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Production of Energy from Biomass: Near or Distant Future Prospects?

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The article is devoted to assessing the prospects for the production of energy from biomass. Based on the experience of European countries Europeans are studying the conditions for successful implementation of such projects, analyzing the government's plans to develop the market in Russia. In Russia, on basis of SWOT-analysis perspectives for the production of energy from waste timber industry, set off those that are environmental factors and internal properties of the technologies that should be considered when developing the widespread use of biomass for energy production strategy. The study draws conclusions about the competitiveness of energy production from biomass technologies among substitutes and the need for governmental support for their developments.

1. Introduction

The high cost of energy, limitation/exhaustible and the non-renewable resources lead to the search for alternative energy sources. The types of energy sources that would not hinder the environment and could compete in efficiency and cost effectiveness against the traditional forms of energy. This could be biomass that is currently the sixth in the ranking of supply availability and the fifth in productivity among renewable energy sources. Biomass refers to the total mass of plants and animals present in biogeocenose, in a definite size or level. Biomass is one of the most promising raw materials to satisfy the growing demand for renewable energy and the needs of "green chemistry".
In many countries is relevant as a topic, the studies of biomass as an energy source, therefore the work of Paiano et al (2016) of biomass plays a strategic role in the development of bioenergy in European Union, using Italy as an example, the author points out the necessity to stimulate economic mechanisms for the development of this sector European researchers actively propose new technology for the production of biomass and extracting energy from it, given its characteristics presumptive use of direction. United State researchers focused on the use of wood biomass (Ray et al, 2014). Roche et al (2015) analyzed the possibility of bioenergy production in Brazil based on 9 lignocelluloses biomasses. Kaltschmitt and Janczik (2015) proved the relevance of biomass as the world’s energy source.
Research perspective development of renewable energy in Russia is carried out by both Russian and foreign authors. According to the work of Kang et al. (2015), carried out was a comparative analysis of the evolutionary trajectory of the knowledge base of Russian biofuel technology from Germany and China, with made conclusions on the lack of an institutional framework for the development of appropriate technologies An interesting idea for stimulating the introduction of renewable energy sources in the energy sector was proposed in Boutte’s article (2012): to remunerate investors for the installed capacity (MW) of their installations, in particular the availability of their installations to produce electricity. Searches for the causes of non-compliance weak development of liquid biofuels from a huge bio-potential of Russia was conducted by

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Pristupa et al (2010), in which he drawn conclusions on the need for economic incentives and political will. Researcher Martinot (1999) identifies five potential markets for renewable energy, including electricity for villages and small settlements from hybrid wind-diesel and biomass, district heating for buildings from biomass. The author argues that the presence of technological opportunities and the challenges of market development affects their commercial usage.

Therefore, foreign authors agree on the necessity to study the Russian market of energy production from renewable energy sources in terms of commercialization of their existing projects.

2. Characteristics of biomass as alternative source of energy

As popularly known, alternative (non-traditional) sources of energy include: solar energy, wind energy, tidal energy, biomass and others. One of the main problems of most widespread use of alternative energy sources is the problem of discreteness of its supply, preservation and transportation. In our opinion, the best way to solve this problem came up by nature. Biomass is the storage (accumulator) of solar energy, as it is being generated by plant through photosynthesis. The task of chemists' scientists is to release this energy with maximum efficiency and minimal costs, to deliver energy to consumers.

The main sources of biomass come from objects of the world plant, animal waste, agriculture and forestry, as well as household and industrial waste. The latter on average consist of 80 % of the combustible materials, of which 65 % are of biological origin: paper, food and animal wastes, rags, plastic. Combustible components are carbon (~ 25 %), hydrogen (~ 3 %) and sulfur (~ 0.2 %), so the heat of combustion of municipal waste is 9 to 15 MJ / kg. The objects of the world plant, in particular woody biomass, can be considered as a renewable energy source only with the cultivation of special energy forests.

Energy production from biomass is produced in two main ways. The first is direct combustion. In this case, biomass is the biofuel without intermediary, the chemical energy of the combustible components of the biomass is converted into thermal energy coolant. Burning wood in the furnace is an example of a centuries-old traditional use of biomass to produce thermal energy. Modern use of this method involves the use of technologies to reduce waste, increase the amount of transmitted energy, and improve fuel performance.

