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TECHNOLOGICAL OPPORTUNITIES SURVEY OF FOREST SHORT ROTATION PLANTATIONS IN BULGARIA FOR ENERGY BIOMASS PRODUCTION* PART 1: ANALYSIS OF THE PRODUCTION OF ENERGY FROM BIOMASS IN BULGARIA AND PERSPECTIVES FOR CREATING ENERGY PLANTATIONS FROM SHORT ROTATION WOOD CROPS

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ABSTRACT

This report presents some problems on the state and future use of biomass as a renewable source for production of heat and electricity in Bulgaria and Europe. The report covers the potential opportunities of the agricultural lands in Bulgaria for production of energy plantations (SRP) and in particular from forest tree species such as poplar, willow and black locust. A review of their main advantages and disadvantages is made and recommendations for their future development in Bulgaria are presented.

Key words: renewable, wood biomass, short rotation coppice

INTRODUCTION

Global climate change is increasingly acting as a driver to change energy generation and consumption patterns in Europe and around the World. The main aim is to reduce greenhouse gas (GHG) emissions, especially carbon dioxide from the burning of fossil fuels. Europe is in the midst of a dramatic energy transition - from fossil fuels, and in some cases from nuclear power - to renewable energy. At EU level, in absolute terms, total gross inland energy consumption fell from 1827,7 Mtoe in 2006 to 1758,7 Mtoe in 2010, while gross inland consumption of renewable energy rose from 123,4 Mtoe to 172,13 Mtoe in the same period.

Biomass for heat and power can offer considerable GHG savings relative to fossil fuel based systems (up to 90 % depending on the systems being compared). In the current stage of technological development, Biomass Sector concluded that the development of a biomass heat sector had the greatest potential to deliver cost-effective carbon savings (Carbon Trust report). In 2010 all the European Member States (MS) worked out national renewable energy action plans (NREAP). These plans contain detailed roadmaps of how each MS expect to reach its 2020 target, expressed as a share of renewable energy in the gross final energy consumption.

Out of this 20 % energy from renewable sources, more than a half was provided by bioenergy. These NREAP are indeed giving the main framework that gives trajectories and plans that will be follow up by the Commission in the coming 10 years. According to the NREAP's biomass delivered in 2010 more than 83 Mtoe to the EU's energy consumption, with 12 % electricity, 18 % as transportation fuels and 70 % as heat. Heating will continue being by far the most important sector for bioenergy in 2020. Taking into account that heat covers more than half of the final energy consumption in Europe, biomass should be a key sector for EU members, with 12 % electricity, 18 % as transportation. By 2020 biomass supply in Europe will increase to meet the demand of all sectors heat, electricity and transport biofuels. Forest and forest based industries

are contributing the most to the biomass supply, and this should still be the case in 2020, however the biggest increase should come from agriculture. The share of forest, agriculture and waste biomass from total biomass supply to 2020 year is shown at Figure 1.

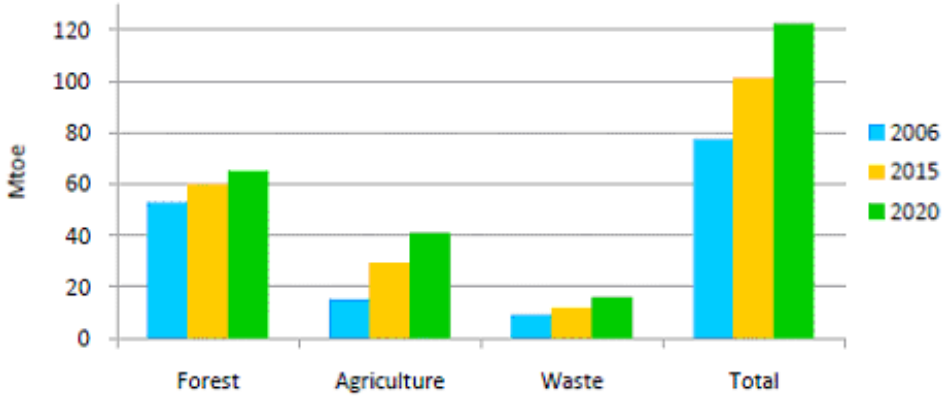

Figure 1: Biomass supply in EU 27. Source AEBIOM

Bulgaria did actively involve in international efforts to prevent negative climate change by adopting the coordinated EU measures and a comprehensive package of measures in the field of energy. These measures give a new boost to energy security in Europe and support the European goals „20-20-20". The widespread use of renewable energy and the implementation of the energy efficiency measures are among the priorities of the energy policy of Bulgaria and correspond to the objectives of the new Energy Policy for Europe.

