Slovak University of Agriculture in Nitra
University of Belgrade

Report from research activities of the
project No. SK-SRB-2013-0039
SRB 451-03-545/2015-09/13

Agriculture Biomass:

its potential in Slovakia and Serbia

Report from research activities of the project No. SK-SRB-2013-0039
SRB 451-03-545/2015-09/13

Title: **Agriculture Biomass: its potential in Slovakia and Serbia**

Autors: Zuzana Palková

Goran Topisirović

František Adamovský

Ondrej Lukáč

Milan Jeremić

Juraj Baláži

Vlade Zarić

Reviewers: prof. Dr. Ing. Imrich Okenka, PhD.

prof. dr. Dušan Radivojevič

Publisher: Slovak University of Agriculture in Nitra

Contents

INTRODUCTION

The natural resources (oil, coal, natural gas) are insufficient to satisfy the needs of the people for electric and heating energy because sources of fossil fuels are limited. Emission of large quantities of carbon-dioxide into the atmosphere, in the course of combustion processes of solid and liquid fuels have been disrupting the environment. The future lies in the renewable energy sources (RES) surrounding us.

The rapid rise of crude oil prices in the early 70-ies of 20th Century focused global attention to the need for efficient use and finding new sources of energy. In addition, energy consumption is growing dramatically in developed countries. EIA expects that demand for energy will grow by 56% between 2010 and 2040 (U.S. Energy Information Administration, 2016).

In order to overcome the problems caused by the constant rise in the global population, rapid exploitation of many natural resources, increase of pollution and climate change, the World and Europe must radically change their approach to the production, processing, consumption, storage, recycling and disposal of biological wastes. European 2020 strategy indicates bioeconomy as a key element for sustainable and "green" development in the region (European Commission, 2012). Bioeconomy includes sustainable production of renewable biological resources and their conversion into food, biofuels, bioenergy and bioproducts (eg. bioplastics, biopesticides, etc.). It includes agriculture, forestry, fisheries, food and paper production, as well as part of the chemical, biotechnological and energy industries.

Progress and development of technologies significantly complicate economical production, distribution and consumption of all forms of energy. From the point of view of survival and development, it is important to search for additional energy resources. Non-renewable energy sources are solid, liquid and gaseous fuels (other than wood and plant mass), as well as nuclear fuel. Renewable energy sources are water, wind, sun and biomass. Conventional energy resources based on fossil fuels and wood are increasingly depleted, while nuclear fuel carry the risk of disposing of waste generated in the production, which is why there is a need for finding adequate, cost-effective and reliable source to obtain energy.

Agriculture is a major consumer but also can become energy producer. Bearing in mind the amount of biomass produced, and the possibilities for its utilization, the negligible amount of biomass that is currently used as an energy source. An important feature is that biomass combustion is not an increased content of CO_2 in the atmosphere, as the ecological point of view is very important. The necessity of integrated approach to the biomass policy is given special importance. Biomass is preferred to other sources of renewable energy, due to the increase in the alternative sources of income it provides to the farmers, and the development of the regional economic structures. It is expected that throughout Europe a new "energy producing" division of agriculture is about to unfold, which, in close cooperation with the energy producing and service providing sections of the national economy, may greatly contribute to the reduction of the energy shortage, while finding new sources of income.

Usage of biomass, which is mostly the agricultural waste, would reduce demand of the country for import of fuels, would promote environment protection, and the economy would prosper, which would contribute to the sustainable development of society.

At this study the sources of biomass and its potential will be described, as well as energy from agricultural biomass, with special emphasis on the situation and potential of Slovakia and Serbia in biomass. The possibilities of the use of alternative renewable energy sources were considered, such as biodiesel, biogas and bioethanol. Also the opportunities for development and implementation of the second, third and fourth generation biofuels are listed. The study included both positive and negative impacts of the production and use of renewable energy from agricultural biomass (biofuels) compared to the fossil fuels.

1 Energy policies strategies in EU level and macro-regional level

1.1 The current EU policy framework

The use of renewable energies (wind power, solar and photovoltaic energy, biomass and biofuels, geothermal energy and heat-pump systems) undeniably contributes to limiting climate change. Furthermore, it plays a part in securing energy supply and creating employment in Europe, thanks to the increase in the production and consumption of local energy. Renewable energies, however, remain on the fringe of the European energy mix as they still cost more than traditional energy sources.

To increase the use of renewable energy sources, in its Renewable Energies Roadmap the EU has set itself the objective of increasing the proportion of renewable energies in its energy mix by 20 % by 2020 (European Renewable Energy Council). To achieve this, EU countries have committed to reaching their own national renewables targets ranging from 10% in Malta to 49% in Sweden. They are also each required to have at least 10% of their transport fuels come from renewable sources by 2020.

All EU countries have adopted national renewable energy action plans showing what actions they intend to take to meet their renewables targets. These plans include sectorial targets for electricity, heating and cooling, and transport; planned policy measures; the different mix of renewables technologies they expect to employ; and the planned use of cooperation mechanisms (European Commission, Renewable energy moving towards a low carbon economy, 2016).

This objective requires progress to be made in the three main sectors where renewable energies are used:

1. an EU based target for GHG emission reductions of 20% relative to emissions in 1990;
2. a 20% share for renewable energy sources in the energy consumed in the EU with specific target for the Member States;
3. 20% savings in energy consumption compared to projections. In addition, there are specific 2020 targets for renewable energy for the transport sector (10%) and decarbonisation of transport fuels (6%). (European Commission, 2014).

In 2014, negotiations about EU energy and climate targets until 2030 EU countries have agreed on a new 2030 Framework for climate and energy, including EU-wide targets and policy objectives for the period between 2020 and 2030. EU countries have already agreed on a renewable energy following targets (European Commission, Climate Action, 2014):

- a 40% cut in greenhouse gas emissions compared to 1990 levels;
- at least a 27% share of renewable energy consumption;
- at least 27% energy savings compared with the business-as-usual scenario.

1.2 THE 20% GHG REDUCTION TARGET AND IMPLEMENTING MEASURES

The 20% GHG reduction target for 2020 compared to 1990 is implemented through the EU Emissions Trading System (EU ETS) and the Effort Sharing Decision which defines reduction targets for the non-ETS sectors, and its achievement is supported through EU and national policies to reduce emissions. In 2011 GHG emissions as covered by the climate and energy package were estimated at 16% below 1990 levels.

The ETS delivers a uniform carbon price for large industrial installations, the power sector and in the aviation sector. It covers more than 10.000 installations and nearly 50% of all EU GHG emissions. This uniform price ensures that climate goals are met cost-effectively and that business across the

EU has a level playing field. The carbon price is now part of EU businesses' operational and investment decisions and has contributed to substantial emissions reductions. But it has not succeeded in being a major driver towards long term low carbon investments. Despite the fact that the ETS emission cap decreases to around - 21% by 2020 compared to 2005 and continues to decrease after 2020, in principle giving a legal guarantee that major low carbon investments will be needed, the current large surplus of allowances, caused in part by the economic crisis, prevents this from being reflected in the carbon price. The low carbon price is not providing investors with sufficient incentive to invest and increases the risk of "carbon lock-in". Some Member States are concerned with this evolution and have taken, or are considering taking national measures, such as taxes for carbon intensive fuels in ETS sectors. There is an increasing risk of policy fragmentation threatening the Single Market, with national and sectoral policies undermining the role of the ETS and level playing field it was meant to create. The Carbon Market Report assesses in more detail the functioning of the ETS.

The Effort Sharing Decision (ESD) sets national targets for GHG emissions in the sectors not covered by the ETS. The aggregate target is a 10% emission reduction at EU level in 2020 compared to 2005. Many EU policies, including sector specific legislation and initiatives, have contributed to reducing emissions in these sectors. They range from policies that improve CO_2 and energy efficiency for cars, the residential sector and energy consuming equipment, to specific waste, environmental, agricultural and land use policies (see annex). The implementation of policies to achieve the renewables and energy efficiency target also contributes to emissions reductions. National targets are distributed between Member States according to economic capacity. Some need to reduce emissions compared to 2005 whilst others are permitted a limited growth in emissions. In aggregate the EU is on track to achieve the 10% reduction target, but significant differences exist between

Member States. Half of them still need to take additional measures. Additionally the ESD enables Member States to meet their targets flexibly, be it through the acquisition of international credits or through trade with Member States outperforming their targets.

1.3 The renewable energy target and implementing measures

The EU is making progress towards meeting the 2020 target of 20% renewable energy in gross final energy consumption. In 2010, the renewables share in the EU was 12,7% compared to 8,5% in 2005. In the period 1995-2000 when there was no regulatory framework, the share of renewable energy grew by 1,9% a year. Following the introduction of indicative targets (2001-2010), the share of renewable energy grew by 4,5% per annum. With legally binding national targets growth has increased but needs to average 6.3% per year to meet the overall 2020 target. The share of renewables in transport reached 4,7% in 2010 compared to only 1,2% in 2005. In the heating and cooling sector, renewable energy continues to grow and its share should nearly double by 2020. However, new measures will be needed for most Member States to achieve their 2020 targets reflecting the scaling back of support schemes and more difficult access to finance in the context of the economic crisis.

The Commission provided a state of play on renewable energy in the EU in 2012. An updated progress report is published alongside this Green Paper. Investments in research and development, innovation and large scale deployment in the sector have contributed to significant reductions in the cost of renewable energy technologies. There are key challenges associated with large scale deployment such as the full integration of renewables into the EU's electricity system in a way that deals with intermittency, and improving co-operation among Member States in meeting targets. The coupling of the EU's wholesale electricity markets will help to integrate renewable energy into the electricity system as will the roll-out of smart grids which provide opportunities to adapt generation, grid control, storage and consumption to the changing situation on markets. However, massive investments in transmission and distribution grids, including through cross-border infrastructure, to complete the internal energy market will also be needed to accommodate renewable energy. Another important challenge is to ensure over time that renewable energy sources become more cost-efficient so as to limit the use of support schemes only to those technologies and areas that still need it. Such schemes should be designed to avoid overcompensation, improve cost efficiency, encourage high GHG reduction, strengthen innovation, and ensure sustainable use of raw materials, to be adaptable to cost developments to avoid subsidy dependence, be consistent across Member States and, in particular with regard to biofuels, ensure WTO compatibility.

1.3.1 The energy savings target and implementing measures

The 2020 target of saving 20% of the EU's primary energy consumption (compared to projections made in 2007) is not legally binding for Member States, but significant progress has nevertheless been made. After years of growth, primary energy consumption peaked in 2005/2006 (around 1825 Mtoe) and has been slightly decreasing since 2007 (to reach 1730 Mtoe in 2011). This trend is partly due to the economic crisis and partly due to the effectiveness of existing policies. It is also due to reduced energy intensity of EU industry which was 149 toe per million euro in 2010, down from 174 in 2000 and 167 in 2005.

With the adoption of the Energy Efficiency Directive (EED) in 2012 there is now a comprehensive legislative framework at EU level. This needs to be fully implemented by Member States. The EED will help to drive progress in this area, although the Commission's preliminary analysis suggests that with current policies the 2020 target will not be met. The lack of appropriate tools for monitoring progress and measuring impacts on the Member State level is part of the problem. Another major challenge is to mobilize the funds needed to ensure continued progress.

Since 2009-2010, implementing measures have been adopted under the Ecodesign and Energy Labelling Directives on energy related products. These measures reduce the energy demand of industrial and household products leading to savings for end-users. Measures have been adopted for a number of electronic appliances, including domestic dishwashers, refrigerators, washing machines, televisions and tyres as well as industrial products such as motors, fans and pumps. The estimated impact of the adopted ecodesign and labelling measures are energy savings in the range of 90 Mtoe in 2020.

