

CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences



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**Faculty of Tropical
AgriSciences**

**Potential of producing and using biofuel
in Republic of Moldova**

Bachelor thesis

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Declaration

I declare that I worked on my Bachelor Thesis entitled “*Potential of producing and using biofuel in Republic of Moldova*” by myself and that I used literature resources listed in references.

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Date

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Signature

Acknowledgement

I would like to acknowledge to my supervisor Ing. Tatiana Ivanova, Ph.D. for her supervising of my Bc. Thesis, support, consultations and recommendations, which she provided during all time of my work on the present thesis. I would also like to thank to my consultant Dipl. Ing. Alexandru Muntean for his valuable advises.

List of tables, abbreviations and graphs

Abstract

Due to fossil fuels reserves depletion and ecological problems concerning to burning of non-renewable fuels, development of alternative renewable sources of energy became one of the main priorities in developed as well in developing countries. Republic of Moldova faced to serious ecological and energy problems such as lack of own energy resources and accumulation of large amount of agricultural wastes. The most optimal solution to solve both problems seems to be utilization of the waste biomass for energy purposes.

The present thesis – Potential of producing and using biofuel in Republic of Moldova comprises two parts: literature review and practical part, based on own research. The literature review was focused on analysis of information about the main economical activities in formation of country's GDP, evaluation of the main sources of biomass produced by agriculture as well as assessment of energy sector and its dependence on import of fuel resources. Literature part also described the current situation in the area of renewable energies' development in Moldova. The objective of the practical part of the thesis was to define active producers of solid biofuels in different regions on the country and to analyze the forms of produced biofuels (briquettes or pellets), productivity, types of raw material used for production, price of the final product and origin of production equipment. The results showed that the most desired raw materials are agricultural wastes, mainly straw, both forms of solid biofuels are produced almost in the same quantities and their production is depended on the main consumers.

Keywords: agricultural wastes, biomass, biofuel, pellets, briquettes, Moldova

Abstrakt

Díky snižujícím se zásobám fosilních paliv a ekologickým problémům spojených se spalováním těchto neobnovitelných paliv, rozvoj alternativních obnovitelných zdrojů energie se stal jednou z hlavních priorit jak v rozvinutých, tak v rozvojových zemích. Moldavská republika čelí vážným ekologickým a energetickým problémům, jako je nedostatek vlastních energetických zdrojů a akumulace velkého množství zemědělských odpadů. Optimálním východiskem pro vyřešení obou těchto problémů se zdá být využití odpadní biomasy pro energetické účely.

Předkládaná práce - Potenciál výroby a využití biopaliv v Moldavské republice, se skládá ze dvou částí: literární rešerše a praktické části, která vycházela z vlastního výzkumu. Literární rešerše byla zaměřena na analýzu informací týkajících se hlavních ekonomických aktivit podílejících se na tvorbě HDP země, vyhodnocení hlavních zdrojů biomasy vyprodukované v zemědělství, jakož i zhodnocení energetického sektoru a jeho závislost na dovozu paliv. V literární části je také popsána současná situace v oblasti rozvoje obnovitelných zdrojů energie v Moldavsku. Cílem praktické části práce bylo definovat aktivní producenty tuhých biopaliv v různých oblastech země a zanalyzovat formu vyrobených biopaliv (brikety nebo pelety), produktivitu, druh vstupního materiálu používaného pro výrobu, cena konečného produktu a původ výrobních zařízení. Výsledky ukázaly, že nejžádanější surovinou jsou zemědělské odpady, především sláma, a že obě formy tuhých biopaliv se vyrábí téměř ve stejném množství a jejich výroba je závislá na hlavních spotřebitelích.

Klíčová slova: zemědělské odpady, biomasa, biopaliva, pelety, brikety, Moldavsko

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1. Introduction

Today, when the earth's population is rapidly growing, along with the traditional fuels' growing consumption, the alternative energy sources' demand is growing as well. The developing of the renewable energy sources is of current interest, as it is intended to resolve a lot of nowadays problems, such as ending resources of traditional fuels. The renewable energy can provide energy insurance and solve many existing environment problems.

Moldova is an agricultural country and its economy is dependent a lot on exporting the agricultural products. The biofuel's developing in Moldova is topical today, as it is almost totally energy dependant on importing the energy sources – approximately 87 % of energy is being imported into the country (National Bureau of statistic of Republic of Moldova, 2014). Moldova is an agricultural country and has a suitable climate for production of crowd of different plants and vegetables, which would provide enough of resources (raw materials) to produce the solid biofuels. The greatest biomass source in Moldova is agriculture – plants production and its wastes. Each year there are available approximately 4 million tons of biomass from this sector, that for sure can be used for heating energy production in form of pellets and briquettes (UNDP in Moldova, 2012). The usage of the pellets and briquettes could solve a lot of problems in the present region – energy dependence, environment issues and poor developed waste management issue, all the wastes can be properly utilized and be useful for this developing country (Moldova Energy and Biomass project, 2011). The main environment issue is based on agricultural wastes accumulation and according to official data, agricultural wastes are not only worsening the environment, it damages the farmers' households as the result (Moldova Energy and Biomass project, 2010).

The developing of the present sector in Moldova is the beginnng stage on the way to the energy independence and could increase the country's economy as the result, what is also topical for Moldova, as for the poorest European conuntry (UNDP in Moldova, 2012).

Moldova is a member of different development programs and is also a priority for the International development cooperation programs (Czech Development Agency, 2010). The biofuels' development in Moldova is today real, mainly thank to the development projects and theirs financing. Along with the financial help, Moldova is supported by transferring the know-how and expansion of production technologies for solid biofuels' production.

2. Literature review

2.1 Background of the Republic of Moldova

2.1.1. Economy

Republic of Moldova - country, which is situated in the southeast Europe. The territory of Moldova is 33.8 thousand km². Moldova borders with Romania on the west and north, with Ukraine on the east and south. The capital of Moldova is Chisinau. Republic of Moldova is one of the smallest republics of the former Soviet Union. It became independent in 1991 (Sinclair et. al, 2014). Population of Moldova is 3.56 million people; among them 75 % are Moldavians, 8.4 % Ukrainians, 5.9 % Russians. A relatively big part of the population lives and works abroad, due to the lack of working places (National Bureau of Statistics of the Republic of Moldova, 2010). From 2007, Moldova borders with European Union, what affected well on country's economy - Moldova became a part of European trade and now country's export of goods and agricultural products has grown, also Moldova became associate member (World Bank, 2007).

Since 1991, before becoming a part of with European's Union trade, country has been in a serious crisis, due to the loss of the biggest available trade for Moldova - USSR's countries (National Bank of Moldova, 2009). The country has started its long way on making its international relations with other countries. It was quite difficult, mainly because Moldova did not have much to offer. Moldova's GDP in the year 2006 was 3.41 billion USD and before 2006 it was even lower (World Bank, 2016).

Figure 1 shows a visible growth of Moldova's GDP during past 8 years. The highest GDP was noticed in 2013. In 2014 it was a bit lower - 7.94 billion USD (World Bank, 2016). It is well seen, from the Figure 1, that since 2006 Moldova's GDP started to grow, it is related with the fact that Moldova started to heavily develop its agricultural sector mainly thank to development cooperation programs (Ministry of Agriculture and Food Industry of Moldova, 2011). The country did not have new technologies and especially knowledge to develop this sector by itself.

Moldova's economy is quite poor now, mainly because of the government structure and high corruption level (World Bank Group, 2014).

