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BIOENERGY BASED ON WOOD CHIPS AS THE DEVELOPMENT DRIVER OF NON-URBAN FORESTED AREAS – THE CASE STUDY OF URAL REGION, RUSSIA

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Abstract: One of the most important key factors for the development of non-urban areas is infrastructure, and energy generation is one of the fundamental infrastructure elements. This paper provides a new solution for energy generation based on wood chips which has a multi-sector effect because the authors offer to combine planning of forest cleaning cutting with bioenergy generation in one complex project, which will have socio-economic and ecological effects. The situation with forest fires makes the authors' idea more attractive because after forest fires the problem of cleaning cutting in forest becomes very important and urgent by ecological and economical points: after cleaning cutting there are a lot of low quality wood which can be recycled into chips for the production bioenergy by the authors' idea. This enriched methodology has successfully been applied into the regional strategical planning in the field of bioenergy and forestry of the Ural region of Russia; however, it is suitable for applications in regional development in any non-urban forested region of the world.

Key Words: *regional development, development driver, non-urban areas, bioenergy, forestry, cleaning cuttings*.

Introduction

Development of non-urban areas that are located far from economic centers is one of the most important tasks and challenges of regional development. Infrastructure plays the key factor in the development of territory. Modern infrastructure for industry and business continuously needs the accessible energy. Without available energy, resources' territory cannot develop sustainably.

Nowadays in forested regions widely known energy generations are actively developing. These projects represent a bioenergy capacity based on wood chips. Statistics shows that it is the cheapest and most accessible raw material for bioenergy with low level of start-up investments (Appendix 1).

The impact of a wood chip project on the regional economy was started to investigate by Ferguson (1972). He found out that it was a very effective solution for regional economy, because the total employment created by a wood chip project had probably doubled the direct employment in the project itself. Also, he concluded that these features made a wood chip project particularly desirable in a depressed area or a less developed region. His research was continued in the works of Schwarz and Steininger (1997). In addition to the theory of Ferguson (1972), they offered to recycle waste based on wood in the industrial recycling network, which integrated the reuse of former waste by an intercompany matching of production processes. They showed that it helped to reduce material and energy through put in the economic system to sustainable level. The effectiveness of using wood chips projects in regional development and the effect of location (North 1955) and facility demand on the marginal cost of delivered wood chips from energy crops were also investigated in the articles of Graham et al. (1997), Abrahamson et al. (1998), Harris et al. (2004), Sipilä (2015), Tammi et al. (2016), and Paolotti et al. (2017).

Over time, the scale at which bioenergy is used has considerably increased due to integral policy approach for bioenergy incorporating energy, agricultural, forestry, waste and industrial policies in the world (Romanova and Lavrikova 2012). Modern research analyses a new approach in bioenergy and regional development, emerging international bioenergy markets and opportunities for socio-economic development (Faaij and Domac 2006, Shegelman et al. 2011, Tretyakov 2015, Cambero and Sowlati 2016, Goncalves et al. 2016, Lenz et al. 2016).

In science and practice, the model of wood chips application based on recycling of the logging waste dominated. The authors propose to change the existing approach and consider as the driver of regional development (Mingaleva and Mingaleva 2013, Tulumović 2015) for forested non-urban distant territories the application of bioenergy based on wood chips, which are the waste product of cleaning cuttings and thinning. With such solution, it is possible to implement a complex approach into the territory development.

Methodology

Fuel chips are a small fraction of wood with bark, obtained by mechanical cutting of the trunk portion by wood chipping machines. By the official data of the Russian statistical Organization ROSSTAT, the production of wood chips for bioenergy has the lowest share in comparison with wood chips to the needs of wood panels and cellulose industries.

Solid fuel, accordingly to Pre-Norm prCEN/TS 14961 European standards is divided into groups. For the generation of electricity and heat, wood chips are used, which belong to an important group of woody biomass (this group includes firewood, briquettes etc.). Woody biomass is classified accordingly to these standards on their origin (method of receipt). Each group is assigned by its own code. Because of the diversity of origin of the fuels in this group it differs in quality: chips obtained from the sanitary and thinning cuttings of forest; chips derived from waste lumber and woodworking, recycled waste, free of chemical impurities.

