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School of Business and Economics

ANALYSIS OF ORGANIC-WASTE-BASED BIOENERGY POTENTIAL IN THE RUSSIAN FEDERATION

Potential of substitution of conventionally produced energy with bioenergy considering current level of forest, agricultural and municipal waste in different federal districts of the Russian Federation

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Abstract

Nowadays energy problems are faced all over the world. One of the solutions in the difficult energy situation is utilization of renewable energy. Even countries that are rich with fossil fuels have recognized the necessity of development of alternative sources of energy. Russia's renewable energy potential is enormous. The Master's thesis studies the potential of the Russian Federation in the bioenergy sector from the waste point of view. Organic wastes from forestry, agro-industrial complex, landfills and wastewater treatment facilities are considered as sources for energy generation. The research discovers how much conventionally produced energy can be substituted with organic-waste-based bioenergy and in what federal districts of the Russian Federation bioenergy from organic waste should be developed. The thorough analysis of secondary data and personal computations have shown that about 17-20% of the total electricity production and 8% of the total heat production can be covered by energy generated from organic wastes. It means that bioenergy from organic waste can substitute coal or nuclear energy. However, a strong governmental support is needed for the bioenergy promotion.

Key words

Russia, bioenergy, organic waste, forestry, agro-industrial complex, MSW, sewage sludge

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1 INTRODUCTION

Nowadays energy issues represent a difficult topic all around the world. Energy is discussed on governmental levels, in non-governmental organizations, in scientific and research institutions and among individuals. Questions arisen vary from depletion of fossil fuels and pollution associated with energy production to energy security and energy efficiency. At the present moment quite often the answer to these questions is utilization of renewable energy potential. However, for some countries, which are rich with natural resources, it might be very difficult to see advantages for adoption of renewable energy technologies since the conventional ways of energy production (such as fossil fuels and nuclear fission) seem to be more economically efficient and familiar and the whole infrastructure for their utilization exists. The Russian Federation may be an example.

Russia is rich with natural finite resources. In addition, its renewable energy potential is also very high. Still, the percentage of energy produced from non-conventional energy sources is very low. Currently electricity generated from renewable sources of energy (excluding hydropower) accounts for less than 1% of the total electricity production. If large hydropower is not considered, biomass contributes to the energy production more than any other renewable source of energy. Bioenergy can be promoted in order to increase the rate of renewable energy utilization. Bioenergy development makes it possible for the Russian Federation to realize its enormous resource potential: 9% of world's agricultural land and 25% of world's wood resources (Ministry of Agriculture of the Russian Federation 2007). It can solve the problem of energy accessibility in remote areas, it can cut down CO_2 and pollution emissions, it can contribute to waste disposal problem – just to name a few benefits of bioenergy production. The aim of the research is to investigate what portion of conventionally produced energy can be substituted with bioenergy produced from forest, agricultural and municipal wastes and what would be the potential geographical distribution of organic-waste-based bioenergy.

Former research in this field mainly includes either global investigation of renewable energy potential or investigation of regional potential (e.g. for the countries with transitional economies). Non-governmental organizations (e. g. IEA, Greenpeace, WWF) tend to conduct in-depth review considering renewable energy, while Russian governmental sources of information are very scarce. In terms of the bioenergy production in different federal districts of Russia, there is the lack of information. All in all, information on bioenergy potential in Russia exists, but it is rather fragmented and limited.

This Master's thesis gathers information, which is difficult to find in open sources and perform an analysis of it. The study includes data on waste as a potential energy carrier in different industrial sectors: forestry and timber processing complex, agro-industrial complex, waste management sector (wastewater treatment and solid municipal waste disposal). The novelty of the investigation lies in the idea to conduct a simultaneous research of bioenergy potential in these industries, which are the biggest organic waste producers. The research that would examine bioenergy in the Russian Federation from the same perspective was not found. Yet, the results would be interesting for evaluation and would be helpful for renewable energy promotion.

The research is carried out in cooperation with Greenpeace Russia energy units in Moscow and St. Petersburg. Recently Greenpeace has issued a research paper "Energy [R]evolution", where an alternative to International Energy Agency's scenario of the world power sector development is examined. According to Greenpeace's findings in terms of bioenergy in countries with transitional economies (where Russia is included) it is possible to increase the installed capacity for up to 50 GW by 2020 (Greenpeace 2007). Half of it is meant to be in Russia. Since Greenpeace's investigation did not cover bioenergy situation in Russia in detail, this Master's degree research is expected to discover what bioenergy potential Russia has. In general, it is supposed to gather justifications for "Energy [R]evolution" findings. If not exactly to prove them, then to show the overall country's ability to reach them. The motivation for the research is its future applicability for promotion of bioenergy in Russia both on governmental and regional levels by Greenpeace.

2 RESEARCH PROBLEMS

For the topic development 2 research problems are outlined:

- To which extent is it possible to substitute conventional energy with organic-waste-based bioenergy in Russia?
- In what federal districts of the Russian Federation certain sources and methods of organic-waste-based bioenergy generation should be developed?

The first research problem is the core question of the thesis. The second one is important because of the geographical peculiarities of the country. As Russian territories are vast, the environmental conditions differ a lot. That is why it is significant to distinguish which sources, methods and technologies would be the most appropriate for different regions of Russia.

Both questions would help to create the general picture of the situation with bioenergy generation from organic wastes in the Russian Federation. Answers to these questions would involve approximate numbers (e.g. of potential bioenergy amount, the amount of fossil fuels reduction) and thorough explanations of where, how and why bioenergy can be produced.

3 METHODOLOGICAL CHOICES

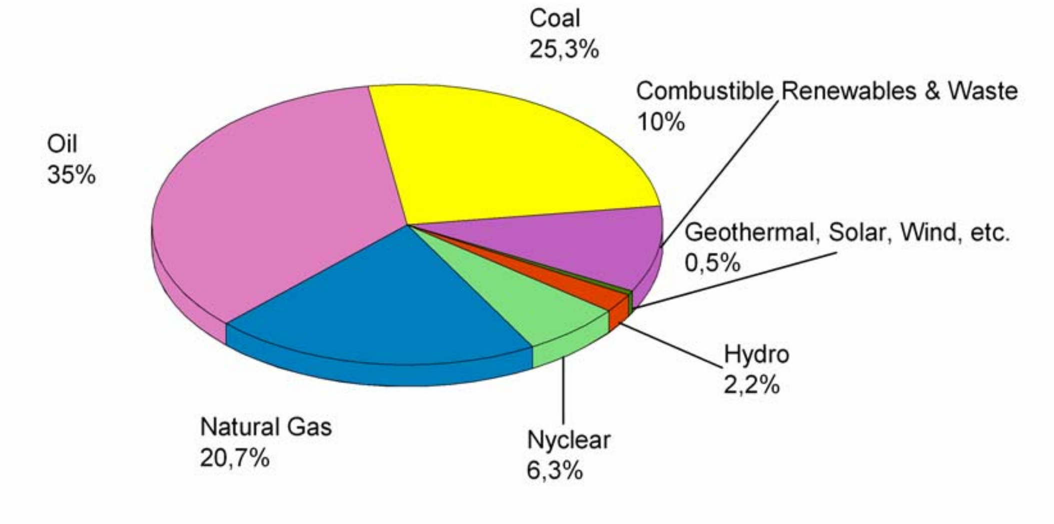
The idea of the research is to describe the potential of biomass utilization in Russia. In order to narrow the scope of the study, bioenergy produced from forest, crop, animal and municipal wastes (landfill gas and digester gas) is considered. Peat, firewood, energy crops, transport biofuels, algae will not be studied. In terms of the geographical scope, at first the overall bioenergy situation in Russia will be described and then the situation in certain federal subjects of the Russian Federation will be evaluated (the ones, where the discussed method of the bioenergy production should be the most effective). Thus, qualitative descriptive research method will be used. The main emphasis is on analysis of secondary data from the official governmental sources, research institutions and mass media (newspapers and industry journals). Throughout the research the comparison of the obtained data will be carried out. At a small extent some calculations will be performed mainly referring to energy amount of certain energy carriers and unification of energy units.

4 INTRODUCTION TO BIOENERGY

There is no any common definition of renewable energy. Generally it is described as "energy flows which are replenished at the same rate as they are "used"" (Sorensen 2000). In fact, the principal source of almost all forms of renewable energy is solar radiation. Solar radiation can be converted to useful energy directly (via thermal collectors or photovoltaics) or indirectly. In the latter case hydropower, wind power, wave power and bioenergy are meant. Tidal energy and geothermal energy do not depend on solar radiation. (Alexander & Boyle 2004.)

Renewables already significantly contribute to the world's total primary energy supply (FIGURE 1). Hydropower, combustible renewables and waste (i.e. biomass, animal product, municipal and industrial waste) and other renewable sources of energy (i.e. geothermal, solar, wind, tide and wave energies) altogether account for 13% out of total. However, combustible renewables and waste are prevailing over others. These sources of energy can be associated with bioenergy.

FIGURE 1. Total Primary Energy Supply in the World in 2005 (International Energy Agency 2007b).



Bioenergy is the general term for energy, produced from biomass, or organic matter that was a living matter relatively recently in contrast to fossil fuels (Larkin, Ramage & Scurlock 2004). Biomass is an enormous energy store. In plants through photosynthesis H_2O and CO_2 are converted to carbohydrates. When biomass decay or is burnt energy, CO_2 and H_2O are released back to the environment. If captured, energy can be used for human needs. The advantage of this type of energy production is that it does not produce more CO_2 emissions and do not generate more heat than it would have been produced by natural processes. In other words, generated CO_2 emissions equal to CO_2 amounts absorbed during photosynthesis.

Bioenergy can be generated in different production sectors from different resources that contain organic matter (TABLE 1). Usually, traditional biomass and "new biomass" are distinguished. Traditional biomass is largely used in developing countries, where sometimes up to 95% of the national energy consumption relies on it (Global Bioenergy Partnership 2007b). In most cases it is directly burnt for heat production, cooking and lighting. The term "new biomass" is used to describe materials for energy production on large and commercial scale, mostly in industrialized countries (Larkin et al. 2004). "New biomass" includes energy crops, i.e. purpose-grown crops that would be used for bioenergy production, and organic wastes. However, at the moment the question of the moral right for growing energy crops instead of food is raised by the international society.

TABLE 1. Biomass Resources (International Energy Agency 2007a).

Production sector	**Industry**	**Agriculture**	**Forestry**	**Waste**	**Traditional biomass**
Feedstock	Food, fiber and wood process residues	Energy and short rotation crops, crop residues, animal wastes	Forest harvesting and supply chain, forest and agroforest residues	Landfill gas, other biogas, municipal solid waste incineration and other thermal processes	Fuelwood, charcoal and animal dung from agricultural production

Numerous technologies can convert biomass feedstock to more convenient energy carriers in the form of solid fuels (e.g. pellets, chips, and briquettes), liquid fuels (e.g. bioethanol, biodiesel and methanol), gaseous fuels (e.g. biogas, methane and synthesis gas) or into direct heat

(International Energy Agency 2007a). In addition to biofuels some valuable by-products can be produced. For example, it can be glycerin in biodiesel production or fertilizers in biogas generation from agricultural wastes or wastewater sludge. Another significant advantage of bioenergy production is that processing of biowaste decreases waste amounts, thus, positively influencing on the ecological situation in the given region.

If properly organized, bioenergy production is economically and ecologically efficient. As a type of renewable energy it plays an important role in sustainable development all over the world. To specify, bioenergy can mitigate global climate change. It can insure energy security and facilitate accessibility to energy in rural areas. It is a “flexible” source of energy as heat, electricity and motor biofuels can be produced from biomass. It can influence on diversification of rural livelihoods and reduction in land degradation, especially if perennial crops are planted. (Global Bioenergy Partnership 2007b.)

Since different regions provide different biomass feedstock and different climatic conditions determine energy consumption habits and selection of technology, bioenergy potential should be studied separately and in detail in all of the regions, countries and even areas within a country. This Master’s thesis focuses on the Russian Federation, the largest country in the world. After Russia’s ratification of Kyoto protocol in 2004 the global rush towards CO_2 emissions reduction and development of alternative sources of energy has started. It is interesting to find out how the development of renewable energy goes in the Russian Federation, what bioenergy potential Russia has and what steps it undertakes in order to incorporate renewable energy, and bioenergy in particular, into its energy sector.