To address the energy consumed in the building stock, in particular for heating and cooling purposes, the EU adopted a revised Energy Performance of Buildings Directive (EPBD) in 2010. Besides the obligation for Member States to apply minimum energy performance requirements for new and existing buildings, the Directive requires them to ensure that by 2021 all new buildings are "nearly zero-energy buildings." However, delays and incomplete national measures to implement this directive risk undermining the necessary contribution of the buildings sector towards lower GHG emissions and reduced energy consumption. The cost-effective savings potential in the building sector is estimated to be 65 Mtoe by 2020. The EU has supported the development of energy efficient technologies, including through public partnerships on energy efficient buildings, green cars and sustainable manufacturing.

In the transport sector, the Regulations establishing performance standards for light duty vehicles have led to substantial reductions in GHG emissions reflected in the fleet average CO_2 emission of new cars from 172 g per kilometer in 2000 to 135,7 g per kilometer in 2011.

1.3.2 Security of supply and affordability of energy in the internal energy market

The 2009 climate and energy package is not the only work stream in this area. In 2009 and 2010, the EU adopted comprehensive legislation on the internal energy market for electricity and natural gas and, in the wake of two gas supply crises, the Regulation on security of gas supplies. As none of the energy policy objectives can be reached without adequate grid connections, the Commission has also proposed a Regulation on Trans-European Energy Infrastructure Guidelines on which political agreement has been reached by the European Parliament and by Council. It addresses infrastructure challenges to ensure true interconnection in the internal market, integration of energy from variable renewable sources and enhanced security of supply.

Other EU measures, such as the European Strategic Energy Technology plan are in place to encourage a technological shift through development and demonstration projects for new and innovative technologies: e.g. second generation biofuels, smart grids, smart cities and intelligent networks, electricity storage and electro-mobility, carbon capture and storage technologies and next generation nuclear and renewable heating and cooling. In early 2013, the Commission also proposed a directive on the deployment of alternative fuels infrastructure which will be supported by the proposed revision of the TEN-T Guidelines.

A number of challenges were not addressed at the time of the 2009 climate and energy package. For example, the necessary transmission and distribution infrastructure were not defined. The management challenges linked to the introduction of renewables, including dealing with the variable supply of certain renewables (e.g. wind and solar) were also not fully considered and the impact of a large number of national support schemes for renewables on market integration was underestimated.

The Third Energy package addressed the issue of how to stimulate competition on the market, but did not address the issue of whether the market offered the necessary incentives to invest in generation, distribution and transmission, and storage capacity in a system with greater shares of renewables. Until renewable energy sources become cost-competitive, the objective of a more sustainable energy system must go hand in hand with the need for a fully liberalized and integrated energy market capable of mobilizing and allocating investment efficiently.

Important developments and trends taking place inside and outside the EU include the growing energy import dependency of the EU and the technological progress of our main competitors, the new supply routes, as well as the rise of new energy producers in Africa and Latin America. This will all have an impact on the energy cost and security of supply in the EU.

1.4 A 2030 FRAMEWORK FOR CLIMATE AND ENERGY POLICIES

The EU has a clear framework to steer its energy and climate policies up to 2020. This framework integrates different policy objectives such as reducing greenhouse gas (GHG) emissions, securing energy supply and supporting growth, competitiveness and jobs through a high technology, cost effective and resource efficient approach. These policy objectives are delivered by three headline targets for GHG emission reductions, renewable energy and energy savings. There are additional targets for energy used by the transport sector. In parallel, the EU has put in place a regulatory framework to drive the creation of an open, integrated and competitive single market for energy which promotes the security of energy supplies. While the EU is making good progress towards meeting the 2020 targets, creating the internal market for energy and meeting other objectives of energy policy, there is a need now to reflect on a new 2030 framework for climate and energy policies. Early agreement on the 2030 framework is important for three reasons:

- First, long investment cycles mean that infrastructure funded in the near term will still be in place in 2030 and beyond and investors therefore need certainty and reduced regulatory risk.
- Second, clarifying the objectives for 2030 will support progress towards a competitive economy and a secure energy system by creating more demand for efficient and low carbon technologies and spurring research, development and innovation, which can create new opportunities for jobs and growth. This in turn reduces both directly and indirectly the economic cost.
- Third, while negotiations for a legally binding international agreement on climate mitigation have been difficult, an international agreement is still expected by the end of 2015. The EU will have to agree on a series of issues, including its own ambition level, in advance of this date in order to engage actively with other countries.

This framework for 2030 must be sufficiently ambitious to ensure that the EU is on track to meet longer term climate objectives. But it must also reflect a number of important changes that have taken place since the original framework were agreed in 2008/9:

- the consequences of the on-going economic crisis;
- the budgetary problems of Member States and businesses who have difficulty mobilising funds for long term investments;
- developments on EU and global energy markets, including in relation to renewables, unconventional gas and oil, and nuclear;
- concerns of households about the affordability of energy and of businesses with respect to competitiveness;
- the varying levels of commitment and ambition of international partners in reducing GHG emissions.

The 2030 framework must draw on the lessons from the current framework: what has worked, what has not worked and what can be improved. It should take into account international developments and spur stronger international climate action. And it must identify how best to maximize synergies and deal with trade-offs between the objectives of competitiveness, security of energy supply and sustainability.

The framework should also take into account the longer term perspective which the Commission laid out in 2011 in the Roadmap for moving to a competitive low carbon economy in 2050, the Energy Roadmap 2050, and the Transport White Paper. The European Parliament has adopted resolutions on each of the Roadmaps1. These Roadmaps were developed in line with the objective of reducing GHG emissions by 80 to 95% by 2050 compared to 1990 levels as part of necessary efforts by developed countries as a group. The scenarios in these Roadmaps suggested the following key findings:

- By 2030 GHG emissions would need to be reduced by 40% in the EU to be on track to reach a GHG reduction of between 80-95% by 2050, consistent with the internationally agreed target to limit atmospheric warming to below 2°C.
- Higher shares of renewable energy, energy efficiency improvements and better and smarter energy infrastructure are "no regrets" options for transforming the EU's energy system.
- For renewables, the policy scenarios in the Energy Roadmap 2050 indicate a share of around 30% in 2030.
- Significant investments are needed to modernize the energy system, with or without decarbonisation, which will impact the energy prices in the period up to 2030.

The aim of this Green Paper is to consult stakeholders to obtain evidence and views to support the development of the 2030 framework. It begins with an overview of the current framework and what has been achieved and then presents the issues where stakeholder input is sought. In parallel, the Commission is consulting on issues relating to the international negotiations of a new legally binding agreement for climate action as well its policy to enable the demonstration of the carbon capture and storage technology.

1.4.1 Key issues for 2030 framework

The 2030 framework for climate and energy policies will build on the significant progress already made in this area. It must draw on the lessons from the current framework and identify where improvements can be made. The experience and views of stakeholders, backed up where possible with sound evidence, are essential on four broad issues:

- targets;
- other policy instruments;
- competiveness;
- the different capacity of Member States to act.

1.4.2 Targets

Fundamental issues for a new 2030 framework for climate and energy policies relate to the types, nature and level of targets and how they interact. Should the targets be at EU, national or sectoral level and be legally binding? There are diverging views on the need for targets and types of targets. While experience with the current framework shows that targets provide political momentum, a long term vision for investment, and a benchmark for measuring progress, some stakeholders argue that the existing targets and policies to reach them are not necessarily coherent or cost efficient, or that they do not take competitiveness and the economic viability and maturity of technologies sufficiently into account. The 2030 framework should recognise the evolution of technology over time and promote research and innovation. There is a need, therefore, to assess which targets can best, and most simply and cost effectively, drive energy and climate policies up to 2030, and whether the current approach can be streamlined particularly with reference to the need for various sub-targets such as those in the transport sector. This analysis should also address the issue of whether having only a GHG emissions target for 2030 would be appropriate, taking into account other objectives such as security of supply and competitiveness.

The current climate and energy targets for GHG reduction, the share of renewable energy sources and energy savings were designed to be mutually supporting and there are indeed interactions between them. Higher shares of renewable energy can deliver GHG reductions so long as these do not substitute other low-carbon energy sources while improved energy efficiency can help reduce GHG emissions and facilitate attainment of the renewables target. There are obvious synergies but there are also potential trade-offs. For example, more than anticipated energy savings and greater than expected renewable energy production can lower the carbon price by weakening the demand for emission allowances in the ETS. This in turn can weaken the price signal of the ETS for innovation and investments in efficiency and the deployment of low-carbon technologies whilst not affecting attainment of the overall GHG reduction target. A 2030 framework with multiple targets will have to recognize these interactions explicitly. It should also recognize that higher shares of renewable energy sources and greater energy savings will not alone ensure greater competitiveness or security of supply. Dedicated policies will remain necessary and there may also be a need for additional indicators that more directly capture these objectives.

There is a broad consensus that interim targets for GHG emissions reductions will be necessary to reach the aspiration of an 80-95% reduction by 2050. The key issue is deciding on the most appropriate level for such an intermediate target. The 2050 Low carbon Economy Roadmap suggests that a 40% reduction in emissions by 2030 compared to 1990 would be cost-effective. A reduction of less than 40% would increase the costs of decarbonizing the economy over the longer term. While the roadmaps suggest that GHG reductions of 40% by 2030 can be achieved without unduly increasing the costs for our energy system, mobilizing the funds necessary to cover the capital costs for significant up-front investments will, however, is a challenge.

The Energy Roadmap for 2050 has shown that the share of renewables in the energy system must continue to increase after 2020. A 2030 target for renewables would have to be carefully considered as many renewables sources of energy in this time frame will no longer be in their infancy and will be competing increasingly with other low-carbon technologies. Consideration should also be given to whether an increased renewable share at EU level could be achieved without a specific target but by the ETS and regulatory measures to create the right market conditions. The shape of a possible renewables target will depend on:

- Whether a target is considered necessary to ensure increased shares in renewables post 2020 and thereby contribute to more indigenous energy sources, reduced energy import dependence and jobs and growth.
- If and how this can be achieved without undesirable impacts of renewables support schemes on energy markets and energy prices and public budgets. It must be established whether objectives on renewable energy can be best met with a new headline target with or without sub-targets for sectors such as transport, industry and agriculture, and/or other specific measures. Any target or policy for renewables will have to take into account the growing evidence-base on sustainability, costs, the state of maturity of technologies and its innovation potential.

The EU framework for energy efficiency policy has just been updated through the adoption of the EED and a review will be carried out in 2014 with respect to the 2020 target. Discussions on a 2030 energy savings target must be seen in this context. There are a number of issues to consider. First, energy efficiency, and the resulting energy savings, is acknowledged in the Energy Roadmap 2050 as a "no-regrets" option for the energy system. While evidence on how the current system is performing will not be fully available until 2014 or later, ensuring consistency of a possible energy savings target with any other targets will be essential. Consideration will also have to be given to whether progress on energy efficiency would best be driven by targets for Member States or by sector specific targets.

It will also be necessary to consider if the metric for such a target should continue to be absolute energy consumption levels or whether ass relative target related to energy intensity would be more appropriate (e.g. energy consumption relative to GDP or gross value added). While an absolute target might better ensure the overall savings objective, a relative target might better take into account the dynamics of the EU economy and the reality of economic development.

