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International Trade of Bio-Energy Products – Economic Potentials for Austria

Olivia Koland, Martin Schönhart and Erwin Schmid

Abstract

TRIOPOL studies the role of domestic bioenergy potentials for agriculture, the wider economy and international trade for Austria. In particular, agricultural biomass production can contribute to significant shares of energy provision in Austria. A detailed scenario is developed to explore the opportunities and challenges of enhanced domestic biomass production based on short rotation forestry (SRF) for heat supply which is currently among the most competitive technologies. To that end, TRIOPOL establishes a model linkage between a sectoral supply-model for Austrian agriculture and a national small open economy general equilibrium model. Model results show that a biomass premium of 65 € per ton dry matter is required to support 250,000 ha of SRF on cropland in Austria by 2020. The thus provided bioheat covers some 33 petajoule (PJ) heat energy demand in Austria; taking into account the likely rising of energy prices by 2020, this number rises to 47 PJ. Substantial land use changes may also be compensated by increases in land use intensity and as well as changes in imports and exports. Scenario results suggest that domestic food production of non-meat commodities falls by 1.3%. The sector meat products profits from the high competitiveness of Austrian livestock production and responds by a slight increase in net exports. The results of the quantitative analysis shall support the scientific and political debate on securing food and energy supply as well as economic development goals.

Keywords: Bioenergie, Landwirtschaft, Nahrungsmittelproduktion, Landnutzung, Wärmebereitstellung, Außenhandel, Modellstudie, Modellkopplung

JEL-codes: C63, C68, E20, F10, Q18, Q21, Q42

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International Trade of Bio-Energy Products – Economic Potentials for Austria

Olivia KOLAND[1], Martin SCHÖNHART[2], Erwin SCHMID[2]

[1] Wegener Center for Climate and Global Change, University of Graz

[2] Institute for Sustainable Economic Development, University of Natural Resources and Life Sciences, Vienna

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A. INTRODUCTION

Climate and land use change are considered as two of the most important global change phenomena. Both are complex and intertwined at various scales, from a local to global level (FOLEY et al. 2005, FISCHER et al. 2005). The vital role of agriculture and forestry in providing biomass is increasingly acknowledged for the transition of a fossil based economy towards a bio-based economy, globally. At national levels, policies to support supply security for food and energy gain importance such that quantitative analysis of international trade impacts on national economies, land use, and environment are increasingly needed.

The political interest for biomass based energy systems and intervention to foster energy supply in form of bio-energy is increasing, since bio-energy systems provide various attractive services. They supply energy in form of heat, liquid/gaseous fuel or electricity at relatively low cost, they emit less greenhouse gases, and they provide supplementary benefits such as enhanced supply security by decreasing the dependence on fossil fuels (cf. SCHLAMADINGER 2006) and regional job creation (cf. TRINK et al. 2010).

In recent time, firms and countries have increasingly engaged in international bio-energy trade. The traded volumes of biomass (products or residues from forestry, agriculture and e.g. paper industry, i.e. food, feed, fuels, and fiber) and energy-carriers derived from biomass (solid, liquid and gaseous bio-fuels e.g. bio-ethanol or wood pellets) as well as vegetable oils (as feedstock for bio-diesel) have grown. More and more biomass is being used for energy production.

According to KALT and KRANZL (2012), the Austrian bio-energy sector imports about one third of the biomass used for energy purposes, with a rising share of liquid bio-fuels and agricultural products for the production of bio-fuels in recent years (KALT 2011). Bio-energy potential studies for Austria indicate that the country's forestry and wood processing potential is well utilised, while the agricultural potential appears underexploited (cf. KRANZL et al. 2008). Austria may profit also from exports in the wood processing industry that is well established (cf. JUNGINGER 2011b).

These developments highlight the importance of future developments in international trade in agricultural goods as pre-products for bio-energy production as well as trade in food. Assessing international price levels and trade flows is also central for the choice of national adaptation capacities (cf. BURTON and LIM 2005). Especially when considering long time horizons, regional impact assessments on bio-energy potentials ignoring trade could lead to misleading results (cf. Reilly and SCHIMMELPFENNING 1999).

For the majority of bio-energy trade flows, still, supportive policies are a key driver (such as e.g. the blending quota for liquid biofuels), because they make bio-energy generation more attractive. However, we also observe changes of market driven trade, where lower production costs abroad (plus low shipping costs) can stimulate imports. Also high domestic demand together with a lack of local resources can be a trigger for bio-energy trade (cf. JUNGINGER et al. 2011a). Designing policies that take into account the potential of agricultural and bio-energy trade can address the specific regional differences in available land and bio-resources globally.

One key challenge that arises from increasing bio-energy extension is the competition of agricultural and forestry production in the provision of food, feed, fiber, or fuels from land, which is specifically true for liquid biomass rather than solid biomass (cf. JUNGINGER et al. (2011b) and TRINK et al. (2010) for Austria). The scarcity of land resources may even increase in the future due to losses to infrastructure and housing as well as increasing demands for nature conservation and recreation areas. Bio-resources thus need a comprehensive assessment in terms of profitability, sectoral and economy wide consequences as well as land use and environmental impacts. Subsidies for biomass products, for example, do not only directly affect domestic agriculture and forestry production but also upstream and downstream sectors in the economy as well as foreign trade flows.

This project, firstly, assesses the Austrian bio-energy potential and exports and imports of bio-energy (pre-) products. Secondly, it develops a detailed scenario to study the provision and effects of bio-energy products for energy and food security and international competitiveness for Austria. For the quantitative analysis, a model linkage is established between a sectoral supply-model for Austrian agriculture and forestry and a national small open economy model at the macro level.

This report has three main sections. Section B reviews the scientific literature on biomass production potentials in Austria to identify the most promising biomass crops and their potentials. Section C develops and uses a cluster of linked models to simulate a scenario of enhanced biomass production in Austria. The scenario explores the needs for and consequences for agriculture and cropland as well as for the wider economy and international trade. As an additional aspect, section C contains some qualitative considerations on sparing land for biomass production in Austria under new private food consumption habits. Section D summarizes and concludes.

B. DOMESTC BIOMASS PRODUCTION POTENTIAL

A growing body of scientific literature from regional to global scales informs about the production potentials of agricultural biomass for energy production and provides scientific evidence for subsequent research and informed policy decisions. However, such consideration by stakeholders is aggravated by the range of results and their underlying uncertainties as a consequence of different methods, assumptions and scenarios. We provide a conceptual framework in order to categorize and evaluate research output on the production potential of agricultural biomass from regional to global levels. This framework is applied in a meta-analysis on Austrian research and discussed with respect to its applicability and limitations.

1. The conceptual framework

The conceptual framework on production potentials is based on two review articles, which have in common a critical perspective on unrealistic estimates of the potential of agriculture to mitigate climate change by carbon sequestration and provision of agricultural biomass for energy production. CANNELL (2003) reviews the UK, European and global potential of carbon sequestration and emission offsets through biomass utilization. The review is structured along a "likelihood" gradient. A theoretical potential capacity (TPC) ignores some or all practical constraints, while a realistic potential capacity (RPC) takes most constraints into account but underestimates their effects. Finally a conservative achievable capacity (CAC) predicts conservatively based on observations. Consequently, CANNELL (2003) for EU15 reveals total potentials of biological carbon sequestration in above and below ground biomass and soils of 200-500 Mt C a^{-1} (TPC), 50-100 Mt C a^{-1} (RPC), and 20-50 Mt C a^{-1} (CAC), which on average corresponds to 21% (RPC) and 10% (CAC) compared to TPC. For carbon substitution from energy crops, EU15 may save emissions in the range of 600-900 Mt C a^{-1} (TPC), 200-300 Mt C a^{-1} (RPC) to 100-200 Mt C a^{-1} (CAC). Compared to TPC on average, it corresponds to levels of 33% (RPC) and 20% (CAC) respectively. SMITH ET AL. (2005) in their review on carbon sequestration potentials of European croplands differentiate among biologically, land and resource constrained potentials as well as potentials limited by economic or social constraints. They identify a realistic although conservative potential of carbon sequestration to be about 10-20% of the biological potential, which corresponds well to the levels presented by CANNELL (2003). A further categorization along potentials is presented by KALTSCHMITT et al. (2006).