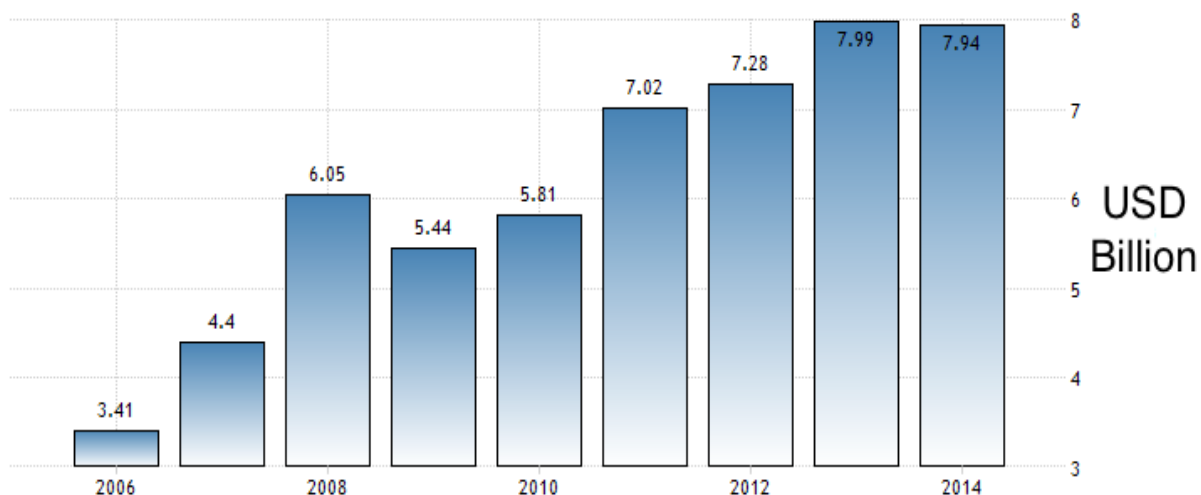


Figure 1. GDP of Moldova (2006 – 2014)

(Source: World Bank, 2016)

The share of the main economic activities in the generation of country's GDP is presented in the Table 1 below.

Table 1. Share of main economic activities in the generation of Moldova's GDP, (%)

Economic activity	2010	2011	2012	2013	2014
Gross Value Added – total	83.4	83.0	83.5	83.3	84.3
of which:					
Agriculture, hunting and forestry	12.0	12.3	11.2	12.3	12.6
Fishing	0.0	0.0	0.0	0.0	0.0
Industry	13.3	14.0	14.0	14.3	14.6
- mining and quarrying	0.4	0.4	0.4	0.5	0.5
- manufacturing industry	10.6	11.4	11.4	11.7	12.1
- electricity and heat, gas and water supply	2.3	2.2	2.2	2.1	2.0
Construction	3.4	3.3	3.4	3.4	3.6
Wholesale and retail trade	12.8	13.5	13.7	13.6	13.5
Transport and communications	11.3	10.9	10.7	10.0	9.8
Other activities	32.7	31.2	32.5	31.4	32.2
Financial intermediation services indirectly measured	-2.1	-2.2	-2.0	-1.7	-2.0
Net taxes on products	16.6	17.0	16.5	16.7	15.7
GDP	100.0	100.0	100.0	100.0	100.0

(Source: National Bureau of Statistics of the Republic of Moldova, 2015)

It is visible from the Table 1 that GDP of Moldova is mainly created by industry, trade, agriculture, and other economic activities.

Moldova is a member of many international organizations and institutions such as: World Trade Organization (WTO), the International Monetary Fund (IMF), European Bank for Investment and Development (EBRD), Commonwealth of Independent States (CIS) (Salem Press, 2014). Moldova has obtained the opportunity to benefit from European Union funds during the period 2008 - 2014. Recently, bilateral agreements on mutual investment promotion and protection were signed with 35 different countries with the impact of compliance with the free-market economy (Bosse, 2010).

After Romania became a part of European Union in 2007, the European Union is close to Moldova more than ever and now it is making its steps in Europe's direction - Moldova has signed different trade agreements and it is one of the first post-soviet countries that has opened borders with European Union (Ministry of Foreign Affairs and European Integration of the Republic of Moldova, 2015). The fact that Moldova now borders with European Union is very important for the country, which has been living together with Romania for a long time. Future convergence between Moldova and the European Union provides the possibility of increasing economic integration and relations in all areas (Davies et. al., 2015). There is many visible consequences as for example significantly lower GDP growth in 2006. In spite of this, Moldova's economics has grown in 6 %, the government controls a big part of economy. Economy of the country suffers of a big inflation (WarenTrade, 2009). Average salary was no more than 100 USD in 2007 (National Bank of Moldova, 2008). It is known that approximately 25 % of the population is working abroad (National Bureau of statistics of the Republic of Moldova, 2014). Because of this, the official unemployment is only 5.1 % (National Bureau of Statistics of the Republic of Moldova, 2014).

Table 2 shows the main indicators that affect the country's economy in period between the years 2010 - 2015.

Table 2. Main indicators affecting Moldova's economy

Indicators	2010	2011	2012	2013	2014	2015
Unemployment Rate (%)	7.4	6.7	5.6	5.2	3.8	5.02
Real Growth Rate (%)	7.1	6.8	-0.7	8.9	5.9	4.8
Exports of goods (million USD)	1,541	2,217	2,162	2,399	2,150	1,885
Imports of goods (million USD)	3,855	5,191	5,213	5,493	5,081	4,206
Export Import Coverage Ratio (%)	40.0	42.7	41.5	43.7	42,6	41.1

(Source: Central Bank of the Republic of Moldova, 2015)

It is well seen from Table 2, that since 2010, Moldova's unemployment rate has decreased; it may be affected by developing country's main sector - agriculture. Also there is noticed change in imports of goods, what a positively affects on country's economy. Positive developments were recorded in all sectors of the economy in 2013 (National Bureau of Statistics of the Republic of Moldova, 2013).

2.1.2. Agriculture

The role of agriculture in the national economy is quite large. About 35 % of the working population is employed in agriculture (National Bureau of Statistics of the Republic of Moldova, 2016). The national policy is oriented on developing this sector, which not only provides export growth and economy growth as the result, agricultural development provides new working places and makes unemployment level lower (National Bureau of Statistics of the Republic of Moldova, 2016). Moldova's population is focused now on developing small business all over the country (National Bank of Moldova, 2012). Moldova has a suitable climate for intensive agriculture and for cultivation of subtropical crops as fruits, vegetables, tobacco and vines as well (Chittom LN, 2014). Since past few years, there were noticed product increases, what may be connected to agricultural development. All these increases in agricultural production happened thank to the good weather conditions in 2013 and due to positive changes in agriculture in 2008, agriculture has been on a higher level till that moment. The fact that there is plenty of rain in summer in the country where irrigation systems are not adequate affects the increase in agricultural products positively (Ministry of Agriculture and Food Industry of Moldova, 2013).

Table 3 shows production of the main agricultural products in the last 7 years.

Table 3. Indices of agricultural production (plant production) in the period 2007-2015

previous year = 100 %					
	Cereals and leguminous crops	Sunflower	Sugar beet (industrial)	Vegetables	Potatoes
2007	39	41	52	47	53
2008	351	239	157	170	136
2009	69	76	35	82	96
2010	111	135	248	111	107
2011	103	112	70	106	125
2012	48	69	99.7	64	52
2013	222	170	172	126	132
2014	109	109	134	112	112

(Source: National Bureau of statistics of the Republic of Moldova , 2015)

Moldova's agriculture is mostly dependent on plant production, other sectors such as animal production and services are developed less and take a smaller share of country's agriculture (see Figure 2).

It is well seen from Figure 2 that there is a big difference between the shares of agricultural sectors inside the country, where plant production plays a great role comparing to the other sectors and as Table 3 shows this part of agricultural production is increasing year to year.

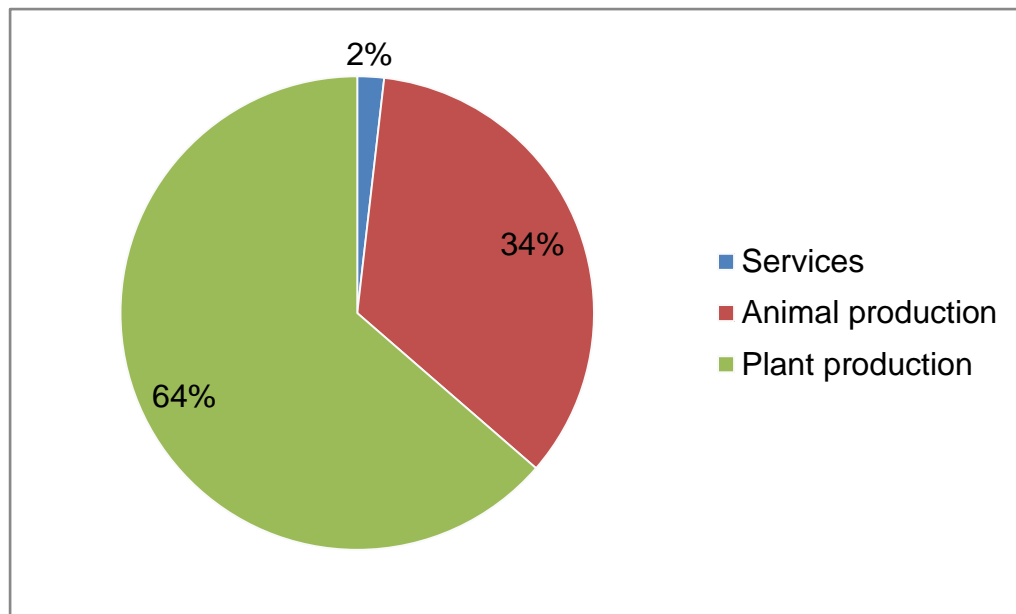


Figure 2. Share of the main sectors of Moldova's agriculture

(Source: National Bureau of Statistics of Republic of Moldova, 2013)

