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# ASSESSMENT OF THE POTENTIAL BIOMASS SUPPLY IN EUROPE USING A RESOURCE-FOCUSED APPROACH

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This paper analyses the potential biomass supply in the 15 EU countries, 8 new member states and 2 candidate countries (ACC10), plus Belarus and the Ukraine. For this purpose five scenarios were designed to describe the short-, moderate- and long-term potential of biomass-for-energy. Our assessments show that under certain restrictions on land availability, the potential supply of biomass energy amounts to up to 12.8 EJy<sup>-1</sup> in the EU15 and 6.1 EJy<sup>-1</sup> in the ACC10. For comparison, the overall energy supply in the EU15 totalled 62.6 EJy<sup>-1</sup> in 2001. Consequently, there are no important resource limitations in meeting the biomass target for 2010, which was set by the European Commission (5.6 EJy<sup>-1</sup> for the EU15 according to the 1997 White Paper on Renewable Energy Sources (RES)). However, given the slow implementation of the RES policy it is very unlikely that the biomass target will be met within 2010.

Keywords: biomass resources, residues, energy crops

## 1 INTRODUCTION

The generation of energy from biomass has a key role in current EU strategies to mitigate climate change and enhance energy security. In 1996 the European Commission set the indicative target of doubling the proportion of renewable energy sources (RES) in the EU's gross inland energy consumption to 12% by 2010. In order to understand the future role of bioenergy in Europe, it is important to analyse biomass potentials.

The objective of this paper is to analyse the potential biomass resources available for energy in the EU15 countries (EU15), eight new EU member states and two candidate countries, plus Belarus and the Ukraine.

This analysis has a purely European geographical scope, in which interactions with the rest of the world are disregarded. Obviously, such an approach to some extent limits the possibility to draw conclusions about the future biofuel markets. This and other simplifications, however, also make the assessments transparent.

## 2 METHOD

### 2.1 General approach

The potential bioenergy supply in Europe is analysed using a resource-focused approach. Biomass categories included in the study are: forestry residues, forest industry by-products, straw, maize residues and energy crops.

The biomass assessments were made on the national level and included the EU15, eight new EU member states and two candidate countries (collectively referred to as ACC10), plus Belarus and the Ukraine. The ACC10 consists of: Bulgaria, the Czech Republic, Hungary, Poland, Romania, Slovakia Slovenia, Estonia, Latvia and Lithuania. Sometimes the first seven enumerated countries are referred to as Central and Eastern Europe (CEE). FSU refers to the countries which belonged to the Former Soviet Union: Estonia, Latvia, Lithuania, Belarus and the Ukraine.

The analyses are carried out for five scenarios: 1, 2a, 2b, 3a and 3b. Each scenario describes the potential for development of biomass production within a given time frame, dependent on a number of factors, where 1, 2, and 3 refer to periods of short-term (10-20 years), moderate-term (20-40 years) and long-term (>40), respectively. The letters in the scenario names indicate (a) low and (b) high biomass harvests in terms of forestry residues and energy

crops. The assumptions are presented in more detail in Section 2.2-2.5.

In spite of the wide time frame in this study, we assume constant population in Europe using data for 2000. Forestry and agricultural data are taken from [1] and [2], respectively.

### 2.2 Forest residues and forest industry by-products

Assessments of the potential supply of forest residues and forest industry by-products are based on forest biomass growth rather than on current national fellings and forest industry locations. Only removals from exploitable forests<sup>1</sup> are included. All roundwood removals, excluding delicate stemwood from thinning operations, are assumed to be used in the forest industry.

The national annual fellings for each scenario are assumed to remain constant in absolute terms at a level of 100% of the increment in 2000.

Final fellings and thinning operations enable harvest of forest residues. The potential harvest of residues varies with species and age of the trees. The residue-to-stemwood ratio for spruce is roughly twice that for pine and three times that for birch [3]. We assume the residue-to-stemwood ratio to be 50% higher for coniferous trees than for deciduous trees.

Since harvesting of forest residues may cause nutrient depletion of the soil, we apply a low and a high harvest ratio. The (a) low harvest ratio takes current ecological restrictions into consideration, which aim to prevent nutrient depletion of forest land. The (b) high harvest ratio, on the other hand, can only be applied if the mineral loss is compensated for through fertilization, for instance by ash recycling [3, 4]. The low residue-to-stemwood ratio is assumed to be 0.15 and 0.1, for coniferous and deciduous trees, respectively. The high harvest ratios are set to be twice as large, i.e. 0.3 and 0.2, respectively.