5 RUSSIAN ENERGY SECTOR

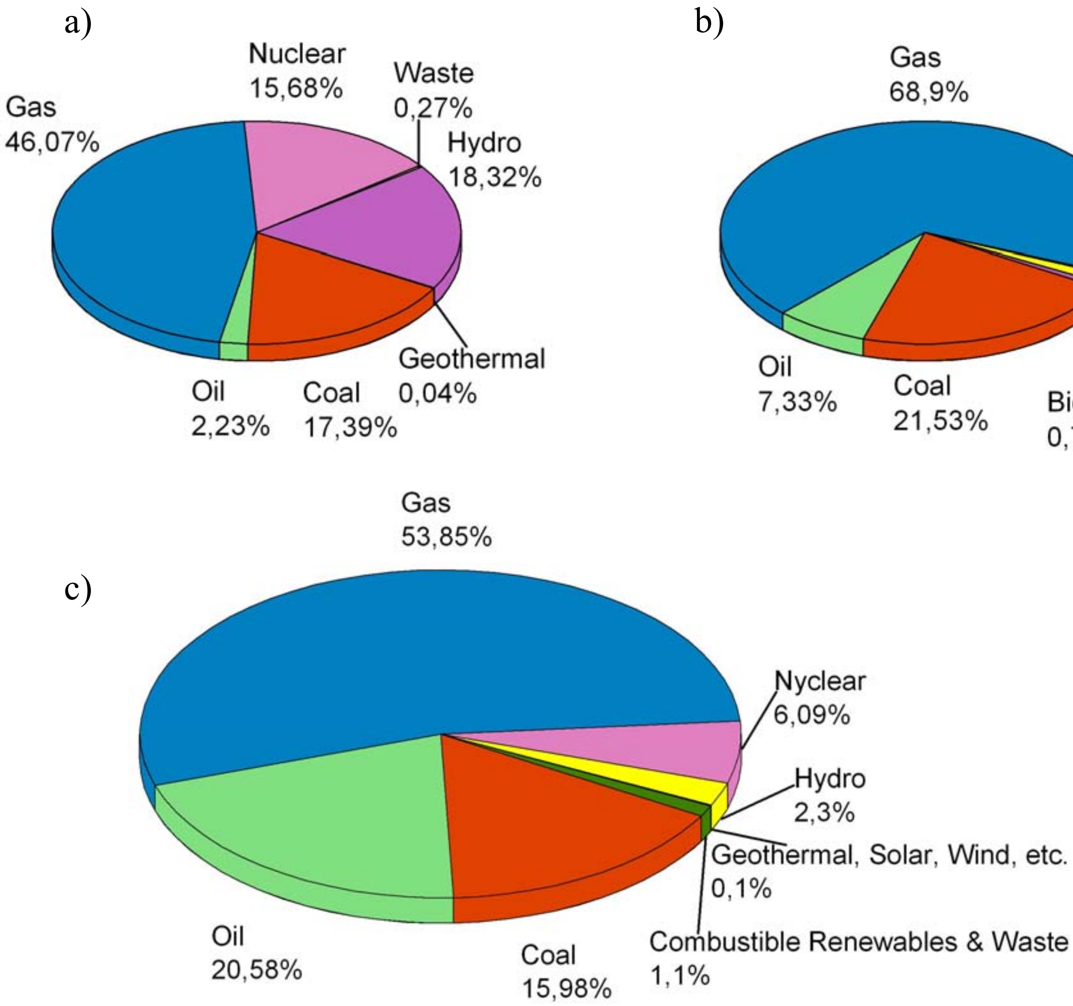
Russian energy sector is totally dependent on fossil fuels. The country is known as an important exporter of fossil fuels (Russia profile in Appendix 1). Fossil fuels dominate national energy mix. Contrarily, the contribution of renewable energy to the total energy generation is very small. This lack of diversification of energy sources makes the country to become dependent on labor-intensive and in many cases expensive conventional way of energy production, based on fossil fuels combustion. All alone traditional methods of energy generation are not capable to fully satisfy national energy demand. Alternative ways of energy production should be considered. Renewable energy can help in solving a number of energy related problems in both areas with centralized and decentralized energy supply.

5.1 Energy mix and share of renewables in it

Russia plays a crucial role on the world energy market especially in natural gas, oil and potentially coal supply. The country has more than 12% of world oil extraction, more than 22% of world natural gas extraction and about 5% of world coal mining (Grigoriev & Salikhov 2007). Further more, Russia has 12% of world discovered oil resources, 35% of world natural gas resources, 16% of world coal resources and 14% of world uranium resources (Bezrukikh 2007). In total Russia produces about 1,4 billion tons of coal equivalent (t.c.e.) of energy sources, 45% of which are exported, and 55% are used for the national energy generation (Grigoriev & Salikhov 2007).

Based on the information from the International Energy Agency (2008a,b), the electricity production in the Russian Federation in 2005 was 953 TWh, heat production was 1629,5 TWh, total primary energy supply equalled to 646 680 ktons of oil equivalent (t.o.e.) (FIGURE 2). Major sources of energy generation are fossil fuels, while hydro power from large hydro power plants, erected in the time of the USSR, is the only renewable source of energy, which is significantly contributing to energy generation.

FIGURE 2. Electricity (a) and Heat (b) Production by Fuel Type, and Share of Total Primary Energy Supply (c) in Russia in 2005 (International Energy Agency 2008a,b).



The high share of natural gas can be explained by low prices on gas within the country. Generally tariffs on electricity and heat and natural gas prices are controlled by the state, and are often kept artificially low. Obviously, this influences prices on renewable energy, making them much higher and thus incapable of competition. However, in future national prices on natural gas are expected to be raised to the level of export prices, in turn, it may give a new impulse to renewable energy development. Yet, another obstacle may appear. According to "the General Scheme for Location of Electrical Power Facilities until 2020" the main attention will be paid to stimulating the maximal growth of nuclear power, hydropower and thermal energy generated from coal. In addition, coal utilization for the energy production should outmatch natural gas utilization. In this manner during the time period 2006-2020 the total energy capacity of new coal fired power units is supposed to increase by 53,9 GW[1], while for gas fired power plants the increase is 34,1 GW, for nuclear power plants - 32,3 GW, and for hydropower plants – 25,9 GW. This means that while some countries see natural gas as a transition fuel for moving towards clean energy generation, in the Russian Federation its portion in the fuel and energy balance is supposed to decline in order to empty the space for coal utilization. Parties interested in this energy scenario are much stronger than the ones promoting renewable energy. Thus, it will be a huge challenge for the latter ones to increase the utilization of renewables in Russian power sector.

Currently the share of renewable sources of energy in the total energy production (excluding large hydro) is less than 1%. To be more precise the share of renewables in the electricity production in 2005 was 0,88% (TABLE 2), while their share in the heat production was 4,9% (TABLE 3). However, according to some points of view, renewable energy production without strong governmental support has already reached its maximum and does not have potential for further development, unless some incentive measures will be developed by the government (Bezrukikh 2007).

TABLE 2. Electricity Production from Renewable Sources of Energy, GWh (Federal State Statistics Service 2001-2005 in Bezrukikh 2007).

Type of energy production unit	**Year**					
	2000	2001	2002	2003	2004	2005
Wind energy power stations	2,917	4,12	6,774	10,381	9,864	9,659
Geothermal power stations	58,2	91,2	149,1	313,1	395	396,4
Small hydro electric stations	2301,2	2371,2	2413	2276,7	2741	2788
Power stations with biomass fuel	1895,3	2226,5	2426,5	4750,3	5520	5184
Total	**4257,6**	**4693,4**	**4994,9**	**7350,5**	**8665,9**	**8378**
Total electricity generation in Russia	877800	891300	891300	916300	931900	953100
% of renewable sources of energy	0,48	0,53	0,56	0,8	0,93	0,88

[1] In basic scenario

TABLE 3. Heat Production from Renewable Sources of Energy in Russia, Tcal (National Scientific Centre of the Federal State Statistics Service, 2004, 2005).

Type of energy production unit	**Year**					
	2000	2001	2002	2003	2004	2005
Power stations with biomass fuel	8900	9720	10668	15550	19592	16773
Boiler houses with biomass fuel	45000	46000	46500	48000	48000	48500
Solar collectors	30	31	32	33	35	36
Heat pumps	380	390	400	410	450	460
Waste incineration plants and installations	300	300	300	300	300	300
Biogas installations and aeration stations	2000	2000	2000	2000	2000	2000
Geothermal systems	1000	1000	1000	1100	1150	1200
Total	**57610**	**59441**	**60900**	**67393**	**71527**	**69269**
Total heat production in Russia (from 191500 enterprises), Pcal	1420	1440	1426,9	1422,1	1402,1	1420
% of renewable sources of energy	4,1	4,1	4,3	4,74	5,1	4,9

As it can be seen from TABLE 2 and TABLE 3, bioenergy is a leading type of renewable energy in the electricity and heat production, if large hydro power plants are excluded. However, this positive first impression is very deceptive. Innovative bioenergy generation technology and methods are not used at large scale. Instead, direct combustion of firewood, peat and, at some extent wood residues are practiced (Bezrukikh 2007). The attitude towards renewable energy has to be changed. It was estimated that by 2012 Russia would suffer shortages of natural gas for national needs in the amount of 170 billion m^3 because of all foreign trade contracts the country has signed and because of the reduction of the discovery of natural gas deposits (Sokolov 2007). The close attention to alternative types of energy sources might mitigate consequences of the coming energy problems.

5.2 Renewable energy resources and their potential

Russia is one of the richest countries in terms of natural finite resources. Similarly, its renewable energy potential is vast. Unlike smaller countries, where usually just one or several forms of renewable energy sources exist, Russia has them all (TABLE 4). All regions of the Russian Federation have one or two forms of renewable energy that can be commercially exploitable. At the same time some regions of the country are rich in all forms of renewable energy sources (for example, Krasnodar Territory, where technical potential of renewable energy is twice higher than region's current energy consumption level) (Bezrukikh 2007) (Map of federal subjects in Appendix 2).

TABLE 4. Geographical Distribution of Renewable Sources of Energy in the Russian Federation (EU-Russia Energy Dialog Technology Centre 2004).

Renewable source of energy	Location
Wind energy	Northern territories: the coasts of the White Sea, the Barents Sea, the Kara Sea, the Bering Sea, the Sea of Okhotsk, the East-Siberian Sea, the Chukchi Sea, the Laptev Sea. Eastern territories: the coast of the Japan Sea. Southern territories: the coast of the Black Sea, the Azov Sea, the Caspian Sea. The middle Volga regions, the Ural mountains, the steppe areas of West Siberia and around the Baikal Lake.
Solar energy	South-Western territories: North Caucasus, the Black Sea and the Caspian Sean regions. Southern Siberia and the Far East.
Bioenergy	North-Western territories, Siberia, the Far East. Central, Volga and Southern federal districts.
Small hydro	Central and Eastern Siberia, the Far East, the North Caucasus and western part of the Ural mountains.
Geothermal energy	Far Eastern territories: Kamchatka, Chukotka, Sakhalin, the Kuril Islands. Southern territories: Northern Caucasus territories, Dagestan. The Central region of Russia, the West Siberian plate, the Baikal lake, Krasnoiarsk territory (Krai).
Tidal and wave energy	The Far East and northern territories.

The total economic potential of all renewable energy resources is estimated to be 320 million t.c.e. (TABLE 5). The economic potential of the biomass is 69 million t.c.e. In future the economic potential of renewables is very likely to grow, if prices on fossil fuels increase and prices on renewable energy technologies decrease.

TABLE 5. Evaluation of the Potential of Renewable Sources of Energy in Russia, in million t.c.e./year (Bezrukikh 2007).

