CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

Department of Sustainable Technologies

Energy use of vineyard waste biomass – Potential for the Republic of Moldova

Master thesis

PRAGUE 2015

Supervisor:

Ing. Tatiana Ivanova, Ph.D.

Consultant:

Ing. Michel Kolaříková

Author:

Tomáš Vacek

Declaration

I declare that the presented diploma thesis entitled “Energy use of vineyard waste biomass - Potential for the Republic of Moldova” was prepared separately with use of the referred literature. I agree with the storage of this work in the library of CULS in Prague and making it available for further study purposes.

....

Date Signature

Acknowledgements

I would like to thank everyone who helped me in preparation of this thesis. My special thanks belong to my supervisor Ing. Tatiana Ivanova, Ph.D. for her guidance, consultations, patience and valuable and helpful suggestions, my aunt Ing. Radka Košťáková for grammar correction, Alexandru Muntean, MSc. and Andrej Gudîma, MSc. both from State Agrarian University of Moldova (SAUM) for their extraordinary help and assistance in laboratory in Moldova and also for their kindness and friendliness, Assoc. prof. Gheorghe Nicolaescu and Cornelia Lungu, MSc. also from SAUM for provision of material, Vasilii Alexeev for help with drying of the material, The National Agency for Rural Development of Moldova (ACSA) for provision of necessary data, Ing. Alexander Kandakov, Ph.D. and Andrej Gheorgitha, MSc. for help and advice during my stay in Moldova, Ing. Michel Kolaříková for assistance with energy balance calculation, prof. Ing. Milan Brožek, CSc. for help with mechanical durability test and of course my friend Bc. Ondřej Novotný for his critical suggestions and advices. I would also like to thank my family for their support and patience.

The present research was supported by Internal Grant Agency of the Faculty of Tropical AgriSciences, CULS – research grant number 20145029 „Energy use of biomass“, which covers travel costs to Moldova.

ABSTRACT

The Republic of Moldova is facing a difficult situation in both economy and energy sector. The later one is caused by negligible fossil fuel deposits or reserves and major share of energy import which leave the country dependant in such matter. On the other hand, Moldovan fertile soils together with favourable climate results in good conditions for growing various agricultural crops including vine Moreover, the area of 137 thousands hectares of Moldovan vineyards each year produces a considerable amount of pruning residues with no efficient utilization so far. The yield of such waste from four examined vine varieties (Chardonnay, Cabernet Sauvignon, Malbec and Merlot) from experimental plantation in the Anenii Noi district in Moldova was calculated within range 2.06 $t.ha^{-1}$ and 2.47 $t.ha^{-1}$ of dry matter material. In order to analyse the quality of the residual material and final briquettes the main parameters such as gross and net calorific values, moisture content, ash content and mechanical durability were measured according to European standards. Based on the ANOVA analysis it was found that the values of measured parameters such as e.g. net calorific value varied among the tested vine varieties which was not considered in previous studies. Generally, the research results show that the tested biomass has a very good properties concerting energy utilization. The main aim, the evaluation of the energy potential of vine residues for Moldova, was fulfilled by the analysis of the overall energy potential of the crop and calculation of its energy balance. Considering the vast areas cultivated with vine and more specifically with European vine varieties among which those four examined varieties belong, the highest energy potential was estimated for Chardonnay (1,554.8 $TJ.year^{-1}$) just from the area of 34,421 hectares. Such potential, if all material would be efficiently utilized for energy purpose, could cover 1.6% share of Moldovan energy consumption. The energy balance for waste material was not so far calculated in previous studies, but the results of this Thesis for vineyard residues proved to be very positive based on the energy efficiency expressed by the EROEI indicator which reached 20.18 which is very high even in comparison with energy crops deliberately cultivated for energy purposed.

Key words: vineyard pruning waste, solid biofuels, Moldova, energy potential, energy balance

ABSTRAKT

Moldavská republika se v současnosti nachází v problematické situaci jak v ekonomickém tak v energetickém sektoru. Později zmíněné je zapříčiněno zanedbatelnými zásobami a rezervami fosilních paliv a převážným podílem importu energie, což je důvodem moldavské závislosti energetického sektoru. Na druhou stranu Moldavské velmi úrodné půdy společně s příznivým klimatem ústí v dobré podmínky pro pěstování různých zemědělských plodin včetně vinné révy. 137 tisíc hektarů moldavských vinic navíc každý rok produkuje značné množství odřezků, bez dosud jakéhokoliv efektivního využití. Výnos takového odpadu u čtyř zkoumaných vinných odrůd (Chardonnay, Cabernet Sauvignon, Malbec and Merlot), pěstovaných na experimentální plantáži v Moldavském region Anenii Noi byl vypočítán mezi 2,06 t.ha^{-1} and 2,47 t.ha^{-1} suchého materiálu. Za účelem analýzy kvalitativních vlastností odpadního materiálu a vyrobených z něho briket, základní parametry jako jsou výhřevnost, spalné teplo, obsah vody, obsah popela a mechanická odolnost byly stanoveny dle Evropských norem. Na základě ANOVA analýzy bylo zjištěno, že hodnoty měřených parametrů, jako například výhřevnost, se liší mezi testovanými vinnými odrůdami, s čímž v předešlých studiích nebylo počítáno. Celkově, výsledky měření prokázaly, že kvalita odřezků je z energetického hlediska na velmi dobré úrovni. Hlavní cíl, zhodnocení energetického potenciálu odpadu z vinic pro Moldavsko, byl dosažen analýzou celkového energetického potenciálu plodiny a kalkulaci její energetické bilance. Bereme-li v úvahu rozsáhlá území, na kterých je vinná réva pěstována, konkrétněji evropské vinné odrůdy, mezi které všechny zkoumané odrůdy patří, nejvyšší energetický potenciál byl vypočítán pro Chardonnay (1 554,8 TJ.rok^{-1}) a to jen z výměry 34 421 hektarů. Takový potenciál, za předpokladu, že všechen materiál bude efektivně využit na energetické účely, by mohl pokrýt 1,6% celkové spotřeby energie v Moldavsku. Energetická bilance neboli energetická efektivita odpadní biomasy z vinic vyjádřená EROEI indikátorem, která zatím v předešlých studiích nebyla stanovená, vyšla v rámci této práce jako velmi pozitivní a dosáhla hodnoty 20,18, což je v porovnání mnohem větší číslo než u energetických plodin záměrně pěstovaných pro energetické využití.

Klíčová slova: odpad z prořezávání vinic, tuhá biopaliva, Moldavsko, energetický potenciál, energetická bilance

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACSA	The National Agency for Rural development of Moldova
AIE	Alliance for European Integration
BEY	Biomass Energy Yield
CIS	Commonwealth of Independent States
CULS	Czech University of Life Sciences in Prague
CV	Calorific Value
DM	Dry Matter
DU	Mechanical Durability
EAP	Eastern Partnership
EIU	Economist Intelligence Unit
ENP	European Neighbourhood Policy
EP	Energy Potential
EQF	Equivalent litre Fuel
EROEI	Energy Return on Energy Invested
FAO	Food and Agriculture Organisation
GCV	Gross Calorific Value
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GNI	Gross National Income
GUAM	Georgia Ukraine Azerbaijan Moldova community
HDI	Human Development Index
HSD	Honest Significant Difference
ILO	International Labour Organization
IMF	International Monetary Fund
ktoe	Thousand tonnes of oil equivalent
MC	Moisture Content
NCV	Net Calorific Value
NRDC	Natural Resources Defence Council
OSCE	Organisation for Security and Cooperation in Europe
PCA	Partnership and Cooperation Agreement
PCRM	Party of Communists of the Republic of Moldova
RES	Renewable Energy Sources
SAUM	State Agrarian University of Moldova
TCM	Thousand Cubic Metre
UN	United Nations
UNDP	United Nations Development Programme
USA	United States of America
USSR	The Union of Soviet Socialist Republics
WTO	World Trade Organisation

I. INTRODUCTION

The Republic of Moldova is one of the poorest European countries (World Bank, 2014). The reasons for such unfavourable conditions are many, history as a member of the Soviet Union and its negative effects on structure of the economy, widespread migration, widespread corruption or low mineral resources (coal, petroleum and gas). The last issue is very much connected to energy sector and the whole energy situation in Moldova, leaving the country dependent on energy imports mainly from the countries from the former Soviet Union (Karakosta et al., 2011). The other sources of energy such as hydro, wind or solar have, from various reasons, only minor roles on the whole structure of Moldovan energy sector, which then results in low energy security. However, the potential of biomass energy is high due to Moldovan fertile soils and favourable climate (Gorton, 2001).

The Republic of Moldova is well known for its wine production. Even though the vineyards and their harvested area are on decrease since the country became independent in 1991 it is still one of the Moldovan most important commodities for export (FAOSTAT, 2014). Vine is not only a source of grapes but also a source of woody biomass residues in form of twigs of small diameters. Moreover, the pruning operation needs to be carried out every year and the yield of vineyard residues, depending on several variables, varies between 1 $t.ha^{-1}$ and 5 $t.ha^{-1}$ of woody biomass (Velázquez-Martí et al., 2011). Vineyard residues may be therefore considered as a perfect source of energy which could lead to higher energy security of the Republic of Moldova.

However, for further effective utilization of such waste material some necessary treatment must be provided. The most suitable conversion of vineyard residues is for solid biofuels, namely briquettes. The most important properties which affect the quality and efficiency of all solid fuels are calorific values (gross and net), moisture content, density and mechanical durability. The other factors which are also crucial in solid biofuels assessment are ash content or possible pollutants contained in the material in form of heavy metals (Obernberger et al., 2006). Analysis of above mentioned properties of solid biofuels produced from vineyard waste including estimation of the biomass yield and calculation of energy balance will lead to overall evaluation of such fuel, its suitability and sustainability, potential feasibility and if necessary some improvements.

II. LITERATURE REVIEW

2.1. Moldova country review

2.1.1. General information about the Republic of Moldova

The Republic of Moldova is a country in the south-east part of the Europe. It is a landlocked country and borders only with two states: with Romania on the west, which is also the border with the European Union and with Ukraine on the north, east and south. Although Moldova does not have the mountains is certainly not flat but relatively profiled. The climate of Moldova is moderate further north with continental character (Encyclopaedia Britannica, 2014). Moldovan territory extends on 33,843.5 km^2 and the capital city is Chisinau, which is also the biggest city (The official website of the Republic of Moldova, 2014). However, during its short history, the Republic of Moldova had already experienced and still experiences some separatist tendencies. Those tendencies were in Trans-Dniester separatist region, which lies in south-east part of Moldova along the border with Ukraine and in the Autonomous Territorial unit of Gagauzia, whose enclaves are situated in south corner of the country. Ethnic groups of Gagauz Khalky were accepted as autonomous and they are also nowadays without any major conflicts. The Trans-Dniester region went through several very edgy periods when the situation was not far from major conflict with central Moldovan government or even civil war (Zabarah, 2012). In these days the situation around Trans-Dniester region is still rather unclear and unsolved and there is still widespread criminality even when the European Union gives a huge emphasis on solving that state (The EU/Moldova Action Plan, 2005).

The situation around the current number of inhabitants living in Moldova is also complicated. This tangled situation is due to the high rate of Moldovan emigrants which is oscillating around the 25% and most of them work in the EU member states or the lower numbers work in Russia as a cheap labour force not seldom as illegal workers (EAP Community, 2014). The authorities of the Trans-Dniester region also do not bring any clear data so the total number of inhabitants living in Moldova is even more biased. Both those factors cause that there are differences in final number between local authorities and international organisations. The estimation of Moldovan population for year 2012 is 3,918,000 (Encyclopaedia Britannica, 2014).

The majority comprise of Moldovans (78.2%) which allegiance to common history of Moldovans and Romanians from the times when those two nations were very close within boundaries of historical area of Bessarabia (Turcescu and Stan, 2003). Other significant ethnic groups are Ukrainians (8.4%), Russians (5.8%), Gagauzes (4.4%), Bulgarians (1.9%) and others (1.3%) (Crowther and Matonyte, 2007). Ukrainians and Russians are both mainly located in Trans-Dniester region (Roper, 2005). The Republic of Moldova is also a country where the religion has strong background and is firmly rooted. The majority of Moldovans belongs to the Eastern Orthodox Christianity (98%) which is very much in accordance with surrounding countries. Apart from that there is also a small share of people who belong to Jewish religion (1.5%) (Turcescu and Stan, 2003). In the field of religion there was a breakthrough in recent years as the Ministry of Justice registered the first Islamic organization in the history of Moldova, the Islamic League of the Republic of Moldova (ENP, 2012).

The history of the Republic of Moldova as it is known today is not very long and began in the 14th century (The official website of the Republic of Moldova, 2014). In 15th century the principality of Moldova flourished under the rule of the voievod Stephen the Great (Stefan cel Mare) who is the patron of current Moldovans. But that was for long time the last century of peace and prosperity for the territory of Moldova as it is known nowadays. The upcoming centuries were characterised by clash of the two main regional powers, the Ottoman Empire on one side and Russia on the other which fought for that territory known as Bessarabia. That turbulent era did not end sooner before the end of the First World War when the territory of Moldova formed the union with Romania. But that union also did not last long and in 1939, at the dawn of the Second World War, the territory of present Moldova was annexed to USSR on the basis of the Molotov-Ribbentrop pact (Matsuzato, 2010). That era lasted more than 50 years and the Moldovan Soviet Socialist Republic was used mainly for agriculture purposes and served as some kind of front garden for the rest of the Soviet Union supplying it mainly with vine and vegetables (Czech development cooperation, 2009). However, the Republic of Moldova became independent on 27th August 1991 and from that moment it tries more or less successfully to reintegrate itself within the European structures. On 27th June 2014 Moldova made a huge step forward in that direction when signed Association agreement with EU (The official website of the Republic of Moldova, 2014).

2.1.2. Political system and Democracy

Although the Republic of Moldova became independent the influence of a Party of Communists of the Republic of Moldova (PCRM) remained strong and even nowadays it still has most seats in Moldovan parliament. However, after two recent elections which were held only in two years after one another, due to lack of majority needed for the election of the Head of the State, coalition of four anti-Communist parties called Alliance for European Integration (AIE) was established (Cantir, 2011). There is also a bit of confusion whether Moldova is parliamentary or presidential republic. Moldova tries to act as a parliamentary but in fact inclines more to presidential type of government which was expressed by the double elections mentioned earlier (Senyuva, 2010). The current president of the Republic of Moldova is Nicolae Timofti who was sworn in to the office on 23rd March 2012 (Presidency of the Republic of Moldova, 2014). The current Prime Minister is Iurie Leanca who was appointed in 2013 and who leads the cabinet of twenty ministers and deputies (The Official website of the Government of the Republic of Moldova, 2014).

The state of democracy in Moldova is slowly improving ever since its declaration of independence. That progress was recognised by both major players in the field of democracy and freedom monitoring and assessment, Freedom House and The Economist – Intelligence Unit (EIU), even if both those organisations rank Moldova among not fully developed democracies. According to the Freedom House (2014) the country is considered still as “Partly Free” country achieving the score 3.0 on the scale from 1 (the best rating) to 7 (the worst rating) which is the exact threshold between the status “Free” and “Partly Free”. The EIU ranks Moldova among the 54 countries with the status “Flawed democracies” and the overall rank of Moldova is 67 out from 167 evaluated independent countries and territories (EIU, 2012). The comparison with Romania, Moldovan example of country successfully accessed into the European Union, is following: EIU considered Romania as a “Flawed democracy” on the overall rank 59 but Freedom House takes the country as a “Free” achieving the score 2.0 (EIU, 2012; Freedom House, 2014). The Republic of Moldova is trying to integrate itself within the EU and to do so it has to fulfil several requirements in the field of democracy. The biggest challenges among those requirements could be fighting with widespread corruption and solving the Trans-Dniester conflict (EU/Moldova Action Plan, 2005).

The progress in first earlier mentioned issue, the conflict with Trans-Dniester region, reached some tangible results when the representatives started to meet and discuss the problem. In September 2011 there was also a conference of those two sides on confidence building sponsored by Organisation for Security and Cooperation in Europe (OSCE) (ENP, 2012). Nevertheless, the Trans-Dniester region or so-called Dniester Republic, on the eastern bank of the river Dniester, still functions as a non-recognised state with its own currency or government (Protsyk, 2012). Good solution of that conflict is vital not only for both sides within Moldovan borders but also for the whole EU which requires stable borders to prevent infiltration by criminal entities from the space beyond EU boundaries. Moldova as a country in accession process and has to fulfil that requirement (Batt, 2003).

As for the corruption problem, Moldova is small but relatively very open economy which relies heavily on external markets. The formal trade barriers are quite small (tariffs, quotas) but the informal barriers, bribes and other forms of corruption, are quite high (Porto, 2005). Even that situation could forestall the foreign companies to start their business in Moldova. That considers mainly the companies from the Western Europe whose policies are very strictly against any kind of bribes and corruption behaviour, which leaves the big part of Moldovan market open for the companies from former Soviet republics which face similar problem. Corruption is still widespread in Moldova but sadly Moldovan people fight against it only when the economic condition of the county is also poor (Klašnja and Tucker, 2013). That attitude needs to be changed in order to fulfil the anti-corruption EU requirements (EU/Moldova Action Plan, 2005). The overall state of democracy could be summed up in one statement. Due to all earlier mentioned flaws or imperfections Moldova is considered as a minimalist democracy. That statement is derived from the position of civil liberties, rule of law and electoral right in Moldovan society (Møller and Skaaning, 2010).