In accordance with Directive 2009/28/EC of the European Parliament and the European Council, Bulgaria adopted the *National Renewable Energy Action Plan* (*NREAP*) in 2010. The plan aims to ensure a sustainable transition to a low carbon economy, based on modern technologies and wide use of renewable energy sources. The Renewable Energy Action Plan introduces a framework for promotion of renewable heat to reach a minimum of 16 % target of heat demand to be met from renewable sources by 2020, of which biomass is 36 %. The new Forest Act (Article 88, paragraph 5, item 2) allows for the plantations of tree and shrub species, created for a rapid biomass production, to be not manage as a forest (Trichkov, 2012).

1. BIOMASS MEANING IN THE EUROPIAN AND BULGARIAN ENERGY POLICY

Biomass is by far the most important source of renewable energy in Europe. Gross inland consumption of renewable energy in the European Union (EU 27) topped 150 Mtoe for the first time in 2008 with biomass contributing 105 Mtoe (AEBIOM' Annual report 2010). Renewable energy development and biomass share in overall energy consumption from 1995 to 2008 year is presented by Figure 2.

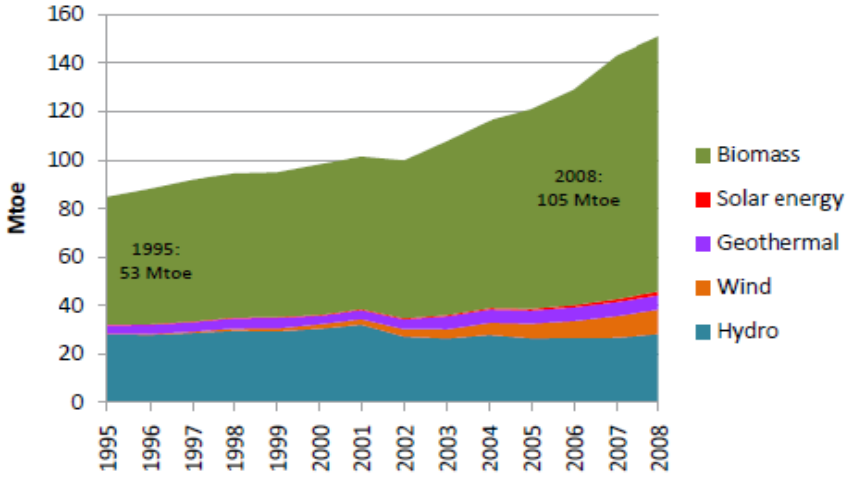

Figure 2: Renewable energy development and biomass share in overall final energy consumption of EU27. Source AEBIOM

According to the last AEBIOM Annual Report 2011, gross inland consumption of bioenergy from biomass accounted 119 Mtoe in 2010 year, representing almost 70 percent of European renewables and showing steady growth. Without considering the losses of electricity and heat in transmission and distribution, biomass delivered in 2010 more than 85 Mtoe to the EU´s final energy consumption. Heating is the most important sector for bioenergy, counting the 72 % of its final energy consumption. Taking into account that heat covers more than half of the final energy consumption in Europe, biomass should be a key sector for EU members to meet the 2020 targets. Biomass electricity output has increased by 13, 5% per year on average during the last decade, which equated to an additional contribution of 78,3 TWh. Thereby bioelectricy counts with 12 % of the final bioenergy consumption.

Biomass achieved a share of 7,16 % of the overall final energy consumption of the EU (AEBIOM). Biomass distribution in overall final energy consumption of EU27 in 2010 is shown at Figure 3. With a 7 % share of biomass energy consumption, Bulgaria occupies an average position in relation to other European countries. This biomass is composed mainly of solid forest wood for heating.