The significant differences among studies fundamentally depend on the choice of constraints and the considered feedbacks in the system. The conceptual framework on the biomass production potential is hierarchical (*Figure 1*), i.e. potentials decrease from the least exclusive biological/technical potential to the most constrained competitive economic potential. Consequently, we move along a "likelihood" gradient from hypothetic/theoretic to realistic potentials. With respect to scientific disciplines, different levels demand different methodologies and disciplinary knowledge. Consequently, a holistic assessment of realistic potentials will require interdisciplinary research based on natural and technical sciences and economics.

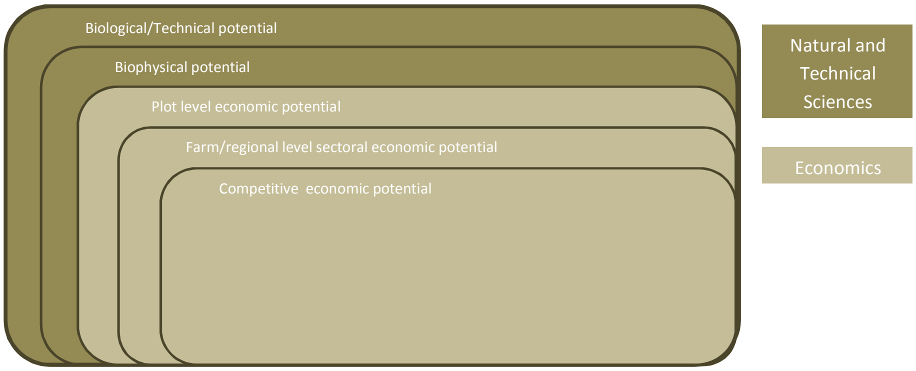

Figure 1: Overview on the conceptual framework for evaluation of biomass potentials

As biological/technical potential, we refer to a genetically determined yield potential of crops under perfect growing conditions, i.e. sufficient nutrient and water availability and temperature for maximum yields. With respect to land, the biological/technical potential may include total land availability in a region or country as resource constraint. The biophysical potential is more realistic on production conditions on a specific site by including spatially-explicit bio-physical data but remains at a natural and technical science perspective. Limitations from soil, slope, or climate are acknowledged. Crop rotations are taken into account as agronomic constraints. Consequently, the biophysical potential reduces maximum attainable yields in a wider region to potentials under local conditions. Secondly, it reduces total available land to the suitable land from an agronomic perspective. The plot level economic potential provides a general judgment on the profitability of a certain crop under local production conditions. It introduces an economic perspective, where a production potential is determined by market conditions for inputs and outputs. Hectar-based gross margin calculations or full cost accounting are applied to reveal, whether a crop is profitable at a specific site and to determine production intensity, i.e. fertilizer application rates or irrigation regimes. The farm or regional level sectoral economic potential takes the farm business organization into account. Opportunity costs are included that acknowledge farm internal resource constraints for land, labor, and capital. A profitable crop may be economically inferior (Pareto inefficient), if resources can be organized such that profits increase. This may or may not include land rent among farms. Frequently, farm models or regional sector models are applied to estimate the farm level economic potential. In any case, cost competitiveness is related to other crops and eventually uses of land. A competitive economic potential takes market adjustments into account and thereby introduces feedbacks into the system. This can include price changes of among different crops due to changing policy incentives or technological change and their corresponding changes in input prices. Typically, indirect land use change effects are part of this perspective if applied at a global level. Indirect land use change effects may not directly influence the production potential in a certain area but globally. SCHNEIDER and MCCARL (2003) differentiate between competitive and complementary strategies for climate change mitigation in agriculture. They point on the importance of simultaneous consideration of all available alternatives in order to reduce underestimation of complementary and overestimation of competitive strategies. It is at the level of competitive economic potentials, where these important aspects can be considered, e.g. by applying partial or general equilibrium models. Competitiveness among crops or land uses now is determined by interrelationships of the whole economy, where agricultural biomass for energy purposes has to compete for resources and against energy substitutes and technologies from regional to global markets.

2. Case study data

We apply the conceptual framework in a meta-analysis. Austrian research results on the production potential of biomass are reviewed and categorized according to the above framework to better compare potential estimates as well as to reveal knowledge gaps. To collect the data, we systematically reviewed the scientific literature from the year 2005 to November 2012. We started with the literature database Scopus® with the following query:
TITLE-ABS-KEY(austria AND energy) AND (EXCLUDE(SUBJAREA, "ENGI") OR EXCLUDE(SUBJAREA, "CENG") OR EXCLUDE(SUBJAREA, "MEDI") OR EXCLUDE(SUBJAREA, "MATE") OR EXCLUDE(SUBJAREA, "CHEM"))

All literature with information on production potentials under some spatial contexts and referring to Austria has been included. In a second step, the references have been reviewed to increase coverage. If several scenarios are presented in one study, e.g. with continually increasing market prices or subsidies, we usually refer to the more extreme values.

3. Results

The results of the review are summarized in *Table 1*. STÜRMER et al. (2013) analyze 1st and 2nd generation biomass production (1G, 2G) in Austria by applying an integrated land use modeling framework. The bio-physical process model EPIC (WILLIAMS, 1995) simulates spatially explicit crop yields based on typical crop rotations modeled by CropRota (SCHÖNHART et al., 2011), which become input to the land use optimization model BiomAT. BiomAT is applied to develop marginal opportunity costs for additional biomass outputs in spatial explicit manner i.e. to compute supply curves. The economic model takes most alternative crops into account in order to estimate regional level static economic potentials at the municipality level. However, fixed capital and labor costs are not considered and livestock production is acknowledged only indirectly, i.e. by assuming standard gross margins for food and feed crop production. The simulation of environmental effects such as nitrogen intensity levels informs the debate about socially acceptable production potentials. In another application, an earlier version of the same modeling framework is applied by ASAMER et al. (2011) to assess production potentials of short rotation forestry on cropland and changes in total nitrogen emissions and soil organic carbon. They compute a bio-physical production potential of 6.4 Mio. t DM a^{-1}. While soil organic carbon remains rather constant, total nitrogen emissions are decreasing with increasing poplar areas.

STÜRMER and SCHMID (2011) analyzed the biogas production potential for 2020 based on feed-in tariff scenarios. They applied a version of the integrated modeling framework CropRota – EPIC – BiomAT. As in other studies based on this modeling framework, an important constraint results from crop rotations that limit potentials to regionally observed typical patterns. This leads to more conservative potentials. There are no investments below 21 ct kWh_{el}^{-1} feed-in tariffs. About 3.1 mil. MWh are produced annually with 26 ct kWh_{el}^{-1}. It includes a mix of substrates from cropland and livestock manure. Such amount would increase the contribution of biogas to the Austrian electricity supply in 2008 from 0.9 to 4.2%.

