# BIOMASS FOR ENERGY USES – EXPLORING PRODUCTION POTENTIAL AND THE PRODUCTION COSTS FOR AUSTRIA

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# BIOMASS FOR ENERGY USES – EXPLORING PRODUCTION POTENTIAL AND THE PRODUCTION COSTS FOR AUSTRIA

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**Abstract**

The expansion of renewable energy sources is an EU strategy to reduce the dependency on fossil fuels and to curb carbon dioxide emission. According to studies estimating technical potentials, significant land resources can be mobilised for the production of energy crops. We estimate the costs of a policy aiming at a stimulation of biomass and bioenergy production in Austria using a model that integrates the production of food, feed, agricultural and forest biomass as well as bioenergy products. The results show that an expansion of domestic biomass and bioenergy production is costly and it diminishes the production of food and feed.

**Keywords:**

Bioenergy, food and biomass production, land use modeling

## 1 Introduction

Among the energy policy targets of the EU is the objective to double the share of the Renewable Energy Sources (RES). Gross domestic consumption was 5.4% in 1997 and it should increase up to 12% by 2010. Various legislative actions have been undertaken in order to facilitate this target, the most important of which are:

- to promote renewable electricity generation by increasing production from 14% in 1997 up to 21% by 2010 for EU 25, corresponding to 22.1% for EU 15 (Directive 2001/77/EC);
- to promote biofuels for transport applications by replacing up to 5.75% of diesel and petrol by 2010 (Directive 2003/30/EC), with the accompanying detaxation of biofuels (modification of the taxation of energy products and electricity directive 2003/96/EC).

In 2001, total biomass production for energy purposes in the EU was 2,340 PJ (equivalent to 56 Mtoe million tonnes of oil equivalent; EC, 2008). To achieve the RES 12% target about 3,095 PJ more are needed by 2010. According to the proposal of the European Commission, the agricultural sector should contribute the following additional amount of biomass energy: electricity 1,338 PJ, heat 1,000 PJ, and biofuels 750 PJ. In combination with other sources, this would lead to a total biomass accumulated energy production of 5,434 PJ in 2010.

This additional biomass production can only be achieved with strong and targeted measures and actions in all three sectors under consideration: electricity, heat, and biofuels for transport. Due to the fact that the EU is lacking a comprehensive energy policy, a better coordination of EU policies and EU Member States is needed. The Community Biomass Action Plan (CEC, 2005) is one initiative of the EU to ensure the achievement of this objective. It is a coherent part of the long term EU strategy to reach the Community's greenhouse gas emission reduction commitments up to 2020 (CEC, 2008).

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The stimulation of biomass production for energy purposes is ranked high on the political agenda in Austria, as well. The substitution of fossil fuels by renewable energy sources is considered as an important mitigation strategy to control carbon dioxide emissions. There is an urgent pressure to take measures to reduce emissions, because Austria is exceeding the Kyoto-targets of carbon dioxide emissions by far. Doubling the biomass output for energy production is therefore a goal of the federal government in Austria (GUSENBAUER, 2007).

In 2005, domestic renewable sources covered 21% of the energy demand of the Austrian economy (production of renewable sources was 307 PJ, gross domestic use was 1,434 PJ; STATISTIK AUSTRIA, 2007). Energy from biomass (159 PJ in 2005) is more important than the total from water, wind and solar radiation (134 PJ). An expansion of the energy production based on biomass is seen to be easier feasible than hydro-energy. The expansion of hydro-power is constrained by the Water Framework Directive which potentially leads to a more extensive use of inland water resources in Austria. In 2005, energy from biomass was obtained from various sources, among them are firewood, plant oil, biogas, sawdust, organic residues of pulp and paper production.

**Table 1: Current and future biomass production of Austrian agriculture and forestry according to recent studies**

| Reference | energy from | unit | 2005 | 2010 | 2020 |
|---|---|---|---|---|---|
| EEA 2006[1)] | agriculture | 1,000 ha | | 204 | 266 |
| | agriculture | PJ | | 25 | 59 |
| | forestry | PJ | | 138 | 138 |
| BMLFUW, 2007 | agriculture | 1,000 ha | | | 400 |
| | agriculture | PJ | | | 76.5 |
| | fuel wood | PJ | 37 | 49 | 56 |
| BRAINBOWS, 2007 | agriculture | 1,000 ha | | | 130 to 455 |
| HENZE, ZEDDIES, 2007 | agriculture | 1,000 ha | | 390 | 747 |
| SPITZER et al.[2)], 2007 | agriculture | 1,000 ha | 82 | 142 | 283 |
| | fuel wood | PJ | 68 | 65 | 74 |

Sources: EEA, 2006; BMLFUW, 2007; BRAINBOWS, 2007; HENZE and ZEDDIES, 2007; SPITZER et al., 2007. Note: the following coefficients were used to convert the units of the sources [1)] 1 MTOE = 41.868 PJ; [2)] 1 t dry wood = 19 MJ.