Nowadays, in practice the main part of wood chips for bioenergy comes from logging, lumber and woodworking. Usually this bioenergy generation capacity is located near wood storages or industrial sites, which are specialized in forest engineering sectors. In such cases, it is mainly recycling of wood chips and bioenergy projects based on wood chips do not have enormous influence on regional economy because of a big share in the regional gross regional product industrial production. In the territories with low level of industrialization, the number of manufacturing enterprises is low. Main economic activity in these regions is connected with farming and agriculture. That is why forestry is one of the leading sectors of regional economy (Niskanen et al. 2003). Mainly non-urban territories do not have enough developed infrastructures, and the situation is the same in energy supply, because for the government budget it is not effective and expensive to invest money in power infrastructure without effective and successful turning back from industries.

The authors offer a solution to combine the interests of different regional stakeholders into one project and to develop the local economy of non-urban areas. The authors' idea is to choose a wood chips bioenergy projects as driver for regional development in non-urban forested areas, while having multi-sector effects (Lavrikova et al. 2015) and a positive impact on local economic development (Fig. 1).

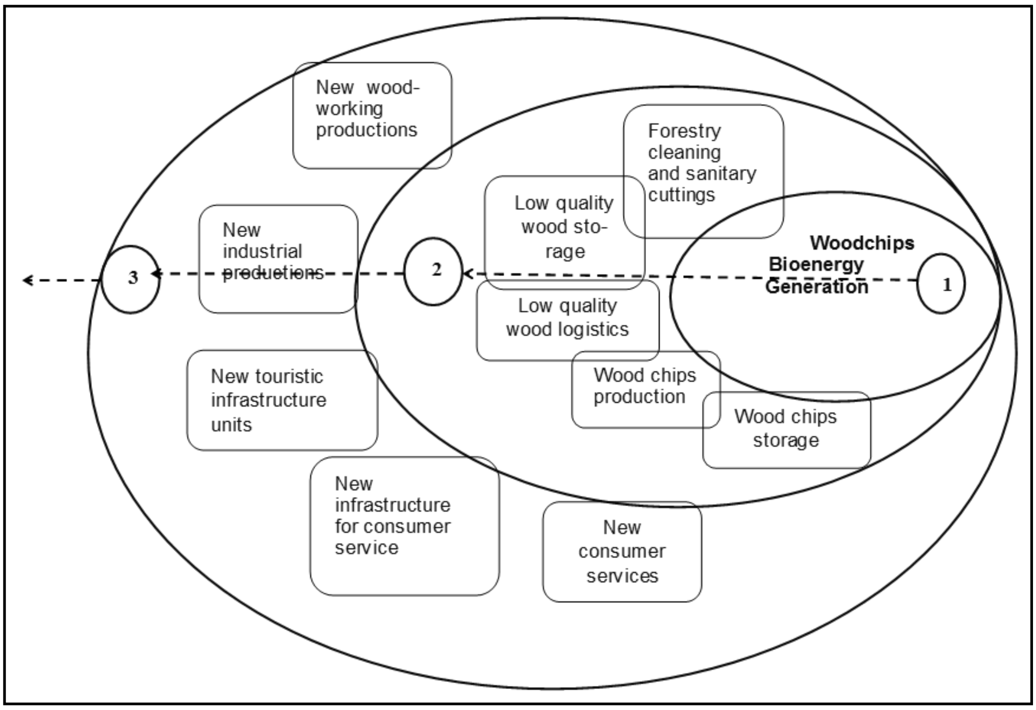

Fig. 1 – **Model of the regional development for non-urban forested areas based on woodchips bioenergy**
Source: Authors (2017)

By the authors' model, the total employment created by a wood chip project probably doubles the direct employment in the project itself, because this project will have a long macro-economic effect. In the first step, the start-up of bioenergy generation based on woodchips in non-urban areas will attract investments into the regional economy and it will stimulate development of new business activities connected with low quality wood – wood storage, wood logistics, wood chips production, and wood chips storage. It is an attractive business because low quality wood is a waste product from cleaning and thinning cutting and usually forestry enterprises give it for free to business because with this scenario they avoid any cost to utilize it.