KRAVANJA et al. (2012) analyzed perspectives of bioethanol production from straw and wood to achieve a 10% share of agro-fuels in gasoline consumption in Austria. They estimated 950 kt of straw from wheat and maize to be available in 2008 for energy purposes, which is 20% of total annual straw resources. On the fermentation process (C6 only or C6 and C5 sugars to be fermented), straw demand is between 446 kt and 695 kt straw to produce 100 kt ethanol annually as well as several by-products. Such amount would be added to the currently 191 kt bioethanol production to achieve the 10% target. The authors estimate a biological/technical potential for bioethanol based on straw and softwood to be 340 kt. However they acknowledge likely price increases for straw – feedstock costs are in the range of 50-55% of total production costs – and therefore suggest a more realistic 100-200 kt annually.

SCHMIDT et al. (2011a) estimated the potential of 1G and 2G agricultural biomass for fuel and electricity production to supply the transport sector based on an integrated modeling framework comprising CropRota, EPIC and the land use optimization model PASMA (SCHMID and SINABELL 2007) for the year 2020. In order to compute biomass supply curves, prices for energy crops in PASMA have been continually increased from 0-300%. Scenarios have been simulated to show minimal cost strategies for a 5, 10, and 15% policy target for agro-fuels in transportation in comparison to the baseline scenario. The most competitive strategies are 2G methanol from short rotation poplar as well as 1G biodiesel from rapeseed. However, total domestic production potentials for 1G biodiesel is lower than 5% of total consumption of transportation fuels in Austria. Straw has not been taken into account. The additional agricultural land necessary to produce 2G methanol from woody biomass depends heavily on the baseline scenario assumptions with respect to biomass consumption for electricity and heat production. In the baseline scenario for 2020, on average 160.000 ha of poplar is grown on cropland to serve electricity and heat demand. With the introduction of transport fuel policies a considerable amount of this poplar production is deviated from electricity and heat production and processed to methanol to serve transportation fuel demand. To achieve 10% methanol from agro-fuels in transportation requires displacement of food and feed production on cropland of about 39,800 ha with a 95% confidence interval between 34,600 and 45,000 ha (SCHMIDT, personal communication), which sums up to about 200,000 ha in total. In SCHMIDT et al. (2011b) the same integrated modeling framework has been applied to analyze cost effective strategies for climate change mitigation. Carbon prices >50 € $(tCO_2)^{-1}$ are required to make short rotation forestry cost competitive in energy supply under a base scenario. With prices >75 € $(tCO_2)^{-1}$, some ethanol is produced from agricultural crops. By introducing taxation, about 22 TWh are produced from agro-fuels at carbon prices of 150 € tCO_2^{-1} mainly from short rotation poplar.

STOCKER et al. (2011) analyzed the effects of increasing biomass utilization for heat and electricity on the economy, employment, and environment. Three scenarios have been defined under stakeholder participation and applied in a set of models. The scenarios include assumptions on energy production capacities and prices for 2020. The authors argue that capacity definition is oriented towards a realistic instead of technically possible potential. In the scenario "biomassive", biofuels account for 65,000 TJ or about 17% of total energy production capacity. However, the authors discuss the trade-offs among different land uses including import substitution and intensification and discuss the importance of socially accepted energy supply strategies (e.g. for wind power). The scenarios are input to the economic model, which takes supply demand relationships into account.

In a case study for the Austrian Sauwald region, SCHMIDT et al. (2012) estimated its potential for energy autarky in fuel and power demand. The agro-fuel supply has been modeled by the integrated modeling framework CropRota-EPIC-PASMA. The most competitive crop is short rotation forestry from croplands. To achieve autarky in heat and power (scenario 2) or heat alone (scenario 4) under current energy efficiency standards, 50% (scenario 2) and 30% (scenario 4) of cropland will be devoted to short rotation forestry besides other renewable energy sources (e.g. photovoltaics) and with considerable costs for energy consumers.

TRINK et al. (2010) conducted another case study for Austria. They applied a CGE model to analyze the welfare effects of agro-fuel production in South-East Styria. Agro-fuels have been integrated by production cost functions. Policy scenarios included a 20% supply objective of heat demand (i.e. 2,000 TJ) as well as a 5.75%, 10% and 20% biodiesel blending target under given import shares (agro-fuels for heat: 8%; biodiesel: 30%, 60% or 90%). The utilization of forestry resources and pellets from miscanthus and straw are the only activities to deliver positive welfare effects in the long run.

KRANZL et al. (2008) applied a dynamic biomass potential assessment and derived biomass supply potentials from Austrian agriculture from land use statistics and assumptions on future land and livestock development. In total about 120 to 150 PJ are available annually with greatest potentials from unexploited grassland and intermediary crops. This scenario data has been input to the energy system model Green-XBio-Austria to provide the cost minimum energy supply strategies (KALT et al. 2010) and greenhouse gas emission scenarios. Depending on energy prices, biomass policies and efficiency scenarios, about 11% to 18% of total energy consumption can be supplied by domestic biomass. This range increases to about 13% to 32% in 2050.

In a multicriteria assessment under stakeholder participation, MADLENER et al. (2007) qualitatively evaluated different energy system scenarios by sustainability criteria. Stakeholders ranked the scenarios "large impact in small-scale use" and "investments into the future" highest. Both include significant technology investments. At the lower ranks have been the "fast and known" and "extensive use of biomass" scenarios with a focus on biomass utilization due to the considerable (fossil) energy requirements of biomass production and the centralized energy systems assumed in both scenarios.

STREICHER et al. (2010) provide estimates on theoretical and technical biomass potentials. They assume a theoretical annual biomass yield potential from total vegetated land cover of 136 Mt., i.e. a heat potential of 2,693 PJ a^{-1}. This category corresponds to a "biological/technical potential" in this study. Technical potentials in STREICHER et al. (2010) acknowledge various resource and utilization constraints such as alternative uses of biomass for food and feed, which can correspond to farm or dynamic economic potentials. For agro-fuels and residues (e.g. food industry), such technical potential is estimated to 89 PJ a^{-1} in 2030 under a constant demand assumption (base year = 2008). Currently, they assume 176 k ha cropland from set aside and export production available for agro-fuel production.

The Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW 2009a) provides estimates on agricultural biomass for energy production based on studies and expert assumptions. For 2020, the authors assume 210-235 k ha available and further 100 k ha from crop residues. This results in 20.6-25.6 PJ. In order to achieve the 10% target on agro-fuels in the transportation sector, further 29.1 PJ would be required from imports with the Danube region identified as important exporting region.

STEININGER and VORABERGER (2003) explore the economic effects of medium term biomass potentials in Austria by applying a CGE model. Input biomass potentials are provided by expert survey. In 2020, pellets from agriculture may account for 34.61 PJ a^{-1}, straw for heating for 14 PJ a^{-1}, biogas for 9.43 PJ a^{-1}, and rapeseed oil for 4.41 PJ a^{-1}, while straw turns out to be the cheapest technology with 17.2 € MWh^{-1}. Nevertheless, introduction of any agro-fuel led to GDP de-growth under the chosen oil price and technological assumptions, while showing positive or negative employment effects. In the CGE application, subsidies are introduced to stimulate agro-fuel supply: pellets from agriculture (49% subsidy rate of total costs; 24.23 PJ a^{-1}), biogas (14%; 8.27 PJ a^{-1}), rapeseed oil (40%; 3.88 PJ a^{-1}) and RME (55%; 3.88 PJ a^{-1}).