Recently, several studies on the potential of biomass for energy production in Austria have been published. A selection of key results is presented in Table 1. In 2005, approximately 85,000 ha of agricultural land were used for biomass production for energy purposes, and about 4.3 million tonnes of timber wood was used as an energy source. The future potential is estimated to be much higher by some authors. The authors of the studies listed in Table 1 estimate that between 130,000 and 747,000 hectares of agricultural land could be used for biomass production by 2020 (arable land was 1.3 million hectares and utilised agricultural land was 3.2 million hectares in 2005). The fuel wood production could be expanded by up to 14% according to recent studies (SPITZER et al., 2007).

The aim of this study is to estimate the costs of an expansion of the domestically produced agricultural and forest biomass in Austria. At the country level, such costs have not yet been analysed. Other studies were confined to exploring the physical and technical potentials but not the costs of activating them. In principle, Austria could import all the necessary feed-stocks for the production of bioenergy to meet its goals. However, in the "burden sharing" process each EU Member State has to utilize a certain amount of domestically grown biomass in order to prevent beggar-the-neighbor strategies. In order to determine the "burden" for Austria, we estimate economic potentials of agricultural and forest biomass production. In this paper, we consider only the following primary energy sources: firewood, feed stocks for biogas and biofuels, as well as short rotation woody plants for combustion. Other sources of biomass that are used for energy purposes (like sawdust or organic residues from industrial processes) are not considered.

The remainder of the paper is structured as follows: in the next section the model used for the quantitative analysis is presented. The policy scenarios and the results are presented next. The paper ends with a discussion on the results and conclusions.

## 2 Research methodology and data

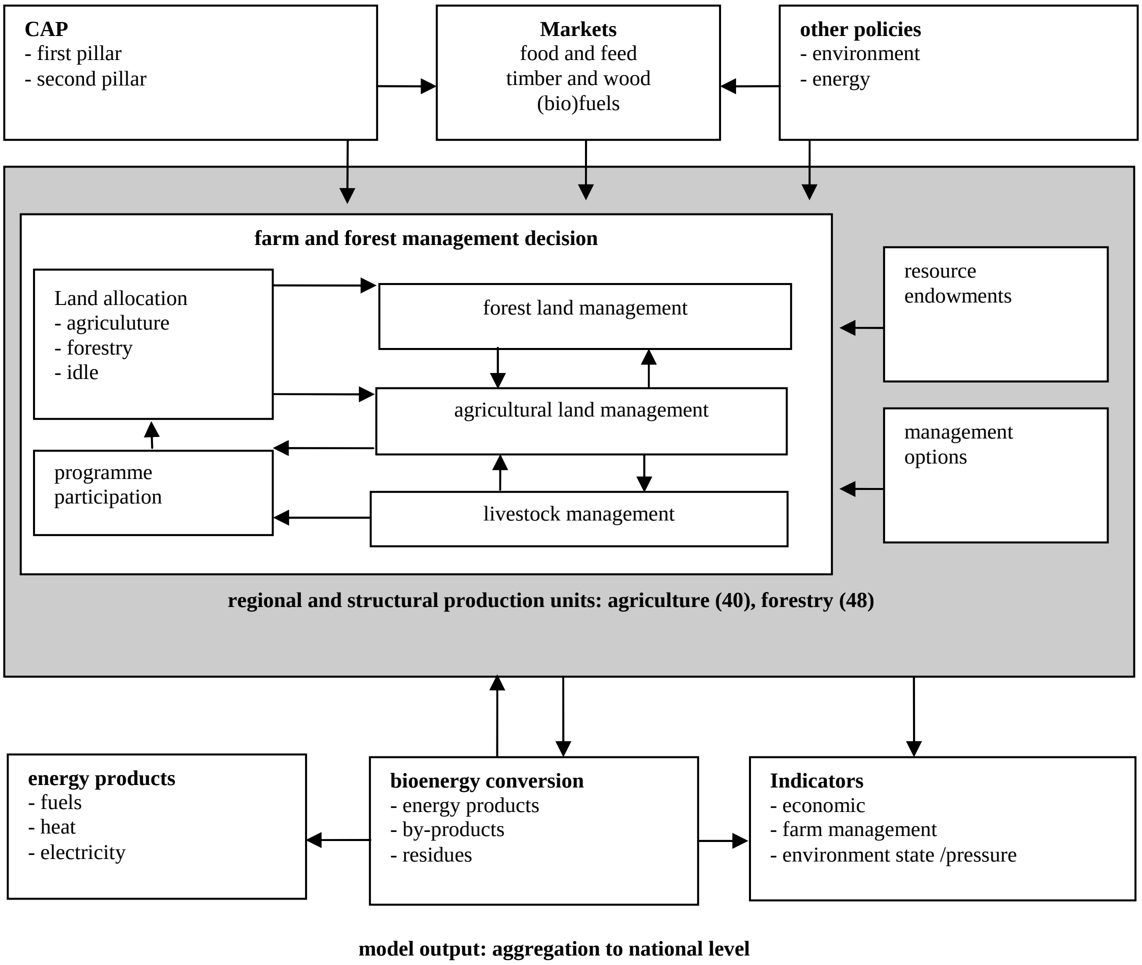
In order to estimate the cost of biomass production in Austria, a comprehensive model was developed that captures three activities: forestry, agriculture, and energy generation based on biomass. Energy can be produced using domestic feed stocks (produced by agriculture and forestry, other activities) or imported ones. Domestic products are preferred if lower transportation costs or product characteristics lead to a competitive advantage. Agriculture and forestry are competing for the same resources: labour, capital and land of which only land is limited. The flow of products (biomass), residues (manure) and by-products (e.g. DDGS, oil cake) and the competition for land are linking the three activities in feed-back cycles (see Figure 1) which are quantitatively implemented in the model LUMA (Land Use Model of Austria).