Unlike for GHG emissions reductions and renewables, the current approach to energy efficiency is based on a combination of aspirational targets and binding measures. The need for EU legislation (e.g. ecodesign framework, the EED, the EPBD) under the 2020 framework is linked, at least partially, to the absence of legally binding energy savings targets for Member States. Any legally binding target for energy savings/intensity would need to leave room for manoeuvre for Member States for meeting the target with possibly fewer binding measures at EU level. However, such an approach would have to take into account that much of the EU legislation which contributes to reduced energy consumption also plays a fundamental role in creating the internal market for these products (e.g. the ecodesign framework). If targets remain aspirational, consideration will have to be given to whether current concrete measures are sufficient or whether new measures would be necessary. A key issue will be to what extent energy markets, through the price signal and demand response, will themselves sufficiently incentivize energy efficiency improvements, including behavioral change of consumers, and whether the ETS and its impact on electricity prices will provide incentives for energy savings also in the absence of specific targets or measures. The relatively low price elasticity of energy demand in many important sectors of the economy and projected future levels as well as the variability of the ETS price will have to be taken into account.

1.4.3 Coherence of policy instruments

The 2020 targets are implemented through policy instruments at EU level which are closely related to the internal market. Member States have larger room for manoeuvre when implementing EU legislation for renewable energy and energy efficiency, and GHG emissions outside the ETS such as in the road transport sector. This has resulted in different national approaches for renewables support schemes, energy and CO_2 taxation, energy performance standards for buildings and other energy efficiency policies.

A combination of instruments is likely to be needed to address the different policy goals and market barriers. These instruments will interact with one another as described above. Some stakeholders have criticized the lack of overall consistency between policies because of such interactions and have pointed to the need to improve the cost-efficiency of various climate and energy measures, considering technological feasibility. In addition, national measures should not lead to fragmentation of the internal market. A strong accent should be put on investments in infrastructure, in particular in networks that will deepen EU market integration and ensure sustainability, competitiveness and security of supply.

The 2030 policy framework should, therefore, strike a balance between concrete implementing measures at EU level and Member States' flexibility to meet targets in ways which are most appropriate to national circumstances, while being consistent with the internal market. The current balance of the approach between EU level instruments and Member States targets/national instruments will have to be assessed in more detail, including the impacts of fossil fuels subsidies. As before, the distribution of efforts will need to be considered as well.

Beyond regulatory instruments, the EU also provides significant financial support linked to climate change and sustainable energy, in particular through Cohesion Policy, the EU Research Programmes, and in the future the Connecting Europe Facility. Climate action objectives will represent at least 20% of EU spending in the period 2014-2020 and therefore be reflected in the appropriate instruments to ensure that they contribute to strengthen energy security, building a low-carbon, resource efficient and climate resilient economy that will enhance Europe's competitiveness and create more and greener jobs.

Future access to international credits after 2020 will need to be assessed. The use of international credits can limit costs but they also contribute to uncertainty on what is required domestically, and have contributed to the surplus of allowances in the ETS. Furthermore, EU industry and governments via the Clean Development Mechanism have subsidized competing sectors especially in emerging economies such as in China, India and Brazil. Shifting away from project-based offsets towards emission trading and other market mechanisms might better incorporate the different capacities of countries to act on climate change and support progress towards developing a more global carbon market with wide international participation.

For sectors like shipping and aviation, the policy efforts also include a coordinated push for globally agreed standards and policies to effectively deliver global emission reductions. As a first step, the Energy Efficiency Design Index agreed at the International Maritime Organization entered into force in 2013 and is expected to slow the increase of GHG emissions from global shipping.

1.5 Legislation & Policy Renewable Energy

Renewable sources of energy - wind power, solar power (thermal and photovoltaic), hydro-electric power, tidal power, geothermal energy and biomass/biogas - are an essential alternative to fossil fuels. Using these sources helps not only to reduce greenhouse gas emissions from energy generation and consumption but also to reduce the European Union's (EU) dependence on imports of fossil fuels (in particular oil and gas).

In order to reach the ambitious target of a 20% share of energy from renewable sources in the overall energy mix, the EU plans to focus efforts on the electricity, heating and cooling sectors and on biofuels. In transport, which is almost exclusively dependent on oil, the Commission hopes that the share of biofuels in overall fuel consumption will be 10% by 2020.

Policy orientations:

- Promotion of the use of energy from renewable sources (EC, Legislation, 2016)
- Renewable Energy Road Map (EC, Energy, 2016)
- Intelligent Energy for Europe programme (2003-2006) (EC, Energy, 2016)
- The Global Energy Efficiency and Renewable Energy Fund (EC, Energy, 2016)

Electricity:

- Renewable energy: the share of renewable energy in the EU in 2004 Electricity (EC, Energy, 2016)

- Renewable energy: the promotion of electricity from renewable energy sources (EC, Energy, 2016)
- Support for electricity from renewable energy sources (EC, Energy, 2016)

Heating and cooling:

- Biomass Action Plan (EC, Energy, 2016)

Biofuels:

- EU strategy for biofuels (EC, Energy, 2016)
- Motor vehicles: use of biofuels (EC, Energy, 2016)

Wind energy:

- Promotion of offshore wind energy (EC, Energy, 2016)

1.5.1 Legislation/strategy/policy in Slovakia and Serbia

European legislation in the energy sector is mainly represented by directive of European Parliament and Council No. 2003/54/ES concerning common rules for the internal electricity market, the directive of European Parliament and Council No. 2003/55/EC concerning common rules for the internal market with natural gas.

The directives were into the law and order of the Slovak Republic fully transposed by Act No. 656/2004 concerning energetic and Act no. 107/2007 concerning the regulation in network industries. Based on this new energy legislation has been issued the Decree of the Ministry of Economy, Regulatory Office for Network Industries and Government Regulation No. 123/2005 were established governing the operation of gas and No. 317/2007 that were established governing the operation of the electricity market.

The RES legislation was developed as a response to the EU Renewable Energy Directive. It is a strategy that outlines how the Slovak republic can reach its 2020 target which is 14 % of energy from renewables by 2020. A major role will play a biomass heat production and promotion of the combined biomass heat and power production. Draft of the Energy Policy was approved by SR Government Resolution no. 29/2006 of 11.01.2006 (Enviroportal, 2016).

Proposal for the Slovakia Energy Security Strategy was approved by SR Government Resolution no. 732/2008 of 15.10.2008 (MH, 2016). The aim of Energy Security Strategy is to achieve competitive power, ensuring safe, reliable and efficient delivery of all forms of energy at affordable prices, taking into account customer, environmental protection, sustainable development, security of supply and technical safety.

Strategic and program documents in the area of using RES:

- 2006 Energy policy of Slovakia,
- 2007 The strategy of higher utilization of RES,
- 2008 Energy Security Strategy,
- 2009 Act No 309/2009 Coll. the promotion of RES and highly efficient CHP 2009,
- Directive 2009/28/EC on the promotion of RES.

From the total arable land area in Serbia of 4 867 000 ha, 40% can be utilized as a source of biomass, as well as 16% of agricultural land under fruits and vegetables can be utilized for this purpose.

The actual annual production of biomass in Serbia is around 12,5 million tons. Of this amount, 1,7 million tons of agricultural biomass, and 1,02 million tons comes from forestry.

2 ENERGY FROM BIOMASS AND BIOGAS

2.1 DEFINITION AND BASIC TERMS

“Biomass shall mean the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste” (Definition according to the Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market). (Obnovljivi izvori energije, 2016a)

Biomass is a plant material, which is used directly as a fuel, or is converted to other forms before the combustion.

The use of biomass as an energy source dates back to ancient times, so that in many developing countries of the world and remains a primary fuel in households.

Given that in recent years starts organized use of biomass outside the household, and that counts as a significant energy source, biomass is treated as a new renewable energy source. Energy potential of biomass is in the first place among the other renewable energy sources.

The potential for bioenergy is very large and very prevalent around the world. Today, biomass is already the main source of the world's energy needs from all available renewable energy sources, reaching 12% (50 EJ/yr.) of the total global needs (406 EJ/yr.) The use of biomass is mainly based on agricultural and forestry wastes.

2.2 BIOMASS FROM AGRICULTURE

Agricultural biomass consists of the remains of various crops: straw, corn stalks, cobs, stalks, husks, seeds. This type of biomass has a low power of firewood and a large proportion of moisture and various impurities.

Agricultural biomass can have multi-purpose use, such as producing of:

- humus (plowed),
- fodder (treated with chemicals, mixing with proteins, etc.),
- heat (combustion),
- building materials (various pressed plates),
- parts of furniture (chipboard),
- alcohol (fermentation),
- biogas (anaerobic fermentation),
- paper and packaging,
- cleaning chemicals, decorative items,
- as well as for many other purposes.

Given that use of agricultural biomass often causes problems in practice, compromise was found in use of: ¼ biomass plowed in order to improve soil fertility, ¼ used for the production of animal feed, ¼ for energy production and ¼ for other purposes (alcohol industry, furniture, packaging, paper, etc.). The production of energy from agricultural biomass would provide significant savings if this energy is used for heating in winter or for drying agricultural crops. (Carić and Soleša, 2014.)

According to the physical state of matter, as well as influence on energy source use, biomass can be: solid, liquid and gas.

Solid biomass are the remains from crop production, the remains of orchards and wine yards pruning, forestry residues, plant mass of fast growers (known as Short Rotation Coppice - SRC), and above all fast growing forests, part of selected municipal waste, residues from the wood processing industry, remains of primary and secondary processing of agricultural products and more.

Liquid biomass is the liquid biofuels – plant oils, transesterificated plant oils – biodiesel and bioethanol.

Gaseous biomass represents biogas, which can be produced from animal manure and energy crops (grass and maize silage), or as a raw material may be used and other waste materials. Gaseous, even liquid, biomass, are the products of gasification and pyrolysis of solid biomass.

Given the existence of a very large number of waste materials, which to some extent includes biomass, but in addition to biomass contains harmful and dangerous substances, developed countries under the term biomass mainly define fuel that can be regarded as a clean fuel, with no harmful and dangerous substances.

The biomass as a renewable energy source usually involves materials made of plant material, including products, by-products, waste and residues, and plant mass, but without the harmful and hazardous substances, which can be found in painted and otherwise chemically treated wood, in the processes in the wood processing industry.

Precise definition of the meaning of biomass as a renewable energy source from German document Biomass Ordinance on Generation of Electricity from Biomass (Biomass Ordinance - Biomass V), from June 2001, is given in Table 1.

Biomass is part of a closed carbon cycle. Carbon from the atmosphere is stored in plants and combustion releases carbon back to the atmosphere as carbon dioxide (CO_2). As long as the principle of renewable development is followed (planting same amount of trees as cut), this form of energy has no significant impact on the environment.

When biomass is used as fuel instead of fossil fuel emits the same amount of CO_2 into the atmosphere. Carbon content in biomass, with approximately 50%

of its total mass, is already part of the atmospheric carbon cycle. When fossil fuels it's different, because their combustion releases in the atmosphere additional carbon amount that was trapped in the long-term carbon reservoirs.

Table 1: Description of the materials that are and are not included under the term „biomass", concerning use as renewable energy source

(Anon., 2012)

Biomass as renewable fuel does include:	**Biomass as renewable fuel does not include:**
Plants and plant parts	Fossil fuels
Fuel produced from plants and plant parts, which all components and mid-products are produced from biomass, also.	Peat
Residues and by-products of plant and animal origin in agriculture, forestry and commercial fish production	Mixture of municipal waste
Organic waste, such as: Biodegradable waste from processes in food industry, biodegradable residues from the kitchen, separated biological waste from households and firms, biodegradable waste from the wood industry and waste to maintain the natural environment. It is necessary that this type of waste has a calorific value of at least 11 000 kJ/kg (criterion of the environmental protection).	Wood Residues containing polychlorinated biphenyls or polychlorinated terphenyls, mercury and other harmful substances that are emitted in above limits quantities during the thermal use of wood.
Gas produced from biomass by gasification or pyrolysis and other products, as a result of these processes.	Paper and cardboard
	Sewage
Alcohol (as fuel) produced from biomass whose components and intermediate products are produced from the biomass, also.	Textile
	Animal body parts
Biogas is produced by anaerobic fermentation, which doesn't include fermentation of materials that do not fall into biomass and in which there is	Gas from sewage treatment

Biomass as renewable fuel does include:	**Biomass as renewable fuel does not include:**
no more than 10% of sewage	
Waste wood from wood processing industry and processing of wood materials	Gas from landfills

2.2.1 Biomass sources

Historically, biomass has been the main source of energy, mainly in the form of wood used for heating and cooking, while the industrial revolution took over the primacy of fossil fuels. Nevertheless, biomass now accounts for 15% of total energy consumption, and this share is significantly higher in developing countries than in industrialized countries. The energy in biomass is chemical in nature, but in its exploitation is no downtime, as is the case with solar or wind energy. From this point of view, biomass has more characteristics of fossil fuels rather than renewable sources, with understandable reason, because fossil fuels are actually fossilized forms of biomass. (Marulić, 2014.)