LANGTHALER et al. (2007) estimated land resource potentials for biomass production in Austria for the year 2020 for three scenarios. Land resources in the "Biomasseszenario" are available from utilized set-aside areas (60 k ha), area for export production (140 k ha), grasslands (50 k ha), reduced feed demand (25 k ha), increased yields through advanced breeding (17 k ha), crop residues (100 k ha), intensification (43 k ha), and cover crops (30 k ha). Based on land use data from 2007 (BMLFUW, 2009b), the total 465 k ha estimated to be available for biomass production to serve energy demand account for about 15% of total agricultural land in Austria in 2007 including alpine pasture, are.

KLETZAN et al. (2008) evaluated the Austrian national biomass action plan from an economic perspective. They modeled the potentials of biogas, ethanol, biodiesel, short rotation forestry (heat), grain and straw (heat) by applying PASMA and PROMETEUS. As policy scenarios, a uniform biomass subsidy per ton dry matter is introduced in PASMA for all agro-fuels. The total agricultural potential ranges from currently 30 PJ a^{-1} to about 130 PJ a^{-1} with corresponding subsidies from 0 to 170 € DMt^{-1}. Higher subsidy levels lead to only small additional potentials. Results from PASMA have been input to the macroeconomic model PROMETEUS.

Besides national studies, a number of research studies on biomass potentials at the European level are available as well. Here, we present those with explicit estimates for Austria. DE WIT and FAAIJ (2010) model the cost and supply potentials of biomass production in Europe under three scenarios of agricultural productivity and livestock development. They approach from a land availability assessment and integrate biophysical modeling of crop yields at 1 km^2 resolution. Land demand for food production, building areas, and nature conservation has been acknowledged. Production costs are estimated based on a full cost approach including land rent. For Austria, low to medium area potentials and medium to high production costs for biomass lead to a comparatively low production potential in economic terms. The physical production potential in 2030 is at about 200 PJ a^{-1} including timber industry residues.

The land potentials of DE WIT and FAAIJ are partially based on the work of FISCHER et al. (2010a). The latter estimate a considerable amount of 40% of European grasslands currently not required for ruminant nutrition. For Austria, they estimate available land for biofuel feedstock production to be about 180 k ha in 2030 in a base scenario (current trends in organic farming and nature conservation, moderate yield increases). In a “Land use-Energy” scenario, the available grassland, i.e. accessible grassland not required for livestock feeding or nature conservation, is utilized for herbaceous energy crops (i.e. energy grasses). For Austria in 2030, 84 k ha of the 1,917 k ha of permanent grassland are estimated to be transferred to build-up areas, 1,027 k ha are demanded for livestock grazing and further 571 k ha for nature conservation (assumedly alpine pastures and meadows). The remaining 235 k ha are estimated to be available for lignocellulosic bioenergy feedstocks (FISCHER et al. 2010a).

The European Environmental Agency estimated the environmentally compatible production potential of biomass based on future land availability in the EU, an environmentally benign crop mix, achievable crop yields and corresponding energy contents (EEA 2006). Considered crops include conventional food and feed crops as well as perennial grasses and short rotation forestry. The available cropland is determined by the utilized agricultural area released from food and feed production under a changing policy and market environment in 2030. However, competition between agricultural biomass for energy purposes and other land uses as well as production potentials from released grassland are not considered in the model implicitly. For Austria, 204 k ha has been estimated for 2010 with a growing potential to 298 k ha in 2030. Considering environmentally benign crop mixes for each country, the Austrian production potential was estimated to 0.6 Mt oil equivalents in 2010, which increases to 2.1 Mt oil equivalents in 2030.

HENZE and ZEDDIES (2007) estimated the available land for agro-fuel production in the EU for 2000, 2010 and 2020. According to their definition, set aside areas and areas utilized to produce export goods including beef and dairy products minus areas required to attain self-sufficiency for other goods are available. Pork and poultry are excluded from reductions to self-sufficiency levels due to the assumed high competitiveness of these goods in some countries. To estimate future potentials, the authors take changes in consumption patterns, productivity gains, and land sealing into account. For Austria a potential of 348 k ha or 10.2% of total available land is estimated for 2000, 390 k ha (11.5%) for 2010 and 747 k ha (22%) for 2020 mainly from grassland.

Table 1: Summary of reviewed studies on production potentials of agricultural biomass provision for energy production in Austria

Publication	Method	Agro-fuel	Level of potential[1]					Year	Scenario/Intervention	Level		
			1	*2*	*3*	*4*	*5*			*area*	*weight, energy*	*relative*
Stürmer et al. (2013)	bio-physical process model and regional economic land use optimization model	1^{st} (1G: cereals, oil crops) and 2^{nd} generation (2G: grass, short rotation poplar)		x		x		2030	Agro-fuel price intervention 1G: 200€ (t DM)$^{-1}$ Agro-fuel price intervention 2G: 240€ (t DM)$^{-1}$		3.7 Mil. t DM 6.4 Mil. t DM	7.7% n.s. of total transport energy demand
Asamer et al. (2011)	bio-physical process model and regional economic land use optimization model	short rotation poplar		x		(x)		-	Marginal opportunity costs: 360€ ha^{-1}	0.6 Mil. ha (50% of total cropland)		
Stürmer and Schmid (2011)	bio-physical process model and regional economic land use optimization model	Biogas (energy plants on crop land, manure)		x		(x)		2020	Feed-in tariffs: 26 ct kWhel^{-1}		3.1 Mil. MWh	share of biogas to the 2008 Austrian electricity supply: 4.2%
Kravanja et al. (2012)	Balancing based on crop yield data	straw	x				(x)	2008	Straw price: 80€ t^{-1}		950 kt straw → 137-213 kt ethanol	5-7% of gasoline demand
Stocker et al. (2011)	Expert-based scenarios and economic modeling	"biofuel"				(x)	x	2020	Scenario definitions on energy production capacities and prices for heating and power production		Capacity biofuels: 65.000 TJ	17% of total capacity
Schmidt et al. (2011a)	bio-physical process model and regional economic land use optimization model	1G: cereals, oil crops) and 2^{nd} generation (2G: grass, short rotation poplar)		x		x	(x)	2020	Agro-fuel price intervention	115 k ha (uncertainty range: 45 – 225 k ha)		10% of fuel demand
Schmidt et al. (2012) [regional application]	bio-physical process model and regional economic land use optimization model	Short rotation poplar, oil crops, biogas		x		x	(x)	2020	Agro-fuel price intervention: short rotation poplar	50% of regional cropland		45% of power and 100% of heat demand
Schmidt et al. (2011b)	bio-physical process model and regional economic land use optimization model	Grains, oil seeds, forage crops, ethanol crops, short rotation poplar, others		x		x	(x)	2020	Carbon price for greenhouse gas emissions: 150 € tCO_2^{-1}		22 TWh	
Trink et al. (2010) [regional application]	CGE model	Pellets: miscanthus, grain, straw, poplar Whole plant: corn, micanthus Biodiesel: rape seed		(x)			X	n.s.	Heating demand target Biodiesel blending target		n.s.	n.s.
Kranzl et al. (2008), Kalt et al. (2010)	Quantitative biomass scenarios	Grassland and cropland biomass	x			(x)	(x)	2020 2050	No – high biomass support policies No – high biomass support policies			11-18% 13-32% of total energy demand