2.1.3. Economic situation

The Republic of Moldova is still very poor country, one of the poorest in the Europe (World Bank, 2014). Its economy is in similar condition and progress as the democracy, still slowly improving, and it also went through some turmoil and suffers with major imperfections. One of the most serious problems is corruption, which was mentioned earlier and connects political and economic sphere of the public sector. The other ones are widespread poverty and job migration of Moldovan citizens in working age (EU/Molodva Action Plan, 2005). Those two main problems are very much connected to one another in some kind of vicious couple. People migrate because there is poverty in their country and lack of good job opportunities and that causes the losses in national economy income and therefore lack of good job opportunities and poverty. The good news in field of poverty reduction is that the poverty headcount ratio at national poverty line actually decreased from 26.3% in 2009 to 16.6% in 2012 (World Bank, 2014). The decrease is even more noticeable in rural areas (Macours and Swinnen, 2008).

Although migration is a big problem it is also a source of public transfers, remittances, which have the relatively great share on national GDP and help to diversify the income of Moldovans (Macours and Swinnen, 2008). The foreign development cooperation could be considered as another source of income for Moldova although it is not only about financial capital support (Czech Republic Development Cooperation, 2010). The whole structure of GDP ergo the whole economy went through several changes in an employment in the sectors as well as in their share in the national GDP. In recent history Moldova was oriented mainly on agriculture moreover there was always the majority of rural population. In 2012 there were still slightly more rural people (52%) but the influence of agriculture on GDP added value decreased to only 13% and employment decreased to 26% of economically active people working in that sector. Industry was never a priority sector for Moldova which was and still is reflected in its share on GDP added value which is 17% as well as in its share of people working in the sector which is 19% both digits were related to year 2012. Services on the other hand are on the rise in Moldova which could be expressed by its share on GDP added value which in 2012 was 70% and employment in that sector accounted for 55% of economically active people in Moldova. The unemployment rate in Moldova reached 5.6% in 2012 which is for example lower than in the Czech Republic where the share is 7% (World Bank, 2014; ILO, 2014).

Table 1 shows other important macroeconomic data and characteristics for years 2005, 2010 and 2012 and ***Figure 1*** represents Moldovan GDP growth in the past twenty one years plus five years forecast. Although especially in Moldova, GDP and its related indicators could be distorted by shadow economy (Schneider, 2005). On the basis of that covered or hidden economies and unrecorded activities the Republic of Moldova belongs among the poorest countries from the former Eastern block (Feige and Urban, 2008). The last important indicator which could be connected to the socio-economic sphere, the HDI index of Moldova, is 0.660 which ranks the country on 113th place out of 187 countries, which means medium development (UNDP, 2014).

Table 1.: Macroeconomic characteristics of the Republic of Moldova

Indicator	2005	2010	2012
GDP per capita (USD)	831	1,632	2,038
GNI PPP per capita (USD)	2,650	3,330	3,630
GDP growth (%)	7.5	7.1	-0.8
FDI (% of GDP)	6.4	3.5	2.5
Inflation (%)	9.3	11.1	7.5
Extern. debt stocks (% of GNI)	66.3	76.8	78.5

Source: World Bank, 2014; International Monetary Fund, 2014

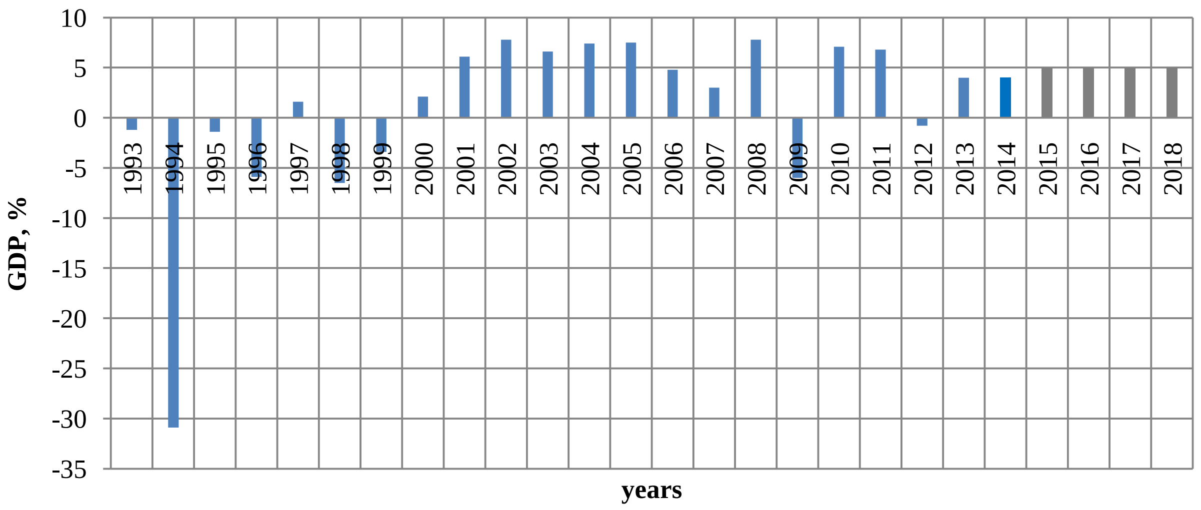


Figure 1.: Real GDP growth of the Republic of Moldova

Source: International Monetary Fund, 2014

2.1.4. International cooperation

The Republic of Moldova is a member of several worldwide organisations as well as several European and regional integrations or agreements. Not even the whole year after Moldovan declaration of independence, on 2nd March 1992, the country joined the United Nations (UN) (UN, 2014). Moldova is also a member of two organisations which unite the former Soviet republics. The first larger one is the Commonwealth of Independent States (CIS) which unites the most of the former Soviet republics (Carmignani, 2007). The second regional organisation is GUAM which is the abbreviation of the first letters of names of member countries (Georgia, Ukraine, Azerbaijan and Moldova). Other international bodies, where Moldova is a member are World Trade Organisation (WTO) and International Monetary Fund (IMF). In Europe the country is a member of OSCE and in last decade it has also worked hard on the integration to the EU (The official website of the Republic of Moldova, 2014).

As it was mentioned, Moldovan current priority number one on the field of international cooperation is integration to the EU. The country has made several important steps towards achieving that goal. Soon after declaration of independence, in 1994, Moldova signed the Partnership and Cooperation Agreement (PCA) with the European Union, which only outlined the future cooperation (Official Journal of the European Union, 1998). The Republic of Moldova is also a member of two programmes which are important for the whole accession process. One of them is Eastern Partnership community (EAP), which is group of states in various stages of accession process (Armenia, Azerbaijan, Belarus, Georgia, Moldova and Ukraine) and the other one is the European Neighbourhood Policy programme (EAP Community, 2014). Probably the biggest step forward in pro-European endeavour was done when the EU/Moldova Action Plan was elaborated in 2005. That plan was and still is the key document which is divided in seven main chapters describing main Moldovan shortcomings and suggests their solution (EU/Moldova Action Plan, 2005). The progress of implementation of that plan is yearly monitored by European Commission (ENP, 2012). In 2007, when Romania joined the Union, Moldova turned into a direct neighbour of the EU (Popescu, 2008). Maybe even that escalated Moldovan efforts which resulted in the victory of the AIE in elections in 2010 and again in 2014. Moreover, Moldova already ratified the Association Agreement with EU in July 2014 and therefore is closer to the membership in the Union than ever before (EU External Action, 2014).

2.1.5. Agriculture

Undoubtedly, agriculture was and even after more than a decade of constant decrease still is the key sector for Moldova. That statement is supported not only through historical records but also by the fact that Moldova has very fertile soils and climate favourable for growing horticulture, grapes or other demanding crops (Gorton, 2001). The majority of Moldovan land is arable land which covers 1,810 thousand hectares which counts for 55% of total land. On the other hand, the country has one of the smallest shares of area covered by forest in Europe which is only on 390.6 thousand hectares which is approximately 11.8% (FAOSTAT, 2014). As it was mentioned the share of people working in agriculture annually decreases and so does its contribution on Moldovan GDP (ILO, 2014; World Bank, 2014).

Current Moldova is focused more on the crop production than on livestock production. The reason of that state could lie in the history when Moldova, as a part of the Soviet Union, had the centrally planned agriculture. In those times there were almost exclusively only large state farms (sovkhoz), collective farms (kolkhoz) or state-owned food processing plans (kombinats). After the breakup of the Soviet Union that system became unsustainable and collapsed. In Moldovan case it even resulted in supply chain failure which hit harder the animal production sector than the plant production. It was caused by problems in land redistribution process which started after the large state farms or collective farms were divided into private owners and because Moldovan rural people were and still are very poor it has been much harder to take care about the cow herd than to grow some plants (Gorton *et* al., 2006). The means for that redistribution were mostly privatisations, restitutions, auctions or distributions which were undertaken under several fulfilled conditions (historic justice, economic efficiency and food security) (Gorton, 2001). Eventually, the current supply chain is slowly reviving and special attention is paid to small local farmers (Dries et al., 2009). Even such a thing as a Database “Tomatoes” which was performed in connection with the Czech Republic development project and should help tomato growers especially with marketing and obtaining information about prices in tomato production sector (Kandakov and Havrland, 2012).

Agricultural sector is also one of the priorities of the Czech Republic Development Cooperation. The mid-term priorities for the planning period 2011-2017 are focused mainly on research, provision of proper equipment and renovation of old technologies for example irrigation system (Czech Development Cooperation, 2010).

The Republic of Moldova is famous for its vine cultivation and wine production which is widespread on high quality and quantity and has a very long tradition in the whole country (Gorton, 2001). The position of vine cultivation through history depended on which historical empire governed Moldovan territory. In recent history, after both world wars, the vineyards were greatly damaged and the whole sector suffered. In 1950s there was a large replanting which resulted in the state that after the year 1960 there were 220,000 hectares of vineyards and practically the whole production headed into the Soviet Union. In mid-1980s the wine production suffered again due to alcohol prohibition in the USSR which hit Moldova really hard because almost every second bottle was fabricated in Moldova. After the declaration of independence the wine sector again started to recover even if slower than before. Many vineyards were privatized and the new investors brought new modern equipment together with European varieties (Aligoté, Sauvignon Blanc, Merlot, Pinot Noir) which became more widespread than the original ones (Feteaska Albă, Rara Neagră). Many winemakers also began cooperating with winemakers in countries which are well-known for their wine production (France, Italy, Australia) (Moldova Wine Guild, 2014). Even if Moldova diversified the wine export the production was yet again badly affected by temporary Russian embargo on Moldovan wine in 2006 and 2007. The Russian sanctions on several agricultural products came again into play after Moldovan ratified the Association agreement with EU in July 2014 (EU External Action, 2014)

Four wine producing regions could be distinguished in Moldova with their own specific conditions and grown varieties. Around Balti, the second biggest city of Moldova, there is the smallest region (5,750 ha), the Northern region. That zone has the coldest winters out from the four regions. Its altitude is ranging between 200 and 250 metres, average rainfall per year ranges between 520 and 620 mm per year, the average sunshine is equal to 2,100 hours and the soils are podzolized chernozems. Those conditions are the most favourable for white varieties (Aligoté, Feteaska Albă, Traminer, Chardonnay). A lot of grapes are also used for brandy production, in Moldova called “divin”. Under that region is Central region which is also called Codru (31,500 ha). Its climate conditions are following: altitude ranges between 100 and 150 metres, rainfall ranges between 550 and 680 mm per year, average sunshine is 2,135 hours and soils are again podzolized chrnozems. That region is very similar to the Northern region which favours the similar grape varieties (Aligoté, Feteaska Albă, Traminer, Chardonnay) but wines produced in Central zone have more stronger floral aroma and are more fresh. In Trans-Dniester region there is South-eastern zone also called Dniester region (15,750 ha). The vineyards in that region are situated in very low altitudes from 60 to 70 metres above sea level. Weather is also different in this part although the duration of sunlight is higher than in previous regions and is equal to 2,200 hours of sunshine per year. The average rainfall is smaller and ranges between 450 and 550 mm per year. The soils in that Dniester zone are podzolized or carbonated chernozems. On the contrary to previous regions this region is famous for cultivation of red varieties (Merlot, Cabernet Sauvignon, Rara Neagră). The last distinguished region in Moldova and what is more the biggest region (52,500 ha) is Southern zone also known as Cahul zone. Conditions which are in this region are quite similar to those in the Mediterranean area because even in this location there are warm and dry summers and short mild winters. The altitude is different than in other Moldovan regions and ranges between 280 and 300 metres making them the highest situated vineyards in Moldova. The sunshine in that region is equal to 2,500 hours per year which is by far the highest digit and the rainfall is on the other hand between the lowest limits and ranges between 350 and 500 mm per year. The soils are mostly carbonated or leached chernozems. In that area the red wines from the red varieties such as Merlot, Pinot Noir or Cabernet Sauvignon are mainly produced and some of the Moldovan best red dessert wines are also made in that region (Moldova Wine Guild, 2014; FAOSTAT, 2014).

Thanks to big demand of the market in Moldova another important commodity is tobacco and following manufacture of cigarettes but even this field was affected by privatisation difficulties (Gilmore et al., 2005). The difficulty in animal production were already mentioned but in last decade the situation is stabilising and the meat production is growing or is not as low as it was right after the declaration of independence (FAOSTAT, 2014). The similar situation occurred in cow milk production (Gorton et al., 2006). However meat production still plays only a minor role. The plant production is in better condition and apart above mentioned vine cultivation and widespread horticulture sugar beet and maize are also largely cultivated. According to FAOSTAT (2014) the top three imported commodities according to the quantity in 2011 were flour of wheat (63,600 t), beer of barley (24,976 t) and food prep (22,273 t). The top three exported commodities according to quantity in 2011 were sunflower seed (218,863 t), apples (195,790 t) and maize (131,064 t). Although Moldova is mainly known for its wines, their export is in a fourth position and in 2011 the quantity was equal to 119,838 t.

Table 2 shows the average yields of selected perennial crops in the Republic of Moldova between years 2008 and 2013 and ***Table 3*** shows the area of their production. Crops were selected on the basis of significance for the country (Statistica Moldovei, 2014). It should be also noted that in 2008 there were large floods in the country (Czech Business Web Portal, 2014).

Table 2.: Average yields of selected perennial crops [t.ha^{-1}]

	2008	**2009**	**2010**	**2011**	**2012**	**2013**
Apples	4.1	3.6	3.6	4.8	5.0	5.7
Plums	2.8	1.6	2.9	1.8	2.5	3.6
Sour cherries	4.2	7.0	3.7	5.8	2.6	1.0
Peaches	1.6	1.8	2.7	2.7	1.4	2.8
Berries	2.0	2.8	2.0	1.7	1.4	1.6
Nuts	3.1	2.5	2.8	3.0	1.8	2.1
Vine grapes	4.4	4.8	3.5	4.6	3.9	4.7

Source: Statistica Moldovei, 2014

Table 3.: Area of production of selected perennial crops [thousands hectares]

	2008	**2009**	**2010**	**2011**	**2012**	**2013**
Apples	66	65	64	64	64	64
Plums	22	22	22	23	23	24
Sour cherries	4	4	4	4	4	4
Peaches	8	7	7	7	7	7
Berries	1	1	1	1	1	1
Nuts	7	8	9	11	12	14
Vine grapes	150	148	145	140	141	137

Source: Statistica Moldovei, 2014

2.1.6. Environment

Natural environment in the Republic of Moldova is in really bad condition and since the agriculture is fundamentally bounded to environment then in not so distant future it could be also hit by continuous natural environment degradation. The European Union pays very close attention to environment and harmful behaviour against it and that was also reflected in several suggestions in EU/Moldova Action Plan. The framework suggests undertaking some necessary steps towards good environmental government and set the conditions for further implementation of provisions under the Kyoto Protocol and the UN Framework Convention on Climate Change. Other advices concern the bigger involvement of Moldovan local and even regional authorities in solving environmental problems or approximation of Moldovan legislation to the commitments of Johannesburg Summit (EU/Moldova Action Plan, 2005). In response to those suggestions the Republic of Moldova prepared environmental strategy for years 2012-2022 but apart from that endeavour the environmental issues are still a bit overlooked. Administrative capacity which should deal with environmental issues at all levels is still small and that is still a major concern. Although the Regional Environmental Centre was established it remains only small entity within the whole Moldovan governmental apparatus (ENP, 2012).

But apart from the legislation acceptation difficulties Moldovan nature took some environmental remnants from its Soviet history. In that era many storages of underground water were dangerously polluted mainly by not used motor oil or petroleum and that is why many developing projects performed in Moldova concern water quality (Czech Development Cooperation, 2009). However, during the research on water access in Moldova the majority of rural people (65.8%) characterized in questionnaire the quality of their water as good which was the largest share from studied post-soviet republics. Only 1.3% of people thought that water in their vicinity is in poor condition. On the other hand in urban areas the proportions were quite different meaning good water condition 29% and bad condition 17.2% (McKee *et* al., 2006). On the contrary to the previous research the river system in Moldova is in bad condition and the two main rivers (Prut and Dniester) especially. But environment is not only water. According to FAOSTAT (2014) soils, on the other hand experienced the large amounts of various artificial substances but in last decade the usage of such kind of pesticides or fertilizers is decreasing.

2.1.7. Energy sector

The Republic of Moldova has only small reserves of fossil fuels and the country is also missing a big power plant because the only one that is on Moldovan territory lies in problematic Trans-Dniester region (Czech Development Cooperation, 2009). Moldovan rivers also cannot provide sufficient amount of energy even if they would be used for it. The Prut and the Dniester, two Moldovan largest rivers which also form country´s borders are just not as big. Alternative or renewable resources of energy are growing rapidly in Moldova in the past few years but still remain minority which lefts Moldova dependent on imported energy, mainly from Russian Federation and Ukraine (Karakosta et al., 2011). Right after the declaration of independence Moldova imported large quantities of both oil products and natural gas. But as it could be observed in ***Figure 2*** the amount of oil products decreased significantly and natural gas remained number one imported energy resource. The situation with coal was similar to one that occurred with oil products although in much smaller amounts and today coal has only minor role for Moldova. Total import of all energy resources in the year 2011 was 3,251 ktoe (International Energy Agency, 2014). That digit represented the share of 87.9% of all Moldovan energy resources structure (Statistica Moldovei, 2014).