Use of biomass includes a number of sources such as:

- agricultural waste: straw, leaves, parts of fruit trees, etc.,
- agricultural crops such as different types of sugar beets, sugar cane, corn, etc.,
- energy crops: crops that grow quickly, such as beets, potatoes and trees such as willow, hybrid poplar, etc.,
- biomass from animal husbandry,
- forestry waste: unused wood, logging residues and stumps, semi wild trees, etc.,
- industrial waste: industries that produce organic waste, as is the case with the drinks industry, food industry and so on,
- municipal waste - although this type of waste often contains toxic materials such as chemically treated wood, batteries that contain

mercury and other hazardous substances, there is waste such as paper and plant residues that can be used as a source of biomass.

2.2.2 Chemical content of biomass

Biomass consists mainly of carbon, hydrogen and oxygen. In addition, significant amounts of trace elements may be found in different types of biomass, such as straw contains very large amounts of chlorine and/or silicon, and rapeseed relatively high amounts of nitrogen. The presence of these trace elements may cause some problems when using, for example, during the combustion of chlorine can cause corrosion in the boiler, silicon can buildup of deposits, nitrogen will increase the nitrogen oxide emissions.

Figure 1: Different forms of biomass

The energy content of certain types of biomass is usually expressed through the Low Level Heat (LHV). LHV depends on the moisture content in the biomass, and the content of hydrogen in the fuel. Actual biomass LHV with known moisture content can be calculated from LHV values of dry biomass with the following equation:

$$H_u(w) = H_u(wf)(100 - w) - \frac{2{,}44w}{100}$$

where:

Hu(w)	[MJ·kg^{-1}] - LHV for determined moisture content in biomass,	
Hu(wf)	[MJ·kg^{-1}] - LHV of totally dry biomass,	
w	[%]	- moisture content,
2,44		- water evaporation const.

2.2.3 Storage of solar energy

Biomass is the result of storing sunlight as chemical energy in plants. Through photosynthesis, the sunlight transforms carbon dioxide from the atmosphere and water in complex plant polymers, for a short period of time. Using these resources for energy enables carbon dioxide circulation and its storage in durable goods.

Biomass is a completely renewable resource, and its use of biofuel, bioenergy, chemical and other products does not increase the content of carbon dioxide in the atmosphere. The production and use of biomass offers significant benefits for the environment, economy and security.

Cellulose and hemicellulose are two of the three main components of most biomass resources as sugar polymers, and can be broken down into its constituent components. These components can be used for fermentation or other processes for obtaining valuable fuels, chemicals, materials, or they can burn for heat, steam and electricity.

The physical shape and a distinctive chemical composition of biomass cause significant difference compared to fossil fuels and emphasize its ecological value. The fact that biomass in its composition does not contain, or contains significantly less Sulphur compared to fossil fuels, giving her ecological significance. Some characteristics of biomass such as heterogeneity, small bulk density, high humidity, variability of the composition, cause difficulties in procedures for collection, transportation and combustion. Good effect is achieved by partly coal substitution with biomass in systems for combustion, or joint combustion of biomass and coal in the process of co-combustion.

The aspect of the production of biomass as a fuel can be seen in two ways. One is the production of a high-yielding plant varieties (energy forests), which organization has to take the country. Another approach to the problem, much more realistic in the present circumstances is that each farm produces electricity for its own needs.

2.3 BIOMASS POTENTIAL

The production of bioenergy creates new jobs and improves, mainly in rural areas, contributing to the balanced growth of agriculture. High demands for conversion technology and use of biomass can be expected in the future and from industrial and developing countries. Implementation of the Biomass Action Plan includes the opening of an additional 18 200 jobs in the EU. At the beginning of 2000 the EU adopted laws on renewable energy, which encourage the use of renewable energy sources. The motive for adoption of this Act and related regulations was an international agreement reached in 1998 in Kyoto Protocol. EU countries have set the goal that by the year 2010 doubled the use of energy from renewable sources.

By 2001, biomass is mainly used for the production of heat and very little to produce electricity, and since then mostly coupled thermal and electrical energy are used, or electricity is produced through biogas. EU Ministers Council and the European Parliament adopted at 2001 directive on the promotion of electricity from renewable energy sources (RES) in the internal electricity market (Directive 2001/77/EC). The Directive applies to the following renewable energy sources: wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas and biogas. The aim is to achieve 22,1% of electricity production from RES, and the participation of 12% renewable energy in total energy consumption by 2010. Evaluation of the compatibility of national targets with the global objectives is provided.

2.4 ENERGY FROM BIOMASS

Biomass energy can be obtained in several ways:

- direct burning to obtain heat (wood, crop residues, waste wood)
- digestion - the processing of animal waste (manure) into biogas,
- processing of biomass into alcohol (ethanol) or the production of vegetable oil

In agriculture, there are large amounts of crop residues which can be partly used for energy purposes. It is not recommended to completely remove all plant residues from the ground, so as not to become poor soil and disturb the natural cycle of the circulation of matter in it. Often, due to ignorance about processing the plant residues, farmers burn the fields, which is very harmful.

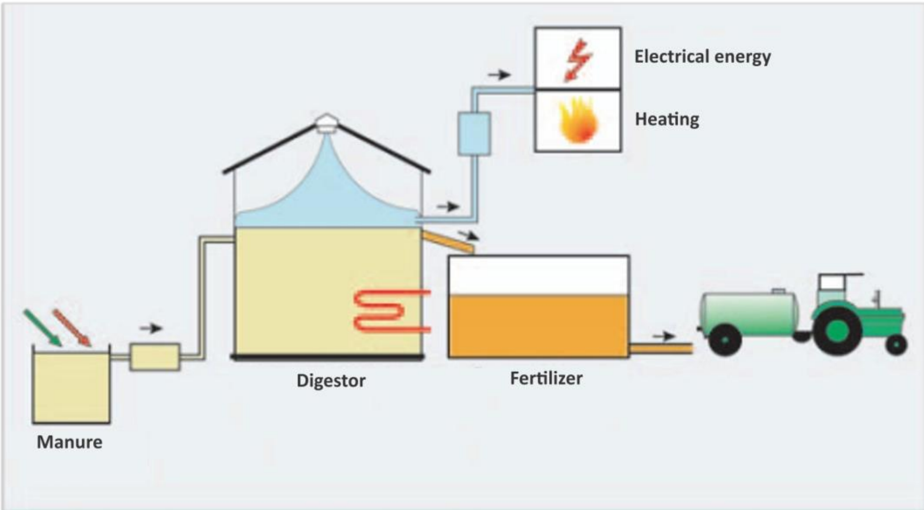

Figure 2. Process of manure treatment and production of organic fertilizer and biogas (Marulić, 2014.)

Biomass from livestock production (livestock manure) is also an excellent energy source. The energy generated from the liquid manure in the exploitation does not emit harmful gases that are produced from combustion of conventional fossil fuels and thus contributing to greater environmental protection. For example, about 10 to 12 kg of liquid manure with 4 to 10% dry matter is needed to obtain 1 m^3 of biogas. Domestic animals whose liquid manure can be economically used for the production of biogas are: dairy cows, cattle, fattening pigs, laying hens.

The most important problem is actually investing in systems for the production of biogas. If the energy invested in the exploitation and processing of an energy source is higher than the energy yield of this resource, the exploitation is total loss. The aim is to create a self-sustainable system. Installations for the production of energy from biomass in the future will enable progress in the development of ecology, agriculture, energy and the whole economy of each region that opt for their use and operation.

3 USING BIOMASS AND BIOGAS AND THEIR ENERGY POTENTIAL

Serbia does not have its own energy in an amount that would meet its needs (due to lack of energy, many must be imported), but so is estimated to have a high energy potential of renewable energy sources (RES), especially in biomass.

Serbia has great potential of biomass in agriculture and forestry for energy production. The aim of the Government of the Republic of Serbia is to make this potential accessible and thus help to increase the share of energy from renewable sources. Heating plants and industrial plants and farms have shown increasing interest in the use of bioenergy for heat and electricity.

The Government of the Republic of Serbia intends to make this potential accessible and thus contribute to increasing the share of renewable energy. The share of 27% of energy from renewable sources in the total primary energy consumption is defined as a goal that should be achieved by 2020.

Program "Development of sustainable bioenergy market in Serbia" (GIZ DKTI) focuses on the prospects and challenges in the development of the bioenergy market in Serbia.

The program aims to strengthen the capacities and create an enabling environment for the sustainable use of bioenergy in Serbia. Sustainable use of bioenergy contributes to rural development and the reduction of emissions of greenhouse gases.

Table 2 Primary energy production of solid biomass (Mtoe)

	Serbia	**Slovakia**
2011	6,351	0,784
2012	6,988	0,717

Table 3 Biofuels consumption for transport (ktoe)

	Serbia	Slovakia
2011	933,9	123,0
2012	823,3	100,9

Table 4 Gross electricity production from solid biomass (TWh)

	Serbia	Slovakia
2011	7,148	0,682
2012	9,529	0,636

Table 5 Heat consumption from solid biomass (Mtoe)

	Serbia	Slovakia
2011	4,787	0,525
2012	4,928	0,499

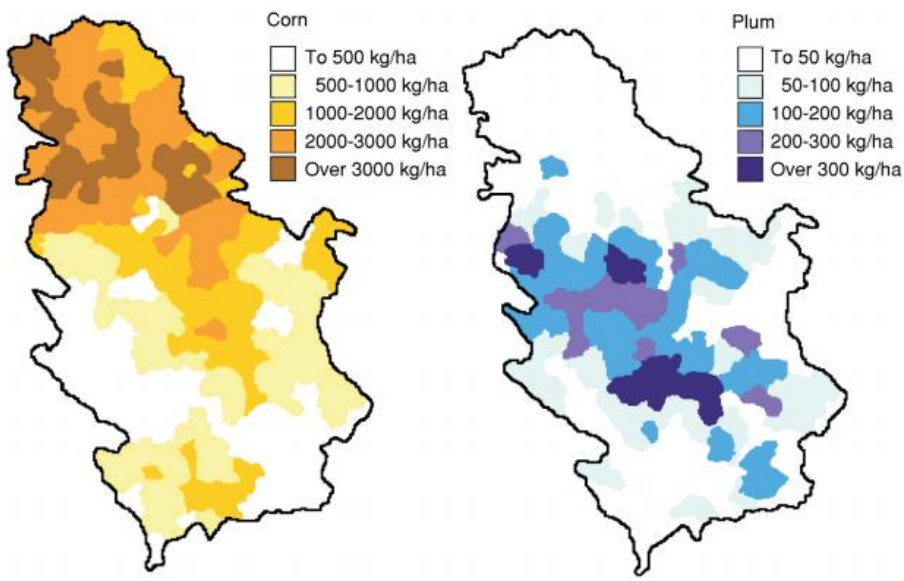

Figure 3. Agricultural land used for production of corn and plum in Serbia

Table 6 Energy use of wood biomass - exploitable potential of wood biomass on forest land

Year	Actual state			Prognosis		Vision
	2005	2010	2015	2020	2025	2050
Indicator	tis. ton					
Firewood of registered mining	480	337	380	396	370	286
Handling waste from registered mining	430	463	445	443	406	346
Management after mechanical processing of wood	130	140	160	180	200	240
Stumps and roots	40	40	40	40	40	40
thinning	30	50	60	70	80	110
Tencin and unrealized Hrubina after mining	1160	1402	1587	1684	1715	2083
Forest biomass fuel together	2270	2432	2672	2813	2851	3105

Table 7 Possibilities for energy production from agricultural biomass in Serbia

Source of biomass	Potential (t)
Crop production residues	1 023 000
Fruit and grape production residues	605 000
Slurry for biogas production	42 240
Agriculture - total	1 670 240

3.1 BIOMASS FROM CROP PRODUCTION

In Serbia, there are a large number of small individual farmers engaged in the production of grain and industrial plants, such as sunflower or soybean. A large part of agricultural production, almost 75%, is achieved in small or medium-sized private farms, while only about 25% of farming belongs to large agricultural companies.