LUMA is a regional model of Austrian agricultural and forest production that builds on PASMA (Positive Agrciultural Sector Model Austria), an agricultural sector model (SCHMID and SINABELL, 2007). The model is based on the method of positive mathematical programming (HOWITT, 1995) and calibrated to the economic accounts of agriculture and forestry as well as to physical and structural endowments at regional scales (NUTS2). In addition, policy restrictions such as the Common Agricultural Policy (first and second pillar) and nature conservation and other environmental restrictions are implemented. An expansion of agricultural land at the cost of forest land is prohibited due to restrictions that reflect the current political situation. Forest land can be expanded, however at relatively high costs. Farmers would loose decoupled payments if the land is no longer used because of the cross-compliance standards defined in the 2003 reform of the Common Agricultural Policy (CAP).

According to the PMP-methodology observations are used to derive model parameters for non-linear cost functions. Observed levels of agricultural and forest land use allocations and crop management practices, as well as productions costs and product prices are the major data sources for deriving model parameters. A special feature of LUMA is the use of historical land use and crop management mixes that improve the quality of the model parameters. All the crops that can be used as raw materials for biofuels or biomass for non-food/non-feed purposes have already been planted – at least to some extent – in the past (e.g. miscanthus, willow, poplar), therefore data on crop-mixes could be used. Consequently it is not necessary to make ad-hoc assumptions or to use synthetic constraints to simulate the effects of policies on biomass production.

Among the data sources used in the analysis are the most recent farm structure survey, production statistics and Economic Accounts of Agriculture and Forestry information at NUTS2 levels. Regions are further differentiated according to structural (size of farms / enterprises) and topographical characteristics (slopes). Data on the adoption of agri-environmental measures at regional and structural scales as well as data obtained from the farm accountancy data network are used to attain a detailed representation of the Austrian farm and forestry sectors. Transport matrices, feed balances and nutrient balances are guaranteeing consistency with the Economic Accounts of Agriculture, foreign trade balances, and environmental restrictions.

**Figure 1: Block-diagram of LUMA**




In the forest module, the production of the Austrian forestry sector is represented in a detailed regional and structural manner using data from the latest forest survey (BFW, 2002), harvest records (BMLFUW, various years) and price tables (STATISTIK AUSTRIA, various years c). Regional production conditions are represented in a detailed manner by accounting for steepness classes, forest systems, ownership structure, harvesting techniques, tree types, and rotation lengths. Decisions on wood harvest and rotation length are based on annuities of discounted net present values of timber and fuel wood production.