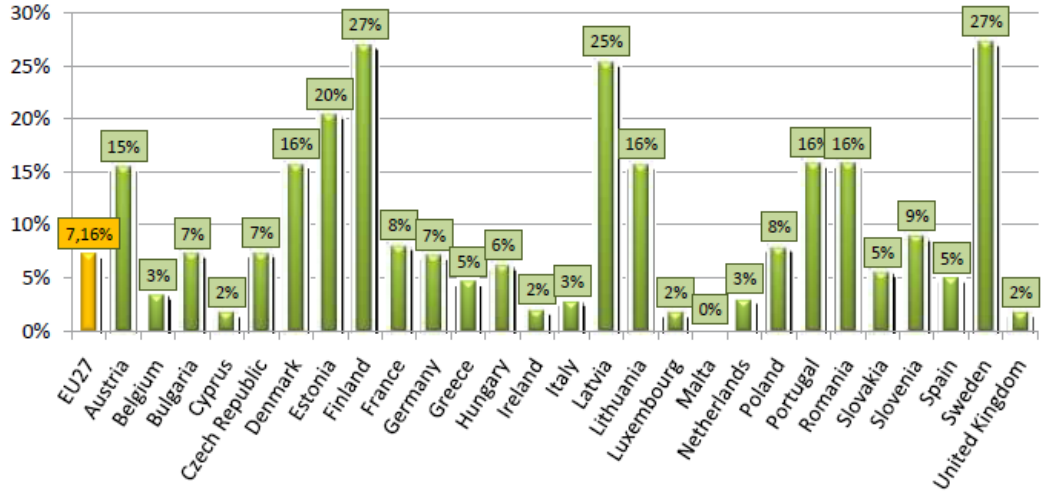

Figure 3: Biomass distribution in overall final energy consumption of EU27. Source AEBIOM

The new European Union climate and energy policy presents several new challenges to the forestry sector. The EU Renewable Energy Roadmap aims to increase the security of energy supply and to reduce greenhouse gas emissions. This should lead to wider use of forest biomass for energy production, bearing in mind that wood biomass accounts for approximately 80 % of the total use of biomass for energy in the EU. Inevitably the growing demand for renewable energy continues to increase competition for wood, especially in the wood panel and pulp sector. In this light the State Forest Management Organisations will face pressure to balance new expectations of different customers and policies (Lindel 2010).

EU Forest Action Plan (COM (2006) 302) provides a framework for forestry related actions at EC and Member States level and serves as a co-ordination instrument between EC actions and the forest policies of the Member States. The Action Plan has four main objectives:

1) improving long-term competitiveness;
2) improving and protecting the environment;
3) contributing to the quality of life;
4) fostering co-ordination and communication.

The Standing Forestry Committee supports the implementation of the Biomass Action Plan, in particular, the development of markets for pellets and chips and the provision of information to forest owners about the opportunities of energy feedstock production. According to the Plan the Commission should facilitate investigations of experience on wood mobilisation and Member States should assess the availability of wood and wood residues and the feasibility of using them for energy production at national and regional level. The Commission will continue to support the researches and developments (R&D) of technologies for the production of heat, cooling, electricity and fuels from forest resources.The Forestry Committee recommends improving wood mobilisation in 8 key areas, resulting in synergies both for the forest-based industries and energy producers. These areas are:

1) to improve data on supply and use of wood;
2) to develop national /regional wood mobilisation strategies;
3) to increase the potential of wood for energy and material use;
4) to ensure sustainable provision of forest biomass;
5) to develop and maintain efficient wood supply chains and markets;
6) to strengthen efforts to increase forest owner motivation, organisation and awareness;
7) to enhance support mechanisms, incentives and coordination efforts for wood mobilisation;
8) to promote research and technological development in the field of forest production, harvesting technologies and wood utilisation.

The Standing Forestry Committee point out that new member States from Central and Eastern European countries, where state forests often dominate, emphasis is required to promote the use of forest residues and low value timber and related markets. From the point of view of state forest managers the following actions should be considered as high priority:

1) to establish task forces to develop national wood mobilization strategies;
2) to disseminate knowledge re the silvicultural potential to increase wood supply from coppice management systems, providing guid-

ance re optimal rotation periods and harvesting techniques;

3) to support forest infrastructure developments by using Rural Development measures;
4) to explore the options to improve road transport, including weight and dimension limits as well as diversification of transport means (railway, water transport);
5) to encourage partnership between private and public players, namely state and municipal forest enterprises for wood mobilisation throughout the whole supply chain.