There is ecological problem in Moldova related to agricultural wastes accumulation, what is actually a threat for environment. The biggest part of agricultural wastes creates the plant production wastes, the animal production takes a smaller part, due to smaller quantities. According to official data, agricultural wastes are not only worsening the environment, it damages the farmers' households as the result (Arion et al., 2008). However, agricultural wastes could be used for biofuels production - contributing to energy sector improvement and solving the waste management issue.

2.1.3. Energy

Unfortunately Moldova does not have oil or natural gas, coal or electricity is not produced in necessary quantities to ensure completely population. As the result the biggest part of electrical energy and fuel is being imported to the country. The country is totally energetically dependent, mainly on Russia (Ticu, 2008). Both countries don't fully agree with the prices for oil and gas, because of that Moldova has limits for its export of vine and agricultural products to Russia, which have been set by Russian government and sometimes has to pay double price to import oil and gas (Bullut R, 2015). Economical situation in the country is not too strong to be able to pay double price for anything without any

consequences, but on the other side the country doesn't have any choice, there is no way to stay without this products and because of this the energy problem is very actual in Moldova.

Figure 3 shows the structure of formation of the energy and fuel resources in Moldova.

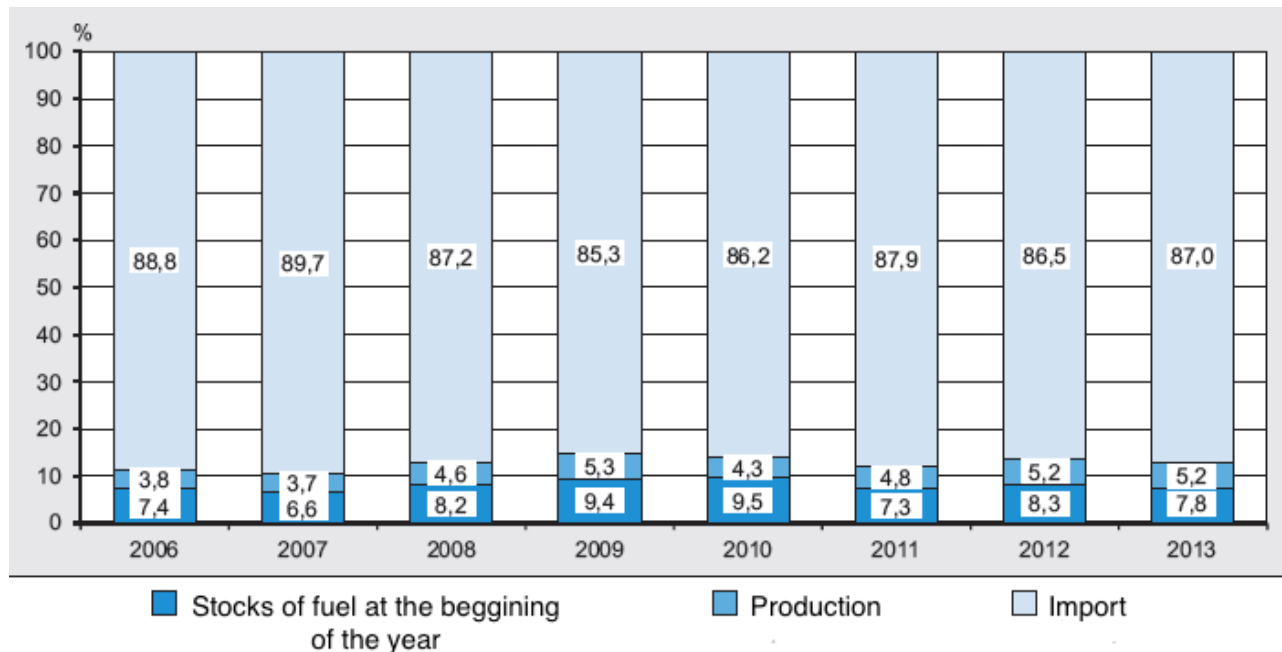


Figure 3. Structure of formation of the energy and fuel resources in Moldova (%)

(Source: National Bureau of statistic of Republic of Moldova, 2014)

As there was noticed - Moldova is very dependent on importing the fuels, and the Figure 3 shows it perfectly, because it is well seen that Moldova imports around 87 % of the energy.

The Moldova's energy independence could start from biofuel's development. As there were noticed in the Figure 2, the biggest part of agriculture takes plant production, what means that there is enough of wastes that could be used as biomass for biofuel's production. The best option for Moldova seems to be production of solid biofuels, because the existing biomass is the most suitable for solid biofuels and it is quite cheap and accessible for the country to develop this type of biofuel. The biomass fuel works on a communal scale, which can be further increased to include larger district heating units and industrial applications, 5 MW and above. Further potential would also arise for high efficiency domestic stoves in the 1-5 KW (World Bank, 2005).

2.2 Background of biomass based solid biofuels and their situation in Moldova

Biomass is organic matter derived from living, or recently living organisms. Biomass can be used as a source of energy and it most often refers to plants or plant-based materials which are not used for food or feed (National Renewable Energy Laboratory, 2014). Biomass is one of the most promising energy sources, as it is an alternative to conventional energy sources such as oil and natural gas (Monteiro et al., 2012). One of its main advantages is that it is a clean and renewable product that contributes to reducing greenhouse gas emissions and dependency on fossil fuels (Daioglou et al., 2016). Local Moldovan research showed that approximately 48 % of natural gas imports could be replaced by the biomass resources. Thus, renewables could enhance Moldova's energy independence (Moldova Energy and Biomass Project, 2011). Given the proper sustainable forest initiatives and agricultural management, biomass is virtually limitless, and has proven to be price stable in comparison with fossil fuels (Pellet Fuels Institute, 2009).

There are 5 basic types of biomass (Biomass Energy Center, 2012):

- Energy crops (the most expensive one)
- Industrial and municipal residues (wastes)
- Agricultural residues (wastes)
- Food wastes

Moldova Energy and Biomass Project (2011) has published that according to analyzed articles and information it was found that nowadays the most developed type of biofuel in Moldova is solid biofuel, especially pellets and briquettes. Use of biomass resources for fuel purposes, which is renewable and clean fuel without polluting emissions, can be the first step on the way of becoming independent on importing a part of raw energy materials (Bailey E, 2014). In this case, this first step could call an economical growth in the country. Biomass can be used in various forms: for burning of loose material or burning of material in a compressed form such as pellets and briquettes (National Renewable Energy Laboratory, 2014). The practice showed that burning the biofuel is more environmental friendly; it has much less emissions than solid fossil fuels (Pellet Fuels Institute, 2009). Up to now, there is good new practice in Moldova for the production of solid biofuels, using the materials as wood, straw, sunflower and its wastes (ProEra Group, 2011).

Available raw materials for producing solid biofuels that can be easily found in Moldova are presented below (ProEra Group, 2011):

- The branches of grapevine
- Sunflowers stalks
- Lucerne
- The branches of fruit trees
- Corn stalks
- Rape straw
- Husk of sunflower
- Wood of different species of trees
- Meadow hay

These materials can not only be used for biofuel production, but they can reduce the fuel prices as well. There were found studies to make the producing process cheaper and final prices lower, by using the agricultural wastes. There is known practice for the production of solid biofuels, especially as pellets and briquettes, using available agricultural wastes, which are normally sold cheaper, and which are easily available to a regular user (Zaharia, 2011).