The second method is to deepen the process of biomass in order to obtain from it a more energy-intensive and pollution-free fuel grades. During biomass thermochemical treatment (pyrolysis, gasification), solid fuel, liquid fuel or gas fuel is formed. In biochemical conversion of biomass (domestic and industrial waste, sewage, animal waste and agriculture), biogas is being formed (CH_4 - 60 ... 70 %, CO_4, N_2, H_2 and O_2). Processed products are biofuels with improved performance.

Tailing this end, scientists are looking for ways of processing biomass, so that it allows the provision of high energy end product and at low cost during its production. From the work of Corbetta et al (2015) the result of the thermochemical treatment of biomass is a gas which can be used as fuel for power generation, as well as for the needs of the chemical industry. It was proven that the efficiency of gasification and chemical composition of the produced gas is strongly dependent on the source material and the process operating conditions. An interesting example of an integrated approach biomass gasification using solar power was proposed in the work of Leon-Garzon et al (2014). Feasibility of solar steam-supplied biomass gasification is demonstrated. This study has shown that the potential economic benefit of the thermocline TES technology is defeated by the need of preserving constant operating conditions in the steam supply to the chemical process. The result of these studies and other studies bring to the conclusion that in order to ensure economic effect, requires large investments in projects to develop production technologies and at the stage of product introduction.

3. Development of markets that uses biomass to produce energy in Europe and Russia

According to the EU Climate Action (2016), the EU set a 20 % reduction in greenhouse gas emissions from 1990 levels and also increases the share of renewable energy sources and energy efficiency. According to the analysis of the National Renewable Energy Action (Scarlat et al, 2015), between 2005 and 2020, renewable energy is projected to increase in absolute terms more than two fold. Solar, wind and heat pumps are expected to be the highest growth with comparatively less increase from biomass and geothermal. In Europe the most demanding method of energy production from biomass, its biochemical conversion processes of producing biogas (report of AEBIOM, 2013). Also the statistic shows that the European Union is leading in the production of pellets use for the production of biomass with 12.2 Mt, however they consumed more than what they produced (Figure 1).

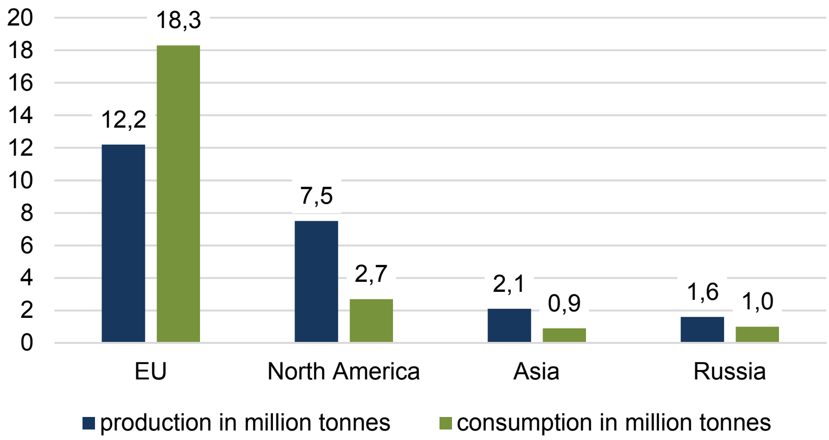


Figure 1: World production/consumption of pellets in 2013

According to experts, the potential usage of renewable energy in Russia is about 30 % from the volumes consumed in the country's energy resources. Pellets (pellets, briquettes) and biogas are universally accepted in any region. Gross potential of biomass energy in Russia is estimated at 467 Mt/y of fuel equivalent (coal equivalent). With large reserves of biomass and guided by the need for competitiveness in the emerging market perspective, Russia has a chance to not only provide themselves with sources of energy, but also to establish their export.

The strategic document defining the plans of the Russian Federation on the development of biomass energy production market is a complex program of development of biotechnology in Russian Federation for the period until 2020 (2012). Among the program's objectives: creation of technology and development of the industrial base for the formation of the biofuels industry, creation of an industrial base of bioenergy development, including the production of electricity and heat from biomass. Tactics defines an action plan ("Roadmap") "The development of biotechnology and genetic engineering" (Report of FSBO REA, 2012). Mechanisms to achieve the plans are implemented through two technology platforms biotech orientation: "Bioindustry and Bioresources – BioTeh 2030" and "Bioenergy". Responsibility of the participants of the program in the field of bioenergy development is a complex of the Russian Federation ministries. Roadmap in respect of biomass is laid in the following indicators (Table 1).