Regarding the forest industry, it is assumed that one quarter of the roundwood ends up as by-products (bark, sawdust, wood chips and black liquor) available for energy purposes.

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<sup>1</sup> Forests available for wood supply according to [1].

### 2.3 Crop residues

*Crop residues* include straw from wheat, barley, rye and oats, plus maize residues. Only part of the residues should be harvested to avoid depletion of organic matter in the soil [4]. We assume the residue generation ratio for straw to cereal grain to be 1.3 and for maize residues to maize to be 1. Moreover, it is assumed that one quarter of the residues can be harvested and that roughly one third of the harvested straw is used in animal husbandry. This leaves 0.22 tonne straw per tonne cereal grain and 0.25 tonne residues per tonne maize available for energy use.

The assessments of these residues are based on the average cereal and maize yields for 1998-2002. During this period agricultural yields were relatively low in the ACC10 compared with the EU15, which primarily mirrors the difference in existing socio-economic conditions between these two regions. Rabbinge and Diepen [5] showed that large increases in rain-fed crop production are feasible for CEE and FSU. Based on their findings, and assuming that soil and climate will be the most important factors for the yields, we set the cereal and maize yields 40% and 100% higher in CEE and FSU, respectively, for scenarios 2 and 3 compared with scenario 1. Such yield increases are not assumed for the EU15, although this may be motivated for certain countries in Southern Europe. As the area used for energy crops increases, from 10% of arable land in scenario 1 to 25% in scenario 2, the cereal crop area is reduced by an equivalent area.

### 2.4 Energy crop yields

A number of energy crops have been investigated with regard to their suitability for bioenergy production in Europe, but few dedicated energy crops have reached beyond the scale of field trials. In this analysis the crop species are not specified. The selection, however, is restricted to short-rotation forestry and herbaceous crops, since these perennial crops generally perform much better in energy terms than annual food crops [4]. Due to lack of experience in commercial cultivation of energy crops in most European countries no reliable statistics on yields are available.

In order to analyse the potential energy crop production, we assumed that the energy crop yields are 50% higher than the wheat yields. The relationship was established on the basis of Swedish willow and wheat yields. In Sweden the average wheat yield is 6.0  $\text{tha}^{-1}$ . Regarding willow, 9  $\text{tha}^{-1}$  is perceived as an attainable yield in the near future for a modern willow clone. In order to achieve this yield the crop must be grown on soils of at least average quality and be well managed. Management includes fertilization and weed control, but not irrigation [6]. Assuming this relationship for all countries is obviously an approximation. In addition, wheat is usually grown on the best soils, whereas, based on Swedish experience, energy crops have mostly been grown on average quality soils [7].

As in Section 2.3 we assume 40% and 100% higher yields in the moderate- and long-term perspective compared to the short term for CEE and FSU, respectively.

In order to account for learning effects over time in terms of crop cultivation and plant breeding, we ascribe 20% higher yields to scenarios 2b and 3b than 2a and 3a.

Based on this method, the Netherlands show the largest yields, 14.6  $\text{tha}^{-1}$  in scenarios 1, 2a & 3a and 17.6  $\text{tha}^{-1}$  in 2b & 3b. Yields are much lower in e.g.

Greece (scenarios 1, 2a & 3a: 4.2  $\text{tha}^{-1}$  and 2b & 3b: 5.0  $\text{tha}^{-1}$ ) and Estonia (1: 3.5  $\text{tha}^{-1}$ , 2a & 3a: 6.9  $\text{tha}^{-1}$  and 2b & 3b: 8.3  $\text{tha}^{-1}$ ).