Prices of solid biofuels in Moldova's market are very different and depend on type of produced biofuel (briquette or pellet), raw material used for production, production technology, energy consumption of equipment and the quality of final product (Moldova Energy and Biomass Project, 2015).

There are more unused wastes in Moldova that could be used as biomass material and final product's price could be even lower, so what can increase the demand (Ministry of Agriculture and Food Industry of Moldova, 2015). Besides reduced prices, the technologies of producing solid biofuels, using the agricultural wastes, which is a clean, cheap and easily available energy from biomass, could solve the current problem of the lack of heat energy. On the other hand, by using people's own wastes and agricultural wastes, which are normally not used at all, appears an opportunity to effectively overcome the environmental problem which consists in the accumulation of large amounts of agricultural waste (Zaharia, 2010).

2.2.1 Pellets

Pellets - biofuel made from compressed organic matter, which is biomass. Pellets can be made from any one of five general categories of biomass: industrial waste and co-products, food waste, agricultural residues (wastes), energy crops and lumber (Petrovic, 2015). Today in general the most popular pellets are wood pellets, as it is the oldest technology it is being used more often, but due to the high price it is not the most suitable type for Moldova (Moldova Energy and Biomass Project, 2011).

Pellets are produced by compressing the wood material (or any other vegetable raw material) which has first passed through a hammer mill to provide homogeneous structure. Normal size of a pellet is 6 mm diameter, sometimes 8 mm or larger. The technology uses high pressure of the pellet mill, which causes the temperature of the wood to increase and the lignin plasticizes it slightly, and works as a natural glue, which later keeps pellets together while it is cooling (Mola-Yudego et. al., 2015).

If there are used agricultural wastes as the raw material for producing the pellets, it is more ecological-friendly way to use the pellets and it will have almost the same amount of energy inside itself (approx. 4 - 4.2 kcal/kg) (Biomass Energy Center, 2015).

Basic pellets standards in EU (UNDP in Moldova, 2015):

- Length = 3.15-40 mm
- Diameter = 6-8 mm
- Fines = ≤ 1 % wt.
- Bulk density = ≥ 600 kg/m³
- Net calorific value = 16.5-19 MJ/kg

Republic of Moldova does not have yet a laboratory in place to test the biofuel quality, although in accordance with Government Resolution No. 1070 dated 27.12.2013, biofuel certification is binding as of January 2015 (UNDP in Moldova, 2015). The solutions to establish the first laboratory that would test the quality of briquettes and pellets manufactured in Moldova is being searched now. The development partners shall provide the necessary support in this regard (UNDP in Moldova, 2015). The manufacturing process starts from the selection of accessible raw material.

Pellets producing process consists of several following steps (Kofman PD,2007):

- Chipping
- Grinding
- Drying
- Pelleting
- Cooling
- Packing

2.2.2 Briquettes

Briquettes - compressed block normally made of coal dust, it's made of different types of biomass as well (agricultural and forestry waste). As a densified product, biomass briquettes benefit from an increased energy density and a convenient shape, typically cylindrical or octagonal. Briquettes made of biomass are becoming popular now as a ecological-friendly solid fuel, that can be used for heating the building or water as well. Burning a briquette is far more efficient than burning firewood. Moisture content of a briquette can be as low as 4%, whereas green firewood may be as high as 65 percent (Bilgin et. al., 2016).

Basic types of material for briquettes producing (Kofman PD, 2007):

- Wood
- Straw
- Paper
- Energy crops
- Agricultural wastes

Comparing to the coal briquettes, biomass briquettes have a lot of positives (Zaharia N, 2011):

- Fewer greenhouse gases
- Producing simplicity
- Availability of the materials
- Higher calorific value
- It emits fewer pollutants
- It cuts down on the release of previously sequestered carbon

- It assists the reduction of fuel wood and deforestation
- There is no sulphur in briquettes
- There is no fly ash when burning briquettes

As well briquettes reduce the costs and problems associated with transport and storage of biomass (Roy, 2012). The energy output of bio briquettes compressed from biomass waste is nearly equivalent to that of common fuel sources when burned in an oxygen-rich environment comparable to unmodified wood and wood pellet stoves, fireplaces, patio heaters and charcoal grills (Eidemiller, 2010).

Briquetting process consists of several following steps (Maninder et. al., 2012):

- Crushing
- Drying
- Densification
- Cooling
- Packing

According to Maninder et. al. (2012) there are four main types of briquetting technologies:

- Piston press densification
- Screw press densification
- Roll press densification
- Low pressure or manual presses

The production technology is almost the same as pellets have. Net calorific value of briquettes is 14-19 MJ/kg. Energy contained in a biomass briquette is dependent on energy content of the used raw material (Biomass Energy Center, 2011).

2.2.3 Support to solid biofuels' production in Moldova

The problem with energy sources is important in the Republic of Moldova, which is highly depended on fuels export from other countries (National Bank of the Republic of Moldova, 2014). The region has enough of materials as biomass from agricultural sector and if it is not used for anything as producing the biofuel (Lakatos et al., 2016). After obtaining the independence Republic of Moldova has started the long way to the European integration. Thanks to European development projects in this country, population has shown the interest to develop biofuel in this region, especially pellets and briquettes

Well known fact that Moldova borders with Romania and European Union is for sure a great opportunity for Moldova to have good interrelationships with EU (Ministry of Foreign Affairs and European Integration of the Republic of Moldova, 2008). As an agricultural country, Moldova's economic is dependent a lot on export and European Union helps in this sector significantly. For example, in 2013 Russia limited Moldova's export; European Union provides another and bigger market. Now Moldova can export goods and agricultural products to EU countries (Ministry of Foreign Affairs and European Integration of the Republic of Moldova, 2011). There a lot of development projects that are now in progress in Moldova such as United Nations Development Program (UNDP), United States Agency for International Development (USAID), Czech Development Agency (CRA), Polish Agency for Enterprise Development (PARP) etc., and there are of course local organizations, that are created to cooperate with all that big projects, using know-how studies and project's financing - such as National Agency of Rural Development (ACSA), National Union of Agricultural Producers Associations in Moldova (UAP) etc. (Ministry of Foreign Affairs and European Integration of the Republic of Moldova, 2016; Czech Development Agency, 2010).

Moldova has a quite good strategy position, between Ukraine, Romania and EU. It makes it easier and importantly cheaper to import all needed products such as materials or technology equipment (Nicholas, 2014). Today technologies of producing the biofuel, especially pellets and briquettes are on a higher level, than it was several years ago. However Moldova had and now still has enough of biomass, it didn't have technologies to use it. Biggest part of technologies are being imported thank to development cooperation projects with well developed countries, mainly EU countries, which provide financing for this projects (Bailey E, 2014). For example - Moldova Energy and Biomass Project (MEBP), this is funded by the European Union and co-funded and implemented by the United Nations Development

Program. The Project total budget amounts for 14.56 million EUR, provided by the European Union (14 million EUR) and UNDP Moldova (0.56 million EUR) (UNDP in Moldova, 2014). The project has finished in 2014 (implementation period was 2011-2014), but there started a new one - Moldova Energy and Biomass Project 2 (implementing period from 2015-2017). The Project 2 budget in amount of 9.41 million EUR, allocated by the EU, and it is implemented by the United Nations Development Program (UNDP in Moldova, 2015).

Above mentioned project organizes trainings and educations in bioenergy field and importantly is that this project provides leasing the biomass processing equipment - activity foresees fostering the development of the private sector market for contractors willing to supply fuels for heating biomass-fired plants installed in public institutions from the rural areas with financial support provided by the Moldova Energy and Biomass Project (MEBP, 2014). The straw gathering and baling equipment along with the briquetting presses is offered for sale by instalment without any interest. This method would enable sustainable development of the fuel cycle with no need to provide grants to fuel supply enterprises from the private sector (MEBP, 2014).

Trainings provide studies and information in the following areas (MEBP, 2014):

- The normative and institutional framework in the areas of power and energy efficiency applicable in the Republic of Moldova
- Possibilities to produce biomass-based heat
- Assessment of biomass local potential and the methods of its employment
- Parameters of the main types of existing biomass-fired boilers

It is not the whole list of the provided areas of study that is just several examples. The assistance is provided for private sector and public sector as well. It is a well-known fact that there are schools in Moldova where is not available many the utilities even such as hot water or complete heating system. So MEBP provides support to public institutions from rural communities to have access to renewable energy sources and ensure energy independence. With the help of the financial support, modern biomass-fired heating systems have been installed by 2014 in more than 130 rural schools and kindergartens (Zaharia, 2012).

