crop production wastes as energy resource for agricultural regions of Russia

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Abstract. The use of woody biomass obtained from pruning and removal of perennial agricultural plantations for energy needs is a relatively new direction, which is now actively explored and developed in Europe. In Russia, horticulture and viticulture is also a traditional direction of agriculture in the southern regions, in particular, in the Republic of Dagestan. Dagestan is a volatile region with a variety of problems in the fuel and energy complex. The solution to these problems may become the use of renewable energy resources in the region. The paper presents the methodology for assessment of bioenergy resources in the region with the use of spatial analysis. The main purpose is to determine the optimal economically and technologically available energy technology for the estimated energy resource. The results show the high importance of social and economic factors for the development of renewable energy in the region, which is not typical for the other regions of Russia and should be taken into account in the further development of the methodology of multi-stage bioenergy resource assessment.

1. Introduction

A high level of agro-industrial production is accompanied by a significant amount of organic waste requiring disposal. The use of these wastes for the production of energy makes it possible to improve energy supply, level the environmental problems associated with the formation of highly toxic waste, and also improve the social status of the region. The experience of a number of countries shows that in areas with developed grain farming such waste may be straw - a by-product of grain production [1].

The use of woody biomass obtained from pruning and removal of perennial agricultural plantings for energy needs may be promising for areas that, on the one hand, have developed horticulture and viticulture, and on the other hand, have problems with energy supply or a difficult environmental situation due to the use of hydrocarbon fuel [2]. In this regard, we have reviewed the southern regions of the Russian Federation, in particular, the Republic of Dagestan.

The fuel and energy balance of the Republic of Dagestan is characterized by a high proportion of natural gas (66.6%) and hydropower (21.3%), and a small share of petroleum products (10.1%), solid and liquid fuels (0.77%) and a small proportion RES (1.2%). At the same time, Dagestan imports 90.6% of natural gas (with an annual consumption of 3.4 billion cubic meters), 76.6% of oil products (with an annual consumption of 416.9 thousand tons) and fully imports coal (about 25 thousand tons), and liquefied gas (15.6 thousand tons) [3]. These figures indicate that Dagestan is an energy-dependent region, and the ratio of imported and local energy resources does not contribute to the republic’s energy security. 98% of the electricity generated in Dagestan is generated through the use of...
hydropower resources [4]. The hydropower industry of Dagestan, concentrated in the basins of mountain rivers, depends on the level of their water content and decreases greatly in the winter months. It is at this time that energy consumption increases. These circumstances, as well as the condition of a number of old power lines in the region, lead to the fact that in hundreds of localities in 22 districts of Dagestan there is no sustainable energy supply. (According to measurements of winter loads, the voltage in the network of a number of consumers at the end of the line is 120-140 V. Technical losses range from 40 to 60 percent.) The solution to the problems of the republic’s fuel and energy complex may be to use the high technical potential of renewable energy resources in the territory of Dagestan [3-7].

2. Methodology
The mass of the annually generated grain crops waste was calculated using statistical data on the annual yield of these crops and the ratio of the useful part of the plant to the waste [7, 8]. To estimate the energy potential of the waste, we took the product of the waste mass to their specific energy content (lower calorific value). When calculating the energy potential of straw, it was assumed that the proportion of straw available for energy is 50% of the total. This is explained by the need to use part of the straw in animal breeding (feed, litter), crop production (fertilizer, mulch), in construction, and in new promising sectors of production: in the pulp industry for the production of cardboard and paper, in the food industry for growing mushrooms, etc.

The energy content of the fruit trees and the grapevine trims was calculated as the product of the mass of the trimmings produced in the garden area and the corresponding energy content of these trimmings (Table 1).

| Type of tree waste | Mass of waste per hectare per year, tons/hectare in a year | Specific heat of combustion, MJ/kg | The energy released during the combustion of waste from 1 hectare per year, tons of coal equivalent / hectare in a year |
|-------------------|----------------------------------------------------------|---------------------------------|-----------------------------------------------------------------|
| Pruning vines     | 3                                                        | 16                              | 1,638                                                           |
| Pruning fruit trees| 5                                                        | 10.5                            | 1,791                                                           |

The technical energy potential of wood for pruning perennial fruit crops and grapes, as well as straw, was calculated on the assumption that electricity and heat can be generated using a mini-TES with direct biomass burning of plant waste wood (conversion rate to thermal energy 75%, consumption for own needs 5 %).