So the cost of wood chips for bioenergy generation includes only the cost of logistics and processing the low quality wood, while the main raw material-wood is free of charge. New investments and cheap accessible energy open new opportunities for the development of local business projects connected with wood-working production, other industrial productions, tourist infrastructure units, new infrastructure for consumer service and other new consumer services. So we can see the wave of economic effect which starts from the start-up of a new bioenergy generation project. By the modern theory of regional development, this scenario can develop by different models such as the model of growth and development of poles (Perroux 1970), the model of unbalanced development (Hirschman 1958), the model of circular cumulative causality (Myint 1954), the dependence model (Prašo 2001), the model of central place and gravity (Christaller 1933), and the model of production specialty (Ibreljić 1994).

From the authors' point of view, the using of bioenergy based on woodchips, given the offered scientific context, for the economic development of non-urban forested regions is the most appropriate approach to the theory of "growth and development of poles" (Perroux 1970). Perroux's (1970) "Space as force" is a view on spatial interaction, which defines space as a type of network that is held together by centripetal forces, and it has formed the basis of most growth pole theories. In Perroux's (1970) original theory, the growth pole referred to linkages between firms and industries. The "propulsive firms" are those that are largely relative to other firms and generate induced growth through interindustry linkages as the industry expands its output. It means that due to cheap energy generation from wood chips it is possible to attract and stimulate new business projects, which will develop and diversify the local economy (Jovanović et al. 2012).

Also, it is well known that such natural disasters as hurricane-force winds, loss of wet snow and freezing rain lead to the formation of forest trash, which latter dramatically increase the risk of reproduction of secondary pests and increasing of forest fires. Recycling of this forest trash is also ignored by foresters due to low marketability of wood. The use of this wood as a biofuel will allow solving major environmental challenges to prevent the spread of hotbeds of forest pests and to minimize wildfires as well.

Usually, non-urban areas are located far from industrial centers and they have problems with logistic infrastructure and in this case the usage of coal, oil, gas and refined products as fuel are connected with the problem of transporting fuel over long distances (Domashchenko 2016), which is not only costly, but also risky to be untimely or not fully performed for the purchase and delivery of fuel, and consequently, it is a great risk for the life of the local population, especially in remote settlements. The problem is not solved only by providing these settlements with electricity, because there is always a danger of outages because of natural (freezing rain, hurricane) and anthropogenic (theft of wires, etc.) factors. The usage of local fuel minimizes the problem of providing electricity and heating in such settlements regardless of their remoteness and availability of transportation routes.

So, implementing this approach in regional development of remote non-urban forested areas improves the local economic situation and it minimizes the different social and ecological risks.

Results and Discussion

The current situation of the Russian economy is very favourable for the implementation of the project of bioenergy on renewable biofuels. The market is full of offers from local and international manufactures of bioenergy equipment for wood chips for the production of heating and electricity with high efficiency, because these energy generations settle the main problems of the Russian economic high energy intensity. The specific energy intensity of GDP in Russia is three times higher than in some other Western European countries. First of all, the problem concerns the housing and communal services. The reason lies in the growing losses and increasing energy costs of utility networks and boiler-houses due to their wear, sometimes reaching 60%. Villages located in the forest areas of the Urals, Siberia and the Far East have to buy fossil fuels (coal, fuel oil, diesel oil) and move it hundreds or thousands of kilometres, while in Russia millions of tons (more than 65) forest residue, sawmill waste and low-grade wood are not used. But such waste, collected within a radius of 50 km from the village and processed into wood chips, can provide heat even at the district center, not to mention the villages and towns in the region. The splint, which is often called the fuel or "green" (as twigs, bark, twigs with leaves, comprising 20 to 25% of tree biomass in grinding machine serves) was not used in slab and hydraulic industries.

It is economically feasible to harvest in regions with distressed forest management, because forests fell and forest management becomes unprofitable. One of the major reasons of underutilization of the allowable cut in such regions is a lack of industries for the processing of low-grade wood (small timber and dead wood from thinning), and reforestation. In addition, it minimizes the worsening of the ecological situation and the growing of environmental pollution connected with the emission of CO_2.