Type of renewable energy	**Potential of renewable sources of energy**		
	Total potential	Technical potential	Economic potential
Wind energy	44326	2216	11
Small hydro energy	402	126	70
Solar energy	2205400	9695	3
Bioenergy	467	129	69
Geothermal energy	$29{,}2 * 10^6$	11869	114
Low potential heat	563	194	53
Total	**2251158**	**24229**	**320**

The evaluated economic potential of bioenergy equals to 561 TWh[2] annually. The number is thrilling. On one hand, it inspires, on the other, it requires thorough investigation and close check. Besides the tremendous energy content, biomass utilization has positive ecological and social effect on global and local scales. Since organic wastes can be used as energy sources, bioenergy is able to solve crucial problem of waste handling and disposal. Biogas capturing contributes to the reduction of greenhouse gas emissions. Bioenergy is capable to influence on human life quality by providing electricity for both areas with centralized and decentralized energy supply.

5.3 Electricity and heat supply

5.3.1 Decentralized electricity supply

About two thirds of Russian territory are not connected to centralized energy supply systems (EU-Russia Energy Dialog Technology Centre 2004). At least about 10 million people are not

[2] Calculation: 1 kWh = 0,123 kg of coal equivalent. Consequently, 69 million t.c.e. are 561 TWh.

connected to the national grid (International Energy Agency 2003) and about 20 million people have unsecured centralized energy supply (Dmitriev & Karlin 2006). The majority of the population from these territories is living in rather small settlements located far from each other in northern regions, Siberia or Far East. There energy problems are usually solved by diesel and gasoline power stations, household fuels (e.g. firewood) and connection to local power grid (EU-Russia Energy Dialog Technology Centre 2004).

Large expenditures are associated with delivery of fossil fuels from other regions. Remote areas in the North and the Far East get their fuel by rail or road and sometimes even by helicopter (International Energy Agency 2003). For example, the delivery of fossil fuels to the regions of the Extreme North and equivalent areas is about 7 million tons of oil products and 23 million tons of coal (Committee for Energy, Transport and Communication of the Russian State Duma 2007). With growing transportation costs the price on fossil energy source becomes twice higher and in the remote areas appears to be more than 400$ per t.c.e. (Dmitriev & Karlin 2006). The development of local renewable energy will minimize transportation costs, will mitigate negative environmental impacts associated with conventional fuels and will secure fuel and energy balances of the territories. In addition, construction of electrical power lines in order to supply low-power agricultural consumers with electricity is relatively expensive. However, all regions of the country have enough renewable sources of energy to supply low-power agricultural consumers with the electrical density load from 0,5 to 70 KW per km^2 (EU-Russia Energy Dialog Technology Centre 2004).

Further on, Russian dachas (summer country houses) can be potential consumers of off-grid connected renewable energy. According to the International Energy Agency report (2003) about 5 million individual farms are not connected to the electricity grid and many dachas experience unreliable and expensive power supply.

5.3.2 Centralized electricity supply

Renewable sources of energy can provide energy security in areas with centralized energy supply. In 2006 RAO "UES of Russia"[3] has named 16 energy systems on the territory of the Russian Federation that potentially can suffer from power shortages. They are Arkhangelsk, Kuban, Vologda, Leningrad, Moscow, Nizhny Novgorod, Sverdlovsk, Tyumen, Ulyanovsk, Chelyabinsk, Saratov, Komi, Tuva, Karlia, Dagestan, and Perm energy systems (Gazeta 2006). Although recently it was stated that the number of energy systems experiencing shortages of electricity supply was reduced to 9, still Far Eastern, Urals and Central federal districts may face power supply problems, especially in peak hours or during cold winter time. Renewable energy, and bioenergy in particular, is capable to ease this situation by allowing some industrial (e.g. wood processing plants) and agricultural enterprises and municipal establishments (e.g. landfills and wastewater treatment plants) to produce energy for their own needs and, in the better outlook, even to sell is to the national grid.

5.3.3 Heat and hot water supply

Use of energy for heat and hot water production is known to be highly inefficient in Russia. Technology and pipes are very depreciated and in many case unable to sustain cold winter conditions. As the result of accidental break-downs now and then towns are experiencing lack of heat supply, while people are struggling harsh winter months.

52% of total heat is generated in heat-only boilers (International Energy Agency 2003). Mostly boilers are diesel or coal-fed. However, as in the example with electricity production, it is very expensive to transport fossil fuels to some regions of the Russian Federation. A number of local renewable sources of energy can be exploited for heat production: geothermal energy (i.e. in Far East and Southern federal districts), solar energy (e.g. in Southern and Siberian federal districts)

[3] RAO Unified Energy System of Russia is the largest company in the power sector of the Russian Federation. It is a state monopoly, since government owns 52,6% of it. The authorized capital of the company includes thermal and hydraulic power plants, trunk transmission lines with substations and other power facilities and blocks of shares in energy companies, research and engineering companies and construction entities of the industry. RAO "UES of Russia" does not own nuclear energy facilities. The company will be restructured in July 2008 in order to create competitive conditions on Russian energy market.

and bioenergy (e.g. in Northwestern, Siberian and Far East federal districts). Additionally, combined heat and power (CHP) technologies should be adopted as they have proved to be more efficient than heat-only production units.

Many rural settlements do not have connection to centralized heat supply. About 12,6 million households use firewood, peat or coal for heat production (International Energy Agency 2003). Stand-alone bioenergy installations with wood or agricultural wastes as a fuel and solar thermal collectors can be promoted for individual use.

6 POLITICAL FRAMEWORK FOR RENEWABLE ENERGY SECTOR IN THE RUSSIAN FEDERATION

On March 2, 2008 a new president of the Russian Federation, Dmitry Medvedev, was elected. Even though it is know that he would continue the political rout of the former Russian president, Vladimir Putin, there are some expectations in terms of the development of ecological regulations and renewable energy. It is very likely that a number of renewable energy projects would start, indicating a new way of Russian development in the energy sector. At the same time, renewable energy projects would be initiated under the pressure of the international society. Thus, they might become “image projects”, used for the Russian Federation reputation improvement in front of the economically developed countries. Yet, the current political framework does not allow renewable energy easy and fast development and widespread.

6.1 Political perspective on renewable energy

On January 24, 2007 the Subcommittee for Renewable Energy Sources of the Committee for Energy, Transport and Communication of the Russian State Duma was formed. Its main responsibility is the facilitation of development of the regulatory and legal framework for renewable sources of energy. Although the renewable energy issue was recognized as an important one and the Subcommittee was formed, it has happened just recently and not much progress has been done so far. Even the chairman of the Subcommittee for Renewable Energy Sources, Valentin Ivanov, is very skeptical about the rapid integration of renewable energy into the Russian energy portfolio (Rubashkin 2007).

The most crucial barrier for the development of renewable energy in the Russian Federation is the lack of the legislative base (Legislative acts in the field of renewable energy and bioenergy in the

Russian federation are in Appendix 4). The main documents, which somehow mention renewable energy and its future development at the governmental level, are “the Energy Strategy of Russia for a Period until 2020” (later used as the Energy Strategy) and the federal targeted programme “the Energy Efficient Economy”. In the Energy Strategy it is mentioned that the technical potential of renewable energy is about 4,6 billion t.c.e., which is five times higher than the total consumption of all fuel and energy recourses of Russia. While the economic potential is evaluated to be about 270 million t.c.e. and that is a bit more than 25% of the annual energy consumption in Russia[4]. However, the poor utilization of renewable sources of energy is outlined among the problems of the Russian fuel and energy complex. BusinessWeek Russia has investigated that according to the Ministry of Industry and Energy of the Russian Federation the rate of non-conventional energy sources (excluding energy form large hydropower plants) in the total energy production, which was 991 TWh, accounted for less than 1% in 2006 (Askochenskaya, Klokova, Orekhin, Skornayakova & Borisov 2007). So, no progress was made in comparison to 2005. To continue, in the Energy Strategy the share of renewable sources of energy in the energy balance is planed to become 5% in 2015 and 10% in 2020. An alternative point of view was presented to BusinessWeek Russia by the RAO "UES of Russia". In its forecast the main Russian power holding company states that the rate of “other” energy carries (not gas, coal, heating oil or nuclear) will still be the same 1% in 2015.

The Energy Strategy does not see renewable energy as one of the main and competitive ways of the energy generation. It is rather considered to be a supplementary tool that can help in solving a number of problems. For instance the Energy Strategy mentions the crucial role of renewables in three spheres: i) in steady energy supply in remote areas with decentralized energy (mainly regions of the Extreme North and equivalent areas); ii) in supporting guaranteed minimum of the energy supply in regions with centralized energy, in regions experiencing shortages of energy or as loss prevention of emergency and restrictive shutdowns; iii) and finally, as a method of reduction of airborne emissions, which are associated with energy production, in areas with a complicated ecological situation or in recreation areas.

[4] Outdated information is used in the Energy Strategy. New estimations of total, technical and economic potentials are presented in TABLE 5.

Still, these very general mentions of renewable energy lack some implementation practices. In other words, the government has not gone any further than just proclaiming some very general plans. All governmental programmes and legislation are in their development phases. For instance, RAO "UES of Russia" and the Ministry of Industry and Energy of the Russian Federation have prepared the draft federal law “On Support of the Use of Renewable Sources of Energy” (Weekly Newspaper of Industry Growth 2007). Another example is the development by the Government of the Russian Federation the federal law on basics of bioenergy promotion. Many other federal laws or draft federal laws are in progress. A lot of recommendations to the Government of the Russian Federation have been issued by the Committee for Energy, Transport and Communication. Yet, none of the bills have been enacted.

A successful example of legislation development is an amendment to the federal law “On Electric Power Industry”. On November 8, 2007 the amendment to the federal law came into force due to the coming restructuring of the Russian energy system. According to the changes, energy units (including renewable energy units) with the capacity of less than 25 MW can receive some financial reductions, when connecting to the national grid. This is a good sign of support of renewable energy producers for their participation in the electricity trade. However, in practice the process of connection to the national grid is very long and complicated.

After all, the problem of legislation is evident to everybody. The Russian Parliament and the Government do not rely just on themselves. Cooperation with foreign experts is more than encouraged in terms of both knowledge and investments.

On November 2, 2007 on the Session of the General Conference of UNESCO a resolution on establishing the International Centre of Sustainable Energy Development in Moscow was adopted. The main goal of the Centre is to ensure energy security. The main tasks are analysis of current energy situation and forecasting the power sector development. Since a chairman of the Board of Governors is a minister of the Ministry of Industry and Energy of the Russian Federation, the Centre is capable to influence on policy making. Yet, its influence on renewable energy development has not been strong.

At the moment probably the most important programme in the field of renewable energy is Russia - Renewable Energy Programme (RREP). The programme is partly funded by the World Bank's Global Environment Facility (GEF). GEF's grant accounts for more than 10 million US$, while the rest of the expenses (total programme's costs are about 80 million US$) will be covered by the Government of the Russian Federation, administrations of subjects of the Russian Federation, the National Pollution Abatement Facility, the Renewable Energy and Energy Efficiency Partnership, the private sector and municipal companies. The general aim of the programme is to reduce green house gas emissions. In addition, the programme sets some development objectives, which are supposed to support the development of enabling policies, institutional capacity, and different financing mechanisms for establishing a market for renewable energy. (Global Environment Facility 2007.)

European Union is also investing in renewable energy development in the Russian Federation. A project with the budget of 2 million Euro has been already started in December 2007 and is planned to be completed by December 2009. The main purpose of the project is to help Russian and regional governments to develop legislation and norms for stimulation of the renewable energy adoption. The targeted regions are Astrakhan, Nizhny Novgorod and Krasnodar oblasts. (Nikiforov 2007.)

However, while the federal law is still under development, several regions have already adopted some programmes and regulations on renewable energy. The World Bank states that 43 regional laws on energy saving, 24 energy saving funds and 75 energy efficiency centers have been established in Russia at the regional level. More than 650 energy efficiency programmes are under implementation, including 45 programmes at the sub-national level, and more than 537 municipal programmes. (World Bank 2007.) Therefore, regional and municipal authorities form the driving force for the promotion of renewable energy in the Russian Federation.

6.2 Political perspective on bioenergy

As it was mentioned above the federal law on bioenergy does not yet exist. That is why there is no any precise definitions of what bioenergy is and from which sources of energy it is produced.

Another problem is that in the State Standard of the Russian Federation (GOST) there is no any standards related to bioenergy. However, legislation refers to utilization of local types of fuels. In turn, from local types of fuels bioenergy can be generated. For example, in the federal targeted programme "Energy Efficient Economy" the increase of production of local types of fuels is stated, namely the production of firewood and fuel peat. Besides increasing existing production capacity of these fuels new technologies based on wood processing plants should be utilized. Even though it is not written explicitly, but it means the utilization of wood residues for fuel production.