Table 1: consecutive

Madlener et al. (2007)	Qualitative biomass scenarios	Biomass for heat and power, biogas						n.s.	n.s.		n.s.	n.s.
Streicher et al. (2010)	Quantitative biomass scenarios	Straw, grassland, crop residues, energy crops	x			(x)		2025 2030	Free land from set aside and production of exports	200-300 k ha 5.2 PJ a^{-1} straw		
BMLFUW (2009a)	Quantitative biomass scenarios	Biodiesel, bioethanol, biogas, thermal fuel, straw	x			(x)		2020	n.s.	210-335 k ha		
Steininger and Voraberger (2003)	Quantitative biomass scenarios, CGE modeling	Pellets from agriculture, biogas, rapeseed oil, RME				(x)	x	2020	Subsidies (% from total costs): Pellets: 49% Biogas: 14% Rapeseed oil: 40% RME: 55%		24.23 PJ a^{-1} 8.27 PJ a^{-1} 3.88 PJ a^{-1} 3.88 PJ a^{-1}	
Langthaler et al. (2007)	Quantitative biomass scenarios	n.s.	x			(x)		2020	n.s.	< 465 k ha		
Kletzan et al. (2008)	regional economic land use optimization model	biogas, ethanol, biodiesel, short rotation forestry (heat), grain and straw (heat)				x	x	n.s.	Subsidy: 0 € DMt^{-1} 170 € DMt^{-1}		30 PJ a^{-1} 130 PJ a^{-1}	
De Wit and Faaij (2010) and Fischer et al. (2010a)	Quantitative biomass scenarios considering production costs	Lignocellulosic crops, Herbaceous lignocellulosic crops, oil crops, sugar crops, starch crops		x	(x)			2030	Free land considering food and feed production, infrastructure and nature conservation	235 k ha from permanent grassland	~ 200 PJ a^{-1} incl. forestry residues	
EEA (2006)	Quantitative biomass scenarios considering land availability and environmental criteria	Arable crops, perennial grasses, short rotation forestry				(x)	(x)	2030	Changes in CAP and international trade regimes	298 k ha from cropland	2.1 Mt oil equivalents	
Henze und Zeddies (2007)	Quantitative land use scenarios	n.s.				(x)		2020	Free land from set aside and production of exports	747 k ha from cropland and grassland		

[1] Level of potential: 1 Biological/Technical potential, 2 Biophysical potential, 3 Plot level economic potential, 4 Farm/regional level sectoral economic potential, 5 Competitive economic potential; n.s. not specified

4. Discussion

4.1 Summary on biomass production potentials in Austria

For Austria, we identified 21 studies that analyzed agricultural biomass production potentials to serve energy demand in recent years. These studies cover a broad range of research questions, scenarios, applied methods, temporal scales, and crops. Despite these differences there appear some general patterns. First, simple estimates on areas available for biomass production range between 200 - 747 k ha for the next decades with most results ranging between 200 - 300 k ha. These results are mainly driven by assumptions on available set aside land, export substitution, and whether or not to consider permanent grassland. Among the production incentives are producer price interventions, feed-in tariffs, taxes on CO2 emissions, and land use subsidies. Several studies are oriented towards policy objectives such as fuel blending targets. For example, to achieve 10% of the Austrian fuel demand, 296 k ha cropland are required for methanol production according to SCHMIDT et al. (2011a). To substitute 10% of demand for total transport energy in Austria including growth in consumption up to 2030, STÜRMER et al. (2013) estimated a required subsidy for methanol production of 85 € (t DM)-1, which corresponds to roughly 500 k ha. Secondly, most reviewed studies do not provide substantial insights on external effects and the social acceptance of biomass production and their effects in Austria. Some, such as STÜRMER et al. (2013) and ASAMER et al. (2011), quantify bio-physical effects such as nitrogen emissions or changes in soil carbon contents. However, most even remain at the level of technical or bio-physical potentials as has already been argued by STÜRMER et al. (2013). MADLENER et al. (2007) present scenarios on the future of energy provision under stakeholder participation. However, they do not quantify production potentials. Thirdly, many studies indicate lignocellulose crops to have the highest potential in terms of land use and environmental effectiveness. Their production costs per energy unit are among the lowest under current and expected future production technologies including 2nd generation agro-fuel production. This is similar to the European level despite today's dominance of oil crops as feedstock (FISCHER et al., 2010b). Besides, perennial energy crops may be superior also from an environmental perspective due to less soil disturbance, reduced water demand, and enhanced species diversity in agricultural landscapes (cf. EEA 2006). Straw is among these feedstocks. It is a crop residue and therefore not in direct competition to food and feed production (for a discussion on the role of such crop residues, see TILMAN et al., 2009). An early study by DISSEMOND and ZAUSSINGER (1995) estimated the potential of straw for energetic use in Austria to 350 k t a^{-1} in the early 90s, which corresponds to about 12% of total straw production. KRAVANJA et al. (2012) assumed an amount of 950 k t a^{-1} straw from wheat and maize in Austria available for energy production, which corresponds to 20% of total straw production in 2008 from both crops. Major alternative uses of straw are fertilization of soils and livestock feed, housing and manure systems. In recent years, there is growing interest in straw as insulation as well as construction material. Such use can contribute to the objective of cascading biomass utilization where it first serves material needs and carbon storage options and finally is burned to provide energy.

4.2 Framework applicability

The conceptual framework in this study has been developed to make the research outcomes on biomass production potentials comparable. This should have been achieved by a gradual integration of criteria, i.e. from biological to economic potentials. As application reveals, the conceptual framework, however, does not allow an exact categorization of some publications. For example, studies on the bio-physical potentials may well include climate change effects and thereby show a dynamic component including feedbacks, although they neglect economic considerations. Obviously, in a practical application, the framework categories can hardly be interpreted as consecutively decreasing potentials as studies may include some more restricting (economic) constraints while neglecting bio-physical constraints or include components from different levels in varying detail (see the adapted graphical representation of the framework in *Figure* 2). An example of these challenges is the work by HENZE and ZEDDIES (2007), who estimated land availability under a number of mainly economic assumptions including changes in technologies, consumption behavior and markets. However, their balancing did not include any dynamic feedbacks from markets such as changes in output prices. This would be necessary to be categorized as farm or regional level sectoral economic potential.

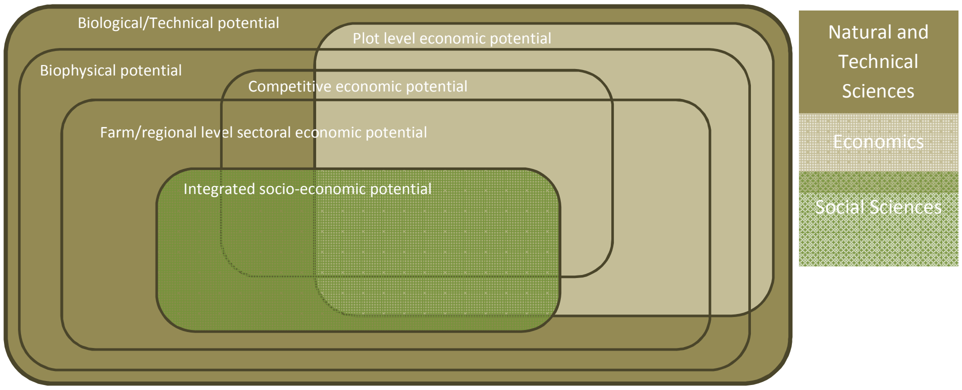

Figure 2: Revised conceptual framework

In this study, publications have been categorized rather superficially according to the framework. To improve its comparability as well as the consistency of results, the categorization may be refined based on a set of better defined indicators.