In the model, agricultural and forestry products are differentiated following the structure of the Economic Accounts of Agriculture and Forestry. In addition to these products the following bioenergy activities are modelled:

methane production: maize- and grass-silage, slurry, wheat and rye and sunflower (green plants)

bio-fuels: ethanol (wheat, maize and sugar beets), bio-diesel (rape and sunflower)

agro-forestry: willows and poplars

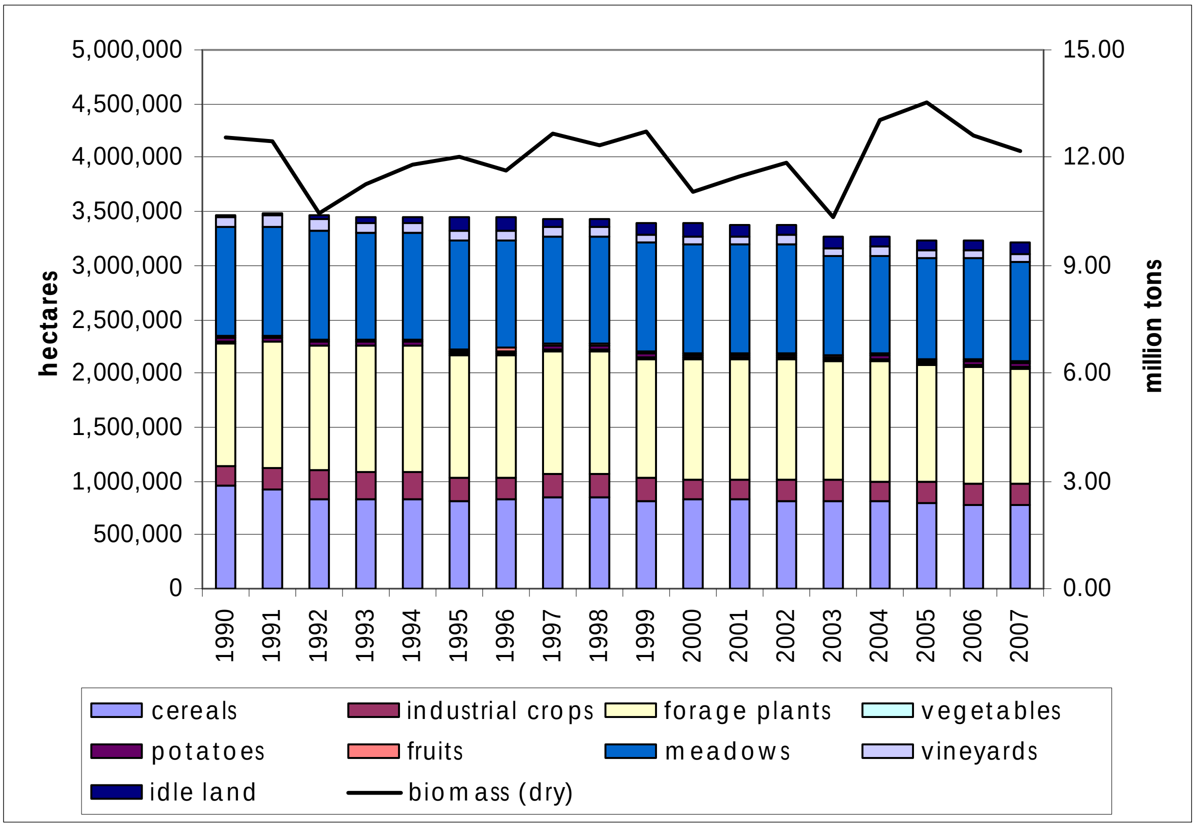
combustion: straw and plants of wheat, rye, maize, and triticale

fuel wood (logs and chips)

The model is driven by exogeneous price changes and policy instruments such as premiums for biomass products. Price expectations are based on OECD and FAO (2007) forecasts for the year 2010. The assumption is made that the observed price hike of the year 2007 will be overcome by this year, however the price levels will be significantly above the observed levels between 2000 and 2005. The model has been applied frequently in applied agricultural policy analyses (e.g. SCHMID AND SINABELL, 2007; SCHMID, SINABELL AND HOFREITHER, 2007), and in energy policy analysis (KLETZAN et al., 2007).