Municipal waste is also mentioned in the Energy Strategy, but just in few words. According to the document favourable condition should be created in order to incorporate municipal waste into the fuel and energy balance of Russia. At the same time it will provide solutions to some ecological problems. However, municipal waste is mostly considered for heat not electricity production.

At small extent bioenergy sector is mentioned in the federal targeted programme "the Development of Agriculture and Regulation of Markets for Agricultural Products, Feedstock and Food for 2008 - 2012". Still, the scope of bioenergy is limited to cultivation of energy crops and technical modernization of agricultural machines for biomass processing.

The federal targeted programme "the Research and Development in Priority Fields of Development of Scientific-Technological Complex in 2007-2012" is usually addressed in terms of the bioenergy as well. A number of bioenergy research projects is currently funded through the programme. Some of them are related to the design of a biostation for electricity generation from agricultural residues, technology development for biogas production in the agro-industrial complex, research of landfill gas utilization and investigations on feasibility of construction of a bioethanol production plant. It is interesting to point out that almost all of the projects funded by the federal programme refer to agro-industrial complex. Quite possible, the reason is that, as usual, the agricultural sector is very unlikely to be capable of development without governmental subsidies and other financial incentives. This seems to be true in terms of the bioenergy in the agro-industrial complex. The development and adoption of bioenergy without governmental support may become quite slow and complicated, yet agricultural sector potentially is an intensive bioenergy consumer as it already generates significant biowaste amounts. Further on, a national project of agro-industrial complex initiated by former president Vladimir Putin is still in its working phase. The ambitious goal of Russia is to become one of the leading producers of agricultural products in the world. Bioenergy technology development would be a reasonable step towards this target. In addition, such attention to the renewable energy generation in agriculture may be explained by the very optimistic governmental approach for energy crops cultivation. Concerning bioenergy development in forest and wood-processing industries it may be predicted that private sector, especially foreign investors with their know-how and technologies, may become a driving force. And finally, development of energy production from landfills and sewage may be designated to the federal subjects of the Russian Federation with all the consequences: development of regional legislation, R&D and energy production.

To continue, there are some polices under development. For example there are hearings in the State Duma "On the Law Delimitating Usage of Ethanol as a Biofuel and Component of Alcoholic Beverage" and "On the National Bioenergy Policy". The Federal Assembly is working on the "Development of Standards to Facilitate Large-Scale Use of Renewable Energy Sources, including Use of Biomass for Energy". (Global Bioenergy Partnership 2007a.)

As it was already mentioned the initiative of renewable energy development mainly belongs to the private sector. This is not an exception in bioenergy. A lot of projects in bioenergy were and are carried out in cooperation with European institutions, companies or organizations. Some of them are working under Kyoto protocol in JI projects (joint implementation projects). All together there are 75 JI project under verification procedure in the Russian Federation. Out of which 18 projects belong to the bioenergy sector, in the sphere of either fuel switch or biogas recovery. Although in many cases implementation of renewable energy projects severely needs foreign investments, it is not the only crucial point in the promotion of renewable energy. Russia needed a national association that would join together national companies operating in forestry, wood industry, pulp and paper production, agriculture, etc. In March 2007 the National Bioenergy Union was established. Its main objectives are to enhance business relationships between business organizations, non-governmental organizations and the Government in order to promote bioenergy, facilitate its adoption and improve bioenergy competitiveness on national and international markets. However, almost the same goals are set by the National Bioenergy Association, while Russian National Biofuels Association deals with bioethanol and biodiesel promotion, production and utilization. It is a bit complicated to distinguish differences between them, especially between the National Bioenergy Association and the National Bioenergy Union. Nevertheless, both of them exist and quite often perform together as sponsors or organizers of bioenergy related events.

7 POTENTIAL OF SUBSTITUTION OF CONVENTIONALLY PRODUCED ENERGY WITH ORGANIC-WASTE-BASED BIOENERGY

The Russian Federation is one of the richest countries in terms of fossil fuels resources. It is one of the leading countries considering energy resources export activities. Still, up to 70% of Russian territories experience shortages of energy and do not have permanent connection to centralized power supply services (Pantskhava, Pozharnov & Shipilov 2007b). In contrast, the renewable energy potential is high. The most tempting option is to produce energy from what is considered to be wastes. This possibility of converting useless into the most wanted seems to be quite realizable.

At the moment it is estimated that technically it is possible to use up to 400 million tons (of dry matter) of organic waste annually in the Russian Federation. This number includes 250 million tons of agricultural waste, 70 million tons of wood waste from lumber industry, about 70 million tons of both municipal waste and sludge from wastewater treatment (Russian Forest Newspaper 2006). However, this potential is underused and waste is mostly left aside to decompose. Thus, instead of producing energy and income it becomes an environmental threat.

7.1 Forest industry

7.1.1 Potential of substitution in the Russian Federation

Russian forest cover accounts for almost 23% of world's wood resources[5]. To be more precise 736,7 million hectares of surface in Russia are covered with forest. 329,2 million hectares of forest can be exploited. Yet, about 184 million m^3 are harvested annually, while the total allowable cut is 500 million m^3 (Federal Forestry Agency 2007). About 79% of Russian forests consist of spruce, pine, larch and birch. The most forested areas of the Russian Federation are Far Eastern, Siberian and Northwestern federal districts (Map of federal districts in Appendix 3). And again wood harvesting potential is underused. It was estimated that technically it is possible to use up to 800 million tons of wood biomass for energy production annually (Babkina 2007). In terms of forest residues it is pointed out that about 6% of residues are left on the site after wood harvesting, about 33% of wood end as wastes at wood processing plants (Rizhov 2006). Even more, Russian Forest Newspaper states that wood waste of the lumber industry can be as much as 60%, depending on the type of production and end-product (Russian Forest Newspaper 2006). In pulp and paper industry about 20% of raw material ends as waste.

Quite often the wood residues may be considered as a burden to enterprises dealing with wood processing, wood harvesting or pulp and paper production. It is associated with occupied storage place, additional payments due to ecological regulation and landfill dumping, high possibility of ignition etc. For these reasons it is much more economically reasonable for enterprises in the mentioned industries either to sell wood residues to pellet production plants or boiler houses, produce pellets on the site or use wood residues as biofuel for local heat and energy generation.

Wood based fuel for bioenergy production from residues can come either from forestry or from wood processing plants. According to the Federal State Statistic Service lumber and wood processing wastes equaled to 15-20 million solid m^3 and wastes from veneer production were 3,7

[5] Calculation of forest cover largely depends on a definition of a forested land.

million of solid m^3 in 2006 (Pirozhenko & Vasilieva 2007). These waste amounts correspond to the statistics in the Bioenergy International journal, where annually available wood waste is calculated to be 13 million m^3 (Kholodkov, Rakitova & Sokolov 2006). Since every 5 solid-m^3 of wood fuel correspond to 1 ton of light fuel oil or 1300 m^3 of natural gas (Kholodkov et al. 2006) energy potential of wood waste can be calculated. Using the currently available wood waste it is possible to produce 36,6-67,6 TWh[6] annually. If we assume that the combustion efficiency is about 90%, then final energy output is 32,94-60,84 TWh annually. Still, it should be pointed out that with forest sector development energy production form forest residues will increase in the direct proportion. However, at the moment forest sector is in stagnation, especially in Siberia and Far East federal districts. All in all, in terms of substitution of fossil fuels with biofuels the head of the Federal Forestry Agency, Valeriy Roschupkin, claims that in industrial sector it is possible to substitute 45-50% of mineral raw materials with biofuels for electricity power generation (Russian Association of Pulp and Paper Organizations and Enterprises 2007). All this indicates the huge potential of the energy production from wood wastes. Meanwhile, current usage of wood fuels correspond just to 0,4% in total energy balance of the Russian Federation (Pisareva 2006).

Depending on the technology, there is a huge variety of fuels that can be produced from forest residues: solid fuel, liquid fuel (e.g. black liquor or bioethanol from cellulose) or gas (wood gasification). Most diverse technologies refer to solid fuel. Solid fuel can be obtained due to pyrolysis (heating initiates chemical decomposition of organic matter in the absence of oxygen), for solid char production, and briquetting of wood residues, mainly in the form of pellets (Babkina 2007). Pellets are produces by condensing sawdust or pulverized forest residues under high pressure and pressing them into small cylindrical rolls, pellets. A beneficial point is that usually little modifications in technology are needed when substituting coal with pellets and no modifications for sawdust. Another beneficial point for pellet utilization (as well as for sawdust and briquettes) in comparison to firewood is that the efficiency of pellet combustion is higher than of firewood combustion due to higher homogeneity of fuel. However, automatic fuel

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[6] 13 million m^3 of wood residues equal to $3{,}38*10^9$ m^3 of natural gas. If natural gas energy content is 39 MJ/m^3, then total energy content is 131,8 PJ=36,6TWh. 24 million m^3 of wood residues equal to $6{,}24*10^9$ m^3 of natural gas. Total energy content is 243,4 PJ=67,6 TWh.

feeders, which are required for pellets and briquettes, are quite expensive, almost 30% of a boiler house cost (Rakitova 2006b).

It should be pointed out that selection of different types of wood-based fuels depends on the region of their utilization (Rakitova 2006b). Likewise in the areas with wood processing and wood harvesting it is economical to use primary wood waste: sawdust, and chips. Pellet production is reasonable near border areas, since at the moment export is more preferable. Pellets could be transported to other Russian areas if their utilization is more feasible than combustion of light fuel oil or coal. Russian private sector (private country houses and summer cottages) is also a potential pellet consumer.

In Russia at the moment all of the pellet production plants are export oriented. Northwest federal district is the most advanced in pellet production and bioenergy promotion. The reasons for it are its huge supply with wood resources, existence of well-developed forest and wood industries as well as pulp and paper mills and its border with European Union, which is the main consumer of Russian pellets.

Northwest Russian territories have about 60% of all forest territories in the European part of Russia and about 17% of all Russian forests. At the moment bioenergy (including both wood waste and firewood) accounts for less than 3% of energy consumption in the Northwestern district. However, since about 16 million m^3 (4 million t.c.e.) of wood waste is produced in the region and the region's energy consumption equals to 80 million t.c.e., 5% of energy consumption could be covered by bioenergy (Rakitova 2006a). The first pellet producing plant was brought into action in 2001. Now there are about 60-65 plants and the same amount is under design or construction (Drankina 2007). The production was expected to be up to 300 000 tons of pellets in 2007 (Drankina 2007). Still none of it was going to be burnt in Russia. As the resources for pellet production are not that expensive (sometimes almost free), European consumers offer 120 Euro/ton for pellets. While the Russian government does not support bioenergy, the obvious conclusion would be to export pellets in order to maintain high return on investments.

Less information is obtained about situation with bioenergy in Far Eastern and Siberian federal districts. The sad reason for it is the stagnation of forestry and lumber industry. The real annual cut is far behind annually available cut. In the regions with more than 70% of all forests in the country there are strong depreciation of equipment and the lack of roads and investments. About 80% of all investments in the wood industry go to Central and Northwestern federal districts (Belomestnikh 2008). In order to change the situation the innovation project "Siberia – Far East" was established. The main purpose of the project is the forest industry and the wood processing industry development. 34 big enterprises in the field of wood cutting and wood processing are to be built during time period 2010- 2015. Construction of a big pellet producing plant in Tomsk, Siberia, is also in plans. Pellet production already exists in Siberia on the basis of a wood processing plant "Enisey". There are pellet production plants in Irkutsk (Siberian federal district) and Khabarovsk (Far East federal district) and some other as well, but pellet production is not well developed in these regions. Export to Japan and China is possible but does not occur on large scale, so producers even think about transporting pellets to the EU (Bioenergy International 2007).

7.1.2 Potential of substitution in Leningrad Oblast (province)

Leningrad Oblast (province) is situated in the Northwest of Russia and belongs to Northwest federal district, one of the most forested federal districts in Russia. Forestry and wood industry are well-developed in the region. Its close location to the country's boarders influence on the economic development of Leningrad Oblast and on wood trade in particular. Leningrad Oblast is a good illustration of the region, which potentially has economic and resource capacity for bioenergy development. Thus, the potential of substitution of conventionally produced energy with wood-waste-based bioenergy would be studied on its example.