Results show that most economic studies neglect external effects of agro-fuel production until now. A few studies, such as those by STÜRMER et al. (2013) apply an integrated approach including bio-physical and economic models and provide indicators on environmental effects, such as changes in nitrogen intensity. However, such effects do not impact the results on production potentials in most studies, although the consideration of externalities may decrease or increase the potential. The direction and magnitude of effects may depend on the social costs and benefits of biomass production and those of other renewable and fossil alternatives as well as energy saving measures. It requires a broader economic perspective than provided by most studies so far (compare to the socially/politically constrained potential in SMITH et al. (2005)). Social values become part of the decision and social sciences may contribute to such research. In economics, the concept of a social welfare function pursues such objective. Typically, the extensive introduction of crops for agro-fuel production, e.g. environmentally inferior monocultures, leads to negative external effects or may increase food prices. Integration of such effects frequently goes beyond bio-physical and standard economic modeling efforts and requires transdisciplinary research. Anyway, this may be the level of long-term production potentials as it considers both competitive economic and social processes. Furthermore, there may be further constraints to achieve the market potential (SMITH 2012). It can include market imperfections such as information or capital constraints, high transaction costs, or path dependencies and long transition periods that all limit adoption beyond a socially acceptable level and should be included in holistic economic assessments.

5. Conclusions

In this section, 21 research studies have been reviewed that provide insights into today's and future production potentials of agricultural biomass for energy production in Austria. Most studies show a significant though limited potential of some 10% of fuel demand. Where studies remain at the level of area potentials instead of physical output units or energy output, 200-300 k ha resulted from several studies. Differences occur with respect to the utilized land use classes, i.e. whether grassland (energy grasses), cropland, or both has been considered. This amount is about 6 – 9% of total agricultural area in Austria including alpine pastures and meadows or 8 – 12% when excluding them. At the European level, OVANDO and CAPARRÓS (2009) presented a similar share of 8 – 30% in EU-25 necessary to contribute with 13 – 52% to the EU greenhouse gases reduction target of 20% in 2020. Such share is significant and requires evaluation and monitoring of landscape changes and its effects (OVANDO and CAPARRÓS 2009) both ex-ante and ex-post to policy and market changes.

Direct comparison of most study results is difficult due to different assumptions, methods, or output standards. However, this article revealed current research foci and underrepresented issues. With respect to the latter, more research seems required on farm level decisions on agro-fuel production and feedbacks from and to the regional and international economy including imports and exports. Land use affects biophysical conditions and landscape patterns, which both trigger social acceptance of land management. Consequently, research should integrate technical feasibility, economic viability, environmental soundness, and social acceptability of domestic and international agro-fuel production. This is relevant due to the high level of policy intervention required to support agro-fuels under current market and policy conditions.

C. SIMULATION OF EXTENDED BIOMASS PRODUCTION IN AUSTRIA

Based on the analysis of agricultural biomass production potentials in Austria in section B, we use quantitative models to explore the conditions for and consequences of a broad biomass extension in Austria. We narrow our focus on a specific biomass technology, namely the provision of biomass based heat through poplar-pellets. Poplars are output of short rotation forestry plantations (SRF), which is a perennial cropland production activity. Consequently, results are reported for the primary sector for biomass (agriculture), the remaining sectors in the economy, and the trade flows.

1. Methods and Data

The literature gives several examples for integrated sectoral and CGE models or bio-physical and economic models. For example BRITZ and HERTEL (2011) link the partial equilibrium model CAPRI with a GTAP CGE model to analyze effects of the EU biofuel directives on global markets and the economy, but do not include spatially explicit bio-physical input data. Such data has been utilized by HAVLÍK ET AL. (2011) in their global assessment of 1st and 2nd generation biofuel targets. They integrated such data in the global partial equilibrium model GLOBIOM. In another global assessment FISCHER et al. (2005) combine bio-physical modeling with an agricultural sector model to analyze climate change impacts from 1990-2080 without considering general economic effects. KOLAND et al. (2012) integrate biophysical impacts from climate change in an economic land use model and a subsequent CGE model to analyze the effectiveness and general economic effects of mitigation and adaptation measures in the Austrian region South-East Styria.

In this study, we apply an integrated modeling framework consisting of bottom-up and top-down biophysical and economic models to represent the Austrian economy (Fig. 1). The modeling approach consists of the crop rotation model CropRota (SCHÖNHART et al. 2011), the bio-physical process model EPIC (Environmental Policy Integrated Climate; WILLIAMS 1995) and the sectoral bottom-up land use model PASMA (SCHMID and SINABELL 2007) for detailed analysis of the agricultural and forestry sectors. A computable general equilibrium (CGE) top-down model for Austria is developed to assess economic effects. The model comprises trade links to the rest of the world and captures impacts on the Austrian economy via import and export markets. The CGE model is based on the GTAP 7 database (GTAP 2007) and calibrated for the year 2004. We extract a heat service sector from this database, and we include specific biomass technologies (cost structures).

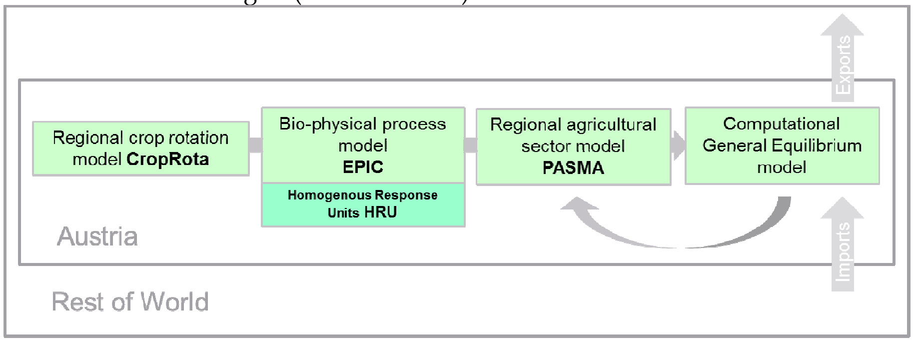

Figure 3: Interfaces of the integrated modeling framework for the Austrian economy including foreign trade flows from/to Austria

1.1 The crop rotation model CropRota, the biophysical process model EPIC and regional agricultural sector model PASMA

CropRota is a linear optimization model that derives the distribution of typical crop rotations on arable land by arranging crops in such a way that the total agronomic value of all preceding and main-crop combinations is maximized subject to historical farm land use mixes. Due to its generic design, CropRota can be applied from single fields to regions. In this study, it is applied at municipality level to provide input data to EPIC.

The bio-physical process model EPIC was originally developedto assess the status of U.S. soil and water resources (WILLIAMS 1990) and has since then been continuously expanded and refined to allow simulation of many processes important crop growth in agriculture (WILLIAMS 1995, IZAURRALDE et al. 2006). Major model components in EPIC are weather simulation, hydrology, erosion-sedimentation, nutrient and carbon cycling, pesticide fate, plant growth and competition, soil temperature and moisture, tillage, cost accounting, and plant environment control. EPIC operates on a daily time step. It is often used to compare alternative land use management systems and their environmental effects. In this study EPIC has been applied on homogeneous response units (HRU) over a period of 20 years utilizing different crop management variants such as land use intensity or regionally specific typical crop rotations from CropRota. HRUs are available for the whole Austrian territory (cf. STÜRMER et al. 2013) and are assumed to be homogeneous with respect to soil type, slope, and altitude at high spatial resolution of one to several km². EPIC provides a rich set of bio-physical output. In this project, we base economic land use modeling on crop yield output for arable land and grassland. Crop yields are averaged over a 20-yrs simulation period and aggregated to the NUTS-3 level to serve as input to PASMA.