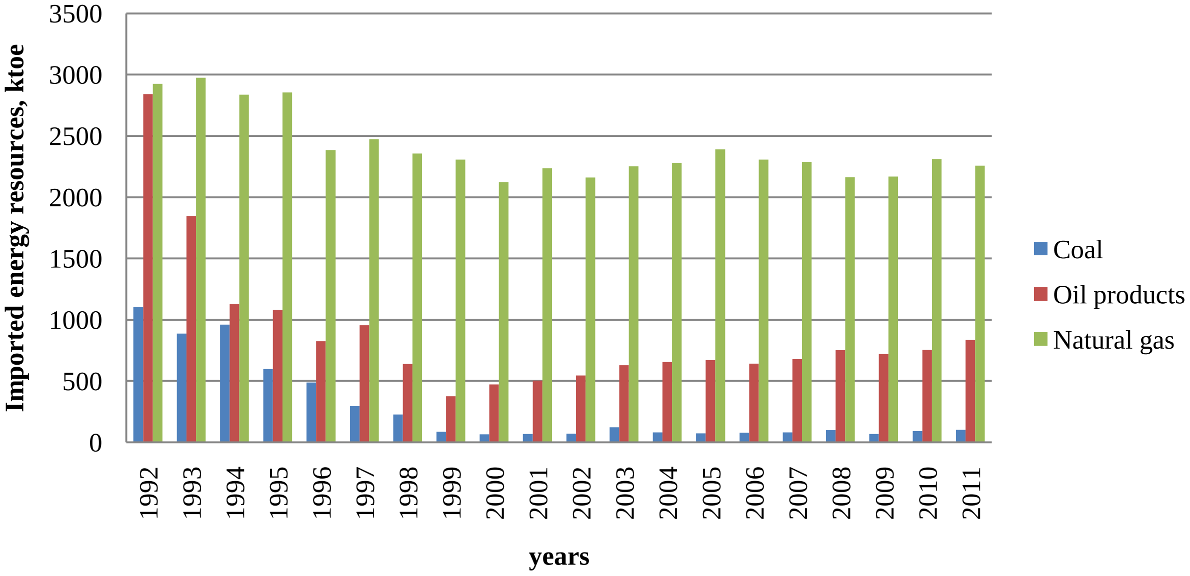


Figure 2.: Import of main energy resources, thousands tons of oil equivalent [ktoe]
Source: International Energy Agency, 2014

With such a big dependence on energy import Moldova is putting itself in very difficult position towards Russia which can dictate the price and make it very high, and Russia is very much aware of that position and sets very high prices for natural gas, Moldovan most imported resource. Those prices were continuously increasing from the level of 80$ per thousand cubic metres (TCM) in 2005 to 190 $ per TCM in 2008 and only Georgia paid more for its natural gas (Newnham, 2011). That situation had and still has very negative effect on such poor country as Moldova.

There is another problem that is tightly connected to the dependence on imported energy and that is the fact that Moldova has almost no emergency oil stock which would cover losses caused by cut off from Russian energy supply. That situation already happened once, in January 2009, when Moldova was between the countries which were cut off from Russian natural gas supply. The negative effect on Moldova was doubled due to earlier mentioned lack of emergency oil stock and the fact that the energy supply interruption came in the middle of the winter season. However Moldova has some operational stock which would last for about thirty days but that stock does not correspond to respective EU directives. Moreover Moldova still has no legal framework dealing with this issue which results in situation where industry is not obliged to maintain any petroleum stock (Tosun, 2012).

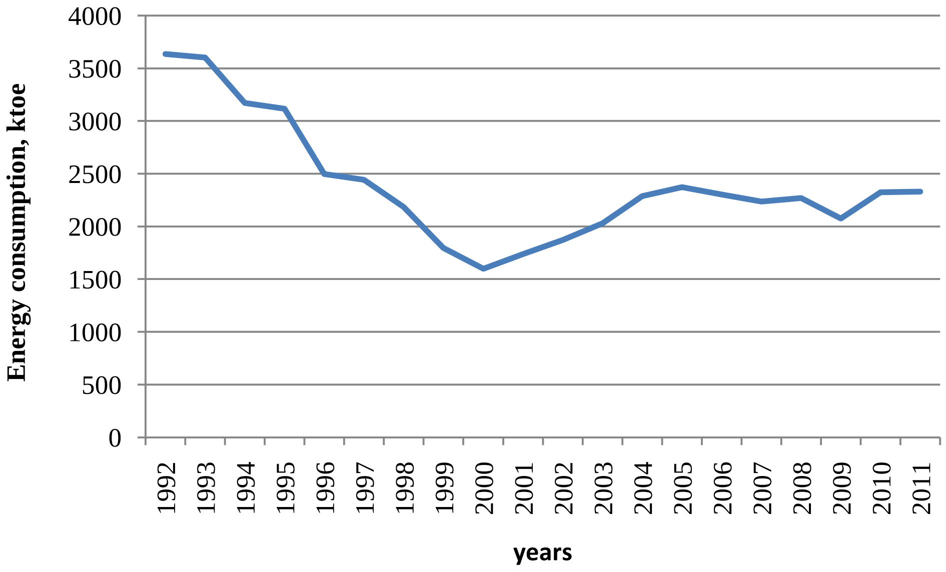


Figure 3.: Total energy consumption in the Republic of Moldova
Source: International Energy Agency, 2014

Figure 3 shows that total energy consumption went through several stages of decreases and increases. However according to most recent data available there is sign that the situation around the energy consumption in Moldova is stabilising although it is almost certain that it will never reach its levels from the 1990s. That could be caused by the better utilisation of energy or simply with decreasing industrial leverage on the total energy consumption. The total energy consumption in year 2011 was 2,329 ktoe (International Energy Agency, 2014).

As it was mentioned earlier the use of renewable energy sources is on the rise in Moldova. The country even introduced a National Programme of Renewable Energy Sources (RES) with very ambitious goal saying that RES should cover the share of 6% of the total energy consumption. It is ambitious plan but not unrealistic because the potential is considered somewhere between 5% and 6% (Karakosta et al., 2011). The National Programme goes very much in line with the EU/Moldova Action Plan suggestion which advise to enhance such kind of energy production (EU/Moldova Action Plan, 2005). The EU in 2011 even started to provide the budget support which in that very year was worth 42.6 million EUR. The main focus of that support was to improve energy efficiency and to promote renewable energy (ENP, 2012). Although the plan was set Moldovan RES still covers approximately 3 – 4% of total energy consumption and the lions share on that number has biomass thanks to good climate and fertile soils. The other renewable sources are minor for Moldova due to not developed technology or lack of attention (wind, solar, geothermal). The hydropower is rather well investigated but Moldova lacks of big rivers or wide river network therefore there are only two significant hydropower stations. One is called Dubasari which is on the river Dniester and has the capacity of 48 MW and the other one is Costesti which is on the river Prut and has the capacity of 16 MW. However, as it was mentioned the biggest potential lies in biomass and bioethanol and biodiesel from rape and sorghum could be produced by rather competitive costs (Karakosta et al., 2011).

However there is a National Programme and the EU budget supports the wider use of alternative energy or “clean” energy has to go in line with broader consensus within Moldovan society. A significant number of households in urban areas still use the so called dirty fuels such as coal and in comparison with other former Soviet republics, namely Armenia and Kyrgyzstan, the situation in Moldova is far worst (Wu el al., 2004).

2.2. Renewable energy sources

2.2.1. General information and position of RES in the World

Renewable energy sources are such sources which have the ability to replenish themselves in at least the same pace as they are consumed (International Energy Agency, 2014). Their consumption could be theoretically infinite. There are several types of renewable sources: wind energy, solar energy, biomass energy and cellulosic ethanol, biogas energy, geothermal energy, hydropower and offshore wind, wave and tidal energy (NRDC, 2014).

The generation of renewable energy during last two decades have not changed much in fact because in 1990 the share of energy produced by RES was 19.5% but due to low growth of that energy sector and several stagnations the share even fell to 19.3% in 2009. The share of generated energy from RES in year 2014 is estimated to be around 20% (International Energy Agency, 2014). There is always also a little difference between production and consumption. In 2010 the consumption of renewable energy reached 16.7% share while the modern renewable energy (hydropower, wind, solar geothermal, biofuels and modern biomass) contributed with 8.2% and traditional biomass used for cooking and heating in rural areas in developing countries contributed with 8.5% (REN21, 2012).

However, there are huge differences between continents and even within one continent. For example the target share of RES on final energy production for EU member countries is 20%. 10% of that also accounts for the share of RES in road transport sector (Official Journal of the European Union, 2003). But there are countries which even in 2010 far more exceeded the resolution such as Sweden with the share of 48%, Finland and Latvia both with the same share of 32% or Austria with 30% share. On the other hand there are countries which lagged behind in 2010 such as Malta with almost zero share, Belgium, Cyprus, Czech Republic, Greece, Hungary, Ireland, Luxembourg, Netherlands, Poland and United Kingdom all with shares less than 10% (Stigka et al., 2014). The situation and potential of RES in other continents differs. In the USA the RES contribute only 10% to total electricity production and only 8% of total energy consumption comes from that source of energy (Barros et al., 2013). Russia has high potential of RES but the government had set only very modest goal to achieve the 4.5% share of RES on total energy consumption by year 2020. Moreover Russia seems to be avoiding that target because it sells out its low cost RES or energy made from them to foreign countries mainly to the EU (Boute and Willems, 2012). China, as always, sets very ambitious national target for 2020 when 15.5 – 19.7% of total energy consumption would originate from RES. However China goes even further and sets also a national target for 2050 until then the share of energy consumption from RES on total consumption should be within 26.4 – 43.0%. The current Chinese situation is that RES cover 8.5% of total energy consumption (Fang, 2011). Other Asian countries differ from the ones where the share of RES on total energy consumption is relatively high such as Philippines (19%) or Indonesia (27%) there are also countries with no energy from RES of very little (Malaysia, Singapore, Thailand) (Bakhtyar et al., 2013). Although Australia still produces a lot of emissions by using fossil fuels the RES are on the rise. Northern parts of Australia has excellent conditions for solar power plants and almost all coastal areas are more than suitable for wind turbines and also the utilisation of biomass and biofuel is more and more popular (Yusaf et al., 2011). In most regions of Latin America more than 50% of total electricity consumption came from RES generated electricity. The reason for that is the fact that a lot of countries have high potential in hydropower production and they use that possibility of clean energy but other renewables are also becoming more significant (Al-mulali et al., 2014). Africa has its big potential for utilization of RES but it depends on the transfer of technology to build such facilities. However many African countries set very ambitious strategic goals in relation with RES. Currently the most utilized renewables in Africa are hydropower, modern biomass, geothermal, wind and solar. The share of RES on total consumption even in Africa varies quite a lot. There are countries with high share such as Ghana (18.20%) or Kenya (9.10%) and on the other hand there are countries like Algeria (0.05%), Tunisia (0.07%) or Morocco (0.68%) (Aïssa et al., 2014).

RES are considered as a clean energy or at least carbon neutral in the way that carbon cycle of biofuels or modern biomass is closed. Therefore utilization of such sources of energy contributes to at least one Millennium Development Goal, namely to ensuring environmental sustainability by reduction of greenhouse gas (GHG) emissions (UN, 2014). Moreover, there could be discussion whether or not the electricity and energy produced from RES and their consumption afterwards contributes to eradication of extreme poverty and hunger via GDP growth (Al-mulali et al., 2014). Other important aspects connected to use of RES are mitigation of climate change and energy security.

2.2.2. Biomass and biofuels

As it was already mentioned the RES could be divided into two groups: modern renewables and traditional biomass. The focus of this thesis is on the potential of modern biomass renewables more specifically modern solid biomass fuel from vineyard waste. Everything that was once living organism could be considered as a biomass (Yusaf et al., 2011). However for renewable energy production the most suitable organisms or biomass are trees, plants, animal manure, agricultural waste or even household waste (Karakosta et al., 2011). There are many ways how to convert biomass into energy source which depend mainly on type of biomass. Therefore there are three main types of biofuels according to the state of matter: gaseous (biogas, woodgas), liquid (bioethanol, biodiesel, biomethanol, etc.) and solid (pellets, briguettes) (Yusaf et al., 2011). All kinds of above mentioned biofuels contribute to sustainable development and their importance is growing while the deposits of fossil fuels are depleting. However, use of modern biomass RES is not a novelty which occurred after introduction of Kyoto Protocol. China, for example, has more than ninety years of history of biogas production when in 1921 Luo Guorui developed technology which enabled utilization of biogas for lightning purposes. But the primitive forms of such technology occurred even times Before Christ (Song et al., 2014).

Every type of biofuel has its own sphere of application due to its specific characteristic and components or different storing techniques. According to Official Journal of the European Union (2003) following biofuels could be used for transportation purposes: bioethanol, biodiesel, biogas, woodgas, biomethanol, biodimethylether, bio-ETBE (ethyl-tertio-butyl-ether), bio-MTBE (methyl-tertio-butyl-ether), synthetic biofuels, biohydrogen and pure vegetable oil (crude or refined but chemically unmodified). As for the solid biomass the traditional types (log, twigs) were used as a source of heat or light from the beginning of human kind and even in present century many households in many developing countries still use such kind of biomass for cooking. However modern types of solid biomass (pellets, briquettes) which could be used in special designed stoves or boilers and have higher density, higher energetic value, lower moisture content and lower ash content therefore are more eco-friendly. Moreover the dispenser of such kind of fuel could be automatic due to standardisation of shape and size (Picchi et al., 2013). Although in almost all regions in the world people are willing to use clean energy sources the major constrain is the economic situation of the people living in that respective region (Ping et al., 2012).

2.2.3. Solid biofuels

Solid biomass is used for heating or cooking purposes, lightning or as a fuel from the beginning of human history. However that kind of biofuel is considered as a traditional biomass fuel called firewood (wood logs, twigs, tree bark etc.). Such kind of biofuel is still used in many rural areas in developing countries for cooking and heating purposes and even in some developed countries for boiler heating. The modern types of solid biofuel are briquettes and pellets which are also used mainly for stationary heating (Johansson et al., 2004). Moreover, solid biomass feedstock is absolutely necessary for production of both gaseous and liquid biofuels through some type of physical, chemical or biological conversion. Therefore solid biomass is the foundation stone on which other modern biofuels depend (Doshi et al., 2014).

The sources from which the solid biofuels could be produced are divided into four groups based on their origin according to norm CEN/TS 14961. Such sources are woody biomass, herbaceous biomass, fruit biomass (non-edible parts of fruit) and blends and mixtures where blends are intentionally mixed with known ratio and mixtures unintentionally mixed (Alakangas et al., 2006).

The composition of solid biomass affects further performance of a fuel made from such a source. Every kind of source has a different composition but carbon, oxygen and hydrogen is fundamental for all types of solid biomass. The C:H:O ratio varies but basically it could be stated that woody biomass shows higher carbon rations while herbaceous biomass has higher ratios of nitrogen, chlorine and sulphur. Wood bark on the other hand could contain higher amounts of several other elements such as calcium, silicon, potassium or iron. The content of such elements in wood bark could be caused by soil composition or water quality (Obernberger et al., 2006).

The influence of those elements on solid biofuels performance is significant and even crucial in some cases. Carbon and hydrogen during combustion react with oxygen and form CO_2 and H_2O. Moreover C and H ratios are positively correlated with the increase of gross calorific value (GCV) while the higher volumes of O decrease GCV. That also explains why woody biomass with higher C content has slightly higher GCV. Hydrogen ratio also affects the net caloric value (NCV) because of the water formation during the combustion process. Emission of CO_2, one of the GHGs, could be considered as neutral due to the carbon cycle if the fuel is suitably utilized. Other pollutants could be also lowered almost to zero levels by optimising combustion process via maintenance of the suitable fuel and air ratio, sufficient retention time and high temperatures (>850°C) and low total lambda (Obernberger et al., 2006). Pollutants could be also diminished by application of proper filter to combustion unit. The causes of incomplete combustion could be very harmful to the environment due to emissions of CO, hydrocarbons, polycyclic aromatic hydrocarbons and tar and soot production (Picchi et al., 2013).

Nitrogen, as it was already mentioned, is more concentrated in herbaceous biomass such as straw, grain and grasses (wheat, barley, rape, miscanthus) and also in fruit biomass (Obernberger et al., 2006). The biggest environmental problem of nitrogen biomass content is a formation of nitric oxides NO_x (NO, NO_2) and nitrous oxide (N_2O) (Bohlin et al., 1998). According to Obernberger et al. (2006) together with NO_x compounds pure gaseous N_2 is also produced. Due to modern combustion technologies amounts of N_2O are very small. However the formation of NO_x is significant only if the temperatures exceed the 1,300°C with low oxygen levels and in presence of hydrocarbons. Therefore the presence of nitric oxides during and after combustion process could be very much mitigated by suitable air supply, observance of temperature limits and proper combustion technology utilization.

Chlorine, in similarity to nitrogen, has also higher concentrations in herbaceous and fruit biomass. During combustion chlorine transform to gaseous forms (HCl, Cl_2) or to alkali chlorides such as KCl or NaCl which depends mostly on alkali content in biomass, earth-alkali metals or silicon content in the fuel which reacts with chlorine. The main negative effect of HCl and chloride salts formation is corrosion of metal parts in furnaces and boilers and mainly in heat exchangers where those salts can condensate. Mitigation of such negative effect could be achieved by implementation of automatic heat exchanger cleaning system, coating of boiler tubes or selection of suitable biomass. Also some HCl emissions are produced during combustion process but they can be diminished by such measure as dry sorption with calcium hydroxide ($Ca(OH)_2$) (Obernberger et al., 2006).