Leningrad oblast is a federal subject of the Russian Federation. It occupies 84,6 thousand km^2. The amount of the population is 1,7 million inhabitants. Electricity demand of the region is 10,3 TWh and heat demand is 308,3 Tcal (TGC-1 2007). In 2006 17,33 TWh electricity was produced (Leningrad Oblast official website, 2007). Most of the energy is produced by Leningrad nuclear power plant and thermal plant. About 3% of all energy units are using wood fuel for energy production. The region exports electricity both to the neighboring regions of Russia and abroad.

Recently it was announced that two new nuclear reactors with 1172 MW capacity would replace two old nuclear units that are already at the end of their lifecycle. Since the process of constructing new nuclear power units is relatively long and very costly, it might be interesting to evaluate the possibility of using an alternative way of energy generation, namely utilization of bioenergy.

Leningrad Oblast is very reach with wood resources. Its gross wood biomass potential is 3,81-4,03 million t.c.e. annually (Sidorenko, Borisov, Titov & Bezrukikh 2000). However, not all of the biomass can be used in energy production. If we roughly assume that about 50% of the total woody biomass will be lost during harvesting and wood processing, the possible energy content of forest residues and waste would be about 1,905-2,015 million t.c.e. It equals to 15,5-16,4 TWh[7]. In turn these numbers very much correspond with other estimations of technically available energy wood residue potential in Leningrad Oblast (TABLE 6).

From the table it can be seen that by utilizing the currently available amount of energy wood (wood residues) it is possible to produce 8,1 TWh. Moreover, there is a great possibility to more than double this amount of energy by meeting annual available cut[8] and conducting thinning[9] operations at a full scale. However, different parts of the region have different potential for energy wood production due to different rates of utilization of forest resources. In addition, better utilization of the bioenergy potential requires investments in infrastructure, building of new roads and better maintenance of the existing ones as well as investments in energy production technologies (Gerasimov et al. 2006). Finally, it should be pointed out that some percentage of wood residues is already used for households heating and for energy production at lumber enterprises or pulp and paper mills.

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[7] Calculation: 1KWh=0,123 kg coal equivalent. Consequently, 1,905-2,015 million t.c.e. are 15,5-16,4TWh.
[8] Annual available cut - the planned and allowable rate of timber harvest from a specified area of land in accordance to the forestry management plans.
[9] Thinning - a selective removal of trees in order to improve the growth rate or health of the remaining trees.

TABLE 6. Technically Available Energy Wood Potential in Leningrad Oblast (over bark) (Gerasimov, Goltsev, Ilavský, Tahvanainen & Karjalainen 2006)

Source	**Scenario for energy wood resources**[10]					
	Actual		Allowable		Potential	
	Million solid m^3	TWh	Million solid m^3	TWh	Million solid m^3	TWh
Wood waste from timber harvesting Including:	3,5	7,0	5,3	10,6	7,2	14,4
- wood waste at cutting areas	2,3	4,6	3,3	6,6	7,2	14,4
- wood waste at central processing yards	1,2	2,4	2,0	4,0	-	-
Wood waste from sawmilling	0,6	1,2	1,0	2,0	2,0	4,0
Total wood waste amount	**4,1**	**8,1**	**6,3**	**12,6**	**9,2**	**18,4**

Still, development of this bioenergy potential is very tempting. To illustrate this, the production capacity of Leningrad nuclear power plant can be mentioned. In 2007 Leningrad nuclear power plant produced 24,2 TWh (Leningrad nuclear power plant 2007). Although bioenergy production is not able to generate the same amount of energy it is capable to produce roughly one third of it and more, depending on the approach to bioenergy production. The utilization of this potential will question the necessity of construction of two new nuclear reactors. In turn the development of bioenergy will influence on the development of forest and wood processing industries, it will solve the problem of the waste disposal in the region and might be more appreciated by the society than new nuclear units.

[10] "Actual" scenario is based on actual fellings in 2004 (5.1 million m^3 final felling, 1.5 million m^3 thinning, 1.3 million m^3 other felling), and sawmill production (0.6 million m^3 sawn wood).
"Allowable" scenario is based on full utilization of annual allowable cut (9.5 million m^3 final felling, 1.5 million m^3 thinning and 1.3 million m^3 other felling), and sawmill production (1 million m^3 sawn wood).
"Potential" scenario is based on also full utilization of thinnings (9.5 million m^3 final felling, 4.6 million m^3 million m^3 thinning and 1.3 million m^3 other felling), and sawmill production (2 million m^3 sawn wood).

7.2 Agro-industrial complex

Up to 70%, including about 30-35% of farm households, of Russian territories can not enjoy permanent centralized energy supply (Pantskhava et al. 2007b). That is why bioenergy from agro-industrial wastes can be one of the solutions to this problem. It is very true, considering the fact that the agro-industrial complex is one of the biggest producers of organic waste in the Russian Federation. Converting organic wastes to energy would not only solve ecological problems of waste disposal, but would provide rural residents and farms with the stable energy supply from local fuels.

Bioenergy in agro-industry can be produced from agricultural wastes or from animal manure. Theoretically, both of these biowaste types can be used for direct combustion, for pellet production or for biogas production. However, for animal manure biogas generation is more advisable. If up-to-date technology for biogas production is used, it is the most promising way of energy generation in rural areas.

The total amount of organic waste in agro-industry accounted for 624,2 million tons (225 million tons of dry matter) with the total energy content of 80,4 million t.c.e. in 2005 (Pantskhava et al. 2007b). Russian Forest Newspaper (2006) states that agricultural waste equals to 250 million tons of dry matter. Still, this numbers are in the same range. The composition, amount and energy content of biowaste are shown in TABLE 7. Although livestock production generates the biggest waste amount, the energy content of this biowaste type is not the largest one. The reason is the high level of water content in animal manure. Unlike, moisture content in crop waste is much lower (for example in straw and hay). That is why the amount of dry matter of crop waste is bigger and, consequently, energy content is higher.

TABLE 7. Composition, Amount and Energy Content of Biowaste (Pantskhava et al. 2007b).

Waste type	Waste amount (million tons)	Amount of dry matter (million tons)	Energy content (million t.c.e.)
Wastes from poultry production	23,1	5,8	1,5
Wastes from livestock production	349,7	58,3	17,5
Wastes from crop production	222,2	147	54,1
Wastes from processing industry (flour and oil milling industries, sugar refining, meat processing, and distilling industry)	29,2	14	7,3
TOTAL	**624,2**	**225,1**	**80,4**

The distribution of organic waste production in the agro-industrial complex in different federal districts is shown in FIGURE 3. As can be seen, the leading districts in terms of the organic waste generation in agro-industry are Central, Southern, Volga and Siberian federal districts. Thus, in the first place bioenergy development is more preferable there. If additionally we are to consider solid waste and sludge generation the distribution of organic wastes by their type and territory is revealed in the TABLE 8.

FIGURE 3. Distribution of the Organic Waste Production in the Agro-Industrial Complex in Different Federal Districts (Pantskhava et al. 2007a).

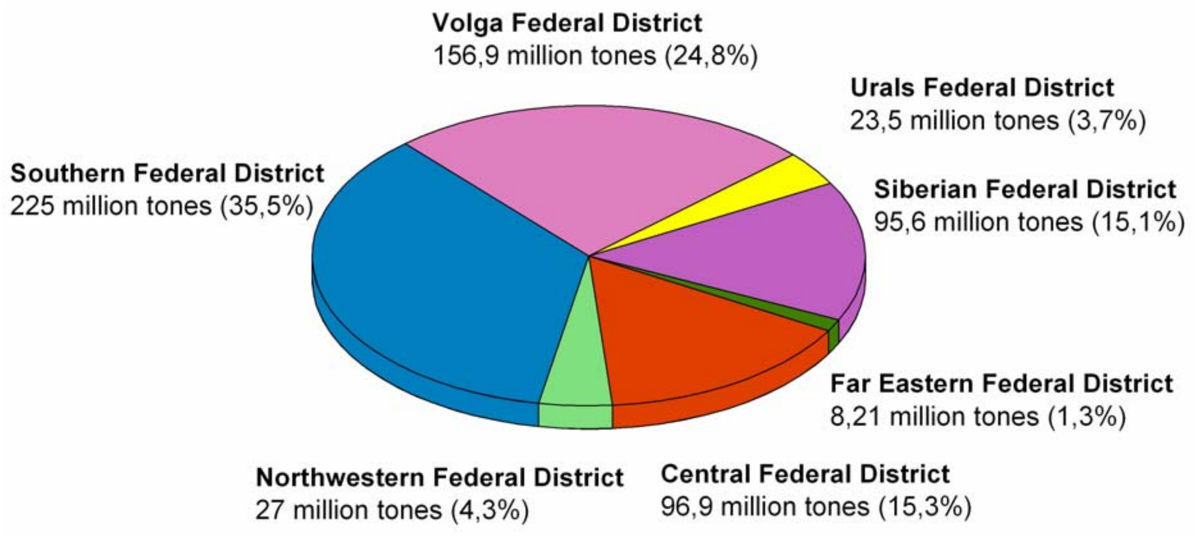

TABLE 8. The Distribution of Biomass Resources (Organic Wastes) by Their Type and by Territoty of Their Generation (Pantskhava et al. 2007a).

Federal district	**Waste type (million t.c.e.)**						
	poultry and livestock production	crop production	processing industry	solid waste	sludge	total	total %
Central Federal District	3,21	8,77	1,5	2,96	0,26	16,7	18
Northwestern Federal District	0,93	0,617	0,083	1,1	0,096	2,83	3
Southern Federal District	3,68	18,59	2,53	1,78	0,156	26,7	28,9
Volga Federal District	6,2	16,3	2,2	2,4	0,21	27,3	29,5
Urals Federal District	1,11	1,99	0,24	0,96	0,085	4,38	4,7
Siberian Federal District	3,53	7,49	0,739	1,36	0,3	13,4	14,5
Far Eastern Federal District	0,34	0,34	0,024	0,52	0,046	1,27	1,4
Russian Federation	19	54,1	7,3	11,08	1,153	92,6	100
%	20,5	58,4	7,9	12	1,2	100	

According to the previous research investigations the leading technology for bioenergy generation from agrowaste in Russia will be biogas technology, which will be followed by pellet production and pyrolysis (Pantskhava et al. 2007b). Later bioethanol production will start to develop at high speed.

7.2.1 Potential of substitution with biogas in the Russian Federation

Biogas can be produced from any organic waste due to its decomposition. This is a gas mixture of CH_4 (30-40%) and CO_2 (60-70%). The most promising source for biogas production is animal manure. After the process of anaerobic decomposition of liquid manure in digester tanks three products are formed: biogas, dehydrated sludge and filtrate water (Karaeva & Nazmeev 2007). Biogas can be used for heat and electricity production, while dehydrated sludge (biohumus) and filtrate water (aseptic nutritious water) are good quality fertilizers.

The leading federal districts in terms of the potential biogas production are Central, Southern, Volga and Siberian federal districts. The potential production of biogas, the potential substitution of natural gas and petroleum products, and the corresponded production of electricity and heat in CHP are summarized in TABLE 9.

TABLE 9. Potential of Biogas Production, Its Utilization for Natural Gas and Petroleum Products Substitution and the Corresponding Amount of Electricity and Heat Produced by CHP Units, by Region (Pantskhava et al. 2007a).

Federal district	**Biogas production billion m^3**	**Natural gas substitution billion m^3**	**Petroleum products substitution million tons**	**Electricity production TWh**	**Heat energy Pcal**
Central Federal District	12,1	8,3	8,3	28,1	27,97
Northwestern Federal District	3,5	2,4	2,4	8	8
Southern Federal District	24,4	16,8	16,8	56,12	56,1
Volga Federal District	18,33	12,6	12,6	42,16	42,1
Urals Federal District	3,1	2,13	2,13	7,13	7,13
Siberian Federal District	11,1	7,63	7,63	25,5	25,5
Far Eastern Federal District	1,18	0,81	0,81	2,7	2,7
Total	73,7	50,67	50,67	169,71	169,5

If this potential is used, then up to 12 %[11] of total heat production and 17% of total electricity consumption can come from bioenergy or about 17% of total electricity production can be bioenergy based (CIA estimations of electricity consumption and production in 2007 were considered[12]). Russia can entirely cover its electricity import, produce enough electricity for export and cover up to 15% of its electricity consumption at the same time just by processing organic wastes from agro-industrial complex to energy.