PASMA is an economic bottom-up land use optimization model for the agricultural and forestry sectors in Austria. It integrates bio-physical data in regional and site-specific contexts. PASMA portrays the natural, structural, economic, and policy contexts of Austrian agriculture and forestry in detail. Particularly, the 1st and 2nd pillars of the Common Agricultural Policy (CAP) are considered including Single Farm Payments and other direct payments, measures of the agri-environmental program ÖPUL, and less favored area payments. Computations are usually based on scenarios to anticipate changes in markets and policy instruments. PASMA maximizes total gross margins from land use and livestock activities for all Austrian NUTS-3 regions. Its strength is in the detailed description of the socio-economic, political and bio-physical systems with high spatial resolution. Thereby it builds on major land use data and statistical sources such as the Integrated Administration and Control System (IACS) and farm survey data. Furthermore, PASMA is made widely consistent with the Economic Accounts of Agriculture.

In this study, PASMA provides detailed output data of seven agricultural and forestry sectors comprising five crop sectors (grain and maize (WHO), oil seeds (OSD), vegetables and fruits (VAF), other crops (OCR), and rest of agriculture (RAGR)), one livestock sector LIV and one forestry sector FRS. PASMA applies positive mathematical programming (PMP) for calibration purposes. This method can overcome data limitations with respect to farm production costs. However, it is challenged by necessary assumptions on the shape of cost functions as well as the availability of empirical land use data. When simulating extreme policy interventions such as the scenarios applied in this study, prerequisites for PMP may be lacking. Consequently, we have developed a linear optimization version of PASMA in this study. It does not calibrate on empirical land use to allow for more flexibility. However, to prevent extreme model reactions, empirical data on different land use types, crops, and livestock have been processed and are included via balance equations and constraints in the model

1.2 The economic model (computable general equilibrium model) for the Austrian economy and its trade partners

In order to capture the impact of changes in agriculture on the rest of the economy (macro-economic effects) and arising feedback effects on the agricultural sector (inter-industry dependencies), we use a static multi-sectoral (21 sectors) small open economy CGE model. The sectoral aggregation of agricultural, industrial and service recognizes its application to bio-energy and trade issues.

The underlying GTAP database has a broad representation of 12 agricultural sectors and consistent bilateral trade flows for 113 countries, which are aggregated to 14 regions for this study (see *Table 2* and *Table 3*). GTAP has thus a clear strength in consistent foreign trade flows for agricultural and non-agricultural goods among countries. Following the Armington hypothesis (ARMINGTON 1969), domestic output and imported goods are imperfect substitutes. Armington elasticities are based on GTAP (2007). Austria is modeled as a small open economy without influence on world market prices. Labor, capital, and land are mobile within the economy but immobile across borders. There are three types of production activities which differ slightly in their production functions: (i) agricultural, land using sectors, (ii) resource using (primary energy) extraction sectors, and (iii) non-resource using commodity production. Agricultural crop sectors (WHO, VAF, OSD, OCR, RAGR, see *Table 2*) are characterized by land as a factor input. In resource using sectors (FRS, COAL, OIL, GAS, RRES), a specific resource input is used. For all types of production activities, nested constant elasticity of substitution (CES) production functions with several levels are employed to specify the substitution possibilities in domestic production between primary inputs, intermediate energy and material inputs as well as the substitutability between energy commodities. At the top level of land using sectors, output is produced with a very low elasticity of substitution (s:0.1) between land and a non-land composite to acknowledge the fixed factor land.

Following the structure of agents used in the social accounting matrix (SAM) generated by GTAP, the so-called regional household is an aggregate of private and public households and thus represents total final demand. To study biomass energy for Austria, we separate the HEAT sector from the SAM based on private heat demand (STATISTICS AUSTRIA 2009). Moreover, we consider the specific costs for biomass heat technologies and the reference technology (oil) using technical and economic coefficients for bio-energy products. The production of bio-energy services is modeled in two steps. First, the pre-energy biomass is produced as a preliminary product with a fixed input coefficient production function (Leontief production function). These specific biomass products can only be used for bio-energy production and do not enter other crop intensive sectors. Land for crop production is available in fixed supply such that producing agricultural biomass replaces conventional agriculture. Land is a central production factor and can hardly be substituted for other production factors.

In a second step, biomass is converted into use energy (with a Leontief production function).

The regional household provides the primary factors capital, labor, land and natural resources for the 21 sectors, and receives total income including various tax revenues. This regional household redistributes this stream of income between the private household demand, public demand and investment. Final demand is determined by consumption of the private household and the government. Both the private household and the government maximize utility subject to their disposable income received from the regional household. Consumption of private households in each region is characterized by a constant elasticity of substitution between a material consumption bundle and an energy aggregate. Public consumption is modeled as a Cobb Douglas aggregate of an intermediate material consumption bundle.

1.3 The interface between PASMA and the economic model

Integrated modeling should consider inter-linkages at high spatial resolution to acknowledge local to regional heterogeneity in bio-physical and farm structural conditions (cf. BRINER et al. 2012) and should moreover transmit these conditions to monetary (aggregated) agricultural sector output.

PASMA and the CGE model can be coupled either via upward (PASMA to CGE) or downward (CGE to PASMA) linkages depending on the modeled scenario to utilize their individual advantages. The sectoral concordance between PASMA and GTAP is established through detailed PASMA model outputs on all major land use and livestock activities, which are mapped to five plant production sectors, one livestock production sector and one forestry sector in the CGE model (see *Figure 4*).

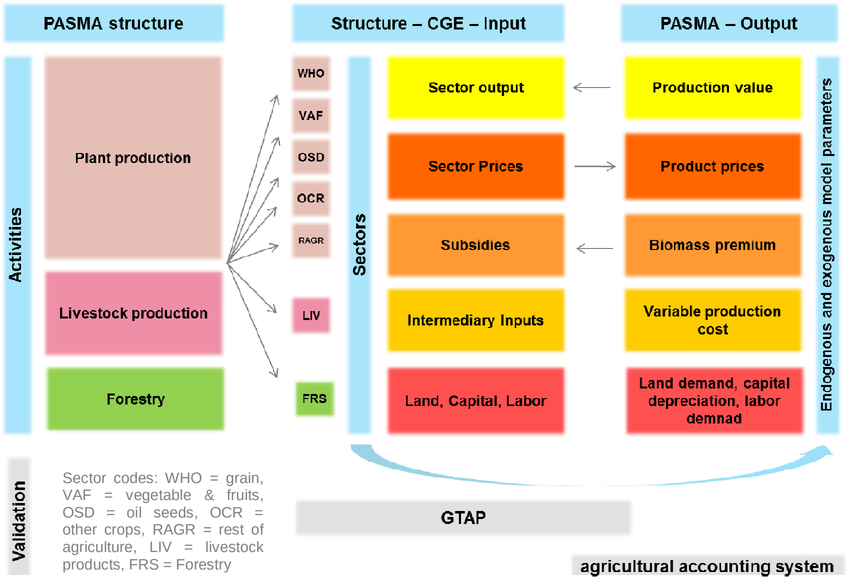

Figure 4: Upward Interface between the agricultural production model PASMA and the CGE model for the Austrian economy

In this study, changes for the five agricultural production levels and biomass premiums are passed on to the CGE model in an upward link. Thereby, the subsidy level in PASMA necessary to reach a specific amount of biomass from agricultural land is consistent with the subsidy necessary to produce the according amount of biomass based heat in the economic model.

