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Current status and potential of bioenergy in the Russian Federation

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ABSTRACT

The article analyses the contradiction between the high biomass resources and low level of bioenergy utilization in Russia. The article presents the total estimation of bioenergy potential of Russia in comparison with the real utilization rate and with the bioenergy potential of other countries. The study gives the analysis of general bioenergy regulating policy in Russia and describes the key objectives of Russian bioenergy community. The authors of this paper made a preliminary evaluation of the technical bioenergy potential of Russia. It was estimated at 2225.4 PJ. Crop residues contribute 42% of the total potential while livestock waste contributes 9%, forest residues 23%, municipal solid waste 25% and biogas from sewage sludge 1%. Only 12% of the bioenergy potential of Russia is being currently utilized. To the extent of the authors' knowledge, this paper is the first attempt to compare the existing bioenergy potential of Russia to the level of its actual use. The technical bioenergy potential is equal to 30% of today's total heat and electricity consumption in Russia. At the same time in some regions the technical bioenergy potential exceeds the existing heat and electricity consumption. Considering the world bioenergy potential to be assessed in the range between 64 and 161 EJ, Russia accounts for 1.3–3.5% of it.

1. Introduction

The Paris Agreement enacted in November 2016 aims to limit global warming to less than 2 degrees compared to pre-industrial levels by limiting the use of fossil fuels and shifting to a low carbon economy. Biomass is one of the most important renewable primary energy sources. In 2014 biomass contributed 10.3% to the annual total primary energy supply [1]. In a broad sense biomass is any organic matter that is available on a renewable basis, including agricultural crops and trees, wood and wood residues, plants, algae, herbs, animal manure, municipal residues, and other residue materials.

Russia has the largest biomass resources in the world. The country leads the world in the forest area (809 million hectares as of 2010, 20% of the world's forest area) [2]. Russia ranks third in the world by the arable land (121 million hectares as of 2008, 8.8% of the world's arable land area) [3] and has the highest potential for enhancing the biomass production [4]. Given a huge amount of biomass, the bioenergy industry could play an important role both in the Russian economy and on the international markets. Nevertheless, the role of bioenergy in Russia is now surprisingly low. This discrepancy attracts the attention of many researchers [5–9]. However, these works are mainly focused only on one type of bioenergy recourses or on the single category of biofuels. Paper [6] is providing analysis of progress of liquid biofuels production in Russia. Researches in [7] and [9] are focused on solid biofuels. The works [5] and [8] are presenting economical and market analysis of biofuel and several aspects of bioenergy applications, respectively. Also, there is a lack of data on utilization of bioenergy potential. Thus, in a present paper we try to answer the next questions:

1) What is the real technical bioenergy potential of Russia?
2) To what extent is it used now?
3) What are the main obstacles for the development of bioenergy sector in Russia and what should the primary steps for its development be?

This article analyses the contradiction between the high biomass resources and low level of bioenergy utilization in Russia. The study gives the analysis of general bioenergy regulating policy in Russia and describes the key objectives of Russian bioenergy community. The article presents the total estimation of technical bioenergy potential of Russia in comparison with the real utilization rate and with other countries.

The paper is structured as follows. Section 2 describes the research methodology. Sections 3–8 cover different types of bioenergy re-

Abbreviations: E85, Motor fuel containing up to 85% ethanol; EJ, Exajoule (10^{18} J); Gcal/h, Gigacalorie per hour; GJ, Gigajoule (10^9 J); GW, Gigawatt (10^9 W); LHV, Lower heating value; MSW, Municipal solid waste; Mtoe, Million tons of oil equivalent (41.868 PJ); MW, Megawatt (10^6 W); PJ, Petajoule (10^{15} J); RPR, Residue to product ratio

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sources: crop residues, livestock waste, forest residues, municipal solid waste, sewage sludge and other types of feedstocks. Section 9 gives an overview of the current bioenergy policy of the Russian Federation. Section 10 provides a general review of Russia's bioenergy potential. Section 11 presents conclusions.

2. Methods

2.1. Methodology for estimating of technical bioenergy potential

The approach used in this study consisted of three steps. Firstly, relevant biomass resources were selected. Secondly, the technical and used biomass potentials were assessed. Finally, their primary energy content was calculated. The technical biomass potential considers all biomass theoretically available in the Russian Federation that can be technically supplied during one year. The used biomass potential is the biomass already energetically utilized. Biomass potentials were assessed based on the analysis of information from published research papers, official reports of the central statistics office, governmental ministries, NGOs, commercial enterprises, Food and agriculture organization (FAO) statistics. The primary energy corresponding to the technical and used biomass potentials was calculated using lower heating values of the selected biomass resources.

