DEVELPOMENT IN RENEWABLE ENERGY PRODUCTION IN SERBIA WITH THE EMPHASIS ON BIOETHANOL

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Abstract: *Production and use of renewable energy sources has become an imperative for development around the world, including Serbia. The aim of this paper is to study the possibilities of production and use of renewable energy sources, especially bioethanol, as well as their place in the strategic objectives in the energy sector in Serbia. For this purpose, we will firstly frame the policies related to the production of renewable energy, and afterwards display the results of the cost-effectiveness of bioethanol production from the most important domestic biomass-based feedstock - corn. Our assumption is that, despite the existence of sufficient quantities of raw materials required for the production, knowledge, and the potential consumers of bioethanol in Serbia, its wider use will not be possible without the application of a systematic approach, especially without the development of adequate infrastructure in the production and use of energy resources.*

Keywords*: renewable energy, bioethanol, sustainable development, Serbia*

1. INTRODUCTION

Energy crisis and environmental pollution are two vital challenges the world is currently facing. Energy is a component of major significance for all sectors of modern economy and plays an essential role in improving the quality of life. The way energy is produced, supplied and consumed strongly affects the local and global environment and is, therefore, a key issue in sustainable development (Mojović et al., 2013). At the current rate of consumption, crude oil reserves, natural gas and liquid fuels are expected to last for between 60 and 120 years (British Petroleum Statistical Review, 2011).

Approximately 80% of world energy supplies rely on rapidly exhausting non-renewable fuel sources (e.g. coal, oil, natural gas) which are used to produce fuels, electricity, chemicals and other goods. Emission of greenhouse gases (GHGs) represents an additional challenge with fossil fuel consumption. Growing global energy needs and release of environmental pollutants from fossil fuels have finally directed the attention towards clean liquid fuel as a suitable alternative source of energy. Even though bioenergy from renewable resources currently already represents an alternative to fossil fuels, in order to meet the increasing need for renewable energy, new and abundant raw materials need to be considered. The alternative renewable energy sources, not only cut the dependence on oil trade and reduce the doubts caused by the fluctuations in oil prices, but also secure reductions in environmental pollution due to their high oxygen content (Huang et al., 2008; Boer et al., 2000).

In this context, the availability of renewable energy in its two main forms, wood and agro energy can offer cleaner energy services to meet basic energy requirements. Biofuels can be obtained from agricultural crops, crop residues and processing wastes from agroindustries, forests, etc. (Mekala et al., 2014). Interest in various agricultural crops such as cereals (maize, wheat, triticale, barley, rye, sugar cane, sweet sorghum, millet etc.) and some tubers (sugar beet, potato, Jerusalem artichoke, cassava, sweet potato etc.), as renewable and biodegradable feedstock for biofuel production are growing (Semenčenko V. et al., 2013). All petroleum-based fuels can be replaced by renewable fuels produced from biomass such as: bioethanol, biodisesel, biohydrogen etc. (Mojović et al., 2013).

Existing biofuel policies have been very costly; they produce slight reductions in fossil fuel use and increase, rather than decrease, in GHG emissions (Wuebbles and Jain, 2001). However, recent fluctuations and rise in international fossil fuel prices make biomass increasingly competitive as energy feedstock. Current renewable energy research around the globe should direct us toward reduced production costs, higher energy conversion efficiency and greater cost-effectiveness of biofuels (Mekala et al., 2014).

By implementation of the Kyoto Protocol, Serbia sends to international community and the EU a clear signal of readiness to implement the concept of sustainable development and monitor of global socio-economic trends, which will improve the investment climate and increase the confidence of potential foreign investors (Mojović et al., 2013).

2. DIFFERENT FORMS OF RENEWABLE ENERGY

There are many forms of renewable energy. Most of these renewable energies depend in one way or another on sunlight. Wind and hydroelectric power are the direct result of differential heating of the Earth's surface which leads to air moving about (wind) and precipitation forming as the air is lifted. Solar energy is the direct conversion of sunlight using panels or collectors.
Biomass energy is stored sunlight contained in plants. Organic matter holding bioenergy sources in side is known as biomass. We can utilize this biomass in many different ways, through something as simple as burning wood for heat, or as complex as growing genetically modified microbes to produce cellulosic ethanol (Adler et al., 2009). Since nearly entire bioenergy can be traced back to energy from sunlight, bioenergy has the key advantage of being a renewable energy source.
Other renewable energies that do not depend on sunlight are geothermal energy, which is a result of radioactive decay in the crust combined with the original heat of accreting the Earth, and tidal energy, which is a conversion of gravitational energy.