The Energy and Biomass Project covers the majority of costs related to the installation of alternative heating systems, while the villages are expected to contribute with at least 15 % of total investment value (MEBP, 2011). To this end, a three-year contract could be devised stating 40 % down-payment and 30 % payment for each of the next two years. By cooperating with different projects and different countries, the technologies and equipment are being imported into the region for better prices, comparing to buying it out of project (Chiriac, 2012).

3. Objectives

The aim is to describe an energy situation and potential of agricultural biomass as biofuel source in the Republic of Moldova with the special focus on evaluation of possibilities and current state of local briquettes' and pellets' producers.

The specific objectives of the present Thesis were:

- to define the most popular form of solid biofuel produced in Moldova,
- to analyze selection of raw materials used for briquettes and pellets production,
- to evaluate prices of produced solid biofuels,
- to analyze production technology from viewpoint of its origin.

4. Methodology

Methodology of this thesis is based on the literature review writing and processing of direct information gained from the existing companies (pellets or briquettes producers) in the Republic of Moldova.

4.1. Methodology of literature review

Literature review is elaborated on the basis of scientific references from international databases like ScienceDirect, Scopus, Web of Knowledge, EBSCO as well as governmental statistics of Moldova. For searching information sources the main following key words were used: Moldova, agricultural wastes, plant production, solid biofuels, pellets, briquettes.

4.2. Methodology of practical part

Methodology of practical part is based on collection and analysis of research data obtained in Moldova and their processing.

4.2.1. Data collection method

In summer 2015, there was contacted Moldova Energy and Biomass Project, which has provided contacts (name of the company, e-mail, phone) to all 84 companies existing in Moldova, which produce and sell the pellets and briquettes.

Using the questionnaire method, the companies were contacted by e-mail and kindly asked to spend their time and fill the document, which contained totally seven questions (opened and closed). The questions were focused to the several aspects such as: type of produced solid biofuel, location and productivity of company, average prices of final product, used raw material for biofuels production and country origin of equipment. The questionnaire was prepared and distributed in Romanian language (English equivalent please see in Annex). The questionnaire survey took place from September 2015 till December 2015. Several companies were additionally contacted and interviewed by phone. There was gained the most accurate data about 74 companies.

4.2.2. Data processing

The gained data has been summarized and processed in Microsoft Excel, and presented in form of diagrams and graphs. Using simple recalculation, the numbers were transformed in percent, to better display the situation.

5. Results and discussions

5.1. Location of solid biofuels' producers

There are totally 84 companies in Moldova that are producing solid biofuels and selling final products. The biggest part of them is located in Central region - 43 companies. There are 23 companies in Northern region and only 18 companies in the Southern region.

Figure 4 below shows location of biofuels' producers – share of producing companies in three regions of Moldova. For better illustration the map of Moldova divided into regions is presented as well.

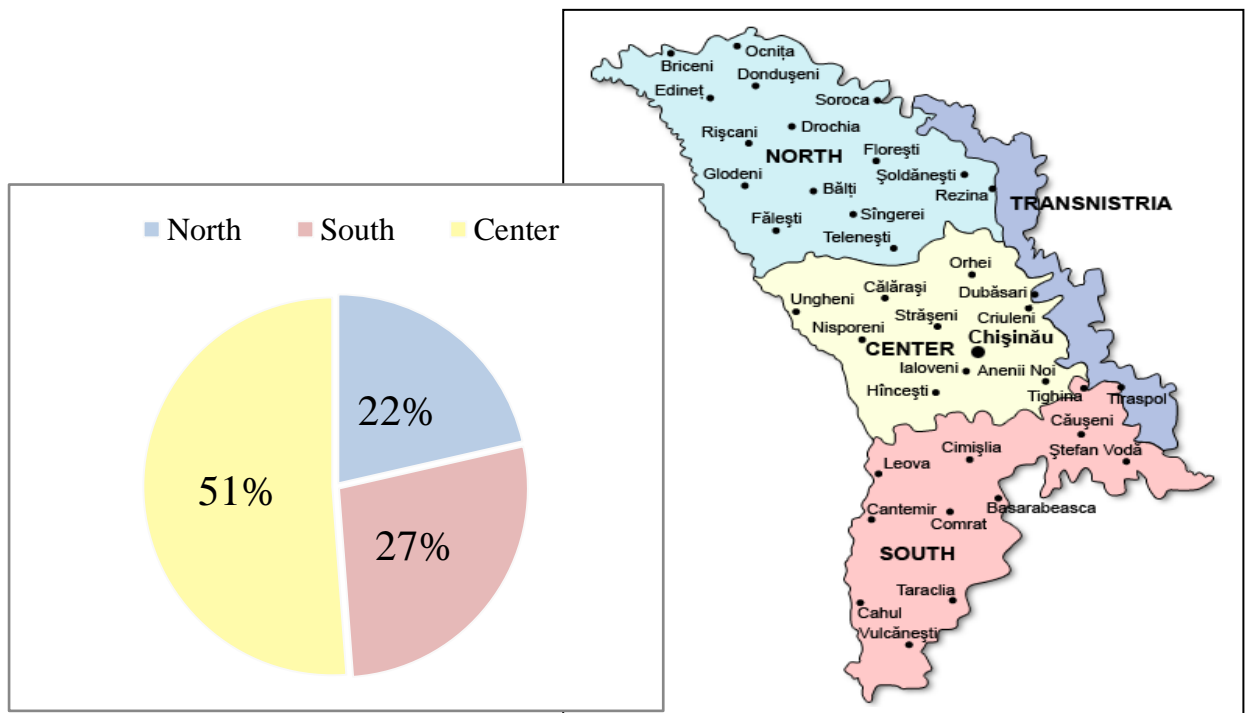


Figure 4. Location of biofuels' producers in different regions of Moldova, including map of Moldova

Distribution of biofuels' producers within the regions - Central, Southern and Northern is unequal. From Figure 4 is visible that the biggest part of companies is located in the Center region. It may be explained by good business strategy location closer to the capital city, where the demand of fuels is greater comparing to the other regions and there are more boiler houses as well as better market possibilities.

5.2. Type of produced solid biofuel and quantities

From 74 analyzed companies – producers of solid biofuels’ in Moldova, which provided required information for this research, 42 companies are producing only briquettes, 28 companies are producing only pellets and 4 companies produce both products.

The productivity – quantities of produced briquettes and pellets vary between producers. The survey showed that productivity of briquettes’ producers is from 68 kg/hour up to 2,000 kg/hour; productivity of pellets’ producers is from 100 kg/hour to 8,000 kg/hour.

Despite the bigger number of briquettes’ producers and due to the higher productivity of companies producing pellets, the total production of each product was found as:

- Pellets – 157,462 tons per year
- Briquettes – 149,395 tons per year

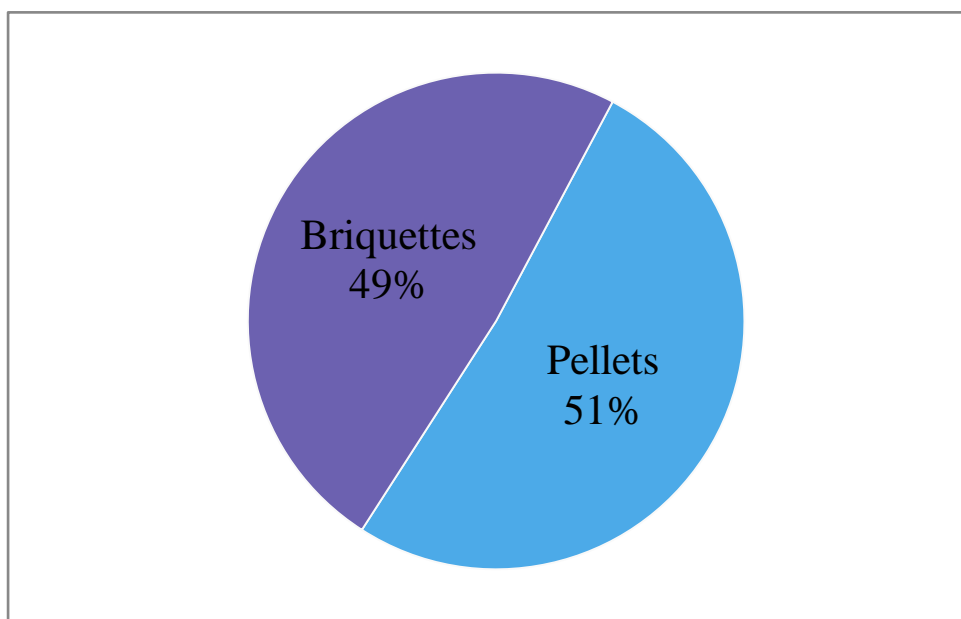


Figure 5. Share of produced briquettes and pellets in Moldova

Figure 5 shows that Moldovan companies produce almost the same amount of briquettes as pellets, with 2% larger pellets’ production.