One basic difference between bioenergy and other renewable forms of energy (hydro, wind, solar) is that in the first case, the primary resource must be produced and/ or collected, with its corresponding cost, while for the other systems, the „fuel“ (water, wind, solar radiation) is available for free. There are several potential types of biomass material including forest resources, energy crops, algae, woody and agricultural residues and biological waste. Biomass can be used directly to generate heat or electricity - domestically in stoves or woodfuel boilers or at a community/regional level through biomass power plants and Combined Heat and Power. Biomass materials (or feedstocks) can also be used on a larger scale through co-firing in existing fossil fuel power stations. Biomass has the advantage of providing a renewable source of energy (referred to as bioenergy) and can help mitigate against climate change. It has the potential to be carbon neutral depending on the way it is produced and in principle can reduce carbon dioxide emissions across all the energy sectors (electricity, transport and heat). Bioenergy is a type of renewable energy which remains under-exploited in Bulgaria and which does not have the disadvantage of intermittency associated with some other types of renewable energy. Interest in bioenergy is also being driven by concerns for energy security, and the desire for diversification in farming and forestry, and rural development.

The biomass is the most widely used RE bio-resource in Bulgaria (Gochev at al, 2012). The production and use of biofuels, such as biogas, bioethanol etc., is still at an initial stage. At present the used biomass in Bulgaria consists mainly of firewood, which is most commonly used for house heating. The use of firewood has grown significantly during the past years due to the price increase of the electricity and other fuels. The stoves and fireplaces used in Bulgaria are in most of the cases old and inefficient and the heat losses are between 60 to 70 %. The heating with highly efficient boilers and heating installations has not been developed yet. According to the Ministry of Agriculture and Foods the biomass yield and utilization may increase notably from forestry, agriculture and energy crops. The production of woody fuels, such as energy chips, pellets and briquettes is still low, not only because of their high price, but also because of the undeveloped supply chain. For the production are used mainly firewood and biomass residues from the wood and pulp industry. Agricultural residues (mostly straw) are for the time being rarely used for the production of densified briquettes. Energy crops, such as SRF or SRC and energy perennial grass are cultivated with experimental goals in small areas and by 2012 they do not have a commercial purpose. For the production of electricity, the biomass needs to be directed to plants for combined heat and power production – co-generation.

According to the Bulgarian NREAP, the role of the biomass in the energy balance will increase and measures are provided in

two ways: 1/ to increase the share of the biomass in the overall final consumption; 2/ to increase heat energy, resulting from the conversion of biomass. In 2020 the energy production from solid biomass is expected to reach 1073 ktoe, and heating and power plant – to 91 ktoe. The electricity producing from biomass in Bulgaria is expected to reach 871 GWh at 2020. The data is given at Table 1 and Table 2.

Table 1: Energy production estimate from solid biomass during the period 2010 – 2020 (1ktoe = 41868 GJ)

Years	2010	2012	2014	2016	2018	2020
Energy production, [ktoe]	734	790	888	963	1003	1073
Heating and Power plant, [ktoe]	5	14	25	40	65	91

Table 2: Estimates of installed power and electricity produced from biomass. Source NREAP

Years	2010	2012	2014	2016	2018	2020
Installed power, [MW]	0	22	102	209	144	168
Electricity produced, [GWh]	0	122	559	1160	783	871

Biomass is a renewable energy source with the highest potential in Bulgaria and a wide variety of applications. For this purpose, a more complete utilization of waste from forestry, agriculture and manufacturing is needed. The logging yield will increase to 7 million m^3/year solid wood until 2020. Estimated energy amounts from biomass from Forestry. Agriculture and residues are given in Table 3 (Bulgarian NREAP).

Table 3: Energy estimates of biomass for period 2015 – 2020. Source NREAP

Year	2015	2020
Biomass from Forestry, *ktoe*	830	892
Biomass from Agriculture, *ktoe*	130	169
Biomass from Residues, *ktoe*	63,5	84

2. ANALYSIS OF THE ENERGY FOREST BIOMASS CROPS

2.1 Biomass crops in EU27 and climatic zones

The resources from European forestry and by-products from wood industry are not sufficient to meet the objective of the EU for bioenergy. In the long term, bioenergy crops from agriculture should to provide a significant resource for the biomass supply. The environmentally-compatible bioenergy potential from agriculture can reach up to 142 Mtoe by 2030 compared to 47 in 2010 (EEA Report). Such a development will occur if the high yield crops are introduced and their productivity is increased. New dedicated energy crops for energy production would enable the EU to diversify its energy sources, provide an income to farmers and reduce CO_2 emissions.