If electricity generated from mentioned above agrowastes was to be used in domestic market it could supply all Russian rural population with enough electricity. 38,4 million of Russian rural population require about 42,7 TWh/year. Biogas from agro-industrial wastes can produce about 4 times more electricity (Pantskhava et al. 2007b).

However, it is not clear whether this optimistic prediction has considered amount of energy consumed by biogas technologies themselves. Energy efficiency of biogas producing technologies in Russian moderate climate might be not that high. Yet, Russian market offers up-to-date CHP biogas installations, where not more than 30% of biogas produced is consumed by the technology itself. Energy is used for maintaining the fermentation process, which undergoes in digester tanks. This operating procedure reduces the energy efficiency of biogas production units. Thus, the numbers shown in TABLE 9 should not be considered as the final numbers of net electricity and heat output. The alternative calculations can be performed. If we suppose that approximately 30% of produced biogas is consumed by the biogas technology the updated results are shown in TABLE 10.

From the table it becomes evident that even if biogas technology produces at least 70% of net biogas the corresponding energy output can provide all rural residents with heat and electricity and cover country's electricity import, export, 5% of total electricity consumption and 8% of total heat production simultaneously. A positive point is that biogas installations are not that expensive. Payback time for biogas technologies available on the Russian market was calculated to be 1,5-2 years and it in turn seems to be a very good economic indicator (Pantskhava et al.

[11] 1 cal = 4,187 J. 169,5 Pcal = 709,7 PJ = 197,1TWh. This is 12% from total heat production (1629,4 TWh in 2005).
[12] In 2007 electricity consumption: 985.2 TWh; electricity production: 1 PWh; electricity export: 18 TWh; electricity import: 2.9 TWh (CIA the World Factbook 2008).

2007b). Yet, in contrast to the potential production of 118,45 Pcal of heat energy just 2 Pcal from biogas installations and from aeration stations were produced in 2005 (TABLE 3).

TABLE 10. Potential of Biogas Production, Its Utilization for Natural Gas and Petroleum Products Substitution and Corresponding Amount of Electricity and Heat by Region, Considering On-Site Energy Consumption by CHP Units.

Federal district	**Biogas production billion m^3**	**Natural gas substitution billion m^3**	**Petroleum products substitution million tons**	**Electricity production TWh**	**Heat energy Pcal**
Central Federal District	8,47	5,81	5,81	19,67	19,58
Northwestern Federal District	2,45	1,68	1,68	5,6	5,6
Southern Federal District	17,08	11,76	11,76	39,28	39,27
Volga Federal District	12,83	8,82	3,78	29,51	29,47
Urals Federal District	2,17	1,49	1,49	4,99	4,99
Siberian Federal District	7,77	5,34	5,34	17,85	17,85
Far Eastern Federal District	0,83	0,57	0,57	1,89	1,89
Total	51,6	35,47	35,47	118,79	118,45

Another significant advantage of biogas generation process is the production of a valuable for agriculture by-product, humus. Market realization of humus, which is an effective fertilizer, or its on-site application (and consequent reduction of expenditures on fertilizers) increase biogas production economic efficiency. In addition, the biogas production solves such crucial problem as animal manure handling and disposal, which appears to be a serious ecological concern.

7.2.2 Potential of substitution with pellets in the Russian Federation

The pellet production or direct combustion of crop wastes is another way of energy generation in the agricultural sector. However, more difficulties are associated with it and at some point this way of energy production seems to be less economically reasonable. Straw and husk are usually used for pellet production or for the direct combustion due to their low moisture content.

Although, heating value of straw and, consequently, of agropellets and briquettes is lower than heating value of wood pellets, because of the moisture content, the final heating value is even higher, as less energy is needed for water evaporation (Isiomin, Kuzmin, Milovanov, Koniakhin & Zorin 2007). Approximately up to 135 million tons of pellets can be produced from crop waste (Pantskhava et al. 2007b). If average straw lower heating value is 17,4 MJ/kg, then total energy content of agropellets is 652 TWh annually. However, agropellet production profitability is under the question due to high production costs, high energy consumption, expenses on agrowaste collection and processing. That is why energy generation from agropellets can be cost effective just in the regions where agriculture is the leading economic sector and fossil fuels are expensive. For example, pellet production from crop waste can be developed on the East of Rostov region (Southern federal district) (Isiomin et al. 2007).

7.2.3 Potential of substitution in the Republic of Tatarstan

The Republic of Tatarstan (the capital is Kazan) is situated in the Volga federal district, which is known to be one of the most important agricultural areas of Russia. Despite its relatively small territory Tatarstan is among of the biggest meat, milk and crop producers. Especially, cattle and hog farming and poultry are well-developed, converting the Republic of Tatarstan to one of the top livestock producers. As a result Tatarstan's makes a great contribution to organic waste generation. In addition, Tatarstan was recognized as a potential region for the bioenergy development in the agricultural sector by the United Nations (Global Bioenergy Partnership 2007a). Hence, it would be interesting to make an evaluation of substitution potential of fossil fuel-based energy with bioenergy.

Tatarstan is among of the leading industrial regions of the Russian Federation specializing in oil extraction and processing, chemical and rubber industries and automobile construction. Agro-industrial complex is another perceived priority sector. In 2007 Tatarstan was one of the 4 federal subjects of the Russian Federation that were able to reach the level of 1990 and produce even more in the agricultural sector. These facts make Tatarstan a highly energy intensive region with a great possibility to influence on its fuel and energy balance. Agriculture is perceived to be a significant contributor to solution of the energy problems.

According to TABLE 8, the Volga federal district, including Tatarstan, produces a lot of organic wastes from the agricultural sector and thus is very promising for widespread of bioenergy technologies. The district is leading in terms of waste generation from livestock and poultry. It means that biogas generation from animal manure can become the main method of bioenergy production.

In 2007 electricity generation in Tatarstan was 24,7 TWh (Official website of the Republic of Tatarstan 2008). The main power generator in the region is Tatenergo. In 2007 the company has generated 21 TWh electricity and 31 Pcal heat (Tatenergo 2008a). 82,72% of all installed energy capacities are thermal power plants and 17,28% are hydropower units (Tatenergo 2008b). However, a little more than 90% of all energy is produced on thermal power plants, while the only renewable source of energy, hydropower plant, is functioning on less than 40% of its capacity due to unrated water level in the reservoir (Finam News 2006).

Since in the Russian Federation there is the goal of being energy efficient, the regional programme on energy efficiency was developed in the Republic of Tatarstan for 2000-2005. In 2006 the programme was prolonged. The updated version of the programme besides energy efficiency concerns recourse efficiency as well. In terms of the agricultural sector the programme “on Energy and Resource Efficiency in the Republic of Tatarstan for the Period 2006-2010” emphasizes the utilization of local and alternative sources of energy. In fact, the Government of the Republic of Tatarstan is very enthusiastic in introducing biogas technologies. Scientific discussions, round tables, conferences and meetings on bioenergy are organized. The preliminary framework for the programme on the development of the small-scale-power-generation on the basis of renewable energy in the Republic of Tatarstan is being worked out. The Ministry of Industry and Trade in cooperation with the Ministry of Agriculture should develop a number of bioenergy projects (biogas generation from biowaste) in the coming 2-3 years. Considering the general apathy of bioenergy support in the Russian Federation on the governmental level, the steps to the bioenergy adoption in the Republic of Tatarstan seem to be quite straightforward. Yet, project implementations are very dependent on foreign investors.

Energy issues have already attracted attention of the Kazan Research Centre on Energy Problems and of the Centre on Energy Savings under the Cabinet of the Republic of Tatarstan. Even though, little information is available, it is known that the study on the bioenergy development was carried out. It was estimated that 12 000 tons of production and consumption wastes are generated in the Republic annually. 80% of waste comes from the livestock industry (Centre on Energy Savings under the Cabinet of the Republic of Tatarstan 2008). 50% of animal manure is used as fertilizers, however not always the composting technology is properly utilized. Thus, the result of the improper disposal is soil and ground water contamination with harmful substances and microorganisms. However, biomass waste is capable to substitute about 46,57% of other conventional energy carriers in the agro-industrial complex. By utilizing biomass for the energy production in the agricultural sector it is possible to reduce the energy generation from conventional sources by 1980,1 GWh annually. (Research Centre of Energy Problems of Kazan Science Centre 2006.)

A very thorough study refers to converting wastes generated by poultry and livestock to biogas in the Republic of Tatarstan (Karaeva & Nazmeev 2007). The utilization of the most appropriate biogas technologies was suggested for different regions of the Republic. The results of the study show that the potential capacity in the agricultural sector of Tatarstan is about 355,26 MW, including 21,84 MW in poultry, 298,11 MW in cattle farming and 35,31 in hog farming. The annual energy output from the livestock wastes, considering on-site energy consumption by biogas installations, may be about 2178,4 GWh[13]. However, in this number the utilization factor of the maximum capacity of energy units is 100%. This is not likely to be true in reality. In fact,

[13] Approximate annual energy production equals to 355,26 MW*8760 hours= 3112 GWh. About 30% of energy produced is consumed by the energy generation unit, thus final annual energy output is 2178,4 GWh.

due to maintenance shutdowns the utilization factor of the maximum capacity is likely to be 90%. Therefore, annual energy output from agricultural wastes might be about 1960,6 GWh. This figure correspond well to the overall stated amount of the energy savings in the agricultural sector (1980,1 GWh annually).

The amount of the potential energy savings due to the agricultural waste conversion to energy corresponds to 9,3% of energy produced by Tatenrgo in 2007. This energy amount may be a significant contribution to the existing energy production level. In addition Tatenergo and the government of the Republic of Tatarstan have ambitious plans of exporting energy to neighbor regions. Production of bioenergy in agro-industrial complex would generate additional energy savings. It means that the energy generation from conventional fuels either can be reduced or, what is more likely to happen, can be sold to boarder regions. Another point is that in 2005, while discussing the project programme for the fuel and energy complex development until 2020, the question of the construction of Tatar nuclear power plant was raised again (Ignatieva 2005). Even though there are no any agreements on the question and obviously bioenergy will not be able to produce same amount of energy as 2 nuclear reactors[14], the complex approach of renewable energy introduction (wind, hydro, solar and bioenergy) would be a compatible solution.

Summing up, in the Republic of Tatarstan potentially it is possible to substitute about 9% of energy produced from fossil fuel with bioenergy. This substitution would solve crucial ecological problems of biowaste (animal manure) disposal, good quality fertilizers as by-products would be produced, and finally there would be energy savings and additional income to the budget of the Republic.

7.3 Sewage and municipal solid waste

Biogas extraction from landfill gas and sewage sludge is not developed in the Russian Federation at all. There are some pilot projects in progress or feasibilities studies on investigation of the potential of these energy sources. Probably the technology development for the biogas extraction from wastewater sludge is easier than the landfill gas extraction. The reason is that at some point

[14] Tatar nuclear power plant is to consist of 2 x 1000MW reactors.

biogas at wastewater treatment plants is either already used for heat extraction or is already captured and then released to the atmosphere. Thus, its caption and conversion to energy seems to be less complicated than for landfill gas. For capturing biogas at landfill the whole approach to waste disposal and the technology of landfill construction has to be changed.

7.3.1 Potential of producing bioenergy from sewage

Aeration gas (biogas) comes from municipal wastewater treatment plants. It is a product of decomposition of sewage water. It mainly consists of 60-65% of CH_4, 30-35% of CO_2, and 2-4% of H_2. Biogas is generated during digestion of bioactive sludge and sediments that were produced during primary and secondary treatment of wastewater. Generally biogas is burnt in a boiler house situated on the site of a wastewater treatment plant. The heat is used for heating tanks, where the biological treatment is taking place, and for economic needs of the plant. The technology is simple, yet the capacity of energy generation is underused. Biogas is either partly used or is not used at all. Reasons for it are numerous: overuse or deficiency of wastewater treatment plants (especially in Southern and Far East federal districts) and low efficiency because of the obsolescence and depreciation of technology (Saraev 2007).