Down-stream industries converting biomass to energy products (biogas, ethanol, electricity and heat from combined heat and power plants, and Diesel substitutes), biomass conversion capacities, and costs are modelled as well. Total biomass can be either used for energy, feed or food production depending on the relative prices paid by the energy, feed and food industries (including policy instruments). A detailed transport matrix and backward flows of residues (e.g. DDGs, oilseed meal) represent the spatial structure and feedback loops of the model.

**Figure 2: Agricultural land use and biomass production in Austria**




Source: Own results based on STATISTIK AUSTRIA (various years a), BUCHGRABER ET AL., 2003; RESCH et al. 2006; Coefficients on losses based on BUCHGRABER ET AL., 2003 (feed) und STATISTIK AUSTRIA (various years b). Note: Dry biomass excluding losses (harvest, transport, storage); straw not included.

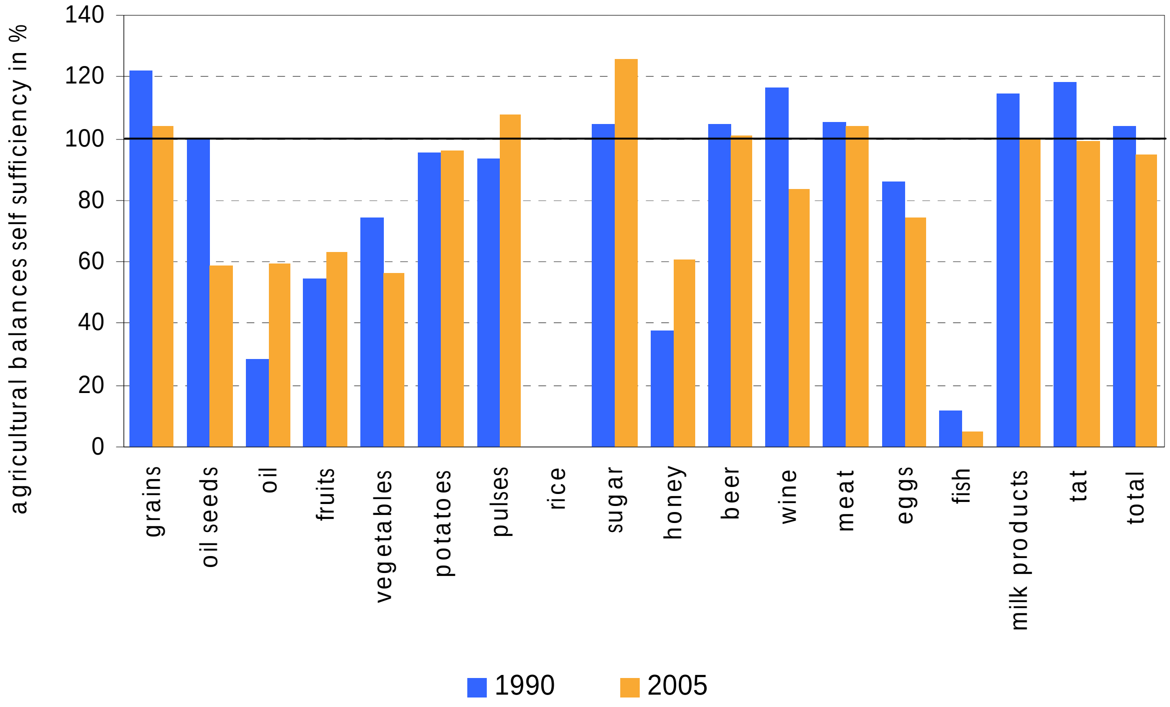
Two figures are provided to helping to understand the specific surrounding conditions of biomass production in Austria:

Figure 2 shows the allocation of agricultural land (left scale) and the agricultural output measured in tonnes of dry biomass (right scale) over the last decade. The long time span covered in the figure reveals important information: The physical output at sector level was practically constant over 18 years apart from the stochastic variance.

Consequently, an average annual increase of the hectare productivity of almost 3% was offset by a reduction of the agricultural productive land at the same pace.

Another fact is that the Austrian self sufficiency rate of food has diminished over the same period. Supply balances (Statistik Austria, various years b) show that Austria has moved from a slight surplus production of food to a deficit situation between 1990 and 2005 (Figure 3). The reason is that food demand grew at a more rapid pace than food production owing to the fact that the population increased significantly. Given such a situation it is obvious that an expansion of biomass production on agricultural land will come at the cost of domestic food and feed production.