The area of the Russian forest is of 1.2 billion hectares, which comprises up to 22% of the world forest area. The forest area of the Ural Federal Okrug is more than 114 million hectares; and it covers about 70% of its territory. The Ural region also has a similar situation on forest coverage; it is all covered with forest between 20% till 38% of its surface (Table 1).

Table 1

The area of forest resources of Ural Federal Districts by regions

Federal District of Russia	The total area of forest land *(thousand hectares)*	The territory forest cover *(%)*	The total stock of standing timber *(million m^3)*
Kurganskaya oblast	1 877	21.5	199
Sverdlovskaya oblast	16 000	68.7	2 141
Tyumenskaya oblast including:	93 976	43.5	5 360
Khanty-Mansiysk Autonomous Okrug	50 312	53.8	3 266
Yamalo-Nenets Autonomous Okrug	32 279	21.8	1 167
Chelyabinskaya oblast	2 961	29.4	406
UrFD Total	**114 814**	**38.5%**	**8 106**

Source: according to data of ROSLESHOZ Russian Federal Department

In all these regions, there is a problem with the utilization of low quality wood but due to their big territories it is always topical for the economic development of remote non-urban areas.

The Ural Federal District is one of the biggest in Russia – 1.8 km^2, which is equal to 10.62% of the Russian territory. The Ural District is almost forested and it has an enormous potential for the development of bioenergy based on biomass and “green” economy (Fig. 2).

But, in the major regions of the Urals, the sanitary cuttings and thinning are carried out in extremely limited volume: foresters have a very limited budget for this. That is why the actual amount for 20 years period thinning and sanitary cutting in the main part of Ural region, Sverdlovskaya oblast, did not exceed 6.5% of the planned forest management. The preliminary calculations of the actually available resources of renewable biofuels show that the same situation we can find in other parts of the Ural Federal Okrug. So there are enough wood resources in the forest for the implementation of the authors’ model and, besides the economic effect, the region will implement the key tasks of sustainable forest management.

Among the silvicultural measures to procure a significant amount of wood for bioenergy wood chips are the following:

1. *Cleaning up after logging*. One way to clear the ground felling is recycling, which consists in using the logging residues as raw material for the chemical or mechanical processing, and also as fuel. To date, this method of cleaning the places of cutting in the Urals and Western Siberia is almost never used. The potential resources of logging residues depend on the type of logging, the inventory indices, the cutting down the forest stands and the applied technology of logging operations (Rubtsov et al. 2011). In particular, according to the Department of natural