3. RENEWABLE ENERGY PRODUCTION IN EU

Heat and electricity production from biomass increased over the past 10–15 years by 2% and 9% per year, respectively, in the European Union between 1990 and 2000, and biofuel production increased about eight-fold in the same period. Today, the EU is the third producer of fuel-bioethanol in the world after the United States and Brazil; however its production is much lower than the first two (by a factor of about 10). Bioethanol production in EU was 4.97 billion liters in 2012, which is an 11% increase over 2011 (Mojović et al., 2013, Renewable Energy Magazine, 2013). However, although the amount of biofuels produced in the EU is growing; the quantities in general remain insufficient and low in comparison to the total volume of mineral-based transport fuel sold.
One of the significant regulations which impact the EU biofuels market is the European Directive 2009/28/EC on the promotion of renewable energy which aims at achieving a 20% share of energy from renewable sources by year 2020 in the EU's final consumption of energy and a 10% share of energy from renewable sources in each member state's transport energy consumption. In order to achieve that effect, EU members follow the Directive implementation with various political, fiscal and technical measures and incentives. Each EU Member State should adopt a National Renewable Energy Action Plan, setting out its national targets for the share of energy from renewable sources consumed in transport, electricity, heating and cooling in 2020 (European Biofuels Platform Technology, Gitiaux et al., 2012). More renewable energy will enable the EU to cut greenhouse emissions and make it less dependent on imported energy. Boosting the renewable energy industry will encourage technological innovation and employment in Europe.
On 27th of March 2013, the European Commission published its first Renewable Energy Progress Report under the framework of the 2009 Renewable Energy Directive. Since the adoption of this directive and the introduction of legally binding renewable energy targets, most Member States experienced significant growth in renewable energy consumption. Figures for the year 2010 indicate that the EU, as a whole, is on its trajectory towards the 2020 targets with a renewable energy share of 12.7%. Moreover, in 2010 the majority of Member States already reached their 2011/2012 interim targets set in the Directive. However, as the trajectory grows steeper towards the end, more efforts will still be needed from the Member States in order to reach the 2020 targets.
With regard to the EU biofuels and bioliquids sustainability criteria, Member States' implementation of the biofuels scheme is considered too slow.
In accordance with the reporting requirements set out in the 2009 Directive on Renewable Energy, every two years the European Commission publishes a Renewable Energy Progress Report. The report assesses Member States' progress in the promotion and use of renewable energy along the trajectory towards the 2020 renewable energy targets. The report also describes the overall renewable energy policy developments in each Member State and their compliance with the measures outlined in the Directive and the National Renewable Energy Action Plans. Moreover, in accordance with the Directive, it reports on the sustainability of biofuels and bioliquids consumed in the EU and the impacts of this consumption (European Comission, 2013).

4. BIOETHANOL

Bioethanol accounts for the majority of biofuel use worldwide (Margeot et al., 2009, Semenčenko et al., 2011). It is a liquid biofuel which can be produced from several different biomass feedstocks and conversion technologies. Nearly all bioethanol is produced by fermentation of corn glucose in the United States, or sugar cane sucrose in Brazil, but any country with a significant agronomy-based economy can use current technology for bioethanol fermentation (Balat and Balat, 2008). This biofuel is produced by fermentation of simple sugars present in biomass or the sugars obtained by prior chemical or enzymatic treatment of the