**Figure 3: Agricultural balances and self-sufficiency in Austria 1990 and 2005**



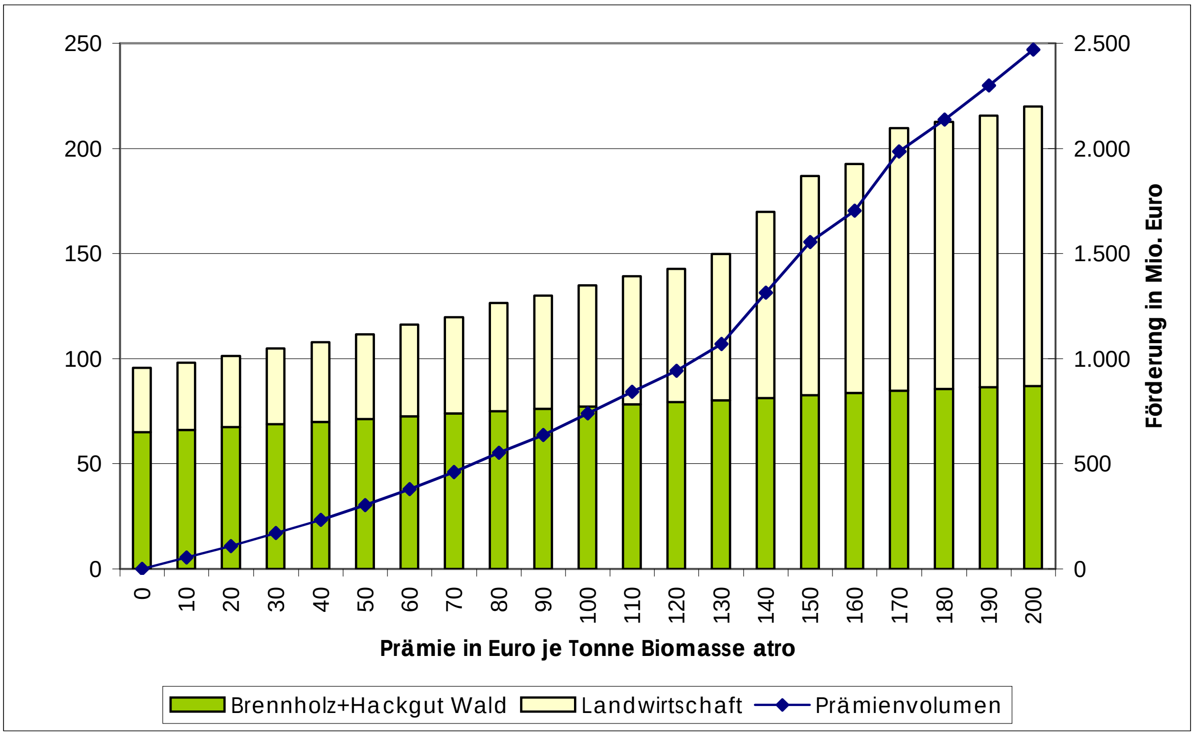

Source: Own results based on STATISTIK AUSTRIA (various years).

## 3 Scenario and results

Currently there are the following instruments in place that aim at stimulating biomass production: hectare premiums on set-aside land for bioenergy crops (financed by the EU), subsidies on electricity generated in plants using biomass, tax breaks for bio-fuels, compulsory blending requirements for bio-fuels, and subsidies for investments in biomass heating plants. The topic of the paper is to estimate the cost of providing more domestically produced biomass for bioenergy purposes from fuelwood and agricultural products as primary energy sources. In 2005, approximately 75 PJ of raw energy have been derived of these materials, which is equivalent to the half of the total energy of organic sources (the rest is of sawdust and similar coupled products).

The results on biomass production of Austrian Agriculture (Figure 2) can be used to calculate the energy equivalent of the agricultural output. Assuming an average of 17.5 MJ/kg dry matter, the potential output of raw energy is ranging from 220 to 270 PJ per year. In 2005 the raw energy equivalent of forestry was 260 PJ (24% fuel wood, the rest logs and paper wood). Summing up, the equivalent of approximately 480 – 530 PJ of raw energy are the potential output of Austrian agriculture and forestry. Biomass equivalent to 159 PJ was actually used according to the energy balance. Not all sources of biomass energy are accounted for in the model. It covers fuel wood and agricultural biomass. In the base run simulations an energy equivalent of 95 PJ (65 PJ of fuel wood, the rest of agricultural sources) is assumed. This is equivalent to the expected output in 2010 (given policies of the year 2007).