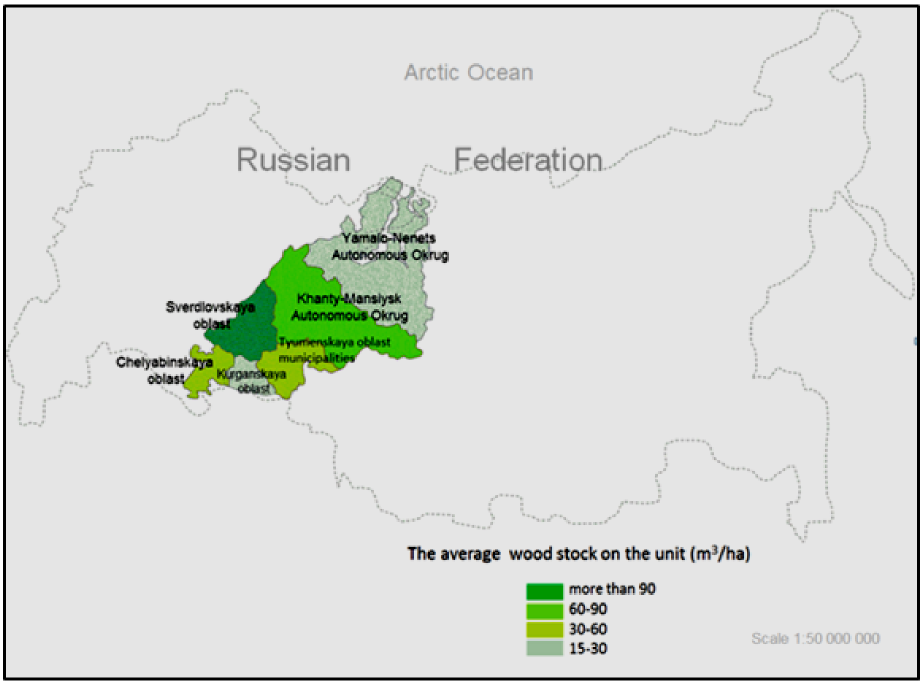

Fig. 2 – **Representation of the average wood stock on the unit of the area in the Ural Federal District**
Source: according to data of ROSLESHOZ Russian Federal Department

resources and non-resource sector of economy of Khanty-Mansi Autonomous Okrug – Yugra (KHMAO - Yugra), on the number of the felling after clear cuttings, made on the assortment technology (harvester+forwarder), the supply of forest residues left after logging is up to 80 m^3/ ha. Considering the allowable cut mature and over-mature stands, it is possible to receive 4.92 million m^3 of logging residues annually in KHMAO-Yugra and over 8 million m^3 in all Ural Federal Okrug.

2. *Cleaning burnt forested areas and burnt wood*. Unfortunately, up to the present time, on the territory of the Ural Federal District (UFD) forest fires are frequent. A part of the mature wood, burnt by forest fires, of course, dies, but the main square, especially the low-grade plants, are transformed into dead forest and it remains on-site undeveloped, creating a real threat of new fires and hampering the process of reforestation. The average range of these stands is of 97 m^3/ha. During 2016, there emerged and were eliminated more than 2.7 thousand fires in the Ural region, while the situation in other regions was: in Sverdlovskaya oblast – more than 760 fires, in Tyumenskaya oblast – more than 90 fires, in the Yamalo-Nenets Autonomous Okrug – more than 530 fires, and in the Khanty-Mansi Autonomous Okrug – more than 450 fires. It should be particularly noted that in the conditions of Yamal-Nenets Autonomous Okrug (YNAD), KHMAO-Yugra and the North of Sverdlovskaya oblast, the dry dead forest can be used as the object of procurement of raw materials for bioenergy for many decades (Table 2). The burned area of UFD has 309.8 thousand hectares with timber reserves of 30.05 million m^3.

Table 2

The average number of forest fires in the Ural Federal District and their area during 2012-2016

Ural Regions	Forest fires, times per year (ha)		Burned forest territory (ha)		Middle square of forest fire (ha)	
	Average for 5 years	2016	Average for 5 years	2016	Average for 5 years	2016
Sverdlovskaya oblast	679	607	8 546.7	3303.4	12.6	5.4
Tyumenskaya oblast	395	89	3 902.7	351.2	9.9	3.9
Chelyabinskaya oblast	849	572	9 158.3	2 679.4	10.8	4.7
Kurganskaya oblast	444	245	4 820.2	523.5	10.9	2.1
Khanty-Mansiysk Autonomous Okrug	703	454	43 576.0	8 117,9	62.0	17.9
Yamalo-Nenets Autonomous Okrug	325	407	50 115.6	64 811.0	154.3	159.2
UFD Total	**3 394**	**2 374**	**120 120**	**79 786.4**	**35.4**	**33.6**

Source: according to data of ROSLESHOZ Russian Federal Department

3. *Continuous and selective sanitary cuttings*. In addition to forest fires, the Urals and Western Siberia have problems with the storm winds, harmful insects and diseases. The possibility of using of low-quality wood as raw material for bioenergy opens unlimited possibilities for continuous and selective sanitary cuttings, and thus it improves forest health. The most conservative estimate of raw material resources for bioenergy, subject to the continuous and selective sanitary cuttings, will make more than 30 million m^3.

4. *Conducting thinning and improvement of felling in young stands*. Thinning in young stands and thinning in whole are the most important from a silvicultural point of view within the types of care for the forest. However, the volume of these cuttings is extremely small, because the young wood is not in demand. On rare occasions, the transfer to intensive care can produce up to 50-75 m^3 of timber on 1 ha. In turn, the implementation of the projects of bioenergy development will start the actual care of the forest, based on research-based recommendations. The resources of low-grade and small-sized wood from thinning in young stands and mainly from thinning exceed 15 million m^3.