7.3.1.1 Potential of producing bioenergy from sewage in the Russian Federation

Biological sludge and sediments undergo anaerobic treatment in powerful biogas generators (digesters) at water treatment stations in Moscow, in Novosibirsk, Sochi, and other Russian cities, but not everywhere (EU-Russia Energy Dialog Technology Centre 2004). There are some energy projects in progress, but their amount is not significant. Mosvodokanal[15] is planning to install energy units for biogas conversion to electricity. Vodokanal[16] in Saint Petersburg is participating in JI project for further practices development for the sludge combustion. In Nizhny Novgorod the feasibility study for installation of technology for heat and electricity production from biogas on wastewater treatment plant is under development. Still, the number of projects can and should be bigger.

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[15] Mosvodokanal is a water and wastewater services company operating on the territory of Moscow region.
[16] Vodokanal is a water and wastewater services company operating on the territory of Saint Petersburg. However, there are water and wastewater services companies with the same name in other cities of the Russian Federation.

It is very difficult to evaluate the potential of energy generation from wastewater sludge, even thought it is known that about 80 million m^3 (dry matter) of sludge are generated annually in the Russian Federation (Kalyuzhnyi 2006). The approximate weight of the annual dry sludge is about 65 million tons (Lotosh 2002). Lotosh (2002) states that just by digesting half of the sludge created it is possible to produce 350 million m^3 of biogas annually. That equals to 0,3 million t.c.e. and 2,4 TWh. This amount is capable to reduce the heat energy consumption of wastewater treatment plants by 40-50%. If all sewage sludge is digested the possible energy production might be around 4,32 TWh annually, considering 90% energy production efficiency. Thus, it becomes obvious that utilization of sludge for the energy generation is not meant to become a large scale energy generation. This way of energy production is mostly interesting for covering needs of wastewater treatment plants. The by-product of biogas generation, organic fertilizers, if are cleaned from toxic and pathogenic compounds, can be used by municipal gardening service. In addition, gas capturing would have a positive effect on the reduction of emissions greenhouse gases and unpleasant odors.

7.3.1.2 Potential of producing bioenergy from sewage in Moscow

A closer look on biogas treatment at Mosvodokanal proves the findings mentioned above. Mosvodokal is the largest wastewater treatment company operating in Russia. It cleans water for Moscow, the largest city of Russia. Moscow population exceeds 10 million inhabitants. This big number of city dwellers together with the habit of excessive water consumption result in large volume of wastewater. Accordingly, Mosvodokanal is the largest producer of aeration gas on the territory of Russia and potentially the largest producer of bioenergy from wastewater sludge.

Although the biological water treatment technology was adopted in Russia in early 1960s, the fully operational digestion tanks remain just in Moscow Kuryanovo and Lyubertsy wastewater treatment plants, the latter is the largest in Europe (Drankina 2007). These water treatment plants are already generating enough biogas to cover their own heat demand. And in addition, soon small scale power plants will be built there in order to produce electricity. Biogas power plant at Kuryanovo is already under construction, while at the Lyubertsy station the situation with ownership of the power plant has to be clarified first (Drankina 2007). As the officials of

Mosvodokanal said the electricity generated from sludge would be able to cover 70% of electricity demand and 50% of heat demand of the wastewater treatment plants (Mosvodokanal 2007). This is equivalent to annual electricity supply of 5000 apartments and annual heat supply of 1500 apartments (averagely with three inhabitants).

On one hand this amount of electricity and heat is not enough to make a significant contribution to Moscow energy demand. The city with a population of more than 10 million inhabitants consumes far more electricity. In fact electricity generated from sewage sludge on Moscow water treatment plants would be enough just for 4 average 16-store apartment blocks. On the other hand, to cover Moscow energy demand is not a target in this case. The main purpose of wastewater treatment plants is to supply city with clean water not with energy. But if in addition to clean water wastewater treatment plants can cover their own energy demand, this opportunity should not be missed. Self energy reliance would help to avoid sewage water discharges, which happen in the case of accidental break-downs in energy supply from the public grid. As a result it would reduce water contamination, which is the main goal of wastewater treatments plants.

7.3.2 Potential of producing bioenergy from landfill gas

Landfill gas extraction is a new bioenergy technology that should be adopted in the Russian Federation. At the moment the product consumption rate is increasing rapidly and that is why the waste management has become an important issue. A lot has to be done in this field in Russia. Even though there is legislation on the waste handling, in practice the control over waste disposal is not that strong. Especially it refers to the disposal of solid municipal waste, which in turn is one of the main anthropogenic sources of greenhouse gases and, consequently, the main source of energy. There are no requirements on landfill gas capturing and flaring, although accumulation of landfill gas is dangerous because of the high possibility of explosion and ignition.

7.3.2.1 Potential of producing bioenergy from landfill gas in the Russian Federation

The main way of solid municipal waste disposal is dumping at landfills. About 97% of waste ends at landfills. Only a small portion is recycled, a bit bigger part of waste is burnt at incineration plants. However, solid waste combustion is done in an unsustainable way, because it is not preceded by waste sorting. This practice results in air emissions of highly toxic compounds dangerous for human health. Unfortunately, disposal at landfills, that theoretically should be the least option, is mostly adopted. Landfills occupy large areas. These sites generate leachate and greenhouse gases, mainly CH_4 and CO_2, which are harmful for the environment if not properly controlled. If improperly constructed, landfills occur to be severe contaminators of soil and ground water and a big threat to ecosystems and residents of surrounding areas.

Landfill gas is generated due to anaerobic decomposition of organic matter, mainly food leftovers and paper. The main components of landfill gas are CH_4 and CO_2. Their balance may vary from 40-70% to 30-60% respectively (Yagafarova, Nasirova, Shaimiva, & Faskhutdinova 2006). Nitrogen, oxygen, hydrogen and different organic compounds are also present but in much smaller quantities. Emissions of methane and carbon dioxide make landfills one of the main anthropogenic greenhouse gas producers.

The landfill gas emission is not a one-day-long process. Usually it takes about 20 years for solid municipal waste to decompose. An average emission of landfill gas is 100 m^3 from 1 ton of solid waste, and an average speed of gas emission is 5 m^3/ton in a year. The most "productive" are first five years, during which about 50% of landfill gas is generated (Gurvich & Lifshits 2006). Due to unsteady, in terms of time, gas emission the calculation of total landfill gas production becomes complicated. According to calculations of IPCC Russian landfills emit 1,5 million tons of landfill gas annually, that makes 3% of the world landfill gas emissions in 1995 (Yagofarova et al. 2006). If approximately 50% of landfill gas is methane, then methane emissions are 750 000 tons. Russian scientists evaluated them as 500 000 - 900 000 tons, or 0,7-1,3 billion m^3 (Kalyuzhnyi, Epov, Sormunen, Kettunen, Rintala, Privalenko, Nozhevnikova, Pender & Colleran 2003).

An advantage of landfill gas utilization is that it can be used as it is, unrefined, for heat production. Refined gas is good for electricity production. It is even possible to refine landfill gas to pure methane. Unfortunately, there are no any cases of landfills utilizing biogas for energy generation. However, pilot projects were carried out in Moscow Oblast at two landfills Kargashino and Dashkovka under JI. These are the largest experiments in the Russian Federation in terms of evaluation of the landfill gas generation capacity and amount of energy that can be produced from landfill gas. Yet, considering the whole territory of the Russian Federation, no statistics is available concerning the number of landfill sites, their size and their waste intake (Lappalainen & Kouvo 2004). Thus, it is quite complicated to evaluate the amount of generated landfill gas and energy that can be produced from it. The research is in progress. It can be assumed that since average methane emission from landfills is 750 000 tons, then 11,5 TWh[17] can be generated. Still, this is obvious that only a part of landfill gas can be recovered. Approximately, 50-60% of landfill gas can be captured (Joint Implementation Supervisory Committee 2006a,b,c.) If cogeneration unit is used for the energy production, then the efficiency of the energy generation can be approximately 90%. Consequently, 5,2-6,2 TWh of energy can be generated from landfill gas. This is a very general number, for specifying which a lot of peculiarities should be considered (climatic conditions, waste intake, age of landfill, waste composition, capturing and conversion to energy efficiency and etc.). For more details 5 JI[18] projects for landfill gas recovery systems in the Russian Federation can be studied. Sadly, in all of them it is clearly mentioned that wide adoption of landfill gas capturing, flaring or conversion to energy is not likely to happen because of high costs for construction and operation of landfill gas treatment plants. Financial assistance can come in the form of increased waste management fees. But according to UN specialists it is politically difficult. (Joint Implementation Supervisory Committee 2006a,b,c.)

7.3.2.2 Potential of producing bioenergy from landfill gas in Moscow Oblast (province)

Landfill sites of Moscow Oblast accumulate waste from both Moscow (there is no landfill sites on the territory of Moscow-city) and Moscow Oblast. Waste handling and waste disposal has become a sever problem there. Considering the large population density on these territories and growing consumption rate, the waste amount is huge. Therefore, it would be interesting to evaluate the landfill gas production capacity near the biggest city of the Russian Federation.

In general, in Moscow Oblast the methane emission capacity on landfills is about 100 000 tons annually. From waste water treatment plants about 33 000 tons of methane is emitted. These two

[17] If methane energy density is 55 MJ/kg
[18] The projects are at the verification stage.

gas emission sources account for 90% of methane emission in Moscow Oblast. The other 10% refer to methane emission from the agricultural sector and the natural gas transmission and handling units. Annually, about 5 million tons of solid waste is generated in Moscow Oblast and on the landfill sites there are already about 110 million tons of solid and industrial waste all together. The annual increase of solid municipal and industrial waste is about 4-5%. (Grankin, Ribalskyi & Snakin 2003.)

At landfills of Moscow Oblast wastes from both Moscow and Moscow Oblast are disposed. In 2002 according to official documentation on landfill sites 5,125 million tons of waste was disposed: 3,125 from Moscow and the rest from Moscow Oblast (Grankin, et al. 2003). This amount of waste was disposed on 167 landfill sites, while just 58 are official landfills and the rest are spontaneous (Litun & Ryabov 2007). 27 landfill sites have already reached their disposal capacity and 19 are 90% full. The situation is worsened because of the unknown number of illegal dumping sites, both small (e.g. near an area of summer houses) and large. But anyway, it was already recognized that landfills do not have enough capacity to take the increasing amount of waste. The solution that was found by Moscow authorities included construction of waste incineration plants. By 2012 6 new waste incineration plants are supposed to start their operations in Moscow. The decision is not favorable among society, as toxic compounds, which are generated during the combustion process, might negatively influence on the ecological situation that is already in the poor state.

While it is under discussion whether to consume less and recycle more or to burn everything, the problem of existing landfills and landfill gas remains. 3 JI projects on landfill gas recovery are proclaimed to be in Moscow Oblast: at Dmitrovsk, Timokhovo and Khmetievo sites. It was calculated that at Dmitrovsk landfill over the period of 5 years 196 tons of CH_4 would be generated, 164 tons at Khmetievo landfill and 239 tons at Timokhovo. If all of it is captured, the energy potential is 9,2 GWh[19] during 5 years, or roughly to 1,84 GWh annually. Of course, it is not possible to capture all landfill gas. With 50-60% of landfill gas capturing and approximately 90% of the energy generation efficiency it is possible to produce 0,9 GWh annually. In turn, in

[19] Total methane emission is 599 tons. If methane energy content is 55 MJ/kg, then $3{,}3*10^7$ MJ is produced, that is equivalent to 9,2 GWh.

the mentioned JI projects it is supposed to burn off captured landfill gas, using just small portions of it for electricity generation for on-site use.

In addition, the experiment, which was conducted at Kargashino and Dashkovka sites, showed that in the studied conditions it is possible to produce 1,3-1,5 kW of electricity from 1 m^3 of biogas. Consequently, under full capacity on the mentioned landfills it is possible to produce 2,5 GWh electricity annually (Yagofarova et al. 2006). But considering the mentioned above landfill gas capturing abilities and the energy generation efficiency the final annual energy output can be about 1,2 GWh.