**Table I** The potential biomass supply in Europe.

	Forest biomass ( $\text{EJ}^{-1}$ )	Crop res. ( $\text{EJ}^{-1}$ )	Energy crops ( $\text{EJ}^{-1}$ )		Total ( $\text{EJ}^{-1}$ )
			Mha		
<i>Scenario 1</i>					
EU15	1.3	0.7	1.4	7.3	3.4
ACC10	0.4	0.2	0.4	4.3	1.0
Bel+Ukr	0.13	0.11	0.32	3.9	0.55
<i>Scenario 2a</i>					
EU15	1.3	0.6	3.4	18.4	5.3
ACC10	0.4	0.3	1.7	10.7	2.4
Bel+Ukr	0.1	0.2	1.6	9.7	1.9
<i>Scenario 2b</i>					
EU15	1.7	0.6	4.1	18.4	6.4
ACC10	0.5	0.3	2.0	10.7	2.8
Bel+Ukr	0.2	0.2	1.9	9.7	2.3
<i>Scenario 3a</i>					
EU15	1.3	0.5	8.8	47.0	10.6
ACC10	0.4	0.1	4.6	30.3	5.1
Bel+Ukr	0.1	0.1	5.1	30.9	5.3
<i>Scenario 3b</i>					
EU15	1.7	0.5	10.6	47.0	12.8