5. *Logging reformation*. The consequence of clear cuttings is a massive change of fir trees derived softwood. From the silvicultural point of view, these forest stands need operations aimed at restoring the indigenous conifers. Such generations are developed, but their implementation is hampered by the lack of marketing of hardwood timber. With 300-350 m^3/ha, the demand is not more than 50% of the stem wood. The usage of low-quality deciduous wood as raw material for bioenergy would allow reshaping and rejuvenating the derived softwood plantations. Raw material resources in the implementation of these types of cabins accordingly to conservative estimates reach more than 14-15 million m^3.

6. *Logging in low fertility rate and low-grade plantings*. When establishing the annual allowable cut, it is calculated as such both for mature and low fertility rate low-grade plantings. However, this cut has never mastered because of the actual lack of sales of timber. The result was the accumulation of over-mature plantings. It is logical that these trees can be mastered if you use

a part of commendable harvested wood as raw material for bioenergy. A resource of that raw material exceeds 10 million m^3.

7. *Other cuttings*. Considerable volumes of timber harvested in the process of conducting other felling. The latter includes the development of routes of communications, area features, etc. The enterprises of bioenergy allow the use of specified wood as well as wood produced for the care of green spaces within settlements and cities. In our current research, we estimate this kind of cuttings to be equal to zero and we do not take this resource in our calculations.

Resuming all sources of low quality wood for chip bioenergy generation, we can see that the potential of resources for wood chips in the Ural Federal Okrug is more than 107 thousand m^3.

Table 3

The wood potential for bioenergy based on chips in Ural Federal District delivered from different kinds of forest cuttings (m^3)

Ural Regions	After logging	After fire	Sanitary care	Thinning	Logging refor-mation	Low-grade plantings	Total:
Kurganskaya oblast	131	491	490	245	229	163	1 749
Sverdlovskaya oblast	1 115	4 188	4 181	2 090	1 951	1 394	14 919
Tyumenskaya oblast includ-ing:	6 548	24 596	24 555	12 278	11 459	8 185	87 621
Khanty-Mansiysk Autonomous Okrug	3 506	13 168	13 146	6 573	6 135	4 382	46 910
Yamalo-Nenets Autonomous Okrug	2 249	8 448	8 434	4 217	3 936	2 811	30 095
Chelyabinskaya oblast	206	775	774	387	361	258	2 761
UrFD Total	**8 000**	**30 050**	**30 000**	**15 000**	**14 000**	**10 000**	**107 050**

Source: Authors (expert calculations based on data of ROSLESHOZ Russian Federal Department)

It is important that our model uses the principles of the “zero kilometre energy” model of Santoli et al. (2015). Due to this model of efficient bioenergy, woodchips are used in the nearest 50-100 km. Taking into account the two main conditions that wood will be cheap and that its logistic will be short, we are able to estimate the total economy in comparison to the traditional fuel for the Ural Federal Okrug (Table 4).

According to the calculations of the leading factory manufacturing boilers of BALTKOTLOMASH, the price of fuel chips, in the case of their preparation on the place of logs or forestry that are not related to the wood business, has the following structure. The price of timber costs from 500 to 1000 rubles per 1 m^3 (the price depends on region and supplier), cutting chips costs are about 170 rubles for one dense cubic meter. Accordingly, the price of fuel per 1 Gcal will range from 420 to 730 rubles. In these calculations, the humidity of wood chips is up to 55% and the boiler efficiency is of 80%. This data collected from practice show that the average price per cubic meter of dense chips is around 1000 rubles. Also, the 1 Gcal in this case will be equal to 625 rubles. Traditional heating is much more expensive, for example, in 2017, by the official municipal unitary enterprise “Ekaterinburgenergo” (Ekaterinburg), the price of 1 Gcal is 1585.22 rubles. So, our final calculations show that if wood chips fuel is based on the waste from logging or byproducts from forestry, the direct effect of the implementation of chips bioenergy is the saving of approximately 1 thousand rubles or $ 17/ Gcal.