According National Bureau of statistics of the Republic of Moldova, 2015, the main energy consumer in Moldova is the private sector – population. Today 44 % of total population lives in the cities. The apartment houses are usually warmed by central communal heating system and private houses are warmed by boilers – heating systems, which use gas

and solid fuel as well. By Market study, which passed in 2012, more than a half of total population (56 %) lives in the countryside, where the most popular way to warm the house is the stove for solid fuel. According to this fact, it could be concluded that briquettes are being mainly popular in the countryside, where they can be used in the heating systems with classic burning process.

Pellets are used mostly in the boiler houses (is cultural social organizations like schools, kindergartens, city halls), which were installed in the framework of Energy and Biomass project. Totally, there were installed 130 heating systems with total power of 36 MWh (Moldova Energy and Biomass Project, 2014). According to National Bureau of statistics of the Republic of Moldova, use of pellet boilers in private households is not common and not popular in Moldova. The reason is the high price of this type of equipment and lack of knowledge about its working principle. The main private consumers of pellet based heating systems are located in the biggest cities (Chishinau, Balti)

The above mentioned confirms that the production of briquettes and pellets is mainly affected by demand or purpose of utilization.

The situation in EU countries is different from Moldova, where the share of both types of solid biofuels is similar.

In EU countries starting from the year 2000, pellet's production is being growing very rapidly – approx. by 1 million tons each year. According to the data of European Biomass Association (2014), the production of pellets in EU was 12 million tons in 2013. The pellet's consumption growth is primarily related to the promotion focused to substitution of traditional types of fuel by renewable energy sources in EU governmental level. Moreover, solid fuel in form of pellets is easier in usage for consumer especially at the automatic heating systems (boilers with the automatic fuel supply), comparing to other types of fuel, for instance to briquettes.

The distribution of pellet (especially wood pellets) production and its quantities within European countries is presented in the Figure 6. Results of the present research showed that production of pellets in Moldova is very low comparing to most of EU countries. This field is new in the country, but rapidly developing, for instance according to MEBP (2011) in the year 2010 it was only 18 producers of solid biofuels in Moldova, and now there are 84 companies.

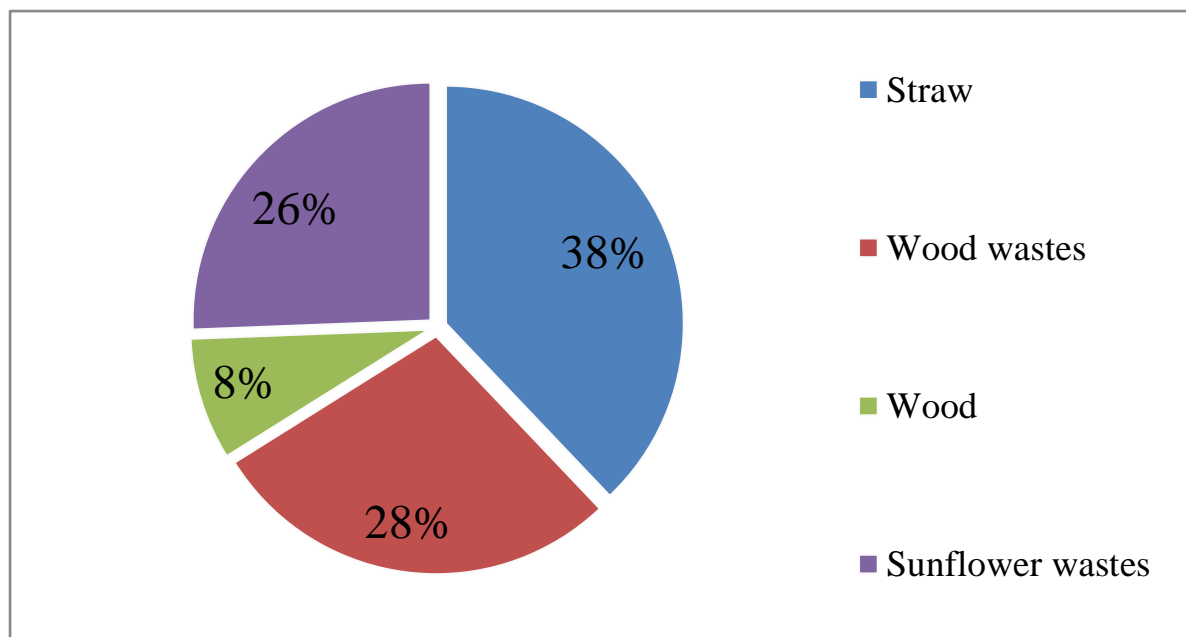


Figure 7. Total use of raw material for solid biofuels' production – briquettes and pellets

Figure 7 shows that straw is the most popular and the most common material for solid biofuels production in Moldova.

According to Moldova Energy and Biomass Projects, 2012, the greatest biomass source in Moldova is agriculture – plants production and its wastes. Each year there are available approximately 2 mil. tons of agricultural biomass.

From Figure 7 follows that primary wood presents only 8 % in the total share of materials, which is different from European countries, where wood biomass is the most required. This fact can be explained by very small amount of trees and forests in Moldova. According to National Bureau of Statistics of the Republic of Moldova (2015), the total area of forest plantations in the region is no more than 450 thousand hectares, what is only 13 % of total country area. The forest density is no more than 10 thousand trees per square km (The Washington Post, 2015). Counting the fact that the forest area is relatively small, it is strictly controlled by the government and it is quite difficult to have an access to this resource. It is only allowed selection cutting of trees of sanitary cutting as a forest maintenance step. There is maximum 335 thousand cubic meters of wood biomass available each year (MEBP, 2012).

The Figure 8 confirms the fact that Moldova belongs to one of the European countries with the smallest number of trees per territory.

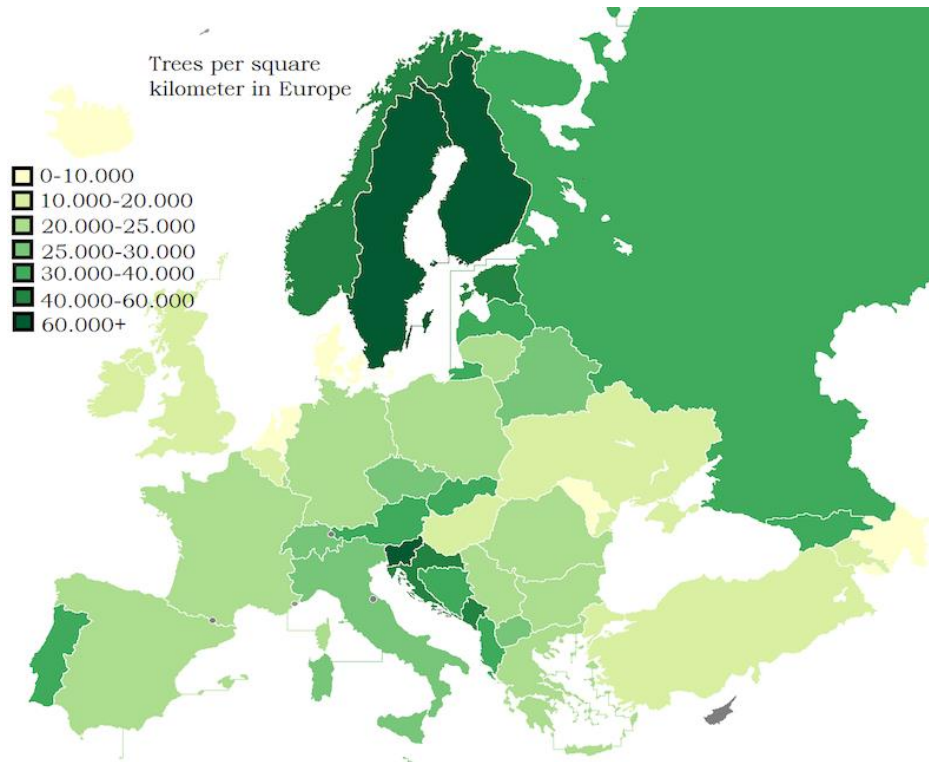


Figure 8. Trees’ density per square km in Europe

(Source: The Washington Post, 2015)

Wood for the industrial use is mainly imported from other countries. Other source of wood biomass is wood wastes generated from the wood processing, but the quantities are not significant at all. Mostly available wood biomass source is the waste of fruit trees and vineyards – approximately 59,000 tons per year and 104,000 tons per year (MEBP, 2012).