According to Obernberger et al. (2006) sulphur occurrence and negative effects bounded to that element are in many ways very similar to the chlorine. Sulphur in form of sulphates can also corrode heat exchangers or other metal parts via sulphation process. The residues of sulphur also form aerosols and gaseous forms of SO_x (SO_2 and in minor quantities SO_3) emissions. Mitigation of negative effects of sulphur and its related sulphates is also the same as in the case of chlorine.

According to Obernberger et al. (2006) other elements could be divided into two groups according to their significant influence on combustion process. First group could be considered as the one with higher influence (Al, Ca, Fe, K, Mg, Na, P, Si, Ti). That group occurs in higher quantities in biomass. The minor elements group (As, Ba, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Sb, Tl, V, Zn) occurs in smaller quantities, but if it is presented it could cause a lot of damage. Those elements negatively affect the whole combustion process and potentially the environment via compounds with sulphur and chlorine. Ash melting, deposit formation, fly ash emissions, aerosol emissions and corrosion could be listed between those negative effects. The presence of those elements and their quantity is mostly based on soil and water structure and quality (Picchi et al., 2013).

The last two characteristics which could very significantly affect the burning performance of solid biomass are ash and water content. Ash content of the biomass ergo fuel and quantity and quality of ash which is produced by that fuel are crucial characteristics for suitable fuel and combustion technology selection and even for environmental concerns (García-Maraver et al., 2014). Therefore the less ash content it is in the fuel the more preferable such fuel would be. Again there are differences between woody biomass which, apart from bark, usually has lower ash content than straw, grasses, grain or fruit residues (Obernberger et al., 2006). Especially wood bark could contain even heavy metals and therefore could be harmful to environment (Picchi et al., 2013). On the composition of ash which is produced during the combustion element constitution, combustion technology, quality of furnace, temperatures during the process and ash extraction system have the highest influence. High ash content in some cases (pellets) could even decrease the calorific value (CV) which only emphasizes the importance of low ash content fuels (García-Maraver et al., 2014). Moisture content could negatively affect not only the combustion process via CV of the fuel but also the quality of the biomass fuel alone before the utilization by biological deterioration. Unfortunately there is no biomass with zero water content therefore the biomass has to undergo some pre-treatment before it could be used as a solid fuel which is even more important in modern biomass solid fuels (Acharjee et al., 2011). Moreover higher moisture content could also affect transportation costs and CV. Moisture content in biomass depends on the growing conditions of respective biomass, its harvest technology but mainly by storage system or technology and drying pre-treatment (Baláš and Moskalík, 2011). It could be concluded that the low moisture content modern and even traditional types of solid biofuels are preferred.

As it was mentioned earlier modern solid biomass fuel are divided on the basis of size on pellets which are smaller (ČSN P CEN/TS 14961 diameter between 6 and 25 mm and the length differ but does not exceed 50 mm) (Stupavský, 2010). However the ratio between pellets diameter and length should be maximum 1:3 (Andert et al., 2006). And as the other type briquettes are considered whose diameter lies between 40 and 100 mm and length usually does not exceed 300 mm (Stupavský and Holý, 2010). Both those forms are produced to improve important energetic characteristics, mainly CV.

Pellets are fabricated in cylindrical shape of parameters mentioned above. Pellets are usually made from woody residues, peat, bark, straw or combination of previous. Such type of biofuel is made via pelletizing process where residues are pressed and pushed through small holes in roller press corresponding with intended diameter (Chen et al., 2009). The pressure together with lignin from woody biomass ensures that pellets will not crumble. Moreover if the biomass material for pelletizing has higher moisture content then the biomass is easily pressed but produced pellets are firstly mechanically durable but in short period of time they start to crumble (Stupavský, 2010b). However pellets usually have only small amount of moisture content (under 7%) and low ash content (under 2.5%) which made them very good fuel for houses as well as for bigger buildings. Due to standardized size and shape pellets are also suitable for furnaces with automatic dispenser and their emissions are in comparison to other solid fuels quite low (Picchi et al., 2013).

Briquettes are larger type of solid biofuel, as it was expressed above, also with variability of shapes (cylindrical, prismatic, hexagonal) depending on briquetting machine. As a material for briquette production almost any plant material (wood brash, sawdust, straw, energy herbs) can be used but mostly woody biomass is utilized. The briquette production technology could be divided into three main types on the press basis: mechanical piston press, screw press and hydraulic press. In piston press biomass is punched through die by reciprocating ram with high pressure. Piston press is durable and has low energy consumption but the maintenance is higher and quality of briquettes is lower. In screw press the material is continuously pressed through heated taper die which ensures high quality of briquettes and noiseless running. However the power consumption and high wear of the screw are the main disadvantages. Hydraulic press is powered by electric motor which transfers its power on the piston. Advantage of such technology is tolerance against higher moisture contents in material but the disadvantage is lower output (Chen et al., 2009). The density of both woody and non-woody briquettes ranges between 600 – 1,200 k.gm^{-3}. The calorific values differ with type of used material. In case of woody material it ranges between 16.5 – 18.5 MJ.kg^{-1} and in case of non-woody material the vale is around 19 MJ.kg^{-1}. Ash content is also higher in non-woody biomass (5 – 6%) while in woody briquettes is significantly lower (0.5 – 1.5%) (Andert et al., 2006).

All kinds of biofuels not only solid biomass fuels have several characteristics but the most important for solid biofuels among them are calorific value, density and mechanical durability. Calorific or heating value could be further divided on gross calorific value (GCV) or higher heating value (HHV) and on net calorific value (NCV) which is the same as lower heating value (LHV). GCV describes released heat during combustion including condensation heat from water vapour while it also considers that the water both original and process-generated was in condensed liquid state. NCV refers to the energy needed to evaporate the water not being accounted as useful heat and therefore is based on the consideration of water vapour as a product. Basically NCV is GCV minus vapour heat of water contained in flue gases and GCV is usually bigger than NCV (García et al., 2014).

Density of solid biomass fuels affects mainly strength, volume and shape. However in solid biofuels it mainly refers to energy density (bulk density plus calorific value) and is presented in kg.m^{-3} or kg.dm^{-3}. Energy density is significantly different through all kinds of solid biofuels (Chin et al., 2013). For example the energy density of briquettes from made from stalk plants is within 600 – 1,200 kg.m^{-3} and pellets from same material within 1,000 – 1,200 kg.m^{-3} (Andert et al., 2006). Mechanical durability is relevant only for briquettes and pellets because it refers to the ability of the product to stay intact and do not crumble during transportation or manipulation. The threshold for utilizable solid biofuel is 90% while every lower value fuel is not suitable (Kotlánová, 2010). The pressure and lignin contained in biomass are the main reasons that modern solid biofuels do not crumble.

Moreover lignin during briquetting or pelletizing acts as a binder and also forms that typical shiny surface which protects the biofuel from humidity (Lyčka, 2011).

2.2.4. Energy potential and utilization of vineyard waste

Grape vine or Vitis genus belongs to a flowering plant family *Vitaceae*. That family contains about sixty vining plants species which most of them originates from Northern hemisphere. *Vitis vinifera* is specie which is cultivated in Europe and in Central Asia and originates from Mediterranean region. After huge disaster in 1867 when parasitic insect *Phylloxera vitifoliae* (grape phylloxera) infested almost all European vineyards the resistant rootstocks have to be grafted onto those European varieties and now there are hundreds of such varieties which are derived from *Vitis vinifera* predecessor (Encyclopaedia Britannica, 2014). Vine could be eaten fresh (27% of global production) but it could be also dried (2% of global production) or most commonly it could be used for wine production (71% of global production) (FAO, 2014).

The majority of Vitis genus consists of lianas and vining plants. However Vitis is usually a woody plant which in vineyards is trained to grow on several kinds of support structure such as standard trellis, high trellis (Y-shape) or horizontal trellis or even without support structure trained as vase shape (Velázquez-Martí et al., 2011). According to Encyclopaedia Britannica (2014) grape climb by the structure using tendrils which are modified branches. If it is not trained and not pruned every year Vitis could grow to length of seventeen metres while in some dry regions it could grow as erect shrub. The leaves have tooth-edged shape are lobed and alternate on branches. The inflorescence of grape is small greenish flowers which form a cluster. The fruit is globural berry of many different colours (almost black, green, red, amber) with juicy pulp which contains the seeds. The fruit contains several minerals such as calcium or phosphorus and also vitamin A and sugar (glucose and fructose). The quantities of those constituents are based on Vitis variety. The varieties with higher volumes of glucose are most suitable for fermentation ergo wine production.

Vitis is propagated by cuttings, segments, canes or it is grafted. The vineyard could last for several decades mostly depending on natural condition. Although there are even hundred years old vineyards their yield does not reach of those from younger vineyards. The best climatic conditions for Vitis cultivation are long, dry and warm summers and cool winters while the vine adapted on several types of soils (FAO, 2014). Vine cane has to be also pruned every year in late winter or early spring when 90 – 95% of year´s growth is cut off (Velázquez-Martí et al., 2011). Countries with widespread vine cultivation are France, Italy, Spain, USA, South Africa, Chile, Argentina or Australia (FAO, 2014).

The area which is under vineyard cultivation is moving around the 8 mil. hectares worldwide (Spinelli et al., 2012). As it was already mentioned vineyards have to be pruned every year which provide quite a lot of woody biomass residues while both energy inputs and operational costs are relatively low (Muzikant et al., 2010). The quality and quantity of such biomass depends mainly on the variety but other factors such as type of support structure or type of vine training, age of vineyard, fruit yield and whether the grapes are used for fresh consummation or for wine production could also play a significant role (Velázquez-Martí et al., 2011). The quantity differs but generally it could be stated that one hectare of vineyard can produce an equivalent of at least one tonne of oven dry waste biomass (Spinelli et al., 2010). Unfortunately that biomass material is either piled and burned in field which is also the case of Moldova or used more meaningfully as mulch (Manios, 2004). Such waste utilization, both burning in field and mulching, is relatively uneconomic because it cost approximately 50 €.ha^{-1}. Moreover it does not provide almost any sort of revenue for the grower and burning in field is also not as environmental-friendly as burning the processed biomass in modern furnaces (Spinelli et al., 2010).

Throughout the history the vineyards have been pruned manually by pruning shears (Roquelaure et al., 2004). Although there is some progress in the field of modern mechanization of pruning process represented mainly by the universal machines or equipment for tractors in countries with cheap labour manual pruning with shears is still more widespread (Spinelli et al., 2012). However some progress was made even in improvement of hand-powered pruning shears especially in mitigation of negative effects of pruning operation on upper arm-shoulder system. The new type of shears is characterized by lateral and vertical inclination of the blades and a rotating lower handle which should diminish the discomfort and increase the efficiency of the worker (Roquelaure et al., 2004). There is also a difference in trimming of vine for fresh consumption and for wine production which affect the biomass yield where the former provide more biomass than the later but again depending on vine training (Velázquez-Martí et al., 2011).

As it is expressed in ***Table 4*** the yield of dry vine waste of selected varieties varies from 0.7 t.ha^{-1} and 5.1 t.ha^{-1} due to all earlier mentioned factors which would be yet further discussed. Data from ***Table 4*** were obtained in Mediterranean region more concretely in Spain vineyards and those data were broadened out by the data from Moldovan Southern vine region which has some similar features as the Mediterranean region. The other factors which were not mentioned in ***Table 4*** and which also affect the biomass yield are age of the vineyard and the grape yield. According to Velázquez-Martí et al. (2011) the age negatively affects the biomass yield. On the other hand the grape yield has positive effect on pruning waste material while the vineyards which produce more than 5 t.ha^{-1} of fruit has higher waste biomass yield than the ones with production below 5 t.ha^{-1}. Moisture content can also affect the yield of dry biomass basis and in case of vine residuals the content varies between 30 – 40% but in case of Moldova could be also much lower mainly due to dry climatic conditions (Muzikant et al., 2010).

However, currently the most expensive operation in relation of vineyard waste utilization is harvesting and transport of the biomass. Again, in poorer countries the material is handled manually but there are also several different types of vineyard waste harvesters which could be distinguished on the basis of waste manipulation on: square balers, round balers, comminuters with drop-down re-usable containers (big bags) and comminuters with build-in dumping bin. The cost for harvesting and processing the material ranges between 19.7 – 32.3 €.t^{-1} where the forwarding is excluded. The whole cost is very much affected by the forwarding while the increase of the distance from 3 to 6 kilometres could result in 25 – 50% higher total cost of the whole harvesting-processing operation (Spinelli et al., 2012). According to Zemánek (2012) the cost for one tonne of pressed vineyard waste in Czech conditions where the transport cost was also considered was equal to 1,220 Kč.

The vineyard waste biomass could be energetically utilized like any other woody biomass either burned non-processed or processed to briquettes and pellets. For processing of such material the vineyard waste should be dried, ideally naturally, to the moisture content 10 – 15%. The dry material could be than briquetted to shape and parameters according to European Standard norm. The utilization and standardisation of briquettes and pellets from vineyard waste would very much suitable for countries with widespread vine cultivation as Moldova and it could also made the vine cultivation more sustainable. It may also decrease the amount of imported energy and made Moldova more energetically secure.

Table 4.: Average yield of dry matter vineyard waste of selected varieties

Variety	Type of training	Purpose of cultivation	Region	Dry biomass yield [t.ha^{-1}]
Aledo	High trellis	Fresh fruit	Mediterranean	2.6
Aledo	Standard trellis	Fresh fruit	Mediterranean	1.9
Italia	Standard trellis	Fresh fruit	Mediterranean	2.9
Italia	Horizontal trellis	Fresh fruit	Mediterranean	5.1
Victoria	Standard trellis	Fresh fruit	Mediterranean	2.6
Red Globe	Horizontal trellis	Fresh fruit	Mediterranean	3.1
Bobal	Vase shape	Wine production	Mediterranean	1.2
Bobal	Standard trellis	Wine production	Mediterranean	1.3
Macabeo	Vase shape	Wine production	Mediterranean	1.7
Macabeo	Standard trellis	Wine production	Mediterranean	1.9
Shiraz	Vase shape	Wine production	Mediterranean	3.9
Shiraz	Standard trellis	Wine production	Mediterranean	1.4
Tempranillo	Vase shape	Wine production	Mediterranean	1.2
Tempranillo	Standard trellis	Wine production	Mediterranean	1.9
Sauvignon	Standard trellis	Wine production	Mediterranean	3.1
Sauvignon		Wine production	Moldova	2.1
Chardonnay	Standard trellis	Wine production	Mediterranean	2.8
Moscatel	Standard trellis	Wine production	Mediterranean	1.6
Monastrell	Standard trellis	Wine production	Mediterranean	1.1
Merlot	Standard trellis	Wine production	Mediterranean	2.5
Merlot		Wine production	Moldova	2.4
Traminer		Wine production	Moldova	1.4
Sucholimanskij		Wine production	Moldova	1.5
Muskat Jantarnij		Wine production	Moldova	0.7

Source: Velázquez-Martí et al., 2011 (Mediterranean); Muzikan et al., 2010 (Moldova)

III. AIMS OF THE THESIS

3.1. Main Aim

The main aim of this presented thesis is to determine and to analyze the energetic potential and the key energetic parameters of vineyard residues from pruning operation and to analyze the quality and main characteristics of solid biofuel made from those residues in the Republic of Moldova.

3.2. Specific Aims

The main aim is supported and supplemented by the specific aims which are set in order to help to fulfil the main objective and demonstrate the energetic potential of vineyard pruning residues in the Republic of Moldova. The specific aims are following:

- Estimation of potential yield of vineyard waste of four chosen varieties on vine plantation in Mereni Noi;
- Collection of desired vineyard biomass after pruning operation of those vine varieties, its treatment and conversion to standardized biofuel (briquettes);
- Measurement of main physical and mechanical characteristics of the material and produced vine briquettes and their comparison with most conventional woody material and biomass briquettes;
- Estimation of energetic potential from vineyard waste from pruning operation for Moldovan plantations;
- Calculation of energy balance of vine cane residues in the Republic of Moldova.

IV. MATERIALS AND METHODS

4.1. Materials

The biomaterial in form of freshly pruned vine cane was obtained on 7th of March 2015 and came from the experimental vineyard located on the north-east corner of the village Mereni Noi in Anenii Noi district in the Republic of Moldova. According to the vine growing regions experimental vineyard was established in the Codru region which is also known as Central region which lies in the similar latitude as Bordeaux and Burgundy vine region in France.

The experimental plantation was used for the reasons of growing new vine clones and for study purposes of students from State Agriculture University of Moldova and was part of the vine plantation which was managed by The Joint Stock Company Dionysos Mereni. Total area which belonged to that company was more than 200 hectares and experimental vineyard itself lied on 30 hectares. The experimental vineyard (further just vineyard) was found in 2005 and was 10 years old in the time of picking samples which applied for all vine varieties which were grown there. Those varieties were Chardonnay (white vine variety) which originates from the French region of Burgundy and is cultivated on most regions from all vine varieties. Apart from France that variety is largely spread in USA, mainly in California. Cabernet Sauvignon (red vine variety) also originates from France, although it is not certain from which region and it belongs among the four most popular red varieties in the world along with Merlot which was the third variety grown on experimental plantation. Merlot originates from Bordeaux region in France and is also widely spread in Italy and USA (California). The last variety grown on vineyard was Malbec (red vine varieties) which has its roots again in France. However, nowadays more than 70% of total area of that variety is located in Argentina (Encyclopaedia Britannica, 2014). All varieties belong among European vine varieties which are most widespread in Moldova and all four varieties were examined in this thesis.