**Figure 4: Output response to a premium for domestically produced biomass**




Source: Own results.

The model presented in the previous section is used for the following scenario: the government is granting a premium for domestically produced biomass that is used for energy production. The operators of bioenergy plants (e.g. methane plant, ethanol plant, combined combustion and electricity units) pay the government premium to the farmer who has to certify the domestic production. A uniform premium is paid per tonne dry matter, wood and plant products are treated equally. Prices of energy products (for heating power, for electricity, for fuel) are set to 2005 levels. Those biomass products fitting best to the current conversion and support structure will therefore be the first ones that enter the solution. In the simulations the premiums range between 0 to 200 Euro per ton dry matter. The currently observed level of support (mainly hectare premiums for energy crops and a subsidy on electricity generated in biogas plants and tax breaks for biofuels) that stimulates the production and import of biomass equivalent to 30 PJ in agriculture is considered to be continued.

The biomass premium is used to derive a price wedge between different uses of a biomass product (e.g. corn as feed in livestock production or as feedstock in a biogas plant). With that we want to answer the following question: what are the cost of stimulating domestic biomass production for energy purposes while minimizing the spillovers to foreign markets.

The results of the model analysis are presented in Figure 4. At the horizontal axis is the premium in Euro per tonne of dry biomass for energy production, the left vertical scale shows the output response measured in PJ of raw energy in the dry biomass (the stacked bars show forestry and agricultural production, respectively) and the right vertical scale relates to the blue line and shows the total of the premiums of such a policy.

The results show that

- in the reference situation approximately 95 PJ of raw energy are available from domestic fuel wood (65 PJ) and agricultural products (30 PJ); the assumption is made that ethanol is produced from domestic grains which offsets exports of wheat, the largest share of oil for bio-diesel production is imported;
- the domestic output of biomass that is used for energy purposes can be stimulated considerably, however, at relatively high costs (105 PJ additional raw energy in dry biomass require subsidies amounting to 2 billion Euros which is approximately one third of the value of the agricultural output);
- the main reason for the high cost is that the output of livestock production (mainly bull fattening and pork production) is reduced because feedstuff is used for energy production purposes; farmers willing to switch to biomass production must be compensated for the opportunity cost;
- in agriculture the total plant biomass production for food, feed and energy hardly changes, but shifts from food and feed to energy uses;
- the small supply responses in biomass from agriculture are due to the fact that significant financial resources are used to support low-input agriculture (approximately 600 million Euro per year);
- the supply of fuel wood is even more inelastic suggesting that fundamental changes in forestry production seem necessary to mobilize the resources.

## 4 Discussion and conclusions

In our analysis we cannot confirm the results of other authors cited in the introduction which suggest that there is significant scope for an expansion of biomass production in Austria. The government could increase the share of biomass channeled into the energy sector, but the food and feed industries would need to import the corresponding commodities from international markets to offset the lacking inputs.

The results presented in this paper have to be seen in the context of several assumptions: (i) productivity growth and loss of land will proceed at a similar pace; (ii) given a growing population, rising incomes and an inelastic income elasticity for food, the demand for food will grow; (iii) environmental legislations put in place during the last decade and agri-environmental programs seem to be continue, therefore the production potential will be confined, (iv) in Austria, there is a broad public refusal of new technologies like genetically modified organisms that could potentially stimulate productivity.

This paper is the first economic appraisal of the cost of a massive expansion of biomass production for energy purposes in Austria. Therefore other studies have to scrutinize the assumption made, the model used and the results obtained. If the major conclusions are confirmed by other studies, there are a few policy implications: The Austrian society might be better off by specialising on high quality food production and curbing carbon dioxide emission by other means like taxes on emissions. Another suggestion is that EU legislation should not be based on model findings that are obtained at high territorial level if these results cannot be confirmed by bottom up approaches.

The paper presents findings that cannot substitute a thorough cost-benefit assessment. However, the results are elements that can be used in a more comprehensive appraisal. Therefore, future research should include information on the full carbon accounting of agricultural and forestry production and link the results to model of the whole economy.

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