According to study of MEBP (2014) one more fact, which confirms that primary wood cannot be reasonably used for solid fuels production, is that the energy potential of wood in Moldova is very low (see Table 4) comparing to the total potential of all biomass generated in the country yearly (Table 5).

Table 4. Energy potential that can be obtained from biomass of forestry and wood wastes in Moldova, (TJ)

North	Center	South
114.97	280.46	88.11

(Source: MEBP, 2014)

Table 5. Total biomass potential in the whole country and in different region, TJ

North	Center	South	Total
10,637.63	3,744.76	6,537.60	21,042.06

(Source: MEBP, 2014)

In the Table 4 and 5 there is also presented the wood and total biomass potential in different regions of the country. The interesting fact is that the total potential of biomass in the North and South regions is several times bigger than in the Center, where the main number of producers is located. It can be concluded that these two regions have big production potential, which is not used up to now and their future development can be expected.

Total potential obtained from all biomass resources (21,042 TJ) can cover 22 % from the total energy consumption of the country, which is 92,544 TJ (MEBP, 2014).

Next graphs (Figure 9 and 10) present usage of raw materials for briquettes and pellets production, separately.

From Figure 9 is visible that the most popular type of material for briquette production is staw from cerials. More than half of all briquettes are produced from this material.

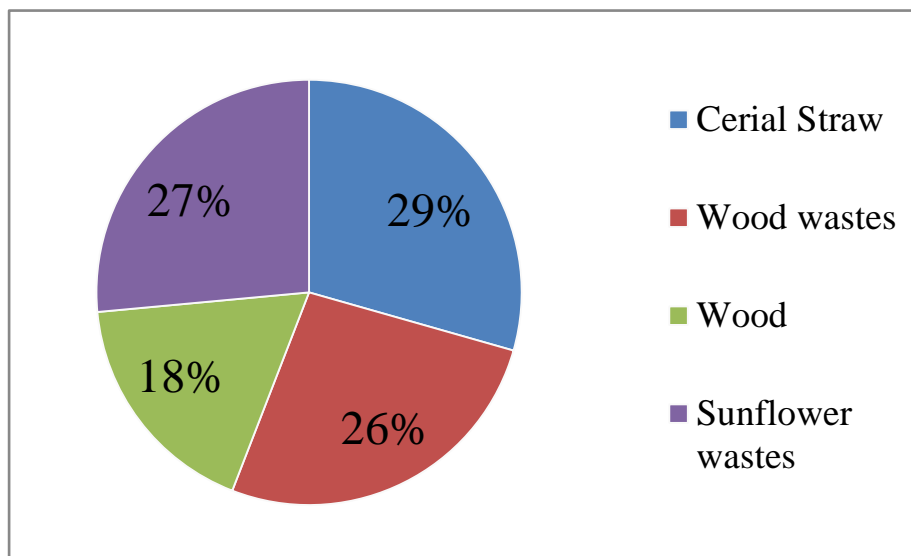


Figure 8. Used raw material for briquettes production

In comparison with briquettes, the materials for pellets production like cereal straw, sunflower wastes and wood wastes are used almost in the same quantities (see Figure 9).

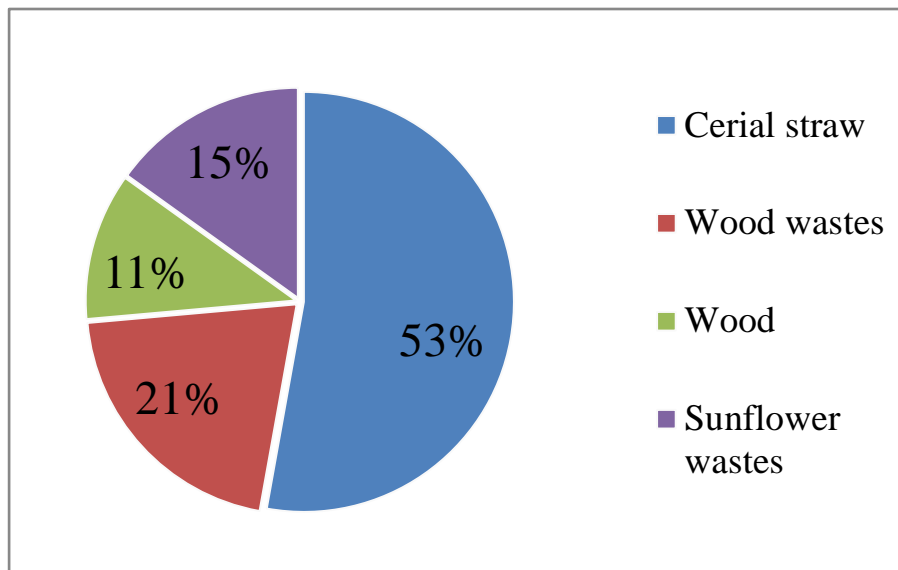


Figure 9. Used raw material for pellets production

All the mentioned facts and the results of this research makes wood as non – attractive for solid biofuels’ production in Moldova especially comparing to agriculture’s wastes.

5.4 Prices of solid biofuels

Figure 9 and Figure 10 show the prices of briquettes and pellets, respectively, according to the raw materials used for production.

Figures 9 and 10 presents that the prices of pellets are in general higher then prices of briquettes and the most expensive in the market are pellets and briquettes made of wood that could be explained by above described fact as lack of wood in the country.

Wood, which is commonly used in Europe, is not such a good option for Moldova, where consumers are looking for cheapest product for heating systems. According to (Market Study, 2012) the cost of one cubic meter of firewood varies between 550 – 650 MDL (approximately 24-29 EUR), as the result the final product’s costs are high as well.



Figure 9. Compression of prices for briquettes from different biomass materials, MDL per ton

As was expected, the cheapest way to produce briquettes as well as pellets is to use agricultural wastes such as cereal straw and sunflower's wastes.

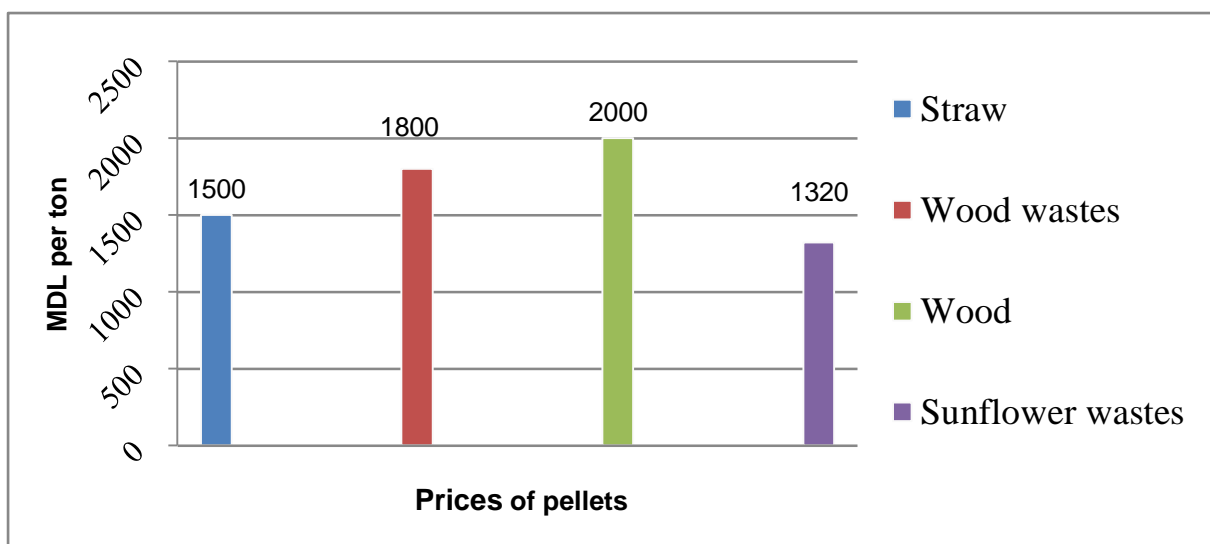


Figure 10. Compression of prices for pellets from different biomass materials, MDL per ton