The vineyard was situated on uniform slopes which were exposed to southern direction from 20 to 25 degrees and medium type of wiring with 0.8 m height of the woody stem. The soil was classified as sandy loam without any irrigation and the climate in the Anenii Noi district was mild and continental with warm summers and short winters with average

January temperatures -4°C and average July temperatures 22°C. The sum of precipitation ranges between 500 and 600 mm per year. All varieties were supported by standard trellis and were used only for wine production (***Figure 4***).

Figure 4.: Experimental vineyard at Mereni Noi: summer (left); winter (right)

Source: Tomáš Vacek, 2014; Alexandru Muntean, 2015

Firstly, the manually pruned biomass by shears was weighed in field on balance weights. A representative sample was collected from trees from three 4x4 m plots for each variety which places were randomly selected from the GIS system according to the methodology of Spinelli et al. (2012). By annual pruning mainly previous year´s fruiting branches were removed. The average yield of freshly pruned biomass per hectare of each variety was then extrapolated from the average yield of sample trees multiplied by the number of the trees per hectare. Additionally the dry biomass yield per hectare was calculated with the use of the formula (7) in Energy potential of pruned material for the Republic of Moldova subchapter.

4.2. Biofuel production and determination of its properties

First of all, according to the norm EN 14774-2 using the oven drying method the moisture content (**w**) in % of raw material was determined. For the purpose of that measuring was used the oven MEMMERT UNB-500 (Schwabach, Germany) which was equipped with programmable timer (***Figure 5***).

The working procedure: The empty steel container was weighed. After that approximately 50 g of the material cut to pieces of maximum length 1 cm was put in the container and the whole was weighed again using the laboratory scale KERN EW 3000-2M with accuracy up to 0.01 g. The container was then placed into the oven pre-heated on 105±2 °C and dried for at least 5 hours. After drying the container was removed from the oven and within 15 seconds weighed again to prevent absorption of moisture from the air. The moisture content (**w**) was then calculated by following formula (1):

$$\boldsymbol{w} = \frac{(\boldsymbol{m_2} - \boldsymbol{m_3})}{(\boldsymbol{m_2} - \boldsymbol{m_1})} * \mathbf{100};\ (\%) \tag{1}$$

where: m_1 – the weight of empty steel container for drying in **g**;
m_2 – the weight of the container with the sample material before drying in **g**;
m_3 – the weight of the container with the sample material after drying in **g**;

The results were calculated on 2 decimal places and for final statement were rounded on 0.1%.

Figure 5.: (left) oven MEMMERT UNB-500; (right) Mobile grinder Muréna I
Source: Tomáš Vacek, 2015; Alexandru Muntean, 2015

The raw material was then shredded for the first time to smaller particles by the Muréna I mobile grinder with optimal performance 5 m^3 of shredding per hour which was powered by small tractor (***Figure 5***). That operation was necessary for the second grinding operation because the hammer mill STOZA ŠV 7 was not able to process the whole branches and twigs in the first place. STOZA ŠV 7 was used to grind the pre-crushed feedstock to final 8 mm fraction. Both Muréna I mobile grinder and hammer mill STOZA ŠV 7 were located in SAUM (State Agrarian University of Moldova).

The process of drying was then accelerated in biomass drum dryer located in the village Lozova in Străşeni district, Moldova to reach the desirable moisture content of 15% and lower (***Figire 6***). Such operation was used only due to unfavourable weather conditions otherwise the natural drying process should be preferred as more economical and less energy demanding.

Dried and grinded material was then briquetted in SAUM according to the norm in the briquetting press Briklis BrikStar 50/12, which is the piston press with maximum operating pressure 180 bar, the input power of 5.4 kW and optimal performance 40 – 60 kg per hour (***Figure 6***).

Figure 6.: (left) Drum dryer; (right) Briquetting press Briklis BrikStar 50/12

Source: Tomáš Vacek, 2015; Alexandru Muntean, 2015

Ten randomly chosen briquettes from each variety were then measured with vernier callipers in diameter and their side length to obtain the average proportions. The same briquettes were also weighted with laboratory scales KERN EW 3000-2M for the purpose of the density analysis (**ρ**) which was calculated according to the following simple formula (2):

$$\boldsymbol{\rho = \frac{m}{V}; (kg.m^{-3})} \qquad (2)$$

where: m – weight of the briquette* in **g**;
V – volume of the briquette* in **cm^3**.

* the density was firstly computed to the g.cm^{-3} and later converted to kg.m^{-3} which represented the final result.

Determination of gross and net calorific value of the vine cane material was performed according to the norm EN 14918. Automatic calorimeter LAGET MS-10A with accessories was used for the purpose of calorific value analysis (***Figure 7***).

The principle of analysis of calorific value: The calorific value was determined by bomb calorimeter. Experimental sample of dried material of known weight (up to 1 g) was burnt in oxygen-present atmosphere in stainless steel high pressure vessel (bomb). That bomb with the sample material was placed in the calorimeter with known volume of water of known temperature. CO_2 and H_2O which were the products of combustion were allowed to cool down to standard temperature. The result heat of combustion was then established from the accurate measurement of the rise in the temperature of water in the calorimeter, the calorimeter itself and the container (Ivanova, 2012). The result of described method was the gross calorific value (**Q_{gr}**) which was calculated according to following formula (3):

$$\boldsymbol{Q_{gr} = \frac{dT_k * T_k - (c_1 + c_2)}{m}; (J.g^{-1})} \tag{3}$$

where: dT_k – temperature jump* in **°C**;
T_k – heat capacity of calorimeter = **9,000.59 J.°C^{-1}**;
c_1 – repair of benzoic acid = **20 J**;
c_2 – repair of the heat released by burning spark fine wire = **70 J**;
m – weight of material sample in **g**.

* calorimeter calculated the value of temperature jump automatically and the value was shown on its display after every measurement.

Net calorific value (**Q_{net}**) was calculated according to following formula (4):

$$\boldsymbol{Q_{net} = Q_{gr} - 24.42 * (w + 8.94 * H^a); (J.g^{-1})} \tag{4}$$

where: Q_{gr} – gross calorific value **J.g^{-1}**;
24.42 – coefficient corresponding to 1% of the water from the sample at 25°C;
w – water content in the sample in **%**;
8.94 – coefficient for conversion of hydrogen to the water;
H^a – hydrogen content in the sample* = **5.5%**

* the value of average hydrogen content in biomass (%) was used for calculation of Q_{net}.

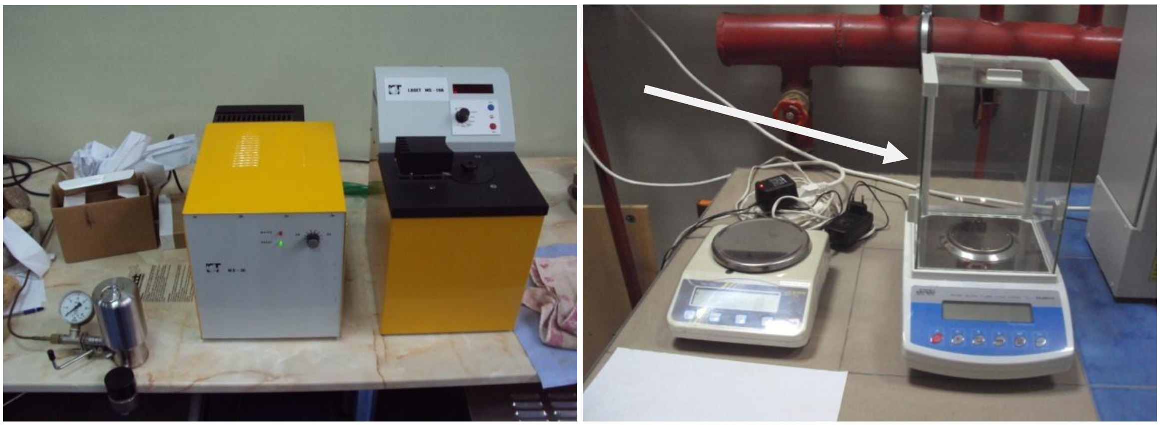


Figure 7.: (left) Calorimeter LAGET MS-10A; (right) Digital balance RADWAG AS 220/C/2

Source: Tomáš Vacek, 2015

The ash content of vine cane in water-free state was established as a mass of inorganic residues after burning the material in specific conditions and was formulated as a mass fraction according to the norm EN 14775. The laboratory muffle furnace LAC LH 06/13 (***Figure 8***), ceramic crucible, desiccator and digital balance RADWAG AS 220/C/2 with 0.0001g accuracy (***Figure 7***) were used during ash content measurement.

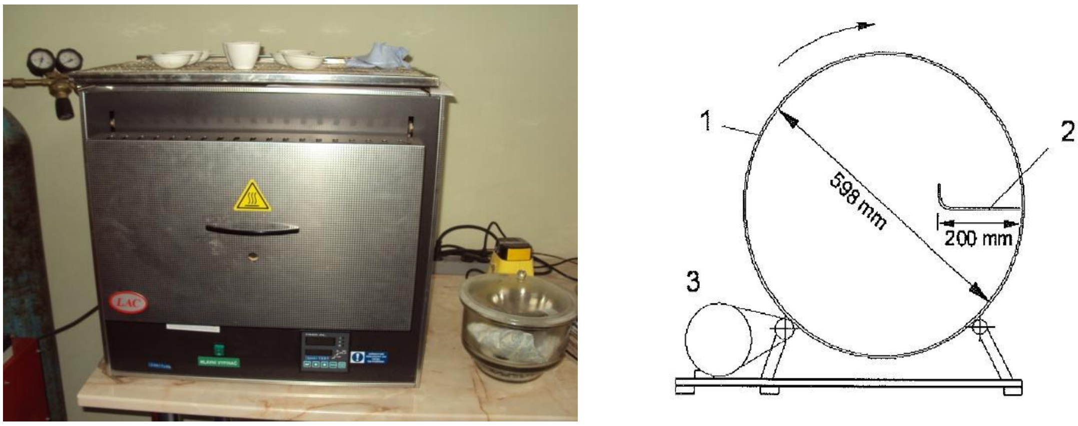


Figure 8.: (left) Muffle furnace LAC LH 06/13; (right) Abrasion drum

Source: Tomáš Vacek, 2015; ČSN EN 15210-2

The working procedure: The experimental sample with upper nominal dimension lower or equal to 1 mm was prepared according to CEN/TS 14780 with laboratory grinder. First the empty crucible was weighted on laboratory weights. Then minimum 1g of prepared experimental sample was equally spread at the bottom of the crucible and the whole was weighed again. The vessel with sample was placed into the furnace which was equally heated to 250°C for 30 till 50 minutes. That temperature was maintained for 60 minutes to release the volatiles. After that the temperature in the furnace was increased equally over

30 minutes till the 550±10°C was reached. That temperature was maintained at least 120 minutes. The crucible with the ash was then placed to desiccator to cool down for about 5 till 10 minutes to lab temperature. The vessel with the ash sample was weighed and the ash content (**A_d**) was calculated according to following formula (5):

$$\boldsymbol{A_d = \frac{(m_3 - m_1)}{(m_2 - m_1)} * 100}; (\%) \tag{5}$$

where: m_1 – weight of empty crucible in **g**;
m_2 – weight of crucible with experimental sample in **g**;
m_3 – weight of the crucible with ash in **g**;

The final ash content was stated as an average of three measurements for each vine variety and the result was rounded to the closest 0.1%.

The mechanical durability of produced briquettes was examined according to the norm EN 15210-2. For the measurement purposes was used steel cylinder-shaped abrasion drum with a nominal volume 160 litres (depth 598±8 mm, inner diameter 598±8 mm). The drum was equipped with rectangular steel partition (length 598±8 mm, height 200±2 mm) and was located in the CULS (Czech University of Life Sciences in Prague) (***Figure 8***).

The working procedure: Before the measurement samples of briquettes were prepared. Each sample of each type of briquettes (based on vine variety raw material) was weighed to reach the required total mass of 2 kg (±0.1 kg). The sample was then inserted into the drum and was rotated for 5 minutes on 21±0.1 revs per minute or for total of 105±0.5 revs. Inside the rotating drum the briquettes faced the partition which caused the abrasion. The mechanical durability (**DU**) was then established according to following formula (6):

$$\boldsymbol{DU = \frac{m_A}{m_E} * 100}; \ (\%) \tag{6}$$

where: m_E – weight of pre-sieved briquettes before insertion into the drum in **g**;
m_A – weight of sieved briquettes after the drum treatment in **g**.

All the data were subjected to statistical treatment and the software Statistica 12 was used for one-way ANOVA test and ANOVA post-hoc analysis in form of Tukey´s HSD test in cases of gross and net calorific values and ash content datasets.

4.3. Energy potential of pruned material for the Republic of Moldova

Energy potential was established on the basis of data and materials about vineyard areas in the Republic of Moldova and their structure according to varieties provided by The National Agency for Rural Development of Moldova (ACSA). The calculation of dry matter biomass yield per hectare (DM) of each of those four varieties was necessary for further analysis and was calculated according to the following formula (7) (Havrland et al., 2013):

$$\boldsymbol{DM = \left(\frac{100 - MC}{100}\right) * BY; (t.ha^{-1})} \tag{7}$$

where: MC – moisture content in **%**;
BY – biomass yield in $\mathbf{t.ha^{-1}}$.

The biomass gross energy yield (BEY) was then calculated on the basis of dry matter biomass and GCV of that respective vine variety. The BEY then described the total amount of energy which was stored in pruned biomass in GJ per hectare. To achieve the overall Moldovan energy potential (EP) in $TJ.year^{-1}$, the number was multiplied by the area on which, whether European white or European red varieties, are grown. All four examined vine varieties belong to European type of grapes for wine production and the information about the area was provided by ACSA. The BEY was achieved according to the following formula (8):

$$\boldsymbol{BEY = GCV * DM; (GJ.ha^{-1})} \tag{8}$$

4.4. Energy balance of vine cane residues in the Republic of Moldova

Energy balance of briquettes produced from vineyard residues was calculated on the basis of difference between energy inputs and energy outputs. The computation considered just the operations which are vital for utilization of such residual biomass. On the side of energy inputs the energy requirements of pruning the vine cane (human labour or machines) were excluded since it is the operation which has to be done every year no matter the further utilization of its residues. Artificial drying was also excluded since natural sun drying is more preferable due to lower financial and energy costs along with second grinding operation which was used just in case of this thesis. Therefore, only the energy inputs necessary for the collection and transport of the residues, grinding with

Muréna I Mobile grinder and final conversion to the briquettes were considered in the final energy balance calculation. The total energy invested was calculated according to following formula (9) (Kolaříková et al., 2014):

$$\boldsymbol{E_{IN} = E_1 + E_2 + E_3 + E_4; (MJ.ha^{-1})} \tag{9}$$

where: E_1, E_2, E_3 – direct energy invested in **MJ.ha^{-1}**;
E_4 – indirect energy invested **MJ.ha^{-1}**.

The total energy invested directly in biofuel production was computed as the amount of human labour (E_1), fossil fuels (E_2) and electricity (E_3) needed for the area or material from one hectare and multiplied by the corresponding energy equivalents (***Table 5***) using following formulas (10;11;12) (Kolaříková et al. 2014):

$$\boldsymbol{E_1 = S_{HL} * E_{HL}; (MJ.ha^{-1})} \tag{10}$$

where: S_{HL} – spent time of human labour per operation, per hectare in **h.ha^{-1}**;
E_{HL} – energy equivalent for one hour of human labour in **MJ.h^{-1}**.

$$\boldsymbol{E_2 = S_F * E_F; (MJ.ha^{-1})} \tag{11}$$

where: S_F – fuel consumption per material from one hectare, per operation in **l.ha^{-1}**;
E_F – energy equivalent for fuel in **MJ.l^{-1}**.

$$\boldsymbol{E_3 = S_{EL} * E_{EL}; (MJ.ha^{-1})} \tag{12}$$

where: S_{EL} – spent electricity per operation, per material form one hectare in **kWh.ha^{-1}**;
E_{EL} – energy equivalent for electricity in **MJ.kWh^{-1}**.

Table 5.: Energy equivalents conversion

Item	Unit	Energy equivalent	Source
Human Labour	1 h	2.3 MJ.h^{-1}	Preininger (1987)
Diesel	1 EQF*	35.8 MJ	Špička and Jelínek (2008)
Electricity	1 kWh	3.6 MJ.(kWh)$^{-1}$	Preininger (1987)
Steel	1 kg	25 MJ.kg^{-1}	Hill *et* al. (2006)

**diesel GCV together with energy consumed for extraction, transport and refining*

The total amount of indirect energy invested (E_4) was calculated on the basis of energy embodied in machines and equipments used. Such values were calculated for truck, grinder, small tractor and briquetting machine and were reached on the base of specification of weight, conversion equivalent (energy necessary to produce one kilogram of steel), maintenance coefficient, time spent on the operation, lifetime and annual use (***Table 6***). The indirect energy invested was calculated according to following formula (13) (Kolaříková et al., 2014):

$$\boldsymbol{E_4 = \frac{W * K_E * T_S * K_{RM}}{T_{WH}}; (MJ.ha^{-1})} \tag{13}$$

where: W – weight of the machine or equipment in **kg**;
K_E – conversion equivalent in **MJ.kg^{-1};**
T_S – time spent on the operation per material from one hectare in **h**;
K_{RM} – repairing and maintenance coefficient;
T_{WH} – total number of working hours per machine or eq. estimated life in **MJ.h^{-1}**.