biomass. The bioethanol fermentation is performed by microorganisms, traditionally by yeasts (*Saccharomyces strains*) (Mojović et al., 2013).
Bioethanol has the potential to be a sustainable fuel, as well as a fuel oxygenate that can replace gasoline, in transport sector which is considered one of the largest energy consumers as well as environmental pollutant (Kim and Dale, 2004). According to the International Energy Agency statistics (2008), the transport sector accounts for about 60% of the world's total oil consumption. It is responsible for about one fifth of CO_2 emission on a global scale (Joint Research Centre, EU Commission, 2007).
The production of bioethanol has been increasing over the years, and has reached the level of 85 billion litres in 2013. According to the Global Renewable Fuels Alliance (GRFA), this level of the bioethanol production was predicted to reduce GHG emissions by 100 million tonnes in 2013 (Renewable Fuels Association - RFA, 2013). An increase in bioethanol production up to more than 125 billion litres until 2020 has been predicted assuming the production support by governmental policies and exemptions (Demirbas, 2013). The fact that the existing fossil fuel infrastructure, eventually with minor modification, can be used for bioethanol distribution and utilization puts this biofuel in front of other energy alternatives (IEA, 2008).
The economic and temporal constraints that crop feedstocks pose are the main downfalls in terms of the commercial viability of bioethanol production (Harun et al., 2014).Even though bioethanol production for decades mainly depended on energy crops containing starch and sugar (corn, sugar cane etc.), new technologies for converting lignocellulosic biomass into bioethanol are under development today.5 As an alternative to crop feedstocks, significant research efforts have been put into utilizing algal biomass as a feedstock for bioethanol production.
With the exception of sugar cane, corn provides the highest bioethanol yields compared to any other traditional feedstocks being used (US Grains Council, 2012). Alternative fuel - bioethanol is mostly produced from starchy parts of the maize grain leaving significant amounts of valuable by-products such as distillers' dried grains with solubles (DDGS), which can be used as a substitute for traditional feedstuff. Maize grain consists of approximately 70% of starch, which makes it a very suitable feedstock for the bioethanol production (Radosavljević et al. 2008). Renewability of maize and growing environmental pollution by oil products represent two principal reasons for maize becoming one of the major raw materials for the energy production (Radosavljević et al. 2009).
The rapid increase in biofuels production from traditional feedstocks during the last few decades has brought dramatic changes to food and agricultural systems especially in countries that are the biggest bioethanol producers (e.g. United States and Brazil).
Studies have found that, in general, with increased ethanol expansion, the prices of both the agricultural feedstock commodities and their competing crops increase with implications for land allocations, food prices, and the environment.(Elobeid and Hart, 2007, Elobeid et al., 2007).
Recent increases in biofuel production, particularly the dry grind corn-to-ethanol process, creates a sizable stockpile of its co-product in the form of dried distillers' grain with solubles (DDGS), which is made by blending distillers' wet grains (DWG) and syrup and drying the mix (Liu et al., 2012). A gallon (3.78 L) of bioethanol produced from corn kernels generates about 7.4 pounds (3.36 kg) DDGS (Pimentel 2003). During the production of bioethanol, starch is removed from the grain and converted to alcohol and carbon dioxide. As a result of starch removal, the concentration of the remaining nutrients in the grain increases approximately three-fold. The DDGS contains higher percentages of protein, fibre and lipid contents than those in corn (Liu et al., 2012).
Application of DDGS in livestock and poultry diets in concentrations greater than traditional could positively affect the economic viability of this biofuel production, but also stabilize the current imbalance in the food and animal feed market. However, DDGS feedstuff should not be treated as a perfect substitute for corn, because the complexity of ration formulation determined at the farm or feedlot level is driven by energy and protein and other nutrient requirements, as well as their relative costs in the ration (Semenčenko et al., 2013 a).

5. RENEWABLE ENERGY PRODUCTION IN SERBIA

Serbia and other Balkan countries interested in joining the EU, has accepted the obligation to follow EU policies and programs, including those that oblige them to introduce the production and use of fuels from renewable energy sources. Among renewable energy sources in Serbia, the most important are biofuels, especially bioethanol. Apart from natural resources, research and development within the National Innovation System of the Republic of Serbia are of great importance (Semenčenko D. et al., 2009). Starting from the first National Innovation Systems, energy has played an important role in stimulating the economic development. National innovation systems of today must, as well, demonstrate a significant level of innovation in research and application of new renewable energy sources (Semenčenko D., 2009). Better coordination between institutions and academic and private sector is a very important step in order to realize cost-effective bioethanol production in Serbia (Mojović et al., 2013). By implementation of the Kyoto Protocol, Serbia sends to the international community and the EU a clear signal of readiness to implement the concept of sustainable development and monitor of global socio-economic trends, which will improve the investment climate and increase the confidence of potential foreign investors.

With the ratification of the Agreement established by the Energy Community (Coordinating European Council - CEC, 2006), Serbia has, among other things, accepted the obligation to implement the Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources and Directive 2003/30/EC on the promotion of the use biofuels and other fuels from renewable energy sources in the transport sector, to ensure the emergence of a certain quantity of biofuels on the market - 5.75 % of the total fuel used in traffic by the end of 2010. This directive is in accordance with the Kyoto protocol signed in 1997, with the aim to reduce emissions of gases that contribute to the greenhouse effect, which Serbia is a signatory. However, in 2009 European Commission has adopted a new Directive 2009/28/EC, which was established to promote the use of energy from renewable sources. This directive changes and consequently abolishes Directives 2001/77/EC and 2003/30/EC, by establishing a common framework for the promotion of energy from renewable sources. It sets obligatory national targets for the overall share of energy from renewable sources in gross final energy consumption, and for the share of renewable sources in transport: at least 20 % share of energy from renewable sources in gross final energy consumption in the Community and a 10% share of energy from renewable sources in energy consumption for transportation of each member country by the year 2020. In addition, sustainability criteria for biofuels and bioliquids have been established. Serbia has adopted the Directive and it is embedded in the Biomass Action Plan which was adopted in 2010.