On the example of a normal family house - approximately 100-200 square meters , there were compared average costs per warming season, what is approx. 192 days, between using pellets, briquettes, gas and electricity used in heating systems (see Table 6). To compare the costs, there were used the average prices for each energy source:

- Briquettes - 1200 lei per ton
- Pellets - 1500 lei per ton
- Gas - 6.55 lei per cubic meter (Union Fenosa, 2016)
- Electricity - 2.58 lei per kW per hour (Union Fenosa, 2016)

Table 6. Compression of prices by using different energy sources during the warming season

	Material	Quantity	Price Lei/season	Price euro/season
Pellets	Straw	7,6 t/season	9 120	414
Briquettes	Straw	7,8 t/season	11 700	532
Gas	-	3 594 m ³	23 540	1 070
Electricity	-	25,906 kW/hour	66 837	3 038

(Source: own calculation according to the data of Union Fenosa, 2016)

5.5 Origin of production technology

Today, there are different types of equipment used for briquettes and pellets production, which have different productivity, electricity consumption and produce the fuel in different forms.

The choice of the equipment for briquettes and pellets production may be related to the factors such as type and form of the used raw material, amount of the raw material, form and quality of the final product (MEBP, 2012)

The main factor for choose of the equipment is the price. By analyzing the available equipment in the region, there was found out that the biggest part of the equipment is being imported from EU and CIS.

The equipment produced in EU is much more efficient in production, more reliable and allowing to produce final product with a higher quality. The share of the equipment from EU

countries used by the national producers of solid biofuels is only 34 %. The main disadvantage of this equipment is high price (MEBP, 2012)

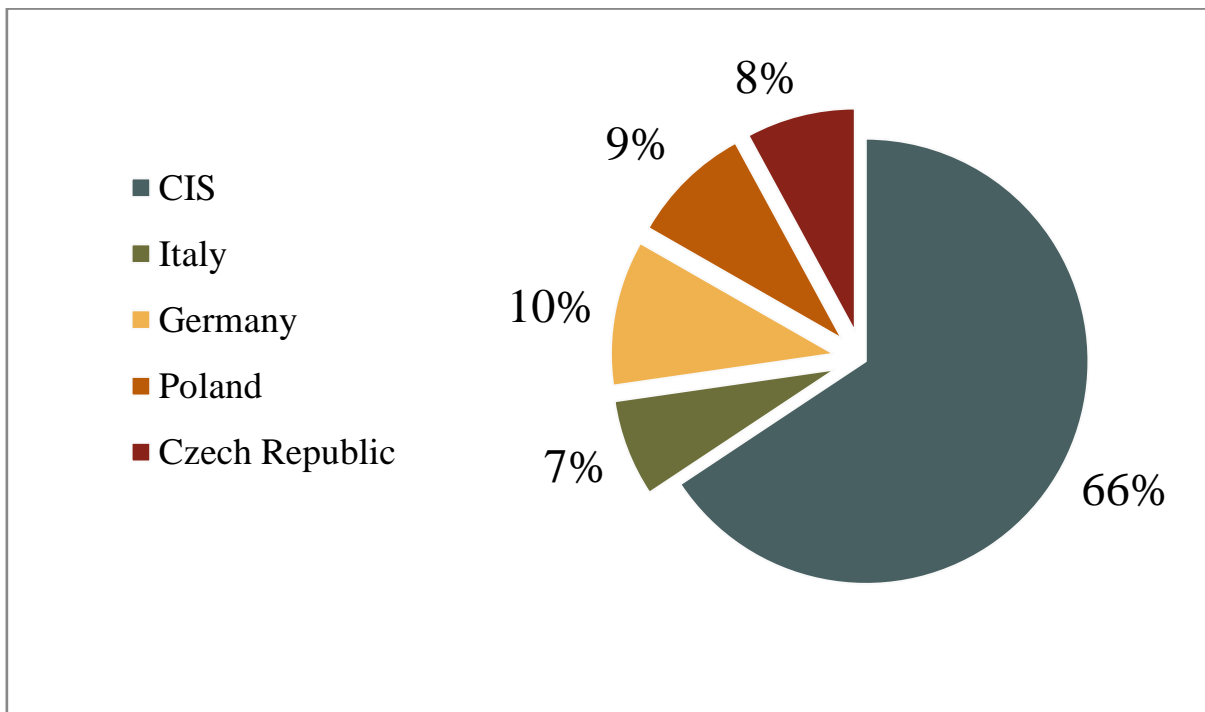


Figure 11. The countries, from which Moldova imports equipment mostly (%).

The most popular equipment used by the producers of solid biofuels is imported from CIS countries. The results of the present research show that the share of this equipment is 66 % (Figure 11). According to Moldova Energy and Biomass project, 2012, due to many parameters this equipment is much more inferior to analogical equipment from EU countries, but has one incontestable advantage – lower price, that finally influent the popularity between producers of briquettes and pellets.

6. Conclusions

The main objective of present thesis was to find out the potential, the actuality of developing the biofuel sector in Republic of Moldova and to study the current situation in the region. According to the analyzed data there was found out that the region and its population is interested in developing this sector, what increases the demand and the actuality itself. The research showed that the energy problem is of current interest in Moldova today, due to high import of energy sources dependence, along with increasing prices on gas and electricity on the other hand. After analyzing the gained data, referring to the current potential of biomass for each separate region, at national level, there was found out that approximately 22% of total needs of energy resources can be covered by biomass and it could call the economic boost and first steps to energetically independence, what will create the energy insurance in Moldova. According to the found data, the solid biofuels' production seems to be good solution for the problems, which are connected not only to the energy independence, such as proper agricultural wastes utilization, due to the fact, that Moldova's waste management is not almost developed and from this point of view, the biofuel technology makes it almost unnecessary, because the wastes can be utilized usefully and moreover ecology friendly, what can solve some environment problems in Moldova. Today the distribution of producers in each region can provide full information with regard to possibilities of using alternative energy sources, especially biomass to produce energy in a comfortable way, what increases the demand as the result.

The practical part of the present thesis, showed current situation in Moldova. There were found a lot of existing producing and selling companies today, which have different location and are reachable all over the republic. By analyzing the gained data, there was found out that there is almost the same quantity of the briquettes and pellets on the market. Comparing to the situation in the European countries, the briquettes take a relatively big part of the Moldavian market, when in Europe briquettes take only approximately no more than 10 %. There were found out the current prices on briquettes and pellets, which are different, due to the type of product and used raw materials for its production. The solid biofuels' costs have been compared to the costs, which are normally paid for warming season using the traditional heating methods, what provided the picture of the solid biofuels' benefits, such as price, what is very important for the consumers in Moldova. From this point of view, briquetting, pelleting and the improvement of combustion technologies would allow cutting expenses for household heating.

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ANNEX

Example of questionnaire



Hello, my name is Valeri Moscovciuc, I am a 3rd year student in Czech University of LifeSciences and I would like to kindly ask you for 5 minutes of your time, to answer a small questionnaire, which would help a lot, with my Bachelor Thesis – Potential of producing and using biofuel in the Republic of Moldova. Thank you, your time and help is highly appreciated!

1) Name of the company -

.....

2) The location of the company, regional center -

.....

3) Choose the type of solid biofuel, you are producing:

Briquettes Pellets Both

4) Please, write your productivity of briquettes/pellets (tons per hour or kg per hour)

.....

5) Choose the applied raw material:

Cereal straw Wood Wood wastes Sunflower wastes

Other please specify.....

6) Please write down the price, you are selling your briquettes/pellets according to material:

.....

7) Please name country origin of your producing equipment:

.....