Table 1: Selected indicators of the road map development of biotechnology in Russia

Indicators	2012	2015*	2018*
The share ratio of biomass in the total volume of raw materials processed in the chemical and petrochemical industries, (in %)	0	5	12
The share of raw materials, processed with the use of biotechnological methods in the timber industry,%	0	5	8
Ratio biofuels and its components in the total fuel consumption,%	0	3	8
Heat production, bln. rubbles	8	60	160
Solid biofuel production, mln. tons	3	6	16
The square fast-growing plantation forests, thous	0	20	68

*- planned indicator

From the indicator (Table 1) it shows that, Russian has started energy production from solid biofuels, it is, above all, the use of waste timber industry (wood chips, pellets ...). Mastering the other forms of energy, biomass is at the stage of developed technologies and self-experienced productions (Report, 2012). Application of biomass as source of energy for the third generation is not indicated in the documents.

In the nearest future Russia has a chance to actively market growth of energy production from woody biomass. Russia is the leader in forest resource security, 45.4 % of the territory is covered by forests. For sustainable use of this resource as a source of energy is necessary to:

- Ensure the Provision of renewable resources,
- Reduce irretrievable losses from timber industry and word-processing,
- Ensure environmental safety in the production of energy.

Waste from wood processing- orderly consist 30-40 %, while forest waste are also significant. Currently in Russia, the raw material uses for the production of pellets are from these wastes.
Their production are mastered in the Republic of Komi, Karelia, Arkhangelsk, Leningrad and Pskov regions, Krasnoyarsk and Khabarovsk Krai (2012 Report). However, this production is oriented to the external market with the most favourable prices on biofuels. Domestic consumption of wood biomass as a fuel is realized on municipal energy facilities in some regions of Russia. But the highest woody biomass usage is in the production of thermal energy for entrepreneur selves' needs at wood-processing companies.

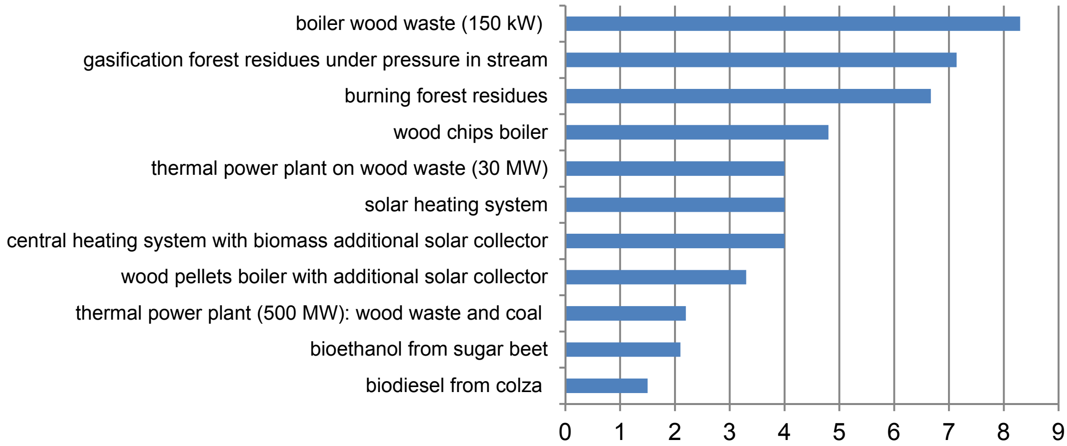
4. SWOT analysis perspective usage of Biomass energy in Russia

In case of indisputable advantages of exportation of wood fuel pellets, we will analyze the prospects of their application by Russian consumers. For this we are using the SWOT method analysis for the assessment of the weakness and strengths of introduction of wood biomass on the market of energy resources in Russia (Table 2). According to the SWOT analysis technique analyzed process of energy production from the point of view of economic efficiency for the producer (the internal environment). The characteristic of external environment consists of the description benefits from usage of wood biomass as a power source for the society.