ACC10	0.5	0.1	5.5	30.3	6.1
Bel+Ukr	0.2	0.1	6.1	30.9	6.4

### 2.5 Energy crop plantation areas

The energy crop potentials are estimated on the basis of three alternatives for available land. These areas suggest the potential for development of energy crop production in Europe in the short, moderate and long term.

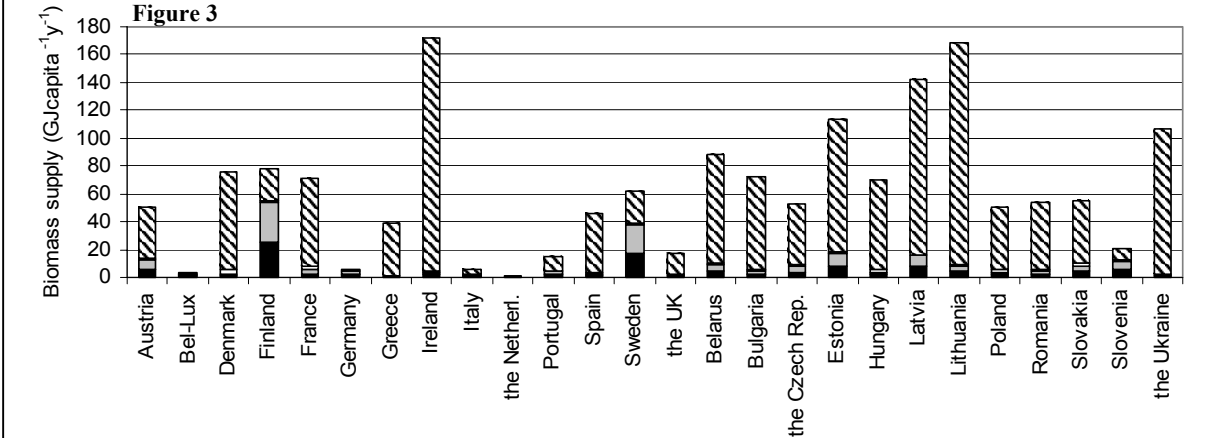
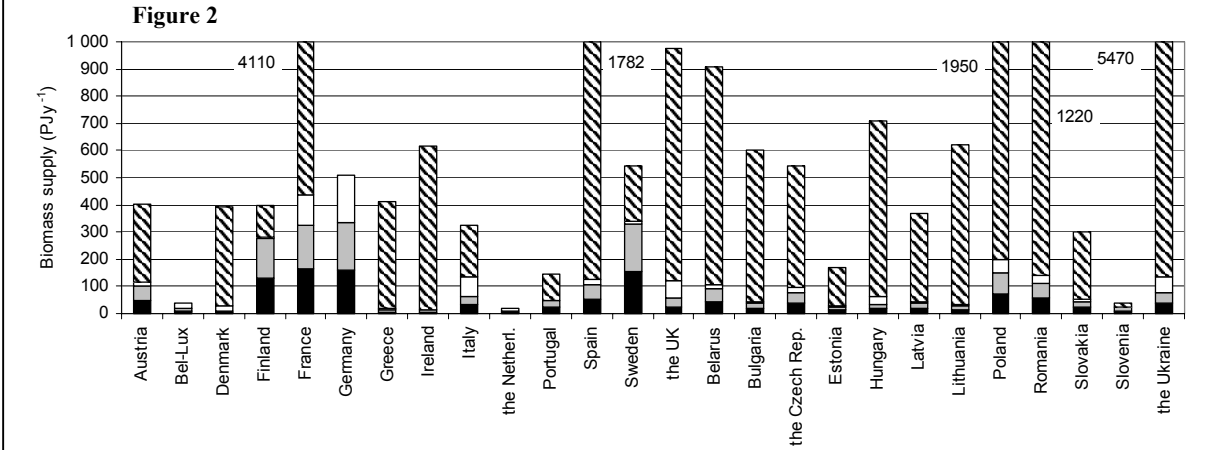
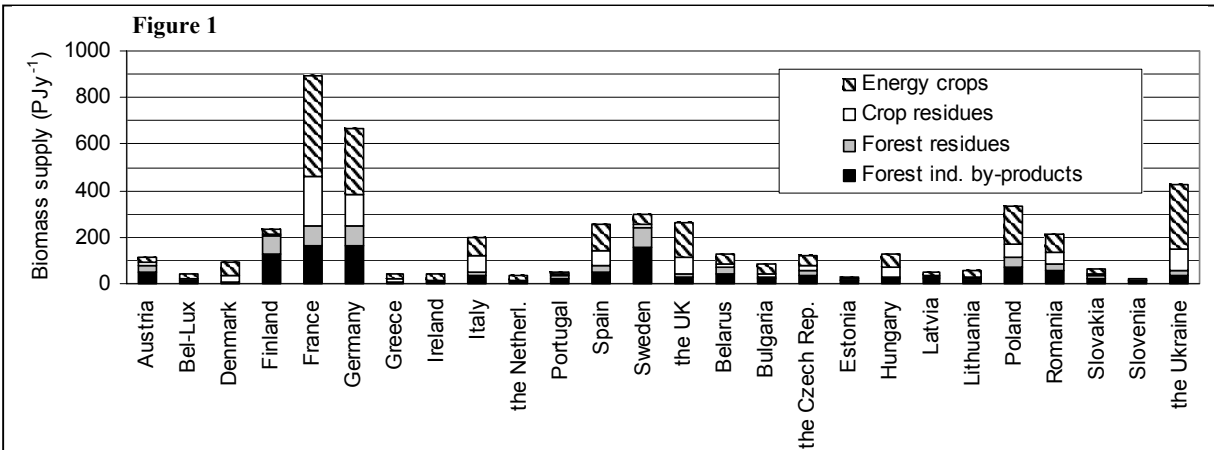
In scenario 1 it is assumed that energy crops are grown on 10% of the arable land, which is the basic rate for set-aside in the EU15 for 2000-2006. Crops intended for non-food purposes, such as energy crops, are, however, permitted on this land.