A specific feature of the methodology is the use of geographic information mapping and multicriterial analysis methods. The use of mapping method is an essential part of territorial planning and natural resources assessment. In this case, one of the most popular and rapidly developing application areas of cartography is energy sector.

Currently accumulated extensive amounts of data, in varying degrees, provide the factual basis for research in the field of renewable energy. At the same time there are problems of data verification, interpolation, adequacy analysis production and processing methods, commercially available potential energy calculations and improving the base for choosing factors and constraints that affect the possibility of renewable energy sources use.

The authors currently work out on methodological base for renewable energy sources potential assessment and mapping in bioenergy sector. The approaches to energy resource assessment on a regional scale, based on compiling a series of natural and technical capacities maps, as well as the complex factors that affect the possibility of their practical use, have been developed. The special focus was made on taking into account social and economic factors.
In this paper we paid special attention to the technological factor, analyzing the spread of modern technologies for processing agricultural waste in the studied region, as well as their cost and environmental effect.

3. Results and Discussion

Dagestan has a developed agriculture. According to a number of works, livestock and plant growing waste in the region is a promising raw material for the production of biogas and thermal energy [5-7]. Farming of Dagestan is represented by two main branches - field cultivation, in which the cultivation of grain crops plays an important role, and fruit growing - horticulture and viticulture. Earlier, we estimated the energy potential of grain waste from three regions of Dagestan [6]. In this work, for all districts of the republic, technical heat potential of waste of those types of plant growing that were not previously considered in the estimates - waste of grain and horticulture was calculated, the possibilities of obtaining thermal energy from this local raw material were determined.

Favorable climatic conditions and age-old experience of the population of Dagestan determine gardening and viticulture as priority areas of the agro-industrial complex. According to the technology of growing grapes every year, after harvesting in the autumn-winter period, obligatory pruning is carried out, as a result of which tons of cut vine are removed from each hectare of vineyards. Also, annual formative and sanitary pruning of fruit plantations of the region is made. The search for the optimal use of a significant amount of woody biomass generated in these processes and determining the feasibility of processing it for energy purposes was carried out in many countries and by domestic researchers [1,5]. Thus, assessments of the energy content of waste pruning of the vine and fruit trees of the gardens of the Crimea were carried out in [6].

With the use of QGIS program we analyzed the spatial distribution of the energy potential obtained values. The above cartograms (Fig. 1) illustrate the uneven distribution of various types of energy-containing waste in the study area. The greatest values of the grain resource are confined to the northern and central parts of the region. Winegrowing waste is concentrated in the coastal areas of Dagestan. Mountainous areas are characterized by the availability of resources of various types: fruit, grain, and, in certain areas of mountainous Dagestan, vineyard waste.

![Figure 1](image1.png)

Figure 1. Technical energy potential distribution for the of perennial fruit crops (a), grapes (b) and grain crops (c) in the municipalities of the Dagestan Republic (according to 2017 official data (Farming of all categories)). A brighter color corresponds to the greatest potential.

At the same time, the analysis of the potential value amount given in Figure 2 characterizes the territories of coastal and central Dagestan, as the richest in crop waste, the conversion of which into
thermal energy can be up to 50-70 thousand Gcal. For the northern and mountainous Dagestan, the total energy potential of crop waste can be up to 20-25 thousand Gcal. Given the lower population density in these areas, this potential is also significant and appropriate to use.

In paper [9], the physicochemical properties of scrim wood of five fruit crops were studied and the obtained characteristics were compared with the quality parameters of the UNI EN 14961-1 2010 standard for forest wastes. It is concluded that the studied biomass is suitable for incineration in
conventional waste wood installations. All tested biomass residues of seedlings meet the established specifications, and also have similar characteristics for ash and calorific value. However, the chemical composition of pear and grape residues may be of some concern due to the high nitrogen content of the first and high ash, sulfur and chlorine contents in the latter.

Straw of cereal crops has a sufficiently high calorific value. It has significant potential for reducing CO2, SO2, NOX and CO emissions to the atmosphere compared to coal-fired plants; its use allows the development of decentralized energy using local fuels. However, straw is difficult to use for direct combustion due to its low energy density, high content of chlorine and alkali metals, significant yield of volatile components during combustion. These problems can be overcome by briquetting straw, features of structural solutions in the production of boiler furnaces. Currently, straw burning technologies to generate heat and electricity have reached the commercial level and are widely used in European countries [1]. There are also companies on the Russian market that offer a wide range of domestic energy complexes that use biofuel: wood waste, wood pellets, hop vine and grapes, straw, sunflower seed husks, etc.