Table 4

The economy of using wood chip bioenergy instead of traditional fuel

Ural Regions	Total *(m^3)*	Production of heating *(Gcal*)*	Total economy in comparison with traditional fuel *(thous. rub/year**)*	Total economy in comparison with traditional fuel *(thous. $/year***)*
Kurganskaya oblast	1 749	5 605.8	5 383	93
Sverdlovskaya oblast	14 919	47 817.3	45 915	792
Tyumenskaya oblast including:	87 621	280 836.5	269 665	4 650
Khanty-Mansiysk Autonomous Okrug	46 910	150 352.6	144 372	2 489
Yamalo-Nenets Autonomous Okrug	30 095	96 458.3	92 621	1 597
Chelyabinskaya oblast	2 761	8 849.4	8 497	147
UFD Total	**107 050**	**343 109**	**329 460**	**5 680**

** Fuel consumption = 0,312 m^3/Gcal*
*** Economy = 960 Rub/Gcal by condition that wood chip is a byproduct of forestry and logging with fixed price close to 0*
**** Economy = $17/Gcal (Exchange rate = 58 rub/$)*

The indirect effects of implementing the bioenergy generation based on wood chips are enormous and connected to the improvement of regional economy and ecology. Today, in Russia and also in the Ural region, losses in heat production and the ways of its delivery to the final consumer reaches up to 40-50%, which means that the equipment heats the streets and it burns precious non-renewable fossil fuels in an almost twice more power than required. Also, the implementation of bioenergy generation based on wood chips will minimize the emission of CO_2, which will influence positively on the local ecological situation and the area can become positive on the market as eco-territory with eco-business.

In previous studies, regional economic impacts of using biomass energy in the world have been examined (Mingaleva and Shpak 2015, Manolis et al. 2016, Picchi et al. 2016). In the research of Timmons et al. (2007), in the study of Massachusetts (USA) and in the 1992 Northeast Regional Biomass study updating the 1985 effort, the same methodology is used: a “hybrid model”, with spending and employment from the biomass industry itself estimated directly and indirect effects using an IMPLAN model. The combination resulted in $ 74.8 million in direct and indirect economic activity, as well as 1 482 jobs (again from both direct and indirect effects). A 2004 report on potential biomass energy impacts in South Carolina (Harris et al. 2004) estimated the impacts of new (rather than existing) biomass use. The study projects that 49% of the total RPS requirement will come from biomass (representing 6.8 million tons), though they calculated that only 13% of the total would come from woody biomass. Annual employment (operations) impacts of all renewables in this scenario are estimated to 2 229

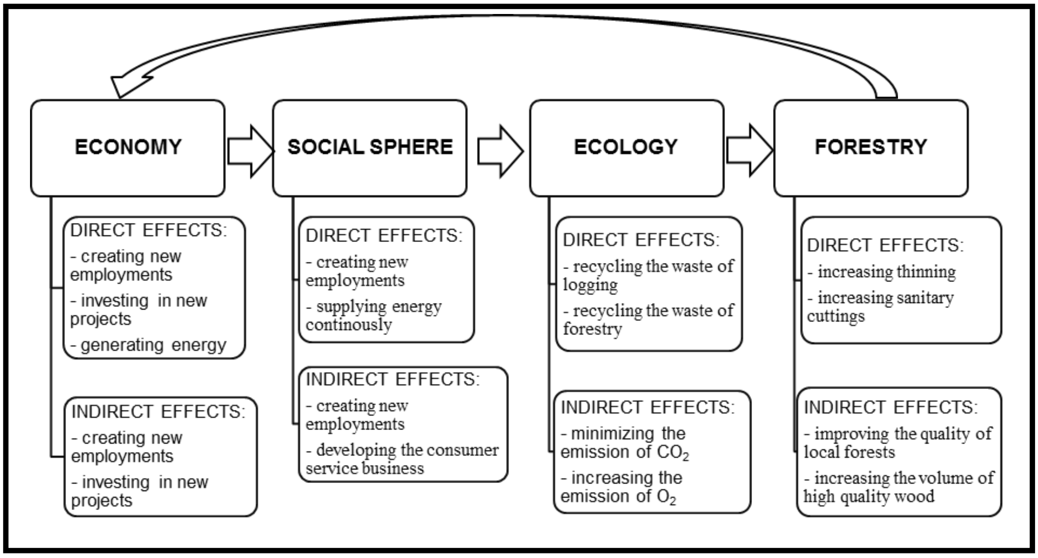

Fig. 3 **– The effects of the implementation of a model of socio-economic development of remote areas on the basis of bioenergy with the application of wood chips**
Source: Authors (2017)