2.2. Crop residues

The values of crops production were taken from the Russian Ministry of agriculture database as of 2012 [10]. Procedures and formulas for the estimation of bioenergy from crop residues were adopted from Kasyanov [11]. The crop residues are by-products of the crop production systems. The amount of crop residues was calculated using the values of the production of crop and the residue to product ratio (RPR) of the crop. The crop residues are used competitively; a part of it is plowed back into the soil to provide soil fertility, another part is consumed as animal feedstock and for many other uses. The unused part, which is the surplus, is what is actually available for bioenergy production, and it was calculated using Formula (1). To estimate this surplus residue potential, the surplus availability factor was used. The surplus availability factor is a ratio of the residues available for bioenergy production after part of it was used for other purposes to the total residue produced.

$$Rs(j) = SUM\ Pij*RPRij*SAFij \quad (1)$$

where Rs(j) is the surplus residue potential at location j in t y^{-1}, Pij is the crop production at location j in t y^{-1}, RPR(ij) is the residue to product ratio of the ith crop at the jth location and SAF is the surplus availability factor of the ith crop at jth location. The values for the surplus availability factors are given in Table 1.

The bioenergy crop residue potential was calculated from the available surplus residues using the Eq. (2).

$$Ec(j) = SUM\ Rs(ij)*LHV(j) \quad (2)$$

where Ec(j) is the technical bioenergy potential at the jth location in PJ y^{-1}, Rs(ij) is the surplus residue available of the ith crop at jth location in t y^{-1} and LHV(j) is the lower heating value of the i th crop in GJ t^{-1}. The lower heating values in Table 1 were obtained for air dry residues with 18–20% humidity from Bezrukih [12].

2.3. Livestock waste

The quantity of livestock waste was estimated using Eq. (3)

$$Rlw(j) = 365*SUM\ N(ij)*Do(ij) \quad (3)$$

where Rlw(j) is the wet dung output per year for ith animal species at jth location, N(ij) is the population of animals of ith species at location j, Do(ij) is the wet dung output per day for ith animal species at jth location. The population of animals data were taken from the Russian Ministry of agriculture database as of 2012 [10].

The annual bioenergy livestock waste potential was calculated from the wet dung output using Eq. (4).

$$Elw(j) = SUM\ Rlw(j)*(1-Hi)*LHV(j) \quad (4)$$

where Elw(j) is technical bioenergy potential at the jth location in PJ y^{-1}, Rlw(j) is the wet dung output per year for ith animal species at jth location, Hi is a water content of the wet dung for ith animal species, LHV(j) is the lower heating value of the ith animal species dung in GJ t^{-1}. The lower heating values in Table 2 were obtained from Bezrukih [12].

2.4. Forest residues

Forest residues can be subdivided into harvesting residues which are generated during timber harvesting, wood processing residues generated during sawmilling, plywood and package processing residues and pulp and paper production residues. Data on quantities of forest residues were obtained from Levin [13] where it was calculated as "economically affordable resource". Average density and lower heating value were also obtained from [13]. The energy potential from forest residues was estimated according to Eq. (5).

$$Efr(i) = SUM\ Qfr(ij)*p*LHV(j) \quad (5)$$

where Efr(i) is the energy potential of forest residues in location j in PJ y^{-1}, Qfr(ij) is the quantity of ith forest residue in location j in mln m^3, p is an average density of forest residues and equal to 0.8 t m^{-3}, LHV(j) is the lower heating value of the ith forest residue at jth location and equal to 7 GJ t^{-1}.

2.5. Municipal solid waste

Energy potential from Municipal solid waste was estimated using Eq. (6).

$$Emsw(j) = SUM\ N(j)*Q(j)*LHV(j) \quad (6)$$

where Emsw(j) is the energy potential from municipal solid waste at jth location, N(ij) is the total human population in jth location, Q(j) is the quantity of waste generated per capita (kg p^{-1} y^{-1}), and LHV(j) is the lower heating value of the municipal solid waste in MJ kg^{-1}. Human population data were obtained from [14].

Table 1
Bioenergy potential from crop residues.

Crop	Residue type	Production (10^6 t)	RPR	Surplus availability factor	Surplus residue (10^6 t)	LHV (GJ t^{-1})	Bioenergy (PJ y^{-1})
Cereals and legumes (without corn)	Straw	62.695	1	0.63	39.5	12.57	496.5
Rape	Straw	1.035	1.8	0.9	1.7	15.33	25.7
Soy	Straw	1.806	1.3	0.9	2.1	15.92	33.6
Corn	Stalk	8.213	1.2	0.75	7.4	13.7	101.2
Sunflower	Stalk	7.993	3.5	0.7	19.6	13.4	262.4
	Husk		0.18	0.9	1.3	15.71	20.3
Total bioenergy from crop residues							940