Table 6.: Specification and coefficients for machines and equipment used

Machine/ equipment	Weight [kg]	Conversion equivalent[a]	Time spent on oper. [h][b]	Maintenance coefficient[c]	Estimated life [years][d]	Annual use [h][e]
Truck GAZ 53	3,250	95.7	0.2	2.0	10	1,800
Muréna I grinder	210	37.5*	2.43	2.0	10	720
Small tractor Cabrio 36 kW	1,186	95.7	2.43	2.0	12	1,800
BrikStar 50-12	790	37.5*	45	1.7	10	720

[a], [b], [c], [d], [e] Sources: Špička and Jelínek (2008), Mikkola and Ahokas (2010), Kolaříková et al. (2014)
** value calculated by Kolaříková et al. (2014)*

As the energy output the BEY per hectare was used in the final energy balance calculation. BEY indicator was based on the dry matter biomass yield per hectare (DM) which was calculated according to formula (7) and GCV calculated according to the formula (3). BEY itself was calculated according to formula (8).

Finally the EROEI (Energy returned on energy invested) or energy efficiency was calculated according to following formula (14) (Kolaříková et al., 2014):

$$\boldsymbol{EROEI = \frac{BEY}{E_{IN}}} \tag{14}$$

All computation within the energy balance calculations used mean values of BEY and yield of fresh and dry biomass from four examined vine varieties to reach the final statement.

V. RESULTS

5.1. Analysis of vineyard pruning residues yield

The total number of vine tree per hectare in Mereni Noi vineyard was calculated and approximated on 5,500 which is common number for small-scale production. Residual biomass yields of four examined vine varieties are shown in ***Table 7*** which contains the yield of fresh biomass and the yield of dry biomass per hectare. The dry biomass yield is usually considered as a better indicator of the residual biomass production and varies between 2.06 and 2.47 $t.ha^{-1}$.

Table 7.: Residual biomass yields of four vine varieties from Mereni Noi vineyard

Variety	Fresh residues per tree [kg]	Fresh biomass yield [$t.ha^{-1}$]	Moisture content [%]	Dry biomass yield [$t.ha^{-1}$]
Chardonnay	0.646	**3.55**	34.2	**2.33**
Cabernet S.	0.687	**3.78**	34.6	**2.47**
Malbec	0.666	**3.66**	41.7	**2.13**
Merlot	0.656	**3.60**	42.9	**2.06**

5.2. Analysis of biomass and biofuel properties

5.2.1. Moisture content

Moisture content was analysed on two samples from each variety. First samples were obtained from the mix of freshly collected twigs of diameter lesser than 10 mm and the second samples from the mix of branches of the diameter up to 30 mm which were pre-crushed on Muréna I mobile grinder. During the crushing process the woody material was also a bit heated by the working body of the machine which led to lower moisture content is the second sample. The results are shown in the ***Table 8*** and as it could be observed in both cases Merlot had the highest moisture content from four varieties.

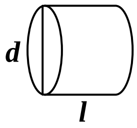
Table 8.: Moisture content of vineyard residues

Variety	MC of smaller twigs	MC of pre-crushed mixture
Chardonnay	34.2%	34.0%
Cabernet Sauvignon	34.6%	34.8%
Malbec	41.7%	34.1%
Merlot	42.9%	38.5%

5.2.2. Dimensions and the density of produced briquettes

The ***Table 9*** shows the average diameter and length of briquettes from each of four vine varieties. The differences in average diameters are small or none due to the same diameter of the pressing chamber of the briquetting machine. However, differences in average lengths are more notable due to the irregular quantities of material entering the piston press chamber likewise the situation with average weight. The density of produced briquettes varies between 774.2 and 793.3 kg.m^{-3}.

Table 9.: Parameters of produced briquettes with Standard deviation (±)

	Diameter (d) [cm]	Length (l) [cm]	Weight [g]	Density [kg.m^{-3}]
Chardonnay	6.74 ± 0.02	5.51 ± 0.55	144.51 ± 15.6	**777.4**
Cabernet S.	6.66 ± 0.03	5.22 ± 0.42	144.27 ± 16.17	**793.3**
Malbec	6.66 ± 0.03	4.89 ± 0.51	131.90 ± 13.5	**774.2**
Merlot	6.73 ± 0.04	5.15 ± 0.53	143.88 ± 11.93	**785.3**

5.2.3. Gross and net calorific values of the material

For each vine variety three samples of dried material were prepared for the analysis. The ***Table 10*** shows the resulting values of all measurements, the averages and standard deviations for gross and net calorific values. As it could be observed three varieties have very similar results, GCV over 20.5 MJ.kg^{-1}, the lowest value was reached on Merlot sample. The one-way ANOVA testified that there is also statistical difference in GCV between those four vine varieties (***Table 11***). As a post-hoc ANOVA analysis the Tukey´s HSD (honest significant difference) test was carried out. The result is the same, average GCV of Merlot varies significantly from the rest varieties at the level of confidence of 95%.

Table 10.: Gross calorific values of completely dried material

Variety	Sample 1 [J.g^{-1}]	Sample 2 [J.g^{-1}]	Sample 3 [J.g^{-1}]	Average ± SD [J.g^{-1}]
Chardonnay	20,639.9	20,467.5	20,653.4	**20,586.9 ± 84.7**
Cabernet S.	20,535.5	20,635.7	20,546.8	**20,572.7 ± 44.8**
Malbec	20,690.9	20,437.0	20,497.6	**20,541.8 ± 108.3**
Merlot	20,350.2	20,222.5	20,282.6	**20,285.1 ± 52.2***

* according to Tukey´s HSD test the average varies from each other at the level of significance α=0.05

Table 11.: ANOVA summary, GCV (independent samples, k = 4)

	Sum of Squares	df	Mean Square	F	Significance
Between groups	182,173.6	3	60,724.5	6.86	**0.0134**
Within groups	70,841.8	8	9,179.9		
Total	253,015.4	11			

The situation with net calorific values of dried material is the same, Cabernet S., Chardonnay and Malbec vary around 19.35 MJ.kg^{-1}, Merlot values are significantly lower with 19.08 MJ.kg^{-1}. The NCV was also calculated for the material with moisture content of 12% which is the actual amount of water in produced briquettes and the results are as expected, the lowest, Cabernet S., Chardonnay, Malbec very around 19.1 MJ.kg^{-1} and Merlot 18.8 MJ.kg^{-1}, which is presented in ***Figure 9***. One-way ANOVA test and Tukey´s HSD test proved the same significance of Merlot value difference at the level of confidence 95% as it is in GCV ANOVA analysis.

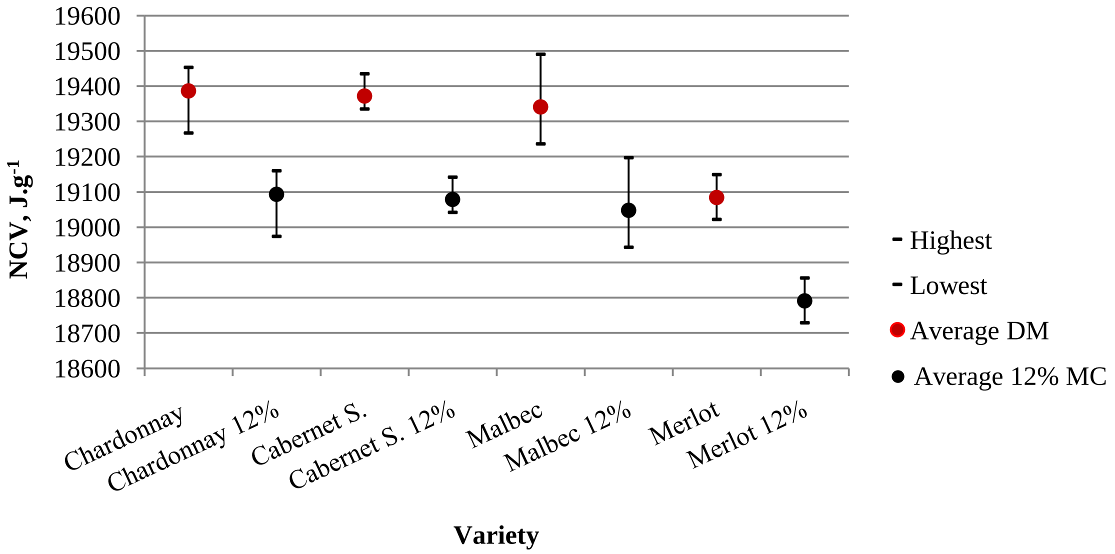


Figure 9.: NCV values of dried materials and materials with 12% moisture content (final briquettes)

5.2.4. Ash content of dried material

Analysis of ash content was performed on three samples of completely dried material from each variety. The resulting values are shown in ***Table 12***. The ash content of four investigated varieties varies between 3.95% and 4.9% and the one-way ANOVA test was conducted to analyse the significance of the differences (***Table 13***). The result of the test was that averages vary significantly and post-hoc Tukey´s HSD test showed that there is significant difference of ash content among each variety at the level of confidence 99%.

Table 12.: Ash content of dried material

Variety	Sample 1 [%]	Sample 2 [%]	Sample 3 [%]	Average ± SD [%]
Chardonnay	3.49	3.67	3.37	**3.51 ± 0.12***
Cabernet S.	2.79	2.99	3.06	**2.95 ± 0.11***
Malbec	4.41	4.39	4.30	**4.37 ± 0.05***
Merlot	4.92	4.86	4.93	**4.90 ± 0.03***

* according to Tukey´s HSD test the average varies from each other at the level of significance α=0.01

Table 13.: ANOVA summary, ash content (independent samples, k = 4)

	Sum of Squares	**df**	**Mean Square**	**F**	**Significance**
Between groups	6.824	3	2.275	193.34	< **0.0001**
Within groups	0.094	8	0.012		
Total	6.919	11			

5.2.5. Mechanical durability of produced briquettes

Each of vine varieties entered the abrasion drum in 2 kilogram batch and the mechanical durability was then calculated according to the given formula. The results of the test are shown in ***Figure 10***. The results are displayed in descending order. The lowest mechanical resistance was measured on the Cabernet Sauvignon sample with 77.7%. Merlot and Chardonnay show results also below 90% which is the minimum value stated by the norm, although minimum mechanical durability allowed could be further established. Only Malbec, one of the red vine varieties, fulfilled the given condition with mechanical durability of 91.6%.

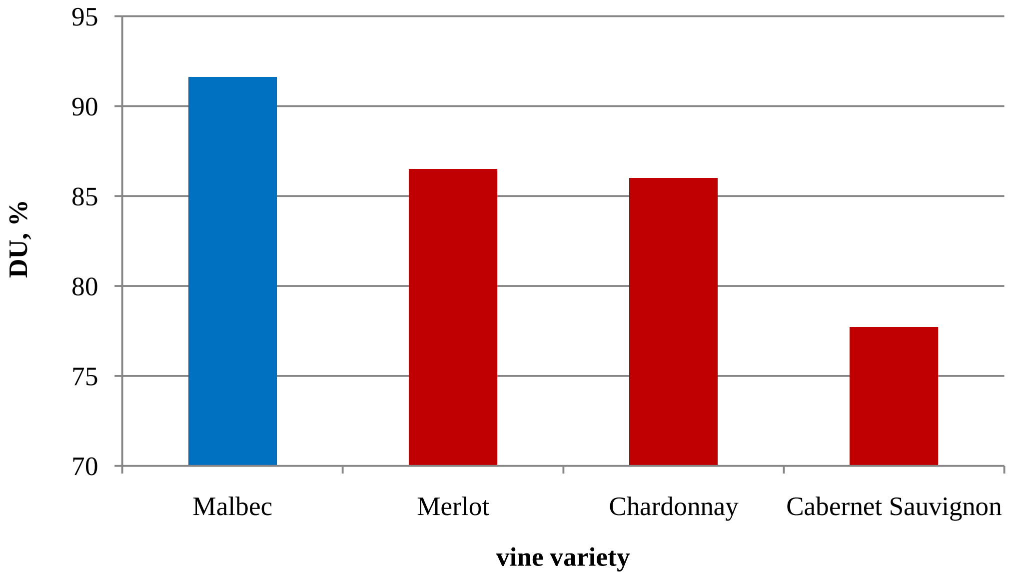


Figure 10.: Mechanical durability of produced briquettes

5.3. Analysis of energy potential of pruned material for the Republic of Moldova

Overall net energy potential of vineyard pruning residues for Moldova is based on the data provided from ACSA about the area of European varieties distribution and their size. While in the latest available vineyard survey only white European and red European varieties could be distinguished and not the particular varieties the resulted BEY of each examined variety was multiplied by the area of that respective type. The area of white European varieties grown in Moldova is 34,421 ha and area of red European varieties is 16,909 ha (Statistica Molodvei, 2011). The final results are shown in ***Table 14*** where the highest energy potential (EP) has the scenario when all area of white European vine varieties would be grown with Chardonnay.

Table 14.: Overall energy potential of vineyard waste for the Republic of Moldova

Variety	Average NCV DM [MJ.kg^{-1}]	DM yield [t.ha^{-1}]	BEY [GJ.ha^{-1}]	Overall EP [TJ.year^{-1}]
Chardonnay	19.39	2.33	45.17	**1,554.8**
Cabernet S.	19.37	2.47	47.85	**809.1**
Malbec	19.34	2.13	41.20	**696.7**
Merlot	19.08	2.06	39.31	**664.7**

5.4. Analysis of energy balance of vine cane residues in the Republic of Moldova

The energy inputs for respective operation necessarily required for production of briquettes from vineyard residues are shown in ***Table 15***. The most demanding process is briquetting which alone stands for 60% of all energy requirements whilst the human labour demands the minimum energy of 23 MJ.ha^{-1}. The overall number was calculated for the mean values from examined vine varieties and reached 2,153.54 MJ.ha^{-1} (7% human labour, 77% fuels and 16% energy embodied in machines). The energy efficiency, the EROEI, was calculated to 20.18 as well for the mean value of BEY, which reached 43.38 GJ.ha^{-1} and represented the gross energy output, from all tested vine varieties.

Table 15.: Energy requirement of certain briquette production operations

Operation	Human Labour (E_1) [MJ.ha^{-1}]	Fuels (diesel, electricity) (E_2, E_3) [MJ.ha^{-1}]	Machines (E_4) [MJ.ha^{-1}]	Total energy requirements (E_{IN}) [MJ.ha^{-1}]
Collecting	23			23
Transport	0.46	85.92	6.91	93.29
Grinding	11.18	697.03	35.97	744.18
Briquetting	103.5	874.8	314.77	1,293.07
Sum	**138.14**	**1,657.75**	**357.65**	**2,153.54**

VI. DISCUSSION

6.1. Vineyard pruning residues yield and it's potential for the Republic of Moldova

The Republic of Moldova has very limited sources of fossil fuels and in that way the country is dependent on the energy import mainly from Russia and former Soviet republics (Karakosta et al., 2011). The situation in the field of renewable energy resources was described in literature review with the statement of high potential of biofuels from biomass due to fertile soils and favourable climate (Gorton, 2001).

Wine production and vineyards play a big role in Moldovan agriculture and export. The energy utilization of the woody residual waste which is generated by every year pruning operation can represent an improvement in the county´s energy situation. However, vineyard waste is still mainly burned directly next to vineyards, used as a mulching or the smallest twigs are even let to decompose which takes a lot of time. Therefore, the utilization of the vineyard residues for the solid biofuel production can be considered as a most effective way how to manage the vine waste due to certain benefits which biofuel represents.

The yield of the freshly pruned biomass waste was in this thesis approximated within the range of 3.60 and 3.78 $t.ha^{-1}$ where Cabernet Sauvignon has the highest yield. In the research of Spinelli et al. (2012), conducted in Northern and Central Italy vineyards, the average yield per hectare of four varieties (Cabernet, Merlot, Prosecco, Verduzzo) was quite lower, 2.0 $t.ha^{-1}$. However the highest yielding variety was the same, Cabernet with 2.56 $t.ha^{-1}$. Another study from Italian region from Spinelli et al. (2010) was more focused on the mechanization of the pruning and collection process but the yield was also calculated and again reached lower average value, 2.1 $t.ha^{-1}$ of fresh biomass. The reason for lower yields in both Italian cases could be caused by the higher altitudes of vineyards location. On the other hand the average yield of fresh vineyard waste in southern Moldovan regions (Albota, Taraklija) which was established in dissertation thesis of Muzikant (2010) fits with the yield 3.66 $t.ha^{-1}$ within the range of this thesis. The examined varieties of Muzikant (2010) research were Sauvignon, Muskat Jantarnij, Traminer, Merlot and Sucholimanskij, where Merlot had the highest yield of 5.47 $t.ha^{-1}$.

The yield of dried biomass was in this thesis approximated between 2.06 and 2.47 $t.ha^{-1}$ where Cabernet Sauvignon again reached the highest digit. Once mentioned research of Spinelli et al. (2012) established the yield of dry residual material on 1.13 $t.ha^{-1}$. The average yield of dry residual matter per tree in this thesis was calculated on 0.41 kg. That digit is in sharp contrast with the research of Velázquez-Martí et al. (2011) conducted on the Spanish Mediterranean coast. The average yield of dry vine cane waste per tree was in that study established on 1.53 kg. However, the average dry matter biomass yield per hectare in the same study reached 2.59 $t.ha^{-1}$ which is just slightly over the range calculated in this thesis. The reason for such different results in yield per tree and on the other hand close results in yield per hectare might be caused by the different training and wiring of the vine cane and different arrangement of the whole plantations. Where in the Spanish case the inter-row and inter-tree spacing was broader which led to bigger trees but lower number of specimen per hectare the situation on vineyard in Mereni Noi was the opposite.

The comparison with other woody crops which are dedicated mainly to energy production, poplar and willow, is in terms of dry matter biomass yield rather unfavourable towards pruned vine cane waste. As in their study Carmona et al. (2015) pointed out the poplar yield can vary between 1.57 and 47.7 $t.ha^{-1}$ of dry biomass. The willow tree according to Stolarski et al. (2013) can produce in average 14.1 $t.ha^{-1}$ of dry woody matter which is six time higher digit than the average yield of vine varieties examined in this thesis.