direct jobs, and to 16 291 jobs in total, including the indirect impacts. Biomass for the generation of electricity is estimated to create 1 681 direct jobs, and 8 256 jobs in total. The study notes that the positive impacts on rural employment are one of the primary attractions of an RPS in general, and of the large dedicated to energy-crop approach in particular.

In the Ural Federal Okrug, wood chips bioenergy can generate more than 343 thousand Gcal of heating with the direct effect of creating more than 345 jobs in total. The indirect effect due to previous theories can represent more than 2 760 jobs. This scenario of development needs low level of investments and it is attractive for regional development through its multi-sector effects.

Given that coal boilers and boilers on wood chips are of broadly similar design, but the basic device itself is of identical boilers, a coal boiler can be transferred into wood chips boiler without replacing the boilers themselves − after minor upgrading (in particular, the provision of supply and automation). It is possible to apply co-combustion of coal and wood chips that is practiced in many European countries. Of course, not all boilers are suitable for such projects. The first thing is to consider problematic boilers, then boiler plants in remote areas, where a very high cost of coal and raw material base of logging waste in the region is sufficient to produce the required amount of fuel chips.

In these areas, the authors' model could give the most enormous effect (Fig. 3). The direct effect of the implementation of bioenergy generation based on wood chips is complex and it consists of creating new employments and new investment projects, energy generating and continuously supplying, waste recycling of logging and forestry, while increasing of thinning and sanitary cuttings.

The indirect effect of the implementation of bioenergy generation based on wood chips is also complex and it consists of creating new employments and investments in new sectors, developing the consumer service, improving the quality of local forests and the emissions of CO_2 and O_2.

The main goal of our research was to approve that bioenergy based on wood chips can be the driver of regional development for remote areas, by the case study of the Ural region of Russia. This was empirically proved through the above calculations. The approximate direct economic effect of the total economy in comparison to the traditional fuel is of more than $ 6 million per year for the case study of the Ural region.

The study found that more than 343 thousand Gcal can be generated by wood chips bioenergy for heating the Ural region, which does not exist in its territories mainly. New wood chips bioenergy projects can create more than 3 000 jobs directly and indirectly. Based on our results, it seems that economic prerequisites for the transition to renewable fuels actually already exist. The competitiveness of fuel chips compared to other alternative solid fuels underlines the success of wood chips in the fuel market and their stable rate of growth.

The study paper also highlights several limitations that might inhibit the efficiency of bioenergy projects based on wood chips: the logistics to boiler must be minimized and it should be less than 50-100 km.

Research results show that the implementation of bioenergy projects based on wood chips in remote areas creates a complex multi-sector effect and it has a lot of direct and indirect economic, social, ecological and forestry effects. Thus, bioenergy based on wood chips represents an interesting driver for the sustainable development of remote forested areas and this enriched methodology has been successfully applied into regional strategically planning in the field of bioenergy and forestry in the Ural region of Russia and it started to be implemented; however, it is suitable for applications in the regional development of any non-urban forested region in the world.

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Appendix 1

Energy Resources Prices 2017

Commodity (% Moisture Content)	pence/ ltr	£/tonne	Net Calorific Value		Pence/kWh (input)	pence/kWh (“on the meter”)
			kWh/ tonne	kWh/ltr		
Electricity (Domestic)					12	12.00
Liquefied petroleum gas (Domestic)	40			6.6	6.06	7.13
Wood Pellet Bagged		250	4800		5.21	6.13
Firewood (30%)		150	3500		4.29	5.04
Heating oil	40			10.3	3.9	4.6
Main Gas (Domestic)					3.50	4.12
Wood Chip (50%)		70	2300		3.04	3.58

Source: Forest Fuels (2017)

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