Ten new countries joined the EU in May 2004 and Bulgaria and Romania are scheduled to join in 2007. Assuming that the yields in the ACC10 approach those in Western Europe within the coming decades, this enlargement will call for a higher set-aside rate. Maintaining the EU15 ratio of *utilized arable land*<sup>2</sup> per capita (0.18 ha/capita) in EU25<sup>3</sup> will require a set-aside quota of 25%, which was defined as plantation area in scenarios 2a and 2b.

In scenarios 3a and 3b it is assumed that energy crops are grown on agricultural land that is not required for food production, i.e. surplus agricultural land. Self-sufficiency in food products is thus prioritized, whereas other claims on agricultural land are disregarded.

<sup>2</sup> Arable land is *one* component of agricultural land. *Utilized* arable land excludes 10% set-aside arable land.

<sup>3</sup> Does not include the two new EU member states Cyprus and Malta, but Bulgaria and Romania



**Figure 1 & 2:** Scenario 1 and 3b, respectively: Potential supply of biomass energy in the EU15, the ACC10, Belarus and the Ukraine.  
**Figure 3:** Scenario 3b: Potential supply of biomass energy per capita in the EU15, the ACC10, Belarus and the Ukraine.

Surplus *agricultural land* is calculated on a national basis, assuming that 0.24 ha/capita is required for food production in each country (average value for the EU15, calculated on the basis of data from [8]). Agricultural land used for growing energy crops is assumed to have the same composition of arable land, permanent crop land and permanent pastures as the national total. Energy crops on permanent pastures, however, are restricted to a maximum of 50% of the total permanent pasture area in

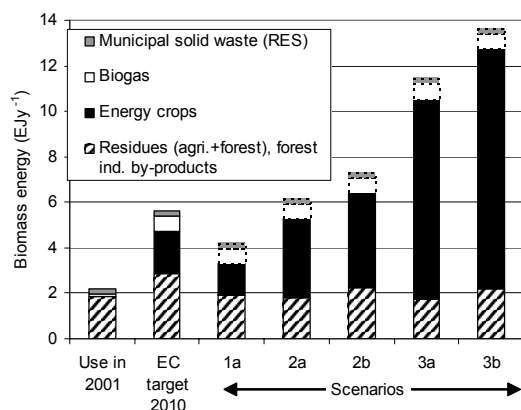
each country. This restriction is included in order to account for the fact that in many cases permanent pastures can not be converted into crop land due to their location in mountainous areas etc.

#### 4 POTENTIAL SUPPLY OF BIOMASS ENERGY

Our study indicates that overall biomass could supply up to 12.8 EJy<sup>-1</sup> in the EU15 and 6.1 EJy<sup>-1</sup> in the ACC10. These potentials correspond to 20% and 57% of the total primary energy supply in 2002 in the EU15 and the ACC10, respectively. Figure 1-3 illustrate the overall potential biomass supply for scenarios 1 and 3b. The aggregated potentials for each biomass category are presented for each scenario in Table I.

Our analysis shows that for all five scenarios, the potential supply of biomass from agricultural land is greater than from forest land. In scenario 1 this predominance for agricultural biomass is fairly moderate. Nonetheless, forest biomass dominates the potential supply in a number of countries. Over time, however, the relative importance of energy crops increases to such a degree that for most countries forest biomass appears negligible in comparison. In Belgium-Luxembourg, Germany and the Netherlands, the energy crop potentials are zero in scenarios 3a and 3b, since given our restriction on land availability there is less agricultural land in these countries than is required for national self-sufficiency in food products.

It comes as no surprise that geographically large countries, such as France and the Ukraine, have large absolute biomass potentials. Productivity, however, is also important, which is illustrated by the fact that Germany has a larger biomass potential than Spain, which is a geographically larger country. The distribution of biomass appears very different when taking the population into account. In scenario 1, Finland and Sweden have the largest biomass potential per capita, whereas the resources are more evenly distributed between countries in scenarios 2a and 2b. In scenarios 3a and 3b Ireland and the three Baltic States have the largest biomass potentials per capita (see Figure 3).



**Figure 4** Use of biomass energy in the EU15 in 2001, the EC biomass target for 2010 and the biomass potentials in the five scenarios, to which MSW and biogas from the EC biomass target have been added. Note: In the first two bars (use in 2001 and EC target 2010) the striped fields include firewood and charcoal.

#### 4 DISCUSSION AND CONCLUSIONS

In order to meet the indicative target of 12% RES in the primary energy supply as laid out in the 1996 Green Paper, the European Commission (EC) suggested a tripling of the use of bioenergy compared with 1996 [9].

Bioenergy would then account for 5.6 EJy<sup>-1</sup> (8.5%) in the EU15. Currently bioenergy, including the renewable part of municipal solid waste, accounts for 3.4% (2.1 EJ, 2001).

This study indicates that domestic biomass could contribute significantly to the total energy supply in Europe, in the long-term perspective up to 12.8 EJy<sup>-1</sup> in the EU15 and 6.1 EJy<sup>-1</sup> in the ACC10 under certain restrictions on land availability. Consequently, there are no important resource limitations in meeting the biomass objectives. However, from the current state of implementation of the renewable energy policy in the EU15, it can be concluded that it is very unlikely that the EC biomass target will be met by 2010 (The biomass target is compatible with scenarios 2 & 3, but not with scenario 1; Figure 4). To do so requires immediate action, especially since our assessments show that the largest biomass potentials lie in energy crops, which have long lead times. For that reason agricultural policy in Europe will also be a key factor for the future of bioenergy. In the light of current surplus food production in the EU, energy crops should be regarded as an interesting alternative to food crops; even more so when considering the enlargement of the EU, since accession of the countries in CEE will accentuate the problem of overproduction.

This analysis also shows that the potential biomass resources are unevenly distributed. Tougher biomass targets in the EU over time may therefore increase international biofuel trade within Europe and be a driving force for biofuel imports from other continents.

#### 8 ACKNOWLEDGEMENTS

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