6.2. Qualities and characteristics of the residual material and produced briquettes

The initial moisture content of freshly pruned vine cane was in this thesis measured between the range 34.2% of Chardonnay and 42.9% of Merlot. According to Muzikant (2010) the average water content in Moldovan pruning residues was established on the level of 34.3% with high disparity between the maximum of Merlot 41.8% and minimum of Muskat Jantarnij 25.8%. Contrasting to those two researches in Moldova stands the study of Spinelli et al. (2012) with the mean moisture content pruned cane 42.9%.

The density of the briquettes produced from vineyard waste varied between 774.2 and 793.3 $kg.m^{-3}$. Such values put the produced briquettes below the DE0.8 category according to the norm EN 14961-1 which is the lowest category for briquettes. That finding is nearing with the one of Muzikant (2010) who measured the density of briquettes only from shredded residual material on 720 $kg.m^{-3}$ while the briquettes produced from mix of two materials (shredded vine cane – hay, shredded vine cane – straw) resulted in lower density than 700 kg.m^{-3}. According to Brožek et al., (2012), the density of briquettes from woody biomass oscillated around 760 kg.m^{-3} which is again similar result as those presented in this thesis. According to Muntean et al. (2012) briquettes produced by piston presses generally have lower density than the briquetted produced by screw presses-extruders.

Gross calorific values of completely dried vine cane waste were in this thesis calculated separately for each variety. There was no significant difference among Cabernet S., Chardonnay and Malbec varieties which ranged between 20.54 and 20.59 MJ.kg^{-1}. Small but statistically significant difference was found in the red variety samples of Merlot, which resulted in 20.29 MJ.kg^{-1}. According to the Spinelli et al. (2012) research the average GCV of Italian vineyard residues was established on 18.7 MJ.kg^{-1} with very little variance among examined samples, however only the Merlot variety was subjected to the GCV analysis. In comparison with the results of this thesis the average value is obviously lower. Nevertheless Spinelli et al. (2012) also stated in his paper that concerning the gross calorific value the vineyard waste represents rather homogenous fuel. Even lower digits stated in his study concerning Spanish biomass waste García et al. (2012) which on the other hand distinguished four different types of vineyard waste and it's GCV. The resulting values were following: vine shoot chips (14.63 MJ.kg^{-1}), grapevine waste (16.47 MJ.kg^{-1}), vine orujillo (17.74 MJ.kg^{-1}) and vine shoot waste (13.29 MJ.kg^{-1}). The reason for such difference between the values stated in this thesis and the ones of García et al. (2012) could be higher moisture content of samples in Spanish case.

The comparison of gross calorific values with once already mentioned energy crops, poplar and willow was as follows. According to Carmona et al. (2015) the GCV of poplar of different clones ranged within 17.69 and 20.75 MJ.kg^{-1} which also proved that the range of values could be very broad just among clones of one crop grown in one state, in that case in Chile. Stolarski et al. (2013) in the study concerning willow measured the average GCV of the crop on 19.33 MJ.kg^{-1}. In both mentioned studies the material was dried.

The net calorific value of oven dried material was in this thesis calculated within the range 19.34 and 19.39 MJ.kg^{-1} for Cabernet S., Chardonnay and Malbec and 19.08 MJ.kg^{-1} for Merlot. Since NCV represents the usable amount of energy stored in material the calculation was made also for produced briquettes with the moisture content of 12%. Such NCV resulted again in significantly different values Cabernet S., Chardonnay and Malbec which ranged between 19.05 and 19.09 MJ.kg^{-1} and for Merlot whose NCV was 18.79 MJ.kg^{-1}. Those values put the produced briquettes in the class A1 because presented calorific values exceeded the 15.5 MJ.kg^{-1} threshold given by norm EN 14961-1. Class A1 is the highest in such matter. The second set of net calorific values will be also used in comparisons with other studies and sources. Muzikant (2010) in his dissertation thesis established the NCV of vine cane scrap briquettes produced in Moldova on 16.2 MJ.kg^{-1} in average which is quite lower value. Somewhere in between the values of this thesis and values from Muzikant (2010) ranks the NCV values of commonly managed vineyard residues measured by Picchi et al. (2013) in Trento province, Italy. In their study the net calorific value of completely dried material was calculated on 17.82 MJ.kg^{-1} and the value for green material of moisture content 27.55% was established on 15.03 MJ.kg^{-1}. However, neither Spinelli et al. (2012) nor García et al.(2012) did not calculated the net calorific values of vineyard residues in their respective studies.

In cases of NCV of poplar and willow only Stolarski et al. (2013) examined this parameter on the second mentioned energy tree. However, the result of the measurement given in their study is more than two times lower while reaching the value of 9.13 MJ.kg^{-1} in fresh matter. Such very low number was very much affected by the high moisture content of the fresh biomass which was in average 46.9%. In their research Telmo and Lousada (2011) examined the NCV of different trees in Portugal and the results of chosen species were following (moisture content 10%): *Pinus pinaster* (16.94 MJ.kg^{-1}), *Eucalyptus globulus* (14.41 MJ.kg^{-1}), *Bowdichia nitida* (17.91 MJ.kg^{-1}) *Acer pseudoplatanus* (15.62 MJ.kg^{-1}). From non-woody biomass, straw, which is widely used for briquetting reached the value 15.58 MJ.kg^{-1} according to Muzikant (2010).

Since net calorific value is more representative digit than GCV in terms of usable energy stored in material the comparison with fossil fuels values presented in International Energy Agency (2015) is shown. The NCVs of following mostly used non-renewable sources of energy are much higher than any king of woody biomass vine cane residues including: gasoline (44.75 MJ.kg^{-1}), coal (29.31 MJ.kg^{-1}) natural gas (45.75 MJ.kg^{-1}).

The ash content of vineyard waste presented in this thesis was established within the range 2.95% of Cabernet Sauvignon and 4.9% of Merlot where the statistical difference between all varieties was calculated with the 99% level of confidence. That finding in the mean value converges to the finding of Muzikant (2010) who established the ash content of vine cane scrap to 3.46%. Presented values of ash content fit in the range established by the norm EN 14961-1 and put the cabernet Sauvignon in the category A3.0 while the three other varieties in category A5.0. Those values are quite higher and only category A3.0 can be considered as class B of briquettes which is the lowest class. Very similar value was also reached in the study of Picchi et al. (2013) on vine residues in Italy where the share of ash was 3.8%. However, considerably higher values were established in study of García et al. (2012) concerning Spanish residual biomass. Ash content of vine shoot chips (9.7%), grapevine waste (13.3%), vine orujillo (12.7%) and vine shoot waste (4.1%) was significantly higher than in presented thesis.

From the other woody biomass García-Maraver et al. (2014) examined the ash content of olive tree where the value for pruned material (branches with leaves) reached 6.34% and branches (without leaves) 3.78% which corresponds to the vine woody material studied in this thesis. Poplar ash content varies between 2.05% and 3.40% according to Carmona et al. (2015) and willow tree examined in research of Stolarski et al. (2013) had the share of ash particles on the level of 2.10%.

The mechanical durability of produced briquettes presented in this thesis is rather poor caused by the transportation from Chisinau to Prague by the bus. Only Malbec variety with durability 91.6% reached the minimum value established by the norm EN 14961-1. Other varieties were below 90%. Although the different type of mechanical durability Muzikant (2010) in his thesis tested the destruction force needed to break the briquette and in case of vine cane shredding established the value on the number 25.53 $N.mm^{-1}$. However, none of the other studies concerning the characteristics of vine cane residues did not consider converting the material to briquettes therefore there is no comparison to that matter. However, according to Zhang and Guo (2014) stated in their study concerning briquettes fabricated from the *Caragana korshinskii* Kom. that with decreasing fracture of the material the mechanical durability increases. The same effect has the decreasing moisture content and for bigger fractures also the increasing temperature of the briquetting process.

6.3. Energy potential of pruned material for the Republic of Moldova

The results of presented energy potential are just scenarios which presume that the all area currently grown with all white or all red European varieties would be grown with just one particular variety examined in this thesis. The highest overall energy potential of

1,554.8 TJ.year^{-1} reached the residues of Chardonnay and the lowest potential 664.7 TJ.year^{-1} reached Merlot. Such disparity between white variety and the red varieties was caused by more than two time larger areas cultivated with white European varieties. Considering the overall 2013 Moldovan energy consumption 97,228 TJ.year^{-1} (Statistica Moldovei, 2014) the highest potential of Chardonnay would cover 1.6% and the lowest potential of Merlot would cover 0.68% of that particular year energy consumption. Chiriac et al. (2012) in his study concerning years 2009 and 2010 also estimated the energy potential of vineyard residues as a mixture of all grown Moldovan varieties in households and enterprises with area of 10 or more hectares of plantations. The total area of such defined vineyards was very similar (around 30,000 ha) to the area of all white European varieties considered in this thesis. However, the estimated energy potential value presented by Chiriac et al. (2012) was 424.2 TJ.year^{-1}. The reason for such huge difference, considering the similarity of planted areas, is in more than two times lower yield of dry residual waste (maximum 1.1 t.ha^{-1}) and considerably lower calorific value (15 MJ.kg^{-1}) with which Chiriac et al. (2012) calculated. The same author also estimated the energy potential of Moldovan orchard residues on 659 TJ.year^{-1} and overall agricultural and forestry biomass energy potential on 21,042.1 TJ.year^{-1} which would in the year when the research was conducted, in 2010, mean the 22% coverage of all Moldovan energy consumption.

The comparison with other studies is difficult due to different size of target areas which are mostly very small or by different crops examined. However, Roberts et al. (2015) estimated the energy potential of woody forest residual biomass for small coastal region (1,492 km^2) in Argentina as 497.5 TJ.year^{-1} which was equal to 19% of all residual biomass energy potential for that particular region. The highest energy potential in that study had herbaceous plants which was in accordance with research of Chiriac et al. (2012) in Moldova. To similar conclusion came also Fernandes and Costa (2010) conducted in small Portuguese region of the size of 154.9 km^2 who stated that agricultural waste, mainly herbaceous, represents higher energy potential. However, the comparison of those two studies with the situation presented in this thesis is unequivocal due to the size and focus of those two mentioned study regions to agricultural, mainly herbaceous production.

6.4. Energy balance of vine cane residues in the Republic of Moldova

Energy balance or energy efficiency has not been calculated yet in available resources for woody residual biomass such as vineyard waste. Therefore, the presented EROEI value 20.18 cannot be compared to similar material. However, Kolaříková et al. (2014) in her study examined the energy balance of hemp cultivated in Moldova for energy purpose. The energy inputs for all operations necessary for briquettes production from such hemp were in her study almost ten times higher. Such difference is caused by much higher yield of technical hemp per hectare and by additional energy expensive operations such as sowing or ploughing. The energy efficiency of hemp cultivated in Moldova was in her study established on 13.1 for the hemp cultivar Bialobrzeskie and 12.6 for the cultivar Ferimon. Given those two values presented by Kolaříková et al. (2014) it could be stated that EROEI of vineyard residues of 20.18 is considerably higher. According to Murphy (2011), the EROEI threshold is located roughly around 8. The reasons for such high difference are hidden in residual nature of vine cane waste, where ploughing, sowing or vast utilization of fertilizers is not required. High calorific value of residual material presented in this thesis also significantly added to such difference. Rosenberger *et* al. (2001) examined the output and input ratio for bioethanol production from winter cereals. The ratio for bioethanol production from winter triticale, winter wheat and winter rye reached values many times lower, ranging around 3 which is considerably lower than the EROEI presented in this thesis. However, the bioethanol production process consists from more energy demanding operations such as distillation and that is the reason for such low values in Rosenberger et al. (2001) study performed in Germany.

Economic balance calculation was not part of this thesis however it is important to mention the observation and results presented in the research of Spinelli et al. (2010) who investigated the cost of pruning residues processing in Italy. The conclusion of his study was that the difficulties bounded to specific nature of vineyards prevents to efficiently utilize the common agricultural machinery which has to be substituted by relatively simple implements attached to vineyard small tractor which results to relatively low collecting or harvesting productivity. On the other hand Spinelli et al. (2010) also stated that the operating cost of those units results in moderate harvesting-processing costs. However, as the most cost demanding operation was established the forwarding to collection point which considerably increases the final cost of recovery.

VII. CONCLUSIONS

Based on the presented research, analysis and data calculation the following set of conclusions could be stated:

- The vineyard residual biomass yield, of both fresh and dry, is relatively high on the territory of the Republic of Moldova reaching in ranges of 3.55 – 3.78 $t.ha^{-1}$ and 2.06 – 2.47 $t.ha^{-1}$ respectively. Considered as a waste biomass such quantities can represent sufficient amount of material for further efficient utilization, such as for energy purposes.
- The characteristics of the material examined according to the European norms are predominantly suitable for further energy use. The net calorific values ranged between 19.08 $MJ.kg^{-1}$ and 19.39 $MJ.kg^{-1}$ of dried material and between 18.79 $MJ.kg^{-1}$ and 19.09 $MJ.kg^{-1}$ of material with moisture content 12% with statistically significant differences at the 95% level of confidence between examined varieties. Such NCV values are mostly well over the other biomass material either woody or non-woody. The ash content is on the other hand slightly higher than in non-woody biomass. However, the presented range of ash content (2.95 – 4.9%) is in accordance with most other woody biomass, even though material with ash content lower than 3% is preferred by norms. The mechanical durability is considered rather poor when just one variety (Malbec) reached over the 90% threshold.
- The energy potential for the Republic of Moldova is relatively high. Considering the highest value of EP of Chardonnay (1,554.8 $TJ.year^{-1}$) which can cover up to 1.6% of energy consumption. Taking that low percentage from the perspective that the material is residual biomass from one crop and originates just on the quarter of Moldovan vineyard acreage, 1.6% can be viewed as rather substantial share of energy consumption which could be cover by such waste.
- Energy balance expressed by the EROEI index which reached 20.18 was very positive. Such result is again caused by the residual nature of vineyard waste where no excessive energy use is needed for the material utilization.
- Considering Moldovan unfavourable energy situation given by most energy being imported and negligible fossil fuel deposits or reserves vineyard waste utilization represents a suitable and sustainable energy solution for improvement of such state.

VIII. RECOMMENDATIONS

Based on presented conclusion and some data limitation of this thesis the following recommendations could be stated:

- Energy utilization of vineyard waste is highly recommended due to its high calorific values and sufficient yield per hectare which would alter the current state of burning such material ineffectively in the field. Such step would improve Moldovan situation concerning energy sector.
- Further research concerning energy potential of respective vine varieties is recommended due to availability of more detailed vineyard register starting in Moldova with the year 2016 (as an output of Czech Development Cooperation project).
- Further research concerning the economic suitability and a cost and benefit analysis is also recommended. Such aspect is also vital for income poor country such as Moldova.

IX. REFERENCES

Acherjee TC, Coronella CC, Vasquez VR. 2011. Effect of thermal pretreatment on equilibrium moisture content of lignocellulosic biomass. Bioresource Technology 102: 4849-4854.

Aïssa MSB, Jebli MB, Youssef SB. 2014. Output, renewable energy consumption and trade in Africa. Energy Policy 66: 11-18.

Al-mulali U, Fereidouni HG, Lee JYM. 2014. Electricity consumption from renewable and non-renewable sources and economic growth: Evidence from Latin American countries. Renewable and Sustainable Energy Reviews 30: 290-298.

Alakangas E, Valtanen J, Levlin J. 2006. CEN technical specification for solid biofuels — Fuel specification and classes. Biomass and Bioenergy 30: 908-914.

Andert D, Sladký V, Abrham Z. 2006. Energetické využití pevné biomasy. Praha. Výzkumný ústav zemědělské techniky, v.v.i. Praha 6 Ruzyně. 59 p.

Baláš M, Moskalík J. 2011. Měření vlhkosti paliv. Available at http://biom.cz/cz/odborne-clanky/mereni-vlhkosti-paliv: Accessed 2014-03-07.

Bakhtyar B, Sopian K, Sulaiman MY, Ahmad SA. 2013. Renewable energy in five South East Asian countries: Review on electricity consumption and economic growth. Renewable and Sustainable Energy Reviews 26: 506-514.

Barros CP, Gil-Alana LA, Payne JE. 2013. U.S. Disaggregated renewable energy consumption: Persistence and long memory behavior. Energy Economics 40: 425-432.

Batt J. 2003. The EU´s new borderlands. London: Centre for European reform. 59p.

Bohlin F, Vinterbäck J, Wisniewski J, Wisniewski J. 1998. Solid biofuels for carbon dioxide mitigation. Biomass and Bioenergy 15: 277-281.

Boute A, Willems P. 2012. RUSTEC: Greening Europe’s energy supply by developing Russia’s renewable energy potential. Energy Policy 51: 618-629.

Brožek M, Nováková A, Kolářová M. 2012. Quality evaluation of briquettes made from wood waste. Research Agronomy Engineering 58 (1): 30-35.

Czech Business Web Portal. 1997. Moldavsko: Ekonomická charakteristika země. Available at http://www.businessinfo.cz/cs/clanky/moldavsko-ekonomicka-charakteristika-zeme-19036.html#sec5: Accessed 2014-02-03.

Cantir C. 2011. The parliamentary election in the Republic of Moldova, November 2010. Electoral Studies 30: 880-883.

Carmignani F. 2007. A note on income converge effects in regional integration agreements. Economics Letters 94: 361-366.

Carmona R, Nuñez T, Alonso MF. 2015. Biomass yield and quality of an energy dedicated crop of poplar (Populus spp.) clones in the Mediterranean zone of Chile. Biomass and Bioenergy 74: 96-102.

Crowther WE, Matonyte I. 2007. Parliamentary elites as a democratic thermometer: Estonia, Lithuania and Moldova compared. Communist and Post-Communist Studies 40: 281-299.