However, about half of the biomass residues from large agricultural farm can be used for energy use, while only about 20% of residual biomass with a relatively small private property can be used as an energy source. (Magó et al., 2010)

Table 8. Yield of more important crops and energy potential of its residues

Crop	Yield (10^3 t)	Total residues (10^3 t)	Residues for energy (10^3 t)	Energy potential (toe)[1]
Wheat	2 905,0	2 905,0	1 365,0	Average energy value 14 MJ/kg
Barley	365,0	295,0	180,0	
Rye	14,1	15,5	4,4	
Corn	4 827,0	5 310,0	1 140,0	
Sunflower	280,0	705,0	240,0	
Soybean	160,0	320,0	130,0	
Rapeseed	2,6	7,8	1,6	
Total		9 560,0	3 060,0	1 023 000

3.1.1 Biomass from fruit and grape production

One of the main activities in the orchards and vineyards is pruning, which residues can be used for energy purposes. Total number of registered fruit trees in Serbia is around 94 million. Half of this number represents plums, about 20% of apples and almost 15% are cherries.

Table 9 Energy potential of biomass residues from production and processing of fruits and grapes in Serbia

Fruit	Orchards area (10^3 ha)	Type of residues	Mass of residues (t)	Energy potential (toe) [2]
Plum	50 630	branches, seeds	393 500	132 600
Apple	17 570	branches, skin	36 200	10 900
Cherries	12 280	branches, seeds	55 000	16 500
Pear	7 080	branches, skin	14 000	4 300
Peach	4 450	branches, seeds	35 100	11 700
Apricot	1 900	branches, seeds	15 500	4 100
Walnut	2 100	branches, skin	55 000	14 100

[1] 1 toe (ton of oil equivalent) = 41,868 GJ

[2] 1 toe (ton of oil equivalent) = 41,868 GJ

Fruit	Orchards area (10^3 ha)	Type of residues	Mass of residues (t)	Energy potential (toe) [2]
Grapes	77 390	branches, skin, seeds	515 000	166 300
Total				360 500

3.2 BIOMASS FROM LIVESTOCK PRODUCTION

Liquid manure (slurry) that is produced during the breeding of cattle and pigs, as well as poultry farms, are also potential sources of energy. Due to the high water content (up to 90%), those suspensions are usually treated by anaerobic digestion. Besides being a source of energy, this way of treating biomass from livestock farming is most suited source of environmentally friendly fertilizers.

In Serbia, the most bred are cattle, pigs, poultry and sheep. Animal manure combined with agricultural biomass is a very good source of energy for treatment in the process of anaerobic digestion for biogas. For example, anaerobic digestion of 110 t of manure and 250 t of maize silage per year is possible to get about 8 million kWh of electricity, which represents a saving of 16 000 tons of lignite.

The largest part of livestock production in Serbia is carried out on small farms with only a few heads of cattle each. Organized collection of manure from these small farms is not technically possible, neither financially visible. For these reasons, for the analysis of the energy potential, only manure produced on the medium and large farms is considered as a potential energy source, because the manure from these farms should not be transported, and can be effectively treated by aerobic digestion.

Table 10 Livestock production at middle and large farms and energy potential of its wastes

Livestock	Terrain	Number of heads	Manure (m^3/day)	Biogas (m^3/day)	Energy potential (toe)[3]
Cattle	Flat	149 300			
	Hilly	111 000			
	Total	260 300	5 270	105 000	20 140
Pigs	Flat	1 369 500			
	Hilly	285 600			
	Total	1 655 100	4 560	91 200	17 500
Poultry		2 350 000	480	24 000	4 600
Total					42 240

The most important source of fossil fuels in the Republic of Serbia is lignite with exploitation reserves of 13 350·10^6 t, while the annual oil production is about 1,5·10^6 t. The Republic of Serbia has to ensure safe, high-quality and reliable supply of energy and fuels, while reducing the energy dependence of the country. This can be achieved by setting appropriate objectives in the state energy policy, i.e., increasing the use of renewable energy sources. According to the Energy Act, renewable sources of energy are the energy produced from non-fossil renewable energy sources such as: watercourses, biomass, wind, solar, biogas, landfill gas, gas from sewage treatment, and geothermal energy sources.

The potential of renewable energy in Serbia is around 6·10^6 t/year. Utilization of this potential can significantly reduce use of fossil fuels. The highest potential of biomass, which represents 64% compared to other renewable energy sources and amounts to about 3,3·10^6 t/year. In addition to biomass, Republic of Serbia can annually provide 1.7·10^6 t/year of hydro-potential, 0,2 ·10^6 t/year from wind energy and 0,6·10^6 t/year of solar energy. Currently, the Republic of Serbia is using less than 33% of available resources.

---

[3] 1 toe (ton of oil equivalent) = 41,868 GJ

4 ENERGY POTENTIALS OF BIOMASS

Biomass is the most common source of alternative energy in Serbia.

In Serbia there is great potential for biomass production from agricultural and forest residues, in a total amount of $2{,}7 \cdot 10^6$ t/year ($1{,}7 \cdot 10^6$ t/year of residues from agriculture, and 1·106 t/year comes as forest biomass). The second large group of sources of biomass is livestock production waste, as well as energy crops (miscanthus, fast-growing poplar, etc.). Also, here are the plants that are used as raw materials for production of bio-fuels (rapeseed, sunflower, corn, etc.).

Serbia has significant energy potential of renewable energy sources in the annual amount of more than $3 \cdot 10^6$ toe. About 80% of this potential makes biomass. At the same time, the total consumption of fossil fuels is at the level of $12 \cdot 10^6$ toe. If only 10% of the biomass potential would be used, in order to provide thermal energy services in the household sector, for which Serbia spends about $2.5 \cdot 10^6$ toe/year, saving on account of reduced imports can amount to about $60 \cdot 10^6$ EUR/year.

Table 11 Number of plants for biomass processing (Brkić, 2013.)

No.	Producers of:	Vojvodina province	Central Serbia	Abroad	Total
1.	Briquetting press	3	3	3	9
2.	Pelleting press	4	1	8	13
3.	Briquetting plant	18	3	-	21
4.	Pelleting plant	20	12	-	32
5.	Boiler	6	8	5	19
6.	Furnace	1	5	3	9
7.	Biogas plant	3	3	-	6
8.	Biodiesel plant	5	3	-	8

Table 12 Biomass potential from agricultural production residues

No.	Variety	Yield (t/ha)	Biomass (10^3 t)
1.	Wheat	3,5	2 975
2.	Barley	2,5	412
3.	Oats	1,6	26
4.	Rye	2	12
5.	Corn	5,5	7 150
6.	Grain corn	2,3	86
7.	Corn cob[4]		1 430
8.	Sunflower	2	800
9.	Sunflower shell		120
10.	Soybean	2	320
11.	Rapeseed	2,5	300
12.	Hop	1,6	8
13.	Tobacco	1	1
14.	Orchards	1,05	289
15.	Vineyards	0,95	72
16.	Manure[5]		110
Total		3 055	12 571

Table 13 Energy potential of the biomass from agricultural residues

No.	Biomass	Biomass for burning (10^3t)	Low heat value (MJ/kg)	Equivalent value of fuel oil (10^3t)
1.	Wheat straw	743,7	14,00	247,9
2.	Barley straw	103,1	14,20	34,9
3.	Oats straw	6,4	14,50	2,2
4.	Rye straw	3,0	14,00	1,0
5.	Corn	1787,5	13,50	574,5
6.	Corn seed	21,6	13,85	7,1
7.	Wheat grain	357,0	14,70	124,9
8.	Sunflower	200,0	14,50	69,1
9.	Sunflower husk	30,0	17,55	12,5
10.	Soybean straw	80,0	15,70	29,9
11.	Rapeseed straw	75,0	17,40	31,1

[4] Corn cob mass included in corn mass

[5] Mass of liquid manure is not included in total biomass

No.	Biomass	Biomass for burning (10^3t)	Low heat value (MJ/kg)	Equivalent value of fuel oil (10^3t)
12.	Hops stems	2,0	14,00	0,7
13.	Tobacco stems	0,3	13,85	0,1
14.	Orchard pruning residues	289,4	14,15	97,5
15.	Vineyard pruning residues	71,6	14,00	23,8
16.	Manure	110,0	23,00	60,2
Total		3 881,6	242,90	1 317,5

In Serbia, there is a professional staff and experience in the construction and operation of plants for biomass combustion or use of biomass for heat production.

Total amount of biomass obtained from agricultural products intended for heating (about $3.8 \cdot 10^6$ t) can save the equivalent amount of about 1.317·103 t of fuel oil. Identical mass of diesel fuel is used in all agricultural production in Serbia.

Vojvodina province has a relatively high potential of biomass, which occurs as a "surplus" in primary agricultural production. The total production of biomass from annual agricultural crops in Serbia amounts to over $12{,}5 \cdot 10^6$ t / year.

Equivalent energy ratio of biomass to heating oil is 3,4 kg to 1 kg or 3 kg to 1 l, and biomass to natural gas 2.9 kg to 1 Nm3[6].

---

[6] Nm^3 – „normal“ m^3 - correspond to standard pressure and temperature conditions: 1 bar and 20°C,

Table 14 Heat potential and possibilities for savings of liquid fuels (Obnovljivi izvori energije, 2016b.)

No.	Biomass	Low heat value (MJ/kg)	Ratio to light oil fuel[7] (kg/l)	Potential heating oil savings (10 l)
1.	Wheat straw	14,00	3.41	872
2.	Barley straw	14,20	3,46	119
3.	Oats straw	14,50	3,54	7
4.	Soybean straw	15,70	3,83	84
5.	Corn stalks	13,50	3,29	2.173

If we use only 25% of the total agricultural biomass in Vojvodina province, which means total mass of 2 500 000 t, can be obtained energy equivalent to 735 000 t / 833 million of liters of heating oil / 860 million Nm3 of natural gas. The same amount of fossil fuels consumes whole agriculture in Vojvodina. Thus, fuel savings can be very significant in economic and environmental terms.

In Serbia, this amount is 2.5 times higher.

According to global research, the total energy potential of biomass residues in our country is estimated at 115 000 TJ/year, of which the total energy potential of agricultural biomass residues is about 65.000 TJ/year, in which 200 000 t/year are remains of pruning fruit trees, vineyards and fruit processing. It is estimated that every year in Serbia is produced 12,5 million tons of biomass, and most of it is not used in a reasonable and rational manner. Estimated energy amount that would be recovered every year using biomass in Serbia is 2,68 million tons of oil equivalents. Of these, 1,66 million tons of oil equivalent relating to agriculture, and about 1 million tons of forest biomass. Total annual energy potential of biomass in Serbia is at a level of 40% of the energy value of coal produced annually in Serbian mines.