Biomass sources can be divided into two main streams: – *energy crops* and *organic residues*. Energy crops are grown specifically for energy purposes. Short Rotation Forestry (SRF), based on the short rotation coppice (SRC) from forest wood species, this is the production of wood fuel through the cultivation of high-yielding trees at close spacing on short time rotations. Species such as Willow and Poplar are preferred for SRF, as they are easy to establish, fast growing, suitable for a variety of sites and resistant to pests and disease. Land for short rotation forestry is likely to come from two sources, namely: non-rotational arable set aside land and land outside the existing arable pool – in beef or sheep production. Other energy crops such as Hemp and Miscanthus (Elephant grass) have been investigated for their suitability as a source of biomass fuel. Biofuel energy crops are grown for the production of liquid transport fuels. Short rotation forestry refers to the growing of trees (usually willow or poplar) in extremely dense stands, harvested at 2 – 5 years intervals and regenerated from the stools, which

are expected to survive 5 rotations at least. As a rotation crop, SRC is harvested at specific intervals, to provide a regular and constantly renewable supply of fuel. The development of SRC for renewable energy production is a new sector with potential for considerable expansion, offering benefits for growers, developers, consumers, local communities and the environment. A typical plot might be from 10,000 to 20,000 cuttings per hectare. Planting in twin rows allows harvesting of two rows at a time, usually using direct cut and chip methods. There would usually be about 1.5 meters between double rows of cuttings so that the side walls of the tires of the tractor are not damaged by the cut crop. 90 cm spacing between rows of cuttings and 75 cm spacing between cuttings in a double row will allow for tractor access. Research is continuing into the optimum spacing between varieties. It is one of the factors, together with better pest management, which may lead to increased productivity. Converting existing arable land to SRC will reduce the amount of agricultural chemicals required as SRC is a low input crop: once established it requires a very much lower input of chemicals than conventional arable crops.

A wide range of crops has been tested as biomass crops in Europe the last two decades in smaller or larger-scale field trials, aiming to test adaptability, yield potentials and quality characteristics under different soil-climatic conditions. The choice of the crops in each region depends primarily on their suitability in the specific climatic constraints (rainfall, maximum and minimum air and soil temperature), the access to irrigation water, if needed, and the soil conditions (good arable soil, marginal land). When the expected yields of the selected crops in each specific region are considered sufficient for industrial the following factors should be taken under consideration: 1/ the existing varieties suitable to the region, requirements for propagation material; 2/ good knowledge of agroforestry practices (soil tillage, sowing methods, fertilization, crop protection, harvest time) and mechanization (establishment, sowing, harvest); 3/ logistics (transport, storage).

The mapping of suitable energy crops for the European climatic regions, based on the findings of 4FCROPS project, is shown in Figure 4 (AEBIOM 2009). According to this mapping, Bulgaria occupies three climatic zones: Continental, Pannonian, Alpine South and Mediterranean North. The Continental climatic zone covers the majority of the area of Bulgaria. The Pannonian climatic zone is dominated by a flat alluvial basin of the valleys of the Danube and Maritsa rivers and the Black Sea coastal region. The Mediterranean North zone covers the South-East and the southern regions of Bulgaria.