Czech Development Cooperation. 2009. Roads of the Czech development cooperation – Moldova [CD/DVD]. Prague: Czech Republic Development Cooperation.

Czech Development Cooperation. 2010. Development Cooperation Programme: Moldova 2011 -2017. Prague: Czech Republic Development Cooperation. 17 p.

Doshi P, Srivastava G, Pathak G, Dikshit M. 2014. Physicochemical and thermal characterization of nonedible oilseed residual waste as sustainable solid biofuel. Waste Management 34: 1836-1846.

Eastern Partnership Community (EaP). 2010. Moldova. EaP. Available at http://www.easternpartnership.org/partner-states/moldova: Accessed 2014-01-15.

Economist Intelligence Unit. 2013. Democracy index 2012: Democracy at a standstill. New York: The Economist. 45 p.

EN 14774-2. 2010. Solid biofuels – Determination of moisture content – Oven dry method – Part 2: Total moisture – Simplified method. Prague. Research Institute of Agricultural Technology, v.v.i. 12p.

EN 14775. 2010. Solid biofuels – Determination of ash content. Prague. Research Institute of Agricultural Technology, v.v.i. 13p.

EN 14918. 2010. Solid biofuels – Determination of calorific value. Prague. Research Institute of Agricultural Technology, v.v.i. 52p.

EN 14961-1. 2010. Solid biofuels – Fuel specifications and classes – Part 1: General requirements. Prague. Research Institute of Agricultural Technology, v.v.i. 53p.

EN 15210-2. 2010. Solid biofuels – Determination of mechanical durability of pellets and briquettes – Part 2: Briquettes. Prague. Research Institute of Agricultural Technology, v.v.i. 12p.

Encyclopaedia Britannica. Not dated. Moldova quick facts. Available at http://www.britannica.com/topic/388005/Moldova-quick-facts: Accessed 2014-01-14.

Encyclopaedia Britannica. Not dated. *Vitales*. Available at http://www.britannica.com/EBchecked/topic/1443059/Vitales: Accessed 2014-03-05.

EU External Action. Not dated. Moldova. Available at http://eeas.europa.eu/moldova/index_en.htm: Accessed 2014-02-02.

European Commission. 2005. EU/Moldova Action Plan. Brussels: European Commission. 46 p.

European Commission. 2012. Implementation of the European Neighbourhood Policy in the Republic of Moldova – Progress in 2011 and recommendations for action. Brussels: European Commission. 16 p.

European Union. 1998. Partnership and Cooperation Agreement. Brussels: Official Journal of the European Union. 53 p.

European Union. 2003. Directive 2003/30/EC of the European parliament and of the council of 8 May 2003 on the promotion of the use biofuels or other renewable fuels for transport. Brussels: Official Journal of the European Union. 5p.

FAO. 2014. FAOSTAT: Republic of Moldova. Available at http://www.fao.org/countryprofiles/index/en/?iso3=MDA: Accessed 2014-02-02.

FAO. 2014. FAOSTAT: Production – Crops. Available at http://faostat3.fao.org/faostat-gateway/go/to/browse/Q/QC/E: Accessed 2014-03-08.

Fang Y. 2011. Economic welfare impacts from renewable energy consumption: The China experience. Renewable and Sustainable Energy Reviews 15: 5120-5128.

Feige EL, Urban I. 2008. Measuring underground (unobserved, non-observed, unrecorded) economies in transition countries: Can we trust GDP?. Journal of Comparative Economics 36: 287-306.

Fernandes U, Costa M. 2010. Potential of biomass residues for energy production and utilization in a region of Portugal. Biomass and Bioenergy 34: 661-666.

Freedom House. Not dated. Moldova. Available at http://freedomhouse.org/country/moldova#.VCKdW5R_uVH: Accessed 2014-01-19.

García R, Pizzaro C, Lavín AG, Bueno JL. 2012. Characterization of Spanish biomass wastes for energy use. Bioresource Technology: 249-258.

García R, Pizarro C, Lavín AG, Bueno JL. 2014. Spanish biofuels heating value estimation. Part I: Ultimate analysis data. Fuel 117: 1130-1138.

García-Maraver A, Teron LC, RAmos-Ridao A, Zamorano M. 2014. Effects of mineral contamination on the ash content of olive tree residual biomass. Biosystems Engineering 118: 167-173.

Gilmore AB, Radu-Loghin C, Zatushevsni I, McKee M. 2005. Pushing up smoking incidence: plans for a privatised tobacco industry in Moldova. Lancet 365: 1354-1359.

Gorton M. 2001. Agricultural land reform in Moldova. Land Use Policy 18: 269-279.

Gorton M, Dumitraskho M, White J. 2006. Overcoming supply chain failure in the agri-food sector: A case study from Moldova. Food Policy 31: 90-103.

Havrland B, Ivanova T, Lapczynska-Kordon B, Kolaříková M. 2013. Comparative analysis of bio-raw materials and biofuels. Engineering for rural development: 541-544.

Hill J, Nelson E, Tilman D, Polasky S, Tiffany D. 2006. Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. Proceedings of the National Academy of Science sof the United States of America 103 (30): 11206-11210.

Chen L, Xing L, Han L. 2009. Renewable energy from agro-residues in China: Solid biofuels and biomass briquetting technology. Renewable and Sustainable Energy Reviews 13: 2689-2695.

Chin KL, H´ng PS, Go WZ, Wong WZ, Lim TW, Maminski M, Paridah MT, Luqman AC. 2013. Optimization of torrefaction conditions for high energy density solid biofuel from oil palm biomass and fast growing species available in Malaysia. Industrial Crops and Products 49: 768-774.

Chiriac L, Secrieru A, Tornea I, Costandachi G, Munteanu I, Znaceni A, Stancu E. 2012. Estimation of the energy potential of biomass for briquetting from agricultural crops at regional and rayon levels for 2009-2010. Chisinau: IDIS Viitorul, 172p.

International Energy Agency. 2014. Medium-Term Renewable Energy Market Report 2013. New York: OECD. 20p.

International Energy Agency (IEA). 2014. Republic of Moldova: Balances for 2011. Available at http://www.iea.org/statistics/statisticssearch/report/?&country=MOLDOVA&year=2011&product=Balances: Accessed 2014-02-05.

International Labour Organisation (ILO). 1996. Republic of Moldova. Available at http://www.ilo.org/ilostat/faces/home/statisticaldata/data_by_country/country-details;jsessionid=zhmtJvppTLW8lb8jMccxsX2TfQTwz2TWkRLT2KQZ24tNGnG8ThjL!1678818735?_afrLoop=589396622940113&country=MDA&_adf.ctrl-state=17zgbgukm4_537#%40%3F_afrLoop%3D589396622940113%26country%3DMDA%26_adf.ctrl-state%3Dputl8otuz_4: Accessed 2014-01-22.

International Monetary Fund (IMF). Not dated. IMF Data Mapper®. Available at http://www.imf.org/external/datamapper/index.php: Accessed 2014-01-22.

Ivanova T. 2012. Research of Energy Plants Processing to Solid Biofuels [PhD.]. Prague: Czech University of Life Sciences Prague, 133p.

Johansson LS, Leckner B, Gustavsson L, Cooper D, Tullin C, Potter A. 2004. Emission characteristics of modern and old-type residential boilers fired with wood logs and wood pellets. Atmospheric Environment 38: 4183-4195.

Kandakov A, Havrland B. 2012. Moldovan Tomato Market Analysis through Use of the Agricultural Marketing Information System. Agricultura Tropica et Subtropica 45/3: 157-165.

Karakosta CH, Dimopoulou S, Doukas H, Psarras J. 2011. The potential role of renewable energy in Moldova. Renewable Energy 36: 3550-3557.

Klašnja M, Tucker JA. The economy, corruption, and the vote: Evidence from experiments in Sweden and Moldova. Electoral Studies 32: 536-543.

Kolaříková M, Ivanova T, Havrland B, Amonov K. 2014. Evaluation of sustainability aspect – energy balance of briquettes made of hemp biomass cultivated in Moldova. Agronomy Research 12 (2): 519-526.

Kotlánová A. 2010. Metody zkoušení fyzikálně-chemických vlastností tuhých biopaliv. Available at http://biom.cz/cz/odborne-clanky/metody-zkouseni-fyzikalne-chemickych-vlastnosti-tuhych-biopaliv: Accessed 2014-03-10.

Lyčka Z. 2011. Význam peletizace dřevní hmoty. Available at http://biom.cz/cz/odborne-clanky/vyznam-peletizace-drevni-hmoty: Accessed 2014-03-10.

Macours K, Swinnen JFM. 2008. Rural-Urban Poverty Differences in Transition Countries. World Development 36: 2170-2187.

Manios T. 2004. The composting potential of different organic solid wastes: experience from the island of Crete. Environment International 29: 1079-1089.

Matsuzato K. 2010. Cultural geopolitics and the New Border Regions of Eurasia. Journal of Eurasian Studies 1: 42-53.

McKee M, Balabanova D, Akingbade K, Pomerleau J, Stickley A, Rose R, Haerpfer C. 2006. Access to water in the countries of the former Soviet Union. Public Health 120: 364-372.

Mikkola HJ, Ahokas J. 2010. Indirect energy input of agricultural machinery in bioenergy production. Renewable Energy 35: 23-28.

Moldova Wine Guild. 2008. Wine Regions. Available at http://www.moldovawineguild.md/wine_industry/wine_regions/index.html: Accessed 2014-02-03.

Møller J, Skaaning SE. 2010. Post-communist regime types: Hierarchies across attributes and space. Communist and Post-Communist Studies 43: 51-71.

Muntean A, Ivanova T, Havrland B, Pobedinsky V. 2012. Comparative analysis of methods for fuel biobriquettes production. Engineering for Rural Development: 496-499.

Murphy D. 2011. The Energy Return on Investment Threshold. Available at http://www.theoildrum.com/node/8625: Accessed 2015-03-03.

Muzikant M, Havrland B, Hutla P, Věchetová S. 2010. Properties of heat briquettes produced from vine cane waste – Case study Republic of Moldova. Agricultura Tropica et Subtropica 43/3: 43-50.

Natural Resources Defense Council (NRDC). Not dated. Renewable Energy for America: Overview. Available at http://www.nrdc.org/energy/renewables/default.asp: Accessed 2014-02-12.

Newnham R. 2011. Oil, carrots, and sticks: Russia's energy resources as a foreign policy tool. Journal of Eurasian Studies 2: 134-143.

Obernberger I, Brunner T, Bärnthaler G. 2006. Chemical properties of solid biofuels—significance and impact. Biomass and Bioenergy 30: 973–982.

Picchi G, Silvestri S, Cristoforetti A. 2013. Vineyard residues as a fuel for domestic boilers in Trento Province (Italy): Comparison to wood chips and means of polluting emissions control. Fuel 113: 43-49.

Ping X, Jiang Z, Li CH. 2012. Social and ecological effects of biomass utilization and the willingness to use clean energy in the eastern Qinghai–Tibet plateau. Energy Policy 51: 828-833.

Popescu G. 2008. The conflicting logics of cross-border reterritorialization: Geopolitics of Euroregions in Eastern Europe. Political Geography 27: 418-438.

Porto GG. 2005. Informal export barriers and poverty. Journal of International Economics 66: 447-470.

Preininger M. 1987. Energy evaluation of manufacturing processes in crop production. Methodology No. 7/1987. Prague. Institute for Scientific and Technical Information in Agriculture. 25p.

Presidency of the Republic of Moldova. 2013. Biography of President of the Republic of Moldova Nicolae Timofti. Available at http://www.presedinte.md/eng/biography: Accessed 2014-01-16.

Protsyk O. 2012. Secession and hybrid regime politics in transnistria. Communist and Post-Communist Studies, 45: 175-182.

REN21. 2012. Renewables 2012 Global Status Report. Paris: REN21 Secretariat. 172p.

Roberts JJ, Cassula AM, Prado PO, Dias RA, Balestieri JAP. 2015. Assessment of dry residual biomass potential for use as alternative energy source in the party of General Pueyrredón, Argentina. Renewable and Sustainable Reviews 4: 568-583.

Roper SD. 2005. The politicization of education: Identity formation in Moldova and Transnistria. Communist and Post-Communist Studies 38: 501-514.

Roquelaure Y, D´Espagnac F, Delamarre Y, Penneau-Fontbonne D. 2004. Biomechanical assessment of new hand-powered pruning shears. Applied Ergonomics 35: 179–182.

Rosenberger A, Kaul HP, Senn T, Aufhammer W. 2001. Improving the energy balance of bioethanol production from winter cereals: the effect of crop production intensity. Applied Energy 68: 51-67.

Senyuva O. 2010. Parliamentary elections in Moldova, April and July 2009. Electoral Studies 29: 171-195.

Schneider F. 2005. Shadow economies around the world: what do we really know?. European Journal of Political Economy 21: 598– 642.

Song Z, Zhang CH, Yang G, Feng Y, Ren G, Han X. 2014. Comparison of biogas development from households and medium and large-scale biogas plants in rural China. Renewable and Sustainable Energy Reviews 33: 204-213.

Spinelli R, Magagnotti N, Nati C. 2010. Harvesting vineyard pruning residues for energy use. Biosystems Engineering 105: 316-322.

Spinelli R, Nati C, Pari L, Mescalchin E, Magagnotti N. 2012. Production and quality of biomass fuels from mechanized collection and processing of vineyard pruning residues. Applied Energy 89: 374-379.

Statistica Moldovei. 2011. General Agricultural Census 2011, Volume 1. Chisinau: National Bureau of Statistics of the Republic of Moldova. 377p.

Statistica Moldovei. 2014. The Energy Balance of the Republic of Moldova 2013, Statistical compilation. Chisinau: National Bureau of Statistics of the Republic of Moldova. 66p.

Statistica Moldovei. 2014. StatBank: Annual average production and area of production of selected crops. Available at http://statbank.statistica.md/pxweb/Database/EN/databasetree.asp: Accessed 2014-02-04.

Stigka EK, Paravantis JA, Mihalakakou GK. 2014. Social acceptance of renewable energy sources: A review of contingent valuation applications. Renewable and Sustainable Energy Reviews 32: 100-106.

Stolarski MJ, Szczukowski S, Tworkowski J, Klasa A. 2013. Yield, energy parameters and chemical composition of short-rotation willow biomass. Industrial Crops and Products 46: 60-65.

Stupavský V. 2010. Kvalita pelet – certifikace a normy pro pelety. Available at http://biom.cz/cz/odborne-clanky/kvalita-pelet-certifikace-a-normy-pro-pelety: Accessed 2014-03-07.

Stupavský V. 2010b. Pelety z biomasy - dřevěné, rostlinné, kůrové pelety. Available at http://biom.cz/cz/odborne-clanky/pelety-z-biomasy-drevene-rostlinne-kurove-pelety: Accessed 2014-03-07.

Stupavský V, Holý T. 2010. Brikety z biomasy - dřevěné, rostlinné, směsné brikety. Available at http://biom.cz/cz/odborne-clanky/brikety-z-biomasy-drevene-rostlinne-smesne-brikety: Accessed 2014-03-07.

Špička J, Jelínek L. 2008. Energy analysis of agricultural enterprises – methodological approach. Economy and Management 2 (3): 1-10.

Telmo C, Lousada J. 2011. Heating values of wood pellets from different species. Biomass and Bioenergy 35: 2634-2639.

The Official Website of the Government of the Republic of Moldova. 2014. Prime Minister´s Biography. Available at http://www.gov.md/pageview.php?l=en&idc=431: Accessed 2014-01-16.

The Official Website of the Republic of Moldova. Not dated. About the Republic of Moldova. Available at http://moldova.md/en/start/: Accessed 2014-01-14.

Tosun J. 2012. Emergency oil stocks in Southeastern and Eastern Europe: What explains variation in convergence towards the EU model?. Energy Policy 46: 417-426.

Turcescu L, Stan L. 2003. Church-state conflict in Moldova: the Bessarabian Metropolitanate. Communist and Post-Communist Studies 36: 443-465.

United Nations (UN). 2014. Member States of the United Nations. Available at http://www.un.org/en/members/index.shtml: Accessed 2014-01-25.

United Nations (UN). 2014. Millennium Development Goals and Beyond 2015. Available at http://www.un.org/millenniumgoals/: Accessed 2014-02-14.

United Nations Development Programme (UNDP). Not dated. Republic of Moldova. Available at http://hdr.undp.org/en/countries/profiles/MDA: Accessed 2014-01-20.

Velázquez-Martí B, Fernández-González E, López-Cortés I, Salazar-Hernández DM. 2011. Quantification of the residual biomass obtained from pruning of vineyards in Mediterranean area. Biomass and Bioenergy 35: 3453-3464.

World Bank. 2014. Data: Moldova. Available at http://data.worldbank.org/country/moldova: Accessed 2014-01-15.

Wu X, Lampietti J, Meyer AS. 2004. Coping with the cold: space heating and the urban poor in developing countries. Energy Economics 26: 345– 357.

Yusaf T, Goh S, Borserio JA. 2011. Potential of renewable energy alternatives in Australia. Renewable and Sustainable Energy Reviews 15: 2214-2221.

Zabarah D A. 2012. Opportunity structures and group building processes: An institutional analysis of the secession processes in Pridnestrovie and Gagauzia between 1989 and 1991. Communist and Post-Communist Studies, 45: 183-192.

Zemánek P. 2012. Provozní náklady u technologií energetického využití réví z vinic. Available at http://biom.cz/cz/odborne-clanky/provozni-naklady-u-technologii-energetickeho-vyuziti-revi-z-vinic: 2014-03-12.

Zhang J, Guo Y. 2014. Physical properties of solid fuel briquettes made from *Caragana korshinskii* Kom. Powder Technology 256: 293-299.