[7] At heat value of light oil fuel of Hd= 41000 kJ/kg

The use of waste as a fuel reduces the overall amount of waste that cannot be used otherwise, contributes to preserving the environment, saving fossil fuel, producing heat that can be used in industry and reduce its costs.

Biomass is mostly used for the production of thermal energy. However, its potential can be used for transport and electricity.

The main problem with the use of biomass is the need for a huge amount for low energy utilization. Significant areas are necessary for the cultivation of so called energy crops, and also there is problem of its storage, control of residues and emissions of harmful gases.

The importance of biomass in Serbia is undoubtedly growing. It should be borne in mind that the Republic of Serbia committed itself to reduce final energy consumption by 9% in 2018 compared to 2008, and to increase the share of renewable energy in final energy consumption to 27% by 2020. In the structure of the planned national primary energy production in 2013, renewable energy sources account for 1,835 Mtoe or 16% of domestic primary energy production.

4.1 BIOFUELS FROM BIOMASS

The world is focused on the development of new processes for the production of biofuels from biomass. Stock of oil sources are globally estimated at 50 years and now is seriously considered the use of biomass, especially in terms of obtaining biofuels. An increasing number of countries in the world is gradually increasing percentage of biofuel mixed with fossil fuels and thus form a new policy of supply.

Biofuels are liquid or gaseous fuels, produced from biomass. Biofuels can be produced directly from plants or indirectly from industrial, commercial, domestic and agricultural waste.

There are three basic methods of biofuel production:

1. The first is based on the burning of dry organic waste (household waste, industrial and agricultural waste, straw, wood and peat).
2. Then there is the fermentation of wet waste (animal manure) without the presence of oxygen to produce biofuel with 60% methane and the fermentation of sugar cane or corn to produce alcohol and ester.
3. Third is energy obtained from forestry, farming or fast growing trees for fuel production.

However, the best known certainly is fermentation, whose products are the two most well-known types of alcohols and esters. They would theoretically be able to replace fossil fuels, but given that it was necessary to adapt the plant, commonly used in a mixture with fossil fuels.

Biofuels have the potential aimed at reducing the production of carbon dioxide, which is primarily based on the fact that the plants from which produce biofuels absorb CO_2 during their growth, which is released during the combustion of biofuels. However, since the energy is required for the growth and cultivation of plants, their conversion into biofuels and later distribution, additionally release carbon dioxide. Emissions of carbon dioxide that is released during the production and distribution of biofuels can be calculated using a technique called "Life Cycle Analysis (LCA)", which is based on the monitoring and calculation of CO_2 emissions from the beginning of plant growth, or putting seeds in the ground, to release gas during engine combustion. Various studies have been made for different biofuels, whose results were also different. Most of the LCA studies showed how biofuels compared to fossil fuels create significantly less harmful greenhouse gases and their use, i.e. the replacement of fossil fuels would mean significant decrease of greenhouse gases. In addition to reduced CO_2 emissions and the emissions of Sulphur oxides, particulate matter and carbon monoxide emissions are reduced, as well.

There are different types of biofuels, which are divided into first and second generation, depending on the source material for production, costs of production, prices and CO_2 emissions.

The first generation of biofuels is based on the production of sugar, starch, vegetable oils or animal fats, while second generation production uses agricultural and forest waste. The raw materials used in the production of biofuels used for food production, thereby increasing prices of raw materials, and with them the cost of production. Therefore, in collaboration with researchers made the second generation of biofuels. The development of second generation biofuels is still in its early stages.

Currently, the market is dominated by: biofuels, biodiesel and bioethanol.

4.2 BIOGAS

When it comes to biogas, it usually refers to gas with a large amount of methane, produced by fermentation of organic substances like manure, sludge from waste water treatment, municipal solid waste or any other biodegradable materials in anaerobic conditions. It is often used for biogas and names such as marsh gas, landfill gas, swamp gas and the like, according to the source. Each variant has different levels of methane and carbon dioxide in it, along with a smaller proportion of other gases.

This process is becoming increasingly popular for the treatment of organic waste, because it provides a convenient way of turning waste into electricity, thereby reducing the amount of waste and the number of pathogenic substances contained in waste. Also, the use of biogas is encouraged, because in this way obtain the power, while not increasing the amount of carbon dioxide in the atmosphere. Also, the methane is burned much cleaner than coal.

Anaerobic bacteria break down the organic matter in the absence of oxygen and produce biogas as a product of the decomposition. The most commonly used organic matter to produce biogas is cattle manure. The primary advantages of biogas production from manure are: nutrient recycling, obtaining high-quality fertilizer for further use in agriculture and avoiding odour of manure. In addition to these primary benefits resulting biogas is a very useful product. Biogas consists of about 70% of methane (CH_4), and the rest consisting of carbon dioxide, carbon monoxide and nitrogen. The relative ratio of gases depending on treated material and treatment process.

Biogas has a significant energy value of about 7 kWh/m^3 which makes it very cost effective and universal fuel, far more cost effective than other fossil fuels and biomass.

Table 15 Energy obtained from gas combustion (Marulić, 2014.)

Gas	Obtained energy (kWh/m^3)
Biogas	7
Natural gas	10
Propane	26
Methane	10
Hydrogen	3

4.3 BIODIESEL

Biodiesel is an environmental friendly energy source, which is obtained from vegetable oils with multiple benefits and advantages compared to conventional types of fuel. Their uses reduce the emission of gases and avoid creating the "greenhouse effect". The combustion of biodiesel produced carbon dioxide, which is neutral. Biodiesel does not contain a sulphur, lead or nitrogen compounds. Better is burned in the engine, and its use reduces pollution of air, water and human environment even three times, because it is biodegradable. The by-products formed during biodiesel production (glycerine, fatty acids, lecithin) can also be used, reducing the need for their imports. Glycerine is a true ecological engine coolant, and has many uses in the pharmaceutical and cosmetic industries.

Unlike the conventional fuel, biodiesel does not contain sulphur (i.e. sulphur content is very low), thereby reducing the potential for acid rain. Biodiesel contains no toxic aromatic compounds such as benzene. The high oxygen content contributes to reducing the content of unburned particulate matter (or soot) in the exhaust gas, while contributing to more complete combustion and reduced emissions of carbon monoxide. As with all fuels, burning biodiesel produces carbon dioxide, however, since plants use carbon dioxide from the atmosphere (photosynthesis) for its growth, carbon dioxide formed by combustion of the fuel balances with carbon dioxide absorbed during the growth of annual plants used as raw materials for the preparation of vegetable oils. Although the expression "diesel" enters his name, biodiesel doesn't contain no petroleum products or other fossil fuels. In bio-diesel are non-toxic, biodegradable and renewable raw materials

4.3.1 Production and use of biodiesel

Biodiesel is defined by European standard EN 14214 from 2003. In Serbia, is defined in 2006 by the state standard SRPS (JUS) EN 14214 "Automotive fuels". Fatty acid methyl esters for diesel engines, requirements and test methods "(which is identical to the European standard EN 14214). In addition, in May 2006 is adopted the "Regulation on technical and other requirements for liquid fuels" which defines technical and other requirements that fuels must fulfill.

In the EU one hectare of oilseed rape provides a sufficient amount of grain for the production of 1 090 litres of biodiesel fuel. However, in Vojvodina province, rapeseed, sunflower and soybean, achieve significantly lower yields than the European averages. With an average yield of 1,69 t/ha, and seed oil content of 36%, 1 ha of oilseed rape in Serbia provides 608 kg of oil, or about 690 litres of biodiesel. Average yield of sunflower in Serbia is 1,79 t/ha, and with the oil content of 40% can be produced 16 kg/ha or 816 l/ha of biodiesel from that sunflower. The average soybean yield in Serbia is 2,25 t/ha, while the oil content in grain of 18% can give biodiesel yield of 405 kg/ha or 460 l/ha.

Serbia has significant potential of land for production of raw materials for processing into biodiesel, which is estimated at about 10% of the total arable land. With this area it is possible to provide sufficient amount of raw materials for production of 210 to 250 thousand tons of biodiesel per year, which is enough to replace 13-16% of fossil diesel in Serbia. Currently, rapeseed appears as the only feedstock for biodiesel production. Unprofitable production, inexperience and inadequate agricultural practices are the main obstacles to increased production of rapeseed. The most important reserve for the provision of large quantities of raw materials for biodiesel is increasing the yield of oilseeds, mainly rapeseed. They are well below the European average. For several reasons, sunflower is imposed as more favourable raw material for biodiesel production in Serbia.

The competitiveness of biodiesel is determined primarily by two factors: the retail price of Euro-diesel fuel and the price of biodiesel, which largely depends on the price of feedstock, and prices of oilseeds. Analysis showed that the price of biodiesel based on sunflower and rapeseed is higher than the cost of Euro-diesel fuel, even assuming a relatively modest purchase price of these oilseeds grains.

In Serbia a decade ago were founded several companies that were involved in the manufacture of biodiesel. However, due to the high excise duties, these enterprises are extinguished or its business refocused on the production of edible oils. With the same reason in Serbia cannot be found either biodiesel imports.

4.4 Bioethanol

Bioethanol can be obtained by fermentation of simple sugars from various types of biomass.

Most often are used different carbohydrate raw materials of the general formula $(CH_2O)n$. Raw materials can be divided into three groups: sugar (sugar beets, sugar cane, sorghum, fruit, etc.), starch (corn, wheat, rice, potato, cassava, sweet potato, barley, etc.) and lignocellulosic (wood, agricultural surpluses, municipal waste, etc.). Lignocellulosic and starch materials are required to undergo a corresponding pre-treatment to make them suitable for the decomposition, while the sugar feedstock directly degrade the action of microorganisms. On the other hand, the use of sugar and starch raw materials affects the economy of the country and the availability of food. Therefore, more attention is paid to the use of second-generation raw materials which include lignocellulosic biomass. In recent years, the production of bioethanol used and algae, chitin and various industrial by-products.

The production of bioethanol from lignocellulosic raw material provides several benefits: lower prices of raw materials, increasing arable land for agricultural crops intended for human and animal nutrition, less use of fossil fuels.

Like alcohol, bioethanol is produced by the alcoholic fermentation of sugar by yeast, followed by a purification process. If the raw material is grains, the starch is converted to sugar by enzymes.

During this process is created a product that can be used as animal feed enriched with protein, with a protein content of 30%.

Bioethanol is used in a mixture with gasoline in various concentrations. In Brazil is even used in the undiluted state (E100). In Germany, the standard DIN EN 228, allows the use of a mixture of fuel containing up to 5% bioethanol (E5). Vehicle engines that are tailored and flexible for different fuels (fuel flexible vehicles - FFV) can use fuels containing up to 85% bioethanol (E85).

Mixing bioethanol fuel in the EU is allowed up to 5% (regulated by the same standard EN228), which requires a limit of water content in order to avoid phase of separation of ethanol and gasoline mixture. The use of bioethanol offers certain advantages that are reflected in lower toxicity and better biodegradability, and its market price does not depend on oil prices. The downside of the use of bioethanol is reflected in the poor sustainability of some sources of biomass, unfavourable energy balance, lack of efficiency of microorganisms, hygroscopic nature of the fluids and higher fuel consumption.

Another possibility is the use of bioethanol for production of ethyl tert-butyl ether (ETBE) that contains 74% of bio-ethanol. ETBE can be used as a replacement for methyl tert-butyl ether (MTBE), which is derived exclusively from non-renewable sources, and as an additive to reduce the knocking in an engine.