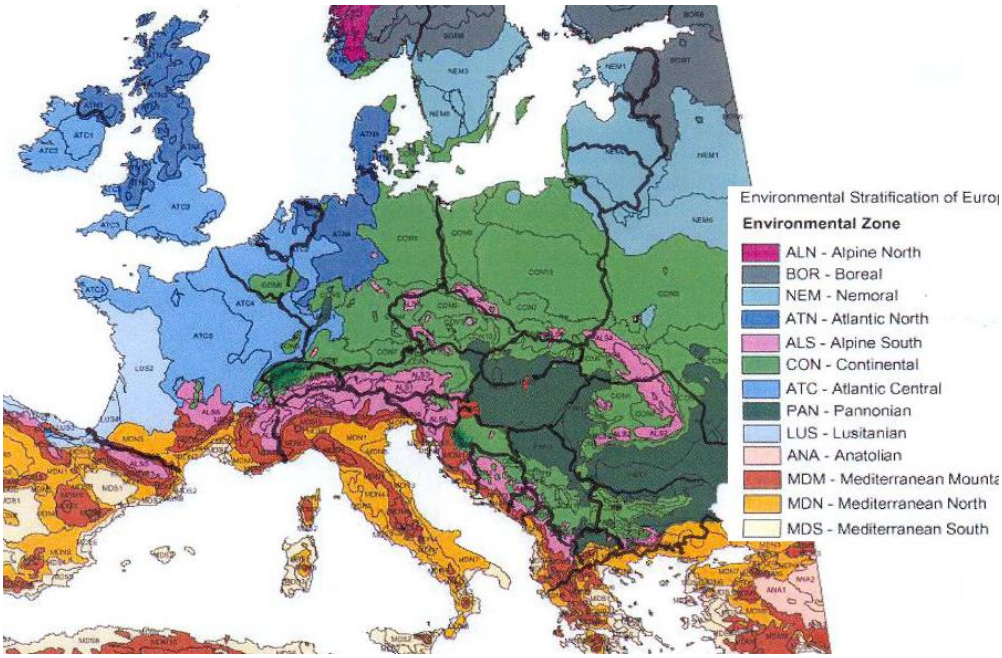

Figure 4: Map of European climate zones and recommended energy crops. Source 4FCROPS
Continental: Wood crops: Willow, Poplar; Agriculture an Perennial grass crops: Miscanthus, Maize, Sunflower, Sorghum, Flax, Reed canary grass, Rapeseed
Mediterranean north: Wood crops: Poplar, Black locust; Perennial grass and Agriculture crops: Miscanthus, Giant reed, Maize, Sunflower, Sorghum, Flax, Sugar beets, soybean, Ethiopian mustard, Rapeseed, Safflower, Kenaf

2.2. Current and future available land for the cultivation of energy crops

The current cultivation areas of energy crops in the EU of the short rotation forestry is around 32,800 ha and comprises mainly willow (27,200 ha; 5,600 ha of poplar). Regarding the herbaceous crops the main crops were reed canary grass (27,000 ha), miscanthus (4,500 ha) and hemp (800 ha), while a total area of 500,000 ha is being devoted in Germany to crops for biogas production (based on AEBIOM data). Based on a recent evaluation for the land available for biomass crops preformed in the frameworks of RENEW and 4FCROPS projects values were estimated for the current situation, for 2020 and for 2030. This has been done by a land allocation model that had been developed in RENEW project, which calculates surplus land available for energy crops after satisfying food and feed demands. Scenario 2020 of available land for the cultivation of biomass crops per country is shown at Figure 5.

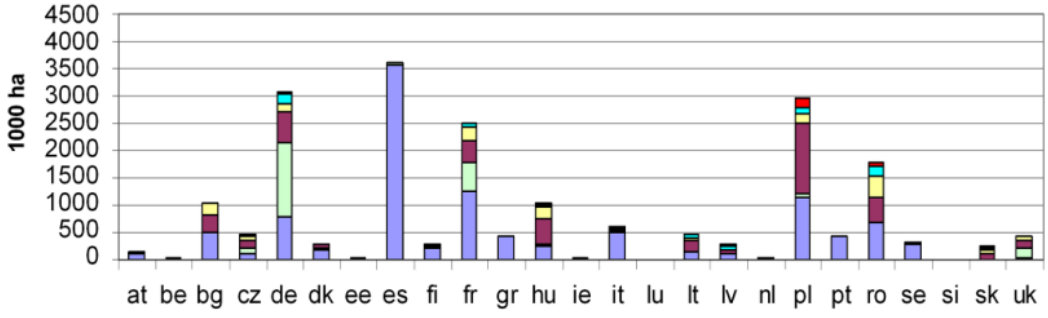

Figure 5: Available land for the cultivation of biomass crops per country (2020).
Source: Krasuska et al. 2010

The results show that the current situation, 80 % of the total available land is fallow land, while the rest refers to the current area of the cultivation of energy crops. The largest potential was found in Spain with 3,6 million ha, followed by Germany with 2 million ha (1, million ha with biomass crops and 0,8 fallow land). France and Poland contribute more than 1 million ha fallow land each. It was estimated that additional land would be released from food and fodder crops taking under consideration two important parameters: 1) yield increases and 2) population changes. Thus the available land for non-food crops will increase to 20,5 Mha in 2020 and to 26,5 Mha in 2030. In 2020 the countries with the largest available land resources by descending order will be Spain, Germany, Poland, France, Poland and Romania. In 2030 scenario the top six countries with the largest available land resources will be Poland, Germany, Spain, France, Romania and France. In the 2030 scenario apart from the mentioned countries Bulgaria and Hungary will play an important role. In all countries the available land will be released from the food and feed crops, while in Spain the available land use will come from fallow land only. In both timeframes more land will be released in the EU12 than in the EU15 countries due to higher crop yield growth rates in EU12.