Table 2: SWOT–analysis perspective of energy production from waste from waste of timber processing complex in Russia

	Strength	Weakness
Internal factors	Advantages	Disadvantages
	Universal availability of raw materials	High transportation costs
	Universality of raw materials	Strong dependence on energy output from raw materials features
	Controllability receipt of raw materials	Individuality of demand
	Low cost of raw materials	
	Big energy efficiency in comparison with other types of biomass	
External factors	Opportunities	Threats
	Reduction of negative impact on climate	Dependence on natural gas prices
	Economical usage of forest resources	Opportunistic benefits of competitors
	Reduce dependency on foreign producers of biofuels	Public awareness with regard to reliability and economic viability of technologies
	Diversification of the energy market	
	Selves waste utilization	

Woody biomass energy has significant advantages compared to other renewable energy sources. Bio-raw is available wherever there are trees, and is a potential source of major energy - liquid, gas, heat and electricity. Solid wood biomass is subject to long-term storage, in contrast to other renewable energy sources, characterized by an irregular and fluctuating seasonality. Compared with other types of biomass, forestry waste has the lowest cost (sometimes zero or even negative with regard to costs of utilization).
The energy produced from the wood pellets have a high calorific value (average 2-fold greater than that of lump wood). Energy content of 1 kg of wood pellets corresponds to 0.5 L of liquid diesel fuel; Wood pellets are not inferior to the calorific value of any coal or fuel oil. To evaluate the efficiency of renewable energy technologies and comparing them with each other using the methods and data proposed by Nussbaumer et al (2004). Efficacy is assessed using EYC_{NR} metric, which is the ratio of the energy of the "output" to the value of non-renewable energy "input" (i.e., the cost of biomass as an energy source of costs not included). According to the author's recommendations is to ensure that energy efficiency minimum value of the coefficient is 2, and the recommended value - more than 5.
The framework for energy efficiency analysis that uses renewable source of energy data designed by European researchers – (Nussbaumer et al, 2004) on combustion, (Pucker et al, 2012) on biomass based methane, (Bird et al 2013) performing LCA, shows that the minimum values of all power plants in the solid biomass corresponds to the recommended range (Figure 2). Compared with other types of fuel usage, woody biomass is more energy-efficient. EYC_{NR} specific value depends on a combination of many factors (type of biomass power and efficiency of energy, transportation etc.). Since thermal power plants have lower indicators, the production of electricity is less energy efficient than the production of thermal energy or combined production.



Figures 2: The minimum energy efficiency ratios installations using renewable energy sources

Comparing energy using different technologies performed in Pucker at al (2012). Operating the boiler on solid biomass (wood chips) and biomass gasification followed by combustion of the product gas in the boiler produces high close value in energy efficiency indicators. Among the disadvantages of using woody biomass as compared to other types of renewable energy: strong dependency on the output characteristics of raw materials usage and the high transportation costs.

One of the most essential opportunities in the usage of alternative sources of energy is - reducing the negative impact on the climate. According to Bird et al. (2013), greenhouse gas emissions from energy production from woody biomass as compared to power plants on minerals is reduced by 80-90 %.The best indicators are bioethanol and biodiesel second generation - for their emissions reduction of more than 90 %. In addition, the use of waste timber and woodworking complex helps conserve the forest resources of the country and get rid of the need for waste management.

In terms of improving the economic security of the use of woody biomass as an alternative energy source in Russia will diversify the energy market. And also to expand the market for biomass products, and accordingly, to reduce the dependency of Russian producers of biofuels in foreign demand for their products.

On the other hand, biomass - is the most difficult of renewable alternative energy sources. The first issue is the need to create efficient logistics, since organization stable and available biomass supplies in sufficient quantity and quality can be a challenge, reducing the project cost-effectiveness. The second issue – achievement of characteristics of energy necessary for the end user (net power, the type and amount of energy). Based on the characteristics of supply and demand for a particular area, it is necessary to choose optimum technology of processing biomass into energy.

External restrictions to wider use of biomass energy are in an ambiguous attitude of the society to the reliability and economic feasibility, as well as the lack of sufficient information about the technologies and market prospects. A critical constraint to the development of the market include the dynamics of natural gas prices, as a substitute for a used processing technology in energy gas is the main competitor of biomass, especially in the face of declining prices for traditional fossil-fuel energy.

5. Conclusions

The analysis of the product and the market showed the presence of the critical advantages of woody biomass as an energy source. In terms of technology, it is necessary to realize these advantages through search methods of biomass processing, to ensure a high-energy consumption of the final product and the low cost of its production. Despite the diversity of technology commercialization most assess abilities (that do not require large expenditures for implementation) expresses in the usage of solid waste only by producers themselves and the biomass briquettes for sale to the public. The scientific development of new efficient technologies for the production of biomass energy remains unused or is converted into product or volume of production which limit the possibilities of scientific laboratory.