Since 2004 is intensified the production of bio-ethanol as a fuel. In 2007, the world production ranged about 40 million m^3 of bioethanol. Brazil is the world's leading producer of bioethanol from sugar cane.

The production costs of biofuels and the requirement for competitiveness affecting the prices of agricultural raw materials. In addition to increasing efficiency in converting raw materials into fuel, introduction of new materials will also generally encourage the use of biofuels.

Placing of by-products of biofuel production on the market is also very important for the final cost-effectiveness of biofuels. For example, glycerine generated during the manufacture of biodiesel can be purified to pharmaceutical quality, and by-products of bioethanol production can be used as animal feed enriched with proteins.

5 Heat production by burning of agricultural biomass

The biomass burning is a complex process with many constants that directly or indirectly affects the level of emissions and efficient use of a heat (Lamarque & et al, 2010) (van der Werf & et al, 2006). If compared with fossil fuels, the biomass is a fuel with a strongly unstable structure (the change in a content of the water and its influence on a calorific value, a content of additions and impurities, etc.), that significantly affects the efficiency of the combustion process itself (McDermitt & Loomis, 1980) (B. M Jenkins, 1998), (Jianfeng Shen, 2010), (Stanislav. V. Vassilev, 2010). On the other hand, the amount of pollutants emitted into the environment during the process of burning biomass largely depends on the type of technology used for combustion (Airuse). Usually the level of emissions decreases with increasing performance of a device designed for biomass combustion. It is possible to reduce emissions by controlling the combustion process or by using a stepped system of air addition which allows to lower emissions of imperfect combustion and NOx emissions (Adamovský & Opáth, 2013).

The work deals with ecological and energy aspects of biomass combustion in standard low-capacity boilers (up to 100 kW). There were created mixtures with different ratio of weight of input materials from selected types of biomass. The aim of subtasks was to determine energy and economical demands of pellet production from given mixtures and define the amount of emissions, that were created during combustion of produced pellets. Values of combustion heat and calorific power of these pellets were defined by using calorimetric methods.

The system (*Figure 4*) allowing to measure basic parameters of processes of biomass combustion in standard low-capacity boilers (up to 100 kW) was designed. It was used hot-water boiler for combustion of lump wood, briquettes and wood chips with capacity 25 kW. The system ensures abstraction of heat in such a way, that the temperature gradient was at least 4°C. Measuring points were installed in the chimney systems to measure emissions. The system allowed monitoring the temperature of the water output and water return flow from the boiler and water flow in pipes; therefore it is possible to calculate the instantaneous power of the boiler. Wheat straw bales, corn stalk bales and unpacked cole-seed straw was used for measurements. The moisture of the wheat straw was 11,5%, the rape straw 11,7% and the corn stalk 11,3%, therefore conditions for trouble-free running of the crusher machine were realized. As an etalon dry material was used a straw. Data about moisture are an average value obtained from 10 measurements made during one hour.

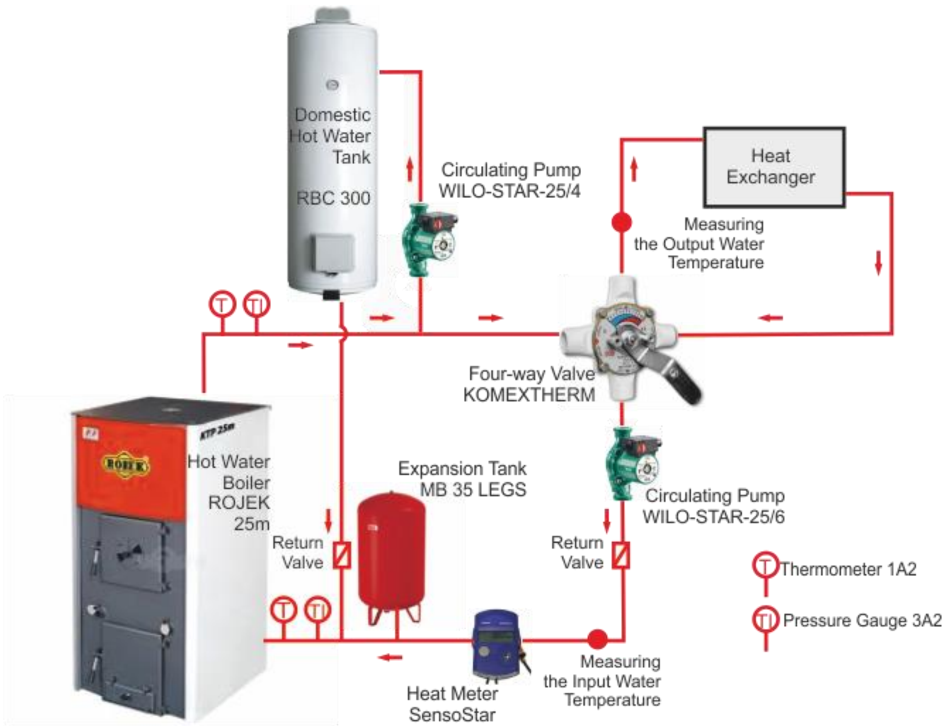

Figure 4:

In the *Figure 5* are showed measured values of consumption of electric energy that is needed to crush various types of biomass.

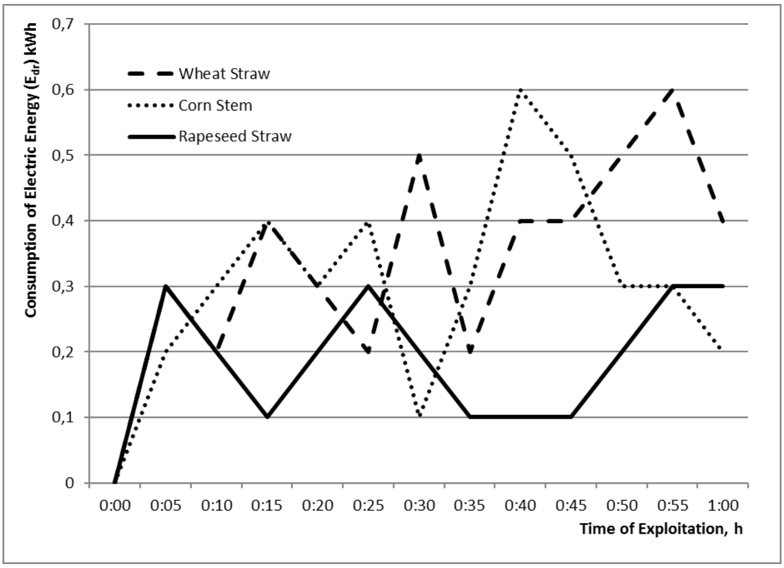

Figure 5: Measured values of consumption of electric energy that is needed to crush various types of biomass

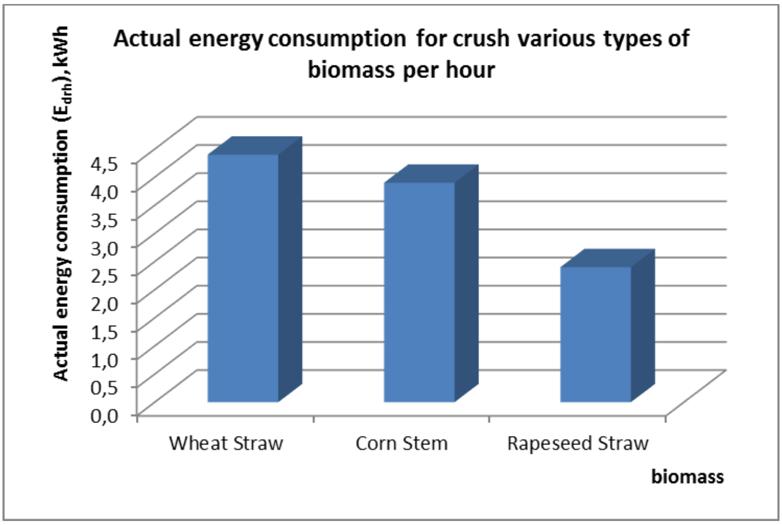

Table 16 Allotment of Biomass Components in Specimens

Template	Wheat Straw (ws)	Rapeseed Straw (rs)	Corn Stem (cs)	Name of Specimen
1	100%			100%ws
2		100%		100%rs
3			100%	100%cs
4	25%	75%		25%ws, 75%rs
5	50%	50%		50%ws, 50%rs
6	75%	25%		75%ws, 25%rs
7		25%	75%	25%rs, 75%cs
8		50%	50%	50%rs, 50%cs
9		75%	25%	75%rs, 25%cs
10	25%		75%	25%ws, 75%cs
11	50%		50%	50%ws, 50%cs
12	75%		25%	75%ws, 25%cs

Table 17 Measured values of consumption of electric energy, which is needed to pressing biomass pellets per hour.

Template	Energy Consumption for Pressing per Hour (Epressh), kWh
1	6,00
2	5,85
3	4,80
4	6,00
5	5,04
6	8,50
7	5,70
8	4,26
9	6,00
10	6,40
11	6,00
12	5,37

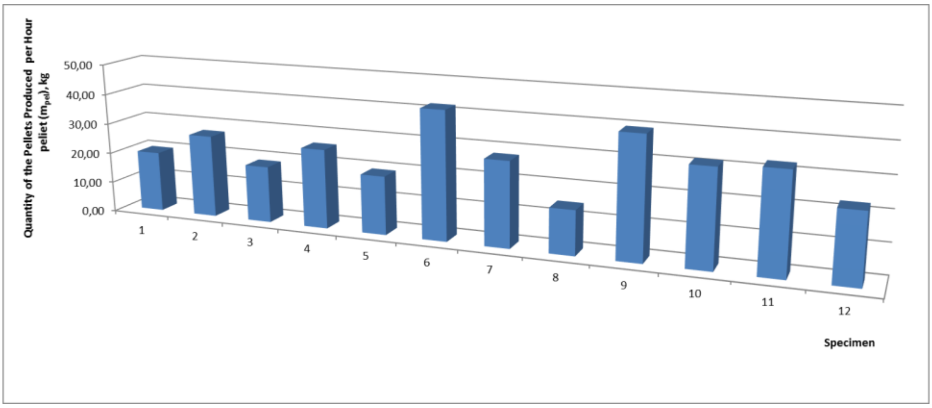

Figure 6: Quality of the pellets produced per hour

For the general economic evaluation of the fuel preparation made out of mixtures of selected types of biomass was taken into the consideration the time, the amount of electric energy used for crushing and pressing input materials and labor costs of the operator.

In the case of mixtures of materials, the percentage according to the content of the base material in the sample was taken into consideration. Table 20 provides the processed data of total costs for production of 1 kg of fuel made out of selected biomass mixtures. These figures are only the direct costs of pellet production. They do not include neither the purchase price of devices, or costs of the raw material.

Table 18 Total costs necessary for production of the fuel out of selected biomass mixtures

Template	Energy Consumption for Production 100 kg Pellets (Ecelk_100), kW.h	Amount of Time For Production 100 kg pellets (Tcelk_100), h	Totall Cost for Production 1 kg pellets, €
1	38,831	6,994	0,163 €
2	26,407	5,703	0,129 €
3	33,166	7,266	0,163 €

Template	Energy Consumption for Production 100 kg Pellets (Ecelk_100), kW.h	Amount of Time For Production 100 kg pellets (Tcelk_100), h	Totall Cost for Production 1 kg pellets, €
4	28,791	5,836	0,133 €
5	32,995	7,198	0,162 €
6	25,993	4,380	0,103 €
7	27,165	5,507	0,125 €
8	35,458	8,839	0,195 €
9	20,637	4,513	0,102 €
10	27,931	5,072	0,118 €
11	26,362	4,986	0,115 €
12	31,289	6,306	0,144 €

For energy analysis of diverse pellet mixtures were made measurements by calorimetric method to determine combustion heat and calorific power of the sample. During calorimetric method were data gathered from the burning test. Calculations correspond with standards (DIN 51900, ASTM 240D, ISO 1928, BSI) to define the combustion value. Processed data are listed in Table 4. The moisture in pellets was measured before calorimetric measuring by device for measuring the moisture GMH 380.