Research on thermochemical processes of biomass conversion into energy still continues. In particular, of interest is the creation of gas-generating household stoves on biomass, which, due to their high energy efficiency and environmental friendliness, substantially exceed traditional furnaces of direct combustion of biomass. [10]

A technical and economic analysis of crop waste burning technologies in countries with already existing experience of use showed that in determining the cost of energy from biomass, its calorific value, efficiency of power plants, capital costs and operating costs play a crucial role. Studies of already functioning bioenergy projects have shown that, in the absence of the need to transport fuel (processing it into energy at the place of origin of waste), the cost of energy can be reduced to zero [11].

4. Conclusions

Currently Dagestan is actively implementing social support programs for the population, including support for agriculture, small business development in rural areas, raising the standard of living of the population, increasing energy security, and using renewable energy sources in the energy structure. Using crop waste as an energy raw material can help solve many of these issues. Our paper shows that in the north of the republic the use of cereal waste (straw) is most effective, and the rest of the republic has significant (up to 50-70 thousand Gcal) thermal energy potential of fruit and grape wood scraps. Due to social features, the most promising way to use this potential is low-cost biomass-to-heat (incineration) technologies that can be used in private farms, such as: biomass gas generator plates, steam boilers for wood waste, water heaters, and etc. The effect of the introduction of such technologies will solve not only the energy problems of the region, but also increase employment, reduce population outflow from rural areas, increase the technical and economic efficiency of horticulture, vineyards and grain farms, promote sustainable development of the region. Such a comprehensive analysis of the resources of various types of crop production, their distribution over the territory, as well as the technological base for their processing for energy purposes is also appropriate in other agricultural regions with a predominance of the rural population and economic and energy problems.

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References

[1] Geletukha G G and Zheleznaya T A 2014 Prospects for the use of agricultural waste for energy production in Ukraine. Analytical note BAU 7
[2] Geletukha G G, Zheleznyaya T A, Dragnev S V and Bashtovy A I 2018 Perspectives of using biomass from trimming and removal of perennial agricultural plantations for energy production in Ukraine *Ind. Heat Eng.* **40** 68-74

[3] Alkhasov A B, Badavov G B, Belan S I and Ninalalov S A 2016 On the implementation of the republican roadmap "The use of renewable energy sources in the Republic of Dagestan" Russia: trends and development prospects 659-662

[4] Alkhasov A B, Badavov G B, Belan S I and Ninalalov S A 2015 Questions of the republican roadmap "The use of renewable energy sources in the Republic of Dagestan" Regional problems of transforming the economy **9**(59)

[5] Gadzhiev G A 2018 Review of the renewable energy sources potential in the Republic of Dagestan *Materials of the XI School of Young Scientists “Actual problems of the renewable energy development”, October 15-18, 2018* (Makhachkala: ALEF) 7 113-115

[6] Andreenko T I, Kiseleva S V and Shakun V P 2015 Assessment of the energy potential of organic waste in the regions of Russia *Materials IV Int. Conference "Renewable Energy: Problems and Prospects" 21-24 September. 2015* (Makhachkala: ALEF) 2 307-314

[7] Atlas of Renewable Energy Resources in Russia (Moscow: Mendeleev RHTU) 2015, 160

[8] Database of municipalities indicators (Rosstat) Electronic resource (date of appeal - 10/20/2018) (http://www.gks.ru/dbscripts/munst/munst82/DBInet.cgi#1)

[9] Picchia G, Lombardinia C, Parib L and Spinelli R 2018 Physical and chemical characteristics of renewable fuel obtained from pruning residues *J. Clean. Prod.* **171** 457-463

[10] Klius V P, Klius S V, Zhovmir N M and Didkovska A G 2018 Biomass gas generator stoves *Alternative Energy and Ecology* **25-30** 60-72

[11] Caplar R and Kulisic P 1973 A technical and economic analysis of three large scale biomass combustion plants in the UK. *Applied Energy Proc. Int. Conf. on Nuclear Physics* (Munich) I (Amsterdam: North-Holland/American Elsevier) 517