All in all, taking into account just the mentioned 5 landfill sites in Moscow Oblast it is possible to produce 2,1 GWh electricity annually. The potential is much higher considering the big number of landfill sites around Moscow. Obviously, energy generation from landfill gas can hardly be compared to plans of Mosenergo[20] that has adopted a programme of annual introduction of about 850 MW energy capacities (Mosenergo 2006). Still, energy can be used for on-site use or for low-energy consuming activities (e.g. greenhouses). Yet, without governmental support renewable energy can not compete with fossil energy carriers.

[20] Mosenergo is the power producer for Moscow and Moscow Oblast.

8 CONCLUSIONS

Renewable energy has a lot of potential for development in the Russian Federation. The research has outlined the general picture of the situation with bioenergy in the country, namely bioenergy generation from organic waste. The outcome of the investigation is that currently it is possible to produce significant amounts of electricity and heat from what is considered to be waste. The reasons why this is not done on large scale are all interconnected. First of all there is no legislation base on renewable energy. Laws, norms and regulations are in progress, yet driving force of renewable energy is not government, but private and regional organizations usually with the help of foreign investors.

Another obstacle on the way of renewable energy widespread is abundance of natural finite resources. For moving towards sustainable development, the mentality should be changed. The necessity of adopting renewable energy does not seem to be so obvious since the country has enough coal, oil and natural gas. Still, availability of fossil fuels does not solve the problem of decentralized energy supply. Somewhere it is too expensive to connect to the national grid, somewhere it is too expensive to deliver fuel. Renewable energy is capable to solve these problems, but it is not enforced to do so. As it was mentioned, there is no legislation and hence there is no well-developed economic support and financial incentives. At the same time huge companies specializing on extraction of fossil fuels merge, sign contracts and make agreement for cooperation development. These economic monsters on the energy market together become much stronger. SUEK[21], Mechel[22], Gazprom[23], Russian railways, etc. are interested in each other and are negotiating with one another for further cooperation. In addition, unlike renewable energy, utilization of fossil energy carriers in huge amounts is registered in “the General Scheme

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[21] SUEK (Siberian Coal Energy Company) is the biggest Russian coal producer.
[22] Mechel is one of the leading mining and metal producing company of the Russian Federation.
[23] Gazprom is a Russian company specializing in gas extraction. It is the largest extractor of natural gas in the world.

for Location of Electrical Power Facilities until 2020". All mentioned above convert companies, which specialize in fossil fuels, into huge power, which is not interested at all in sharing percents with renewable energy in the fuel and energy complex of the Russian Federation. For the mentioned above reasons at the moment the development of renewable energy should rely mainly on initiative of regional governments and individuals. Kyoto mechanisms, especially JI projects, can also significantly influence on renewable energy evolvement.

Different federal districts should utilize different sources for bioenergy production. Likewise, bioenergy from forest and wood residues should be developed in Northwest, Siberian and Far East federal districts. The energy potential equals to about 32,9 - 60,8 TWh annually. The energy output from forest residues can increase significantly if forest sector stagnation will be overcome. Forestry development in Siberian and Far East federal districts might have a direct influence on bioenergy development in these regions as well as on improvement of accessibility to energy, which would result in improvement of living conditions of the population. An advantage of wood waste utilization is that for substitution coal with wood residues, boiler modifications are not needed or these modifications are minor. In terms of pellet production, it is not likely that national pellet market would be developed, even though pellet industry is in its development phase. Pellet production plants would remain to be export oriented. In terms of pellet utilization in remote areas of Russia, further research is needed for evaluation of pellets' economic advantages and disadvantages in comparison to fossil fuels.

Bioenergy from agricultural wastes is of potential interest in Southern, Volga, Central and Siberian federal districts. The conducted analysis has shown that first of all biogas production should be adopted in the agricultural sector. Since biogas production is the most effective energy production method, CHP technologies are considered. The energy potential is about 118,8 TWh_e and 138 TWh of heat energy (pellet production is not taken into consideration, as at the moment it is not economically viable). Farms, or some parts of them, e.g. greenhouses, grain elevators, hog houses, etc. can function as stand alone energy systems, with on-site energy generation from organic wastes. This way of energy production would not only cover energy demand, but in addition would solve problem of waste utilization and produce fertilizers. National market offers biogas installations of national origin with short payback time. Biogas technology adoption is very likely to happen due to very strong governmental intention to develop agricultural sector.

Bioenergy generation from wastewater sludge and landfill gas can take place almost anywhere. Still, most profitable it can be in megalopolises. Energy potential of wastewater sludge is about 4,3 TWh and of landfill gas is 5,2 - 6,2 TWh. As the investigation has shown, landfill gas recovery is very attractive in terms of projects under Kyoto mechanisms. This is pleasant news as construction works for landfill gas capturing are very expensive. In addition, considering Russian mentality and relationship to waste and waste disposal it is not very likely that landfill gas recovery systems (and conversion to energy) would be initiated without foreign help. The fact is that as long as energy production from fossil fuels is cheaper than energy production from landfill gas, emission allowances (from JI projects), not energy, would be the most attractive part of landfill gas capturing. In a way, energy would appear as a positive by-product.

Biogas production from sewage sludge is likely to be developed just for on-site use of wastewater treatment plants. Still, this process might be hindered by the poor state of many wastewater treatment plants. This problem should be tackled, as biogas production from wastewater sludge can be a useful back-up energy source, which might prevent sewage discharges in the case of breakdowns of energy supply from the public grid.

Summing up, the total current energy potential of bioenergy generated from organic wastes is about 299,2 - 328,1 TWh annually. This is about 17-20% of the total electricity production and 8% of total heat production. It significantly can reduce coal utilization or question the necessity of nuclear power plants construction. Indeed, if the current potential of forest, agricultural and municipal organic wastes is used, it is possible to completely substitute nuclear fuel or coal (completely substitute coal in electricity production and reduce coal utilization in heat production). It should be pointed out that besides energy generation, waste minimization is also a very significant driving force for bioenergy promotion. Contrasting mentioned above figures, economic potential evaluated by Bezrukikh (2007) equaled to 561 TWh annually. However, the researcher considered all sources and all methods of bioenergy production (including firewood, energy crops, motor fuels, peat, etc.), while the given research was limited just to bioenergy generated from organic wastes.

The analysis was conducted basing on the information obtained from official sources (official web-sites, legislation of the Russian Federation and federal subjects), from industry journals (their electronic or hard copies) and at small extent from newspapers and weekly business magazines. Sometimes in the information sources some contradictions in numbers appeared. It can be explained by different methods of calculation or lack of information for more precise figures. Official statistics and official indicators that could characterize conditions of renewable energy sector, energy efficiency and energy conservation do not exist in the data of the Russian Federal State Statistics Service (Committee for Energy, Transport and Communication of the Russian State Duma 2007). Obviously, without unification of indicators the results would be different. Still, for making the research more reliable, numbers from different information sources were presented. This benchmarking method was used both in giving initial data and in describing own research results. The idea of it was to show the same range of figures.

Another obstacle in the research process relates to technological specifications of different energy producing units (e.g. heat or electricity-only production units, CHP units) and biological characteristics of organic waste decomposition. Meaning that under certain conditions from certain waste type the amount of generated energy would differ from energy amount produced in another situation. That is why the research tends to give just the general picture and evaluate approximate, not exact, amounts of energy. In other words, it can be pointed out that due to continuous number comparison, the research is in reliance with previously conducted investigations, yet it should be considered as a general picture of bioenergy situation.

Obviously, for specification of the bioenergy situation in Russia further research is needed. Future research can describe waste-to-bioenergy situation from geographical (by federal districts or by federal subjects) or waste generation source point of view. An important and useful research would investigate the possibility of job creation in renewable energy sector and comparison to job creation in fossil fuel energy sector. In fact, currently in Russia there are two types of research works available. Either they are too general (e.g. analysis of all renewable sources of energy) or they are too technical and scientific. As the result none of them gives the exact picture of bioenergy condition. From my point of view future research should combine economical and geographical characteristics of Russian bioenergy.

To conclude, it is evident what an enormous potential bioenergy has in the Russian Federation. In fact, the potential will increase proportionally with the rise of prices on fossil fuels and with country's economic development. Development of forestry and agriculture might have positive influence not only on Russia's economy, international trade, food supply, rural development, but indirectly on fuel and energy complex, via bioenergy development. However, this miracle can not happen by itself. Population education, research and development in the renewable energy field, economic incentives and financial support are needed. Government's role in influencing on all the positions mentioned above is the major one. While general guidelines and legislation are on their way, individuals can take personal actions. Gladly, a variety of actions is possible in the renewable energy field: from energy efficiency practices and installation of small renewable energy units to self-education and information dissemination on renewable energy and environmental matters. Thus, every one of us is capable to make his own contribution to the creation of the better and cleaner world.

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Appendix 1. Russia Profile [24]

Full name: the Russian Federation.

Capital: Moscow

Total area: 17,075,200 km^2 (50,7 size of Finland; 1,8 size of the USA).

Climate: steppe, humid continental (on much of the territory), subarctic in Siberia, tundra climate in the polar North.

Population: 142 million.

Form of government: federal semi-presidential republic.

President: Dmitry Medvedev.

Legislative branch: bicameral Federal Assembly (the Federation Council and the State Duma).

Administrative division:
The country consists of 83 federal subjects: 46 oblasts (provinces), 21 republics, 4 autonomous okrugs (autonomous districts), 9 krays (territories), 2 federal cities, and 1 autonomous oblast. All federal subjects form 7 federal districts: Northwest, Central, Volga, Southern, Ural, Siberian and Far East federal districts. The division is done in order to improve the communication between governments of the federal subjects and the Federal Government.

GDP (PPP): 2 076 trillion US$.

[24] Based on the CIA (2008) information.

GDP per capita (PPP): 14 600 US$.

Export: petroleum and petroleum products, natural gas, wood and wood products, metals, chemicals, and a wide variety of civilian and military manufactures.

Import: machinery and equipment, consumer goods, medicines, meat, sugar, semifinished metal products.

Appendix 2. Division of the Russian Federation by Federal Subjects

Source: Wikipedia 2008.

Appendix 3. Division of the Russian Federation by Federal Districts

Appendix 4. Legislative Acts in the Field of Renewable Energy and Bioenergy in the Russian Federation

Legislative/ legal regulatory act	Level of progress	Comments
the Energy Strategy of Russia for a Period until 2020 and	Exist	The main energy strategy of the Russian Federation.
the federal targeted programme “the Energy Efficient Economy”	Exist	The main legal act describes energy efficiency policy of the Russian Federation.
Federal programme “on the Development of Agriculture and Regulation of Markets for Agricultural Products, Feedstock and Food for 2008 – 2012”	Exist	Concerns bioenergy development. Increase of cultivated crop land areas (for rapeseed cultivation and for energy crops) and modernization of agricultural machines are mentioned.
Law “on Electric Power Industry”	Exist	Amendment concerns financial incentives for small energy units (less than 25 MW) connecting to the national electrical grid.
Federal programme “Research and Development in Priority Fields of Development of Scientific-Technological Complex in 2007-2012”	Exist	Concerns development of innovative technologies, in the renewable energy sector as well.
On Support of the Use of Renewable Sources of Energy	Draft legislation	Concerns renewable energy development and implementation of financial incentive mechanisms.
“On the Law Delimitating Usage of Ethanol as Biofuel and Component of Alcoholic Beverage”	Hearings in the State Duma	Concerns bioethanol production.
On the National Bioenergy Policy	Hearings in the State Duma	Concerns bioenergy production sector and transport sector for biofuels.
Project of the Government Decree “on Classification of Energy Units Utilizing Renewable Sources of Energy”	On approval in the Government of the Russian Federation	Classification of Energy Units.
Project of the Government	On approval in the Ministry of	Target values of electricity

Decree "on the Main Polices in the Sphere of Promotion of Electrical Power Efficiency from Renewable Sources of Energy until 2020, with Target Indicators"	Industry and Energy of the Russian Federation	production from renewable sources of energy are presented.
Project of Government Decree "on Approval of Activities for Meeting Target Indicators of Electricity Production and Consumption from Renewable Sources of Energy for 2008-2009"	On approval in the Ministry of Industry and Energy of the Russian Federation	The list of activities for meeting target values of electricity production from renewable sources of energy.