In Figure 6 the land availability in the EU NUTS-2 regions is presented based on the findings of the 4FCROPS project. In the current situation the surplus land contribution to the total agricultural land is below 9% in most regions. It is higher in parts of Germany, as well as in central Spain and in southern Greece. In 2020 the share of surplus land in most regions is expected to increase and to be in the range of 14–21 % of total agricultural land in most of the countries, while for 2030 it is expected to increase further to 22–42 %. In 2020 the highest percentage of surplus land is expected to be located in central Spain, Germany, Poland, Bulgaria and Greece. In 2030 scenario, large regions with the highest percentage of land potentially available for energy crops (over 20 %) expected to be located in central and eastern Spain, in central and eastern Germany, in western Poland, Hungary and northern Bulgaria, hence including almost all regions of the Central–East Europe.

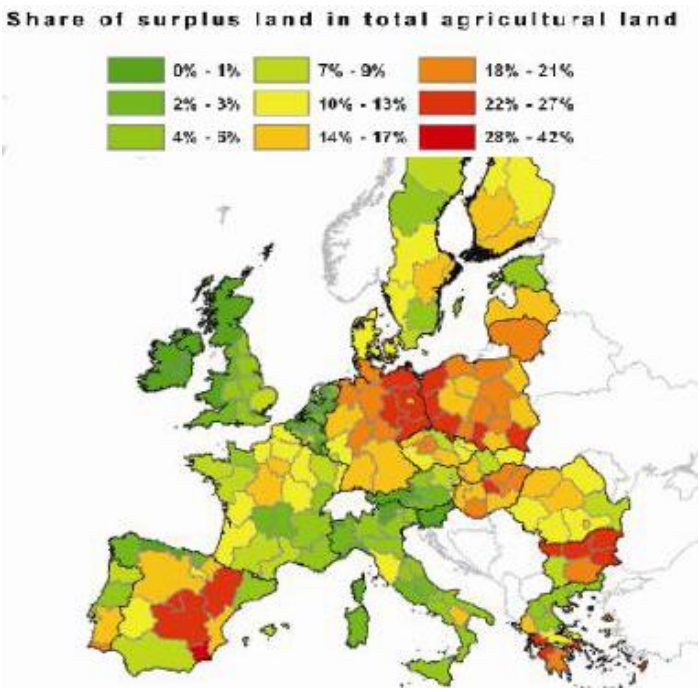

Figure 6: Share of surplus land in total agricultural land at 2020. Source 4FCROPS

According to an estimate of the Ministry of Agriculture and Foods, the abandoned areas in Bulgaria were 461 142 ha, including 348 118 ha of uncultivated areas in 2010. In order to promote the utilization of such areas in the country for the production of energy crops, the "European agricultural fund for rural development" provides subsidies.

3. PURPOSE-GROWN SHORT ROTATION COPPISE CROPS FOR ENERGY PRODUCTON, ADVANTAGES AND DISADVANTAGES

The widespread biomass source is the short rotation coppice of forestry wood species – SRC. Short rotation coppice is densely planted crop (8000 – 15000 plants/ha), high yielding, harvested on a 2 to 5 year cycle. SRC is a woody, perennial crop with the rootstock or stool remaining in the ground after harvest after which new shoots emerge. The SRC plantation should remain viable for 20 – 30 years. In Europe and North America, the woody species used or considered most often for purpose-grown biomass are the specifically-bred varieties of willows (*Salix* spp.) and poplars (*Populus* spp.). These crops do not fully match either the conventional forestry or the ordinary agriculture. Cultures are completely new and raise new problems and requirements. The plantations for biomass production are consistent agroforestry systems. Usually they are created at a high density, often over inefficient agricultural areas, weakened due to erosion or intense and prolonged growing of crops or on difficult terrains - steep slopes, coastal and floodplain lands, areas, inaccessible for the use of agricultural machinery, etc. The concept of SRF implies the cultivation of fast growing tree species on agricultural land at extremely high density of plantation; the use of intensive tending techniques, and particularly a high grade of mechanization in every phase; the repetition of harvest at 1 – 3 year intervals, and the regeneration of the crop as a coppice with sprouts arising from a permanent stool.