6. BIOETHANOL PRODUCTION IN SERBIA

Today in Serbia, the bioethanol production is being conducted in seven plants, with total production capacity of 23,225 t per year. Raw materials predominantly used in these plants are molasses and cereals. In these plants, 96% vol. bioethanol is produced, and it is subsequently being used mainly for alcoholic beverages and medical and pharmaceutical purposes (Mojović et al., 2013). Bioethanol production in Serbia from fermented substrates amounted 8.69 million liters in 2011, which is only 30% of annual production capacity in Serbia. This indicates that the capacity utilization of bioethanol plants is rather small. The highest bioethanol production of 19.17 million liters was achieved in 2007 (Statistical Office of the Republic of Serbia, Biomass Action Plan for the Republic of Serbia 2010-2012). It is important to point out that despite current low level of industrial production of bioethanol, Serbia has main prerequisites to develop and improve this production since it possess a large feedstock potential, tradition and also educated human potential.

In Serbia, conventional energy crops such as starch-based raw materials are the most suitable and available agricultural raw material which can be used for industrial bioethanol production. However, a growing demand for the corn and wheat on global market are currently increasing their price and make these feedstocks less appropriate. For these reasons, possibilities of using cheaper substrates such as damaged crops and for example, triticale are being investigated (Pejin et al., 2009, 2012).

By applying the methodology used by the International Energy Agency – IEA, estimation of the amount of bioethanol that could be produced in Serbia in the future (from 2015 to 2030) was performed (Mojović et al OECD/IEA, 2010). The agency in its regional and global estimates of energy potentials used data recommended by FAO that assume global annual crop growth of about 1.3% and about the same global growth of agricultural biomass (waste). For Serbia, this analysis assumed slightly lower amount of crop growth of 0.9%. The estimation of first generation bioethanol production in Serbia based on available feedstocks taking advantage of surpluses of crops and use of marginal land showed there is a great potential for bioethanol production in Serbia of $1,188,030 \cdot 10^3$ lifters, i.e. 937,356 tons in 2015. Similar analysis has been performed to estimate the country potential for the production of second generation of bioethanol. The analysis was performed for two possible scenarios, the first for the possible utilization of 10% of the lignocellulosic biomass for the production of bioethanol and the second for the utilization of 25% of the biomass for the production of bioethanol. Results calculated for year 2015 were $258,385 \cdot 10^3$ lge (liter of gasoline equivalent), i.e. $645,962 \cdot 10^3$ lge, for these two scenarios, respectively.

Recently conducted studies revealed that Serbia will need to build new bioethanol plants in order to produce enough bioethanol for use as a fuel and thus follow the aims of the European Directive 2009/28/EC. Based on the given replacement of 20% of gasoline by bioethanol by year 2020 according to European directive 2009/28/EC, it has been reported (Dodić et al., 2009) that it will be needed to produce 233,000 t of bioethanol until 2026. If it is assumed that the needs of the ethanol industry and pharmacy stay the same (52,000 t), total demand for bioethanol would be 285,000 tons, which is 12 times the installed capacity in Serbia.

There is a great interest in the world today in the development, selection and cultivation of maize hybrids that can produce higher bioethanol yields. In that manner, maize hybrids with higher content of fermentable sugars are being developed. In the USA, two great companies "Pioneer" and "Monsanto" make efforts to identify and develop new corn hybrids, examine the impact of the environment on their growth, and the impact of corn varieties on the composition of useful by-products. Both companies have commercial corn varieties specifically cultivated for use in bioethanol production with obtained ethanol yield up to 4% higher than with conventional varieties (for the annual production of bioethanol of 150 million liters it means annual

profit increase of 1-2 million US dollars). Further research in the world should result in modification of properties of starch and other complex carbohydrates by methods of genetic engineering (Mojović et al., 2013).
Furthermore, significant efforts have been made at the Maize Research Institute, Zemun Polje, Serbia, in order to determine the suitability of local maize hybrids for bioethanol production. The calculation of average potential costs of bioethanol production from corn grain in Serbia performed on some of these hybrids is shown in Table 1.