In terms of market expansion prospects of Russia has sufficient reserves of raw materials for the production of product, which, however, mostly exported to the EU. The objective of sustainable development of Russia is to find ways for increasing the use of biomass for energy production. Restrictions on the widespread use of

biomass are attachment to a certain territory, that determine the need for development and implementation of specifics for the suitable territory (region, country), obstacles and program for their removal.
The answer to the question of how far the prospects for the use of biomass as an alternative energy source depend on the ratio of its price and the cost of the use of traditional energy resources. According to the analysis, we can state that there is the need for governmental support for scientific bioenergy development to the volume of industrial production and consumption, by taking into account the results obtained from the introduction of biomass environmental benefits. This ratio stimulated consumers in the use of biomass as an energy source.

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References

AEBIOM (European biomass association), 2013, Biogas <european-biogas.eu>, accessed 25.12.2015.
AEBIOM (European biomass association), 2015, Biomass count: statistic <biomasscounts.eu>, accessed 14.02.2016.
Bioenergy Russia in the XXI century, 2012, Report FSBO REA Ministry of Energy, 37 (in Russian).
Bird N., Cowie A., Cherubini F., Jungmeier G., 2013, Using a Life Cycle Assessment approach to estimate the net greenhouse gas emissions of bioenergy, Report on IEA Bioenergy <www.ieabioenergy.com>, accessed 20.01.2016.
Boute A. 2012, Promoting renewable energy through capacity markets: An analysis of the Russian support scheme, Energy Policy, 46, 68-77.
Comprehensive program of development of biotechnology in the Russian Federation for the period until 2020, 2012, 1853p-P8, Russian government <government.ru>, accessed 14.02.2016 (in Russian).
Corbetta M., Bassan, A., Manenti F., Pirola C., Maggio E., Pettinau A., Deiana P., Pierucci S., Ranzi E., 2015, Multi-scale kinetic modeling and experimental investigation of syngas production from coal gasification in updraft gasifiers, Energy and Fuels, 29(6), 3972-3984.
Eurostat Statistics Explained, 2016, Renewable energy statistics <ec.europa.eu>, accessed 20.02.2016.
Kaltschmitt M., Sebastian J., 2015, Biomass to power is on the rise globally. Renewable Energy Focus, 16(5-6), 174-176.
Kang J., Kholod T., Downing S. 2015, Analysis of Russia's biofuel knowledge base: A comparison with Germany and China, Energy Policy, 85, 182–193.
Kartha S., Leach G., Rajan S.C., 2005, Stockholm Environment Institute, Advancing Bioenergy for Sustainable Development: Guideline for Policymakers and Investors, ESMAP report no. 300/05, Washington, D.C. World Bank.
Leon-Garzon A.R., Manenti F., Ravaghi-Ardebili Z., Pirola C., 2014, Assessing thermal energy storage technologies of concentrating solar plants for the direct coupling with chemical processes. The case of solar-driven biomass gasification, Energy, 75, 45-52.
Martinot E. 1999, Renewable energy in Russia: markets, development and technology transfer, Renewable and Sustainable Energy Reviews, 3(1), 49-75.
Nussbaumer T., Oser M., 2004, Evaluation of biomass combustion based energy systems by cumulative energy demand and energy yield coefficient, Report for International Energy Agency and Swiss Federal Office of Energy, Verenum, CH – 8006 Zurich, Switzerland.
Paiano A., Lagioia G., 2016, Energy potential from residual biomass towards meeting the EU renewable energy and climate targets. The Italian case. Energy Policy, 91, 161-173.
Pucker J., Zwart R., Jungmeier G., 2012, Greenhouse gas and energy analysis of substitute natural gas from biomass for space heat, Biomass and Bioenergy, 38, 95-101.
Raucha P., Wolfsmayra U., Borzb S., Alexandru M., Krajncc N., Kolckd M., Oberwimmerd R., Ketikidise C., Vasiljevicf A., Stauderg M., Mühlbergg C., Derczenib R., Oravech M., Krissakovah I., Handlosi M., 2015, SWOT analysis and strategy development for forest fuel supply chains in South East Europe, Forest Policy and Economics, 61, 87–94.
Ray C., Ma L., Wilson T., Wilson D., McCreery L., Wiedenbeck J., 2014, Biomass boiler conversion potential in the eastern United States. Renewable Energy, 62. 439-453.
Scarlat N., Dallemand J-F., Fabio M-F., Banja M., Motola V., 2015, Renewable energy policy framework and bioenergy contribution in the European Union – An overview from National Renewable Energy Action Plans and Progress Reports, Renewable and Sustainable Energy Reviews, 51, 969–985.