Advantages and disadvantages of short rotation coppices

The SRC crops grown for the production of energy chips for heating and power

installation are a new challenge for the Bulgarian agroforestry development.

The advantages of SRC include:

- Long-term, sustainable and secure local fuel sources, grown to meet the needs of the market – not intermittent as are wind or solar power which have to be harnessed as and when they occur;
- Increased diversity within the agricultural landscape provided the plantations are located appropriately;
- SRC provides good cover for game birds;
- It will withstand flooding but not permanent water logging;
- Compared to conventional arable cropping SRC offers significant reductions in the use of herbicides, pesticides and fertilizers;
- The humus content of the soil improves over time as does soil fauna diversity due to reduced machinery passes and the deciduous nature of the crop;
- The ability to reduce water pollution where it is used for the treatment of wastewaters e.g. farmyard run-off, sewage and landfill leachate;
- Opportunities for farm diversification, the development of specialist contracting skills and improvement to the local economy, etc.

The disadvantages of SRC include:

- Requires relatively intensive silviculture and higher production costs (1 tone of dry biomass of short rotation forestry costs almost twice as high compared to classic forestry;
- Impossibility to obtain high yields from currently used wood species and branches, due to noncompliance with local habitat and climatic conditions;
- May negatively impact biodiversity if replacing natural forest, meadows and pasture;
- Change of habitat from open to forested when replacing agricultural land will negatively impact rare open landscapes species;
- Absence of adequate normative and technical support, financial tools, information, etc.

Sweden, Finland, Germany, Denmark, Austria, the UK, Italy, Ireland, Belgium and Nederland, and last years Spain, France, Poland, Czech, Slovakia and Hungary have been actively developing purpose-grown woody biomass crop systems, using poplars and willows grown at high crop densities (10,000 – 15,000 stems per hectare) and short crop cycles (2 – 5 years). These systems are based on a coppice approach, where these crops are harvested in the dormant season, allowing the live stumps to re-sprout new shoots for the next crop cycle. This crop approach is very suitable to Bulgarian conditions. Although Bulgaria has also been involved in research and development of these crops, currently there are no serious investors to commercialize the concept. Nowadays there are no commercial SRC crops for biomass output for production of heat and electricity in our country. The currently grown intensive crops from poplar and willow are primarily designed for timber output for the production of cellulose or wood assortments. That situation is expected to be changed as a result of the high oil prices and the need to limit production of greenhouse gasses from fossil sources.

CONCLUSIONS

Thanks to our large forest area (33 % of the territory of Bulgaria) and the relatively large supply of wood, at present, Bulgaria has the necessary resources to meet its Kyo-

to commitments as well as the EU aims for the production of renewable energy by 2020, as the biomass share is greatest. This will undoubtedly affect the more intensive use of forest timber. In order for this use to be effective and in order to limit the use of valuable timber for direct combustion or for processing of energy wood chips, pellets and briquettes, the more complete utilization of wood residues from logging, woodworking and pulp industry is needed.

Bulgaria has large reserves of approximately 462,000 ha arable and fallow agricultural lands, which are a potential source for growing of short rotation coppices and forest plantations for the production of energy chips. In accordance with the national and international scenarios, these lands are expected to increase significantly in the future. Some of these areas are perfectly suited for creating of energy plantations of forest species, shrubs and perennial grass. Currently in our country there are appropriate programs and measures for the financing of private investment projects to create such agroforestry plantations, but there is a lack of some basic economic and commercial conditions for the functioning of the market for energy chips. The main economic conditions for creating and growing of energy SRC plantations are:

1) Construction of heat and power installations, functioning with biomass;
2) Creating of an active trading market for wood chips;
3) Developing an appropriate legislative and regulatory framework for trade, production and operation of energy SRC plantations.

Based on the above analysis we can conclude that Bulgaria has a significant potential of agricultural lands suitable for growing of energy plantations. We have the necessary funds to finance such investments and we also have some experience in growing Short Rotation Forestry, but so far there is a lack of a great part of the above-mentioned economical conditions. Finally, it should be noted that the development of energy plantations should focus primarily on the construction of a suitable economic and regulatory framework of energy chips producing, trading and exploiting.

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