Table 1: Average potential costs of bioethanol production from corn grain in Serbia calculated for 2012 prices, for most widely used local maize hybrids (Source: Semenčenko V, 2013)

Cost component	Average price, € l^{-1}
Feedstock costs	0.132
By-product credits	
DDGS	0.042
Carbon dioxide	0.001
Net feedstock costs	0.089
Cash operating expenses	
Electricity	0.011
Fuels	0.041
Waste management	0.001
Water	0.0007
Enzymes	0.008
Yeast	0.001
Chemicals	0.007
Denaturant	0.01
Maintenance	0.012
Labor	0.011
Administrative costs	0.008
Others	0.0009
Total	0.1116
Total cash & net feedstock costs	0.2006
Ethanol yield per hectare, l	3888.67
Ethanol production costs per hectare, €	778.69
Net income per liter, €	0.3094
Net income per hectare, €	1204.53

From the data presented in Table 1 it can be concluded that the average net income per liter of bioethanol produced from maize grain 0.3094 €, and the net income per hectare of 1204.53 €. The table shows the fact that the price of bioethanol fermentation by-product – dried distillers' grains with solubles (DDGS) amounts 0.042 € l^{-1} ethanol, which means that based on the total revenue from the sale of one liter of this fuel represents about 14%.

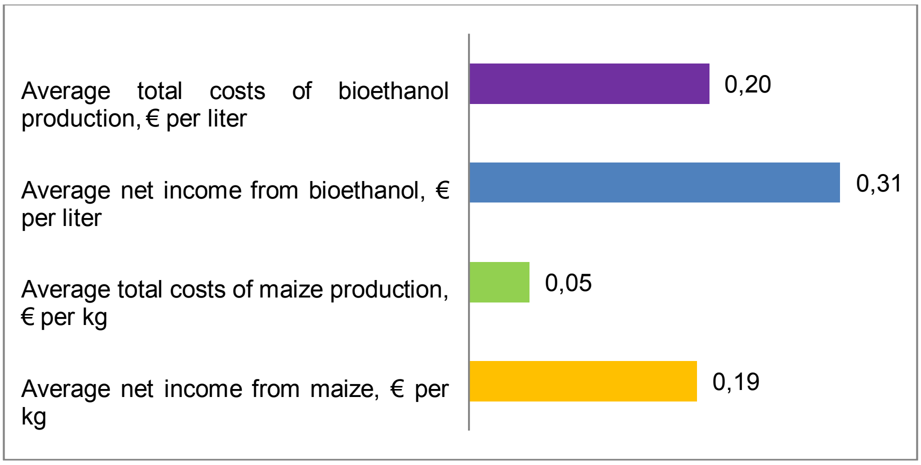

Figure 1: Average net income and costs of maize and bioethanol production in Serbia, calculated for prices from 2012 for most widely used local maize hybrids (Source: Semenčenko V, 2013)

From Figure 1 it can be concluded that by selling one liter of bioethanol higher profit can be achieved than by selling one kilo of maize grain. However, profitability per hectare of commercial maize grain sold is higher. This can be explained by the fact that for the production of one liter of ethanol was requires, on the average, 2.5 kg of maize grain.

In real terms it cannot be expected that all maize grain, intended primarily for human and animal nutrition will be used for the production of biofuels. The obtained results indicate that the production of a certain quantity of bioethanol from corn grain could be cost-effective, and it is necessary to design the production process in a way to find appropriate measures between the food industry and the alternative fuels production. Taking into account the fact that Serbia is a signatory of the Kyoto Protocol (1997), which refers to the reduction of greenhouse gas emissions and that the Biomass Action Plan (2010) established sustainability criteria for biofuels and bioliquids, the start of production of at least and the minimum amount of bioethanol would be a significant step towards achieving these goals (Semenčenko V, 2013).

7. CONCLUSION

Bioethanol production in Serbia is now at a very low level, even lower than the production scale at the very end of the twentieth century, and it is not sufficient enough to fulfil the country's ethanol needs for beverages, medical and pharmaceutical purposes. This is the main reason why in Serbia, there is still not an organized production and utilization of bioethanol or other biofuels for gasoline and diesel substitution. Recently conducted studies revealed that Serbia will need to build new bioethanol plants in order to produce enough bioethanol for use as a fuel and thus follow the aims of the European Directive 2009/28/EC. The obtained results, furthermore, indicate that the production of a certain quantity of bioethanol from corn grain could be cost-effective, and it is necessary to design the production process in a way to find appropriate measures between the food industry and the alternative fuels production. The revenues from corn bioethanol co-product – DDGS sold for animal feed could reach 14% of total income. In Serbia, it is necessary to introduce new strategies for the bioethanol production - large capacity plants that apart from bioethanol also include the production of animal feed and carbon dioxide; or introduce a network of small plants for the production of bioethanol within the petroleum industry.

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