Table 19 Combustion heat (Qs) and calorific power (Qi) of each types of biomass and its mixtures

Template	Pellets Moisture (u), %	Combustion Heat (Qs), MJ/kg	Calorific Power (Qi), MJ/kg	Calorific Power (Qi), kW.h/kg
1	13,6	17,013	15,889	4,384
2	16,0	16,241	15,368	4,240

Template	Pellets Moisture (u), %	Combustion Heat (Qs), MJ/kg	Calorific Power (Qi), MJ/kg	Calorific Power (Qi), kW.h/kg
3	12,4	16,522	16,149	4,456
4	11,1	16,335	16,431	4,534
5	13,5	16,511	15,911	4,390
6	13,5	16,743	15,911	4,390
7	11,2	16,159	16,410	4,528
8	12,7	16,269	16,084	4,438
9	12,8	16,740	16,062	4,432
10	13,8	16,987	15,845	4,372
11	13,7	16,940	15,867	4,378
12	14,6	16,335	15,672	4,324

The biomass burning is a complex process with many constants that directly or indirectly affect the level of emissions and efficient use of energy. To measure emissions arising from direct biomass combustion, were made pellets processed into bales with 5 kg weight. The system was heated up to the desired operating temperature and data were recorded by the probe of the measuring device TESTO 330LL placed in the system of the chimney.

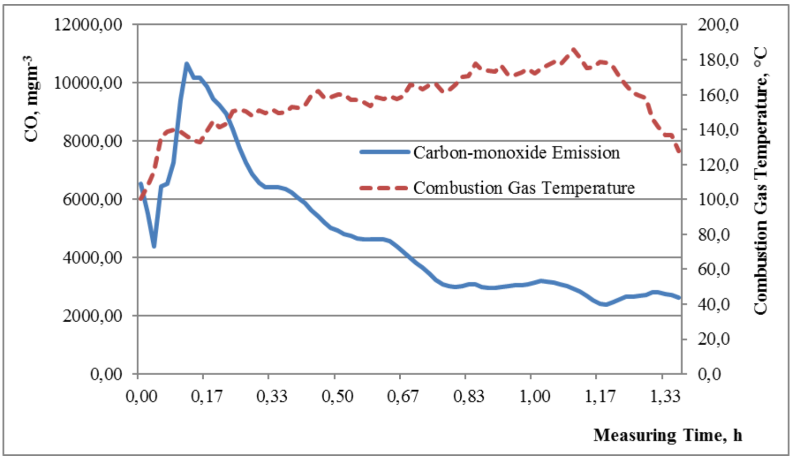

Figure 7 Emissions of CO and TS in a sample of 100% PS + molasses

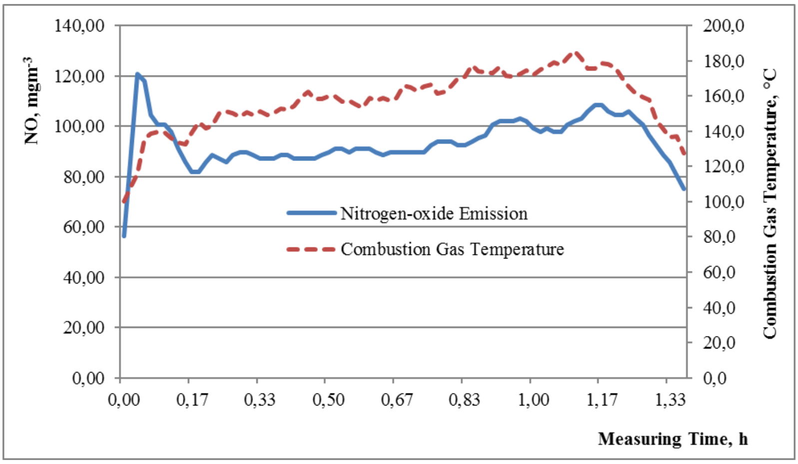

Figure 8 Emissions of NO and TS in a sample of 100% + ps molasses

From obtained data and combustion time, during which burned down 5 kg sample (the example shown in Fig.11, Fig.12) and by using description statistics, was performed data processing for all specimens. For further processing we used the median, because it removes large deviations in measurements (*Table 20*).

Table 20 Carbon Monoxide Emissions, Nitrogen Oxide Emissions and Combustion Gas Temperature in all specimens

Template	Combustion Period, h	Combustion Gas Temperature, °C	Carbon-monoxide Emission, $mg.m^{-3}$	Nitrogen-oxide Emission, $mg.m^{-3}$
1	1,92	159,10	3990,00	91,12
2	1,43	144,85	9089,38	89,78
3	0,88	119,75	1833,13	49,58
4	1,05	159,95	12783,13	105,86
5	1,33	148,90	9936,88	116,58
6	0,77	185,20	3845,00	134,00
7	0,53	183,65	4721,88	136,68
8	1,53	192,50	2563,75	158,79
9	2,12	166,80	4721,88	63,65
10	1,50	183,65	3395,00	104,52
11	0,93	192,50	3715,63	134,00
12	1,50	131,70	1457,50	93,80

We measured the biggest air pollution CO, for sample No. 4. The highest air pollution NO was for the sample No. 8.

High values of CO were probably related to the imperfect secondary combustion, which was the result of an incomplete combustion of volatile components in the secondary combustion zone. The temperature of flues was in the range of 119,75 °C - 192,50 °C. The main influence on the production of NO and NO_x has a temperature of the combustion, too high temperature of the combustion will result in high values of NO and NO_x. We measured emissions NO in the range of 30,07 mgm^{-3} to 256,28 mgm^{-3}, the average value reached up to 95,79 mgm^{-3}, which according to current standards meets specified limits.

Recently, the importance of the biomass as an energy source for direct burn is growing. In Slovakia, Serbia, but also in other economically developed countries, it is possible to observe a tendency, that not only the amount of new heat sources for direct burning of biomass with medium and high power (> 100kW) is increasing, but that direct biomass combustion in devices of low power (<100kW) starts to develop. This trend is directly related to the preparation of the fuel. It is not possible for the manufacturer of the heat to do without the specialized manufacturer of the fuel, while using bigger scale devices, the situation with smaller scale devices is quite different. Tendency to lower economic demands of heat production leads to the production and use of fuels not only from woody biomass, but especially in rural areas, it is also about the use of agricultural biomass.

As a solution to the problem, the system for processing biomass into pellets was designed, adapted its performance to the domestic conditions. In contrast with other authors, we focused not only on the basic biomass, but mainly on the mixtures of diverse types of biomass with aim to find out the effect of the combination of diverse basic materials on the final price of pellets. The first operation in achieving the objectives of this research was to process pellets from selected types of biomass and its mixtures. In processing 100 kg of input biomass, it was monitored the processing time (T_{celk_100}) and the consumption of electric energy (E_{celk_100}). From measured and calculated values were obtained data about total costs of the pellet production from selected types of biomass and its mixtures. Direct costs of the fuel production were derived from counting expenses on electric energy and expenses on minimum hour-wages. Because of the need of energy analysis, pellets were created from defined biomass mixtures observed by calorimetric methods to find out their combustion heat and calorific power. We carried out emission measurements for selected types of biomass and its mixtures.

From the measured data we detected Carbon-monoxide Emission and Nitrogen-oxide Emission values for all measured samples.

We measured the biggest air pollution CO, from the sample containing 25% Wheat Straw and 75% Rapeseed Straw, air pollution NO was the highest from the sample containing 50% Rapeseed Straw and 50% Corn Stem. High values of CO were probably related to the imperfect secondary combustion, which was the result of an incomplete combustion of volatile components in the secondary combustion zone.

6 References

(dátum neznámy). Dostupné na Internete:
http://www.erec.org/media/publications/roadmap-2020.html .

EC. (2016). *Energy*. Dostupné na Internete:
http://europa.eu/legislation_summaries/energy/renewable_energy/l27065_en.htm

EC. (2016). *Energy*. Dostupné na Internete:
http://europa.eu/legislation_summaries/energy/renewable_energy/l27046_en.htm

EC. (2016). *Energy*. Dostupné na Internete:
http://europa.eu/legislation_summaries/energy/renewable_energy/l27063_en.htm

EC. (2016). *Energy*. Dostupné na Internete:
http://europa.eu/legislation_summaries/energy/renewable_energy/l27058_en.htm

EC. (2016). *Energy*. Dostupné na Internete:
http://europa.eu/legislation_summaries/energy/renewable_energy/l27035_en.htm

EC. (2016). *Energy*. Dostupné na Internete:
http://europa.eu/legislation_summaries/energy/renewable_energy/l24452_en.htm

EC. (2016). *Energy*. Dostupné na Internete:
http://europa.eu/legislation_summaries/energy/renewable_energy/l27014_en.htm

EC. (2016). *Energy*. Dostupné na Internete:
http://europa.eu/legislation_summaries/energy/renewable_energy/l28175_en.htm

EC. (2016). *Energy*. Dostupné na Internete:
http://europa.eu/legislation_summaries/energy/renewable_energy/l21061_en.htm

EC. (2016). *Energy*. Dostupné na Internete: http://europa.eu/legislation_summaries/energy/renewable_energy/en0001_en.htm

EC. (2016). *Legislation.* Dostupné na Internete: http://europa.eu/legislation_summaries/energy/renewable_energy/en0009_en.htm

Enviroportal. (2016). *Energeticka politika.* Dostupné na Internete: http://enviroportal.sk/environmentalne-temy/vplyvy-na-zp/energetika/dokumenty/energeticka-politika-sr-2006

MH. (2016). *Ministerstvo hospodarstva.* Dostupné na Internete: http://www.economy.gov.sk/energeticka-politika-sr-5925/127610s

Anon. 2012. Ordinance on the Generation of Electricity from Biomass (Biomass Ordinance – BiomasseV, 2012.). Available through: http://www.bmub.bund.de/fileadmin/bmu-import/files/english/pdf/application/pdf/biomasse_verordnung_en_bf.pdf [Accessed date: 15.05.2016.]

Obnovljivi izvori energije. 2016a. Bioenergija – Biogorivo. Available through: http://obnovljiviizvorienergije.rs/bio-energija/biogorivo/ [Accessed date: 15.07.2016.]

Carić, M., Soleša, D. 2014. Biomass as renewable energy source and waste treatment technologies for biogas production. Cross-border competitiveness through renewable energy and biomass use Project ref: 2007CB16IPO006-2011-2-19 . The project is co-funded by EU through the Bulgaria-Serbia IPA Cross-border Programme.

Marulić, M. 2014. Bio Energija - Bio Energy. Centrala – Renewable Energy Resources Promotion, Development and Implementation Centre. Available through: http://www.centrala.org.rs/knjiga%20liber%20perpetuum/06Bio_energija_Bio_Energy.pdf. [Accessed date: 19.08.2016.]

Mago, L., Topisirović, G., Oljača, S., Oljača, M. 2010. Solid biomass potential from agriculture in Hungary and Serbia. Poljoprivredna tehnika, Vol. XXXV, No. 4. Faculty of Agriculture. Belgrade. p.p. 35 - 45.

Brkić, M. 2013. Resources and technical and technological problems of usage biomass. Dani energetike, Novi Sad. Privredna komora Srbije.

Obnovljivi izvori energije. 2016b. Bioenergija – Biomasa. Available through: http://obnovljiviizvorienergije.rs/bio-energija/biomasa/ [Accessed date: 12.07.2016.]