2. The bio-energy content in Austrian trade

The Global Trade Analysis Project database (www.gtap.agecon.purdue.edu) (GTAP database) used to calibrate the CGE model is unique in its sectoral and regional coverage of input output and trade tables (113 countries and 57 commodities for 2004). GTAP is very much suitable to study trade issues, because it ensures internationally consistent input output and trade tables. The database supplies thus information on imports and exports of agricultural and forestry (biomass) commodities from and to Austria with other countries and regions as well as to the rest of the world. We will use this information to draw a picture of the most relevant trade flows for Austria. Beforehand, we present an overview of the aggregation scheme for sectors and regions used in this study (see *Table 2* and *Table 3*).

Table 2: Sectors in the CGE model based on the GTAP 7 database)

	TRIOPOL sectors	model code
	land using sectors	
1	Wheat and meslin; other cereals (maize, barley, rye, oats)	WHO (=WHT + GRA)
2	Vegetables & fruits	VAF
3	Oil seeds	OSD
4	Fodder crops, bioenergy crops, seeds	OCR
5	Livestock (cattle, milk, other animal products, wool)	LIV
6	Rest of agriculture (sugar cane & beat; vegetable materials; rice)	RAGR
	food industry	
7	Food (other than meat: vegetarian & beverages)	FOOV
8	Food (meat)	FOOM
	resource using sectors	
9	Forestry	FRS
10	Mining of coal	COAL
11	Extraction of crude petroleum	OIL
12	Gas extraction; gas manufacture and distribution (heat)	GAS
13	Rest of resource using sectors (other mining; fishing)	RRES
	energy, construction and crop intensive industries	
14	Refined oil products (petroleum/fuels, coal products)	PC
15	Electricity	ELY
16	Construction	CNS
17	Energy intensive industries	EII
18	Crop intensive industries (e.g. wood and paper products)	CII
	rest of industries	
19	Transport	TRN
20	Other industries	OI
21	Services	SEV

The chosen sectoral aggregation contains the necessary detail to analyse biomass issues (cf. IGNACIUK and DELLINK 2006). Among the 21 sectors, there are six agricultural sectors (WHO, VAF, OSD, OCR, LIV and RAGR), two food sectors distinguished by non-meat and meat commodities (FOOV, FOOM), and one forestry sector (FRS). Moreover, it considers primary energy carriers (COAL, OIL, GAS), refined oil products (PC), electricity (ELY), energy intensive industries (EII) and crop intensive industries (CII). Potential bio-energy sectors include wheat and other cereals (comprised in WHO for e.g. the production of ethanol as well as of straw pellets as a side product), oil seeds (comprised OSD for the production of bio-diesel), bio-energy crops from agriculture such as rape, poplar and willow (comprised in OCR for e.g. the production of short rotation forestry pellets), and forestry (FRS).

The regional aggregation into four groups (EU Group 1 to 4) is carried out based on numbers for arable land per capita (and grouped into quartiles) for all European countries (based on FAO data). Within these four groups, Germany (GER), Italy (ITA), the Netherlands (NLD) and the Czech Republic (CZE) are most intensively interlinked with Austria via exports and imports of agricultural biomass products and thus modeled separately (see *Figure 5* and *Figure 6*). Moreover, for the regional specification we draw on KALT and KRANZEL (2012) who identify Germany and Italy as major bio-energy trading partners for Austria on wood log, wood chips and residues, pellets and wood waste.

Table 3: Regions in the CGE model based on the GTAP 7 database

	TRIOPOL regions	**model code**
1	Austria	AUT
2	Germany	DEU
3	Italy	ITA
4	Netherlands	NLD
5	Czech Republic	CZE
6	EU Group 1 (Belgium, Cyprus, Malta, Portual, Slovenia, United Kingdom)	EU1
7	EU Group 2 + Switzerland (Greece, Ireland, Luxembourg, Slovakia, Switzerland)	EU2
8	EU Group 3 + Norway (France, Poland, Romania, Spain, Sweden, Norway)	EU3
9	EU Group 4 (Bulgaria, Estonia, Denmark, Finland, Hungary, Latvia, Lithuania)	EU4
10	Rest of Europe (Iceland, Albania, Croatia, Moldova, Turkey, Liechtenstein, rest of Europe)	ROE
11	North America (incl. USA, Canada), Latin America (incl. Brazil) & Oceania	RAO
12	Emerging economies, Tiger states (East Asia) and less developed Asian countries (Rest of South & South East Asia)	ASI
13	Russia & rest of GUS	GUS
14	Middle East, North and Subsaharan Africa	AFR

Here and in the following, we concentrate on the use of short rotation forestry (SRF) for bio-energy provision. It is an agricultural PASMA production activity and part of the OCR sector, and it has been selected due to the results from the literature review (see section B). The GTAP based OCR is used to analyse trade flows of SRF and products based on it. Nevertheless, the interpretation of OCR trade has to be treated with caution, because it comprises bio-energy crops, fodder crops, seeds and flowers and cannot be disaggregated to a finer level within GTAP. We will thus understand OCR as a proxy for SRF.

Table 4 shows that, relative to the output in each sector, Austria (AUT) imports a high amount of OCR (import intensity 42%) and moderate amounts of FRS (23%) and WHO (18%). With respect to the amount of exports relative to sector output, Austria is low in the export intensity of OCR (8%) as well as FRS (5%) and high in WHO (32%).

Table 4: Trade balance, import and export intensity in M EUR (2004 real prices) (Source: GTAP 2007, own calculations)

	2004 in M EUR		**2004** in %		**2004** in %
trade balance		**import intensity**		**export intensity**	
WHO	87	WHO	18%	WHO	32%
VAF	-695	VAF	47%	VAF	6%
OSD	-44	OSD	54%	OSD	25%
OCR	-367	OCR	42%	OCR	8%
LIV	-160	LIV	11%	LIV	5%
RAGR	-35	RAGR	16%	RAGR	3%
FOOV	415	FOOV	16%	FOOV	18%
FOOM	61	FOOM	28%	FOOM	31%
FRS	-383	FRS	23%	FRS	5%
COAL	-210	COAL	90%	COAL	0%
OIL	-1,598	OIL	88%	OIL	0%
GAS	-687	GAS	74%	GAS	3%
RRES	-326	RRES	27%	RRES	11%
PC	-1,588	PC	37%	PC	5%
ELY	-202	ELY	14%	ELY	10%
CNS	17	CNS	4%	CNS	4%
CII	2,314	CII	24%	CII	30%
EII	-69	EII	32%	EII	32%
OI	-2,274	OI	36%	OI	34%
TRN	3,938	TRN	13%	TRN	24%
SEV	-3,749	SEV	12%	SEV	10%

Austria (AUT) is a net exporter of WHO (see *Table 4*). The majority of Austrian exports in grain sectors WHO (WHT, 56%, and GRO, 34% of total Austrian exports in these sectors) go to Italy (ITA) (see *Figure 5*). Within EU3, France (FRA) is the main importer of GRO from AUT (12%). 62% of forestry exports go to ITA, and main destinations for OCR exports from AUT are Germany (DEU, 11%) and Russia (23%, within GUS). Both OCR and FRS are of minor overall importance because AUT is low in export intensity in both sectors, while OCR is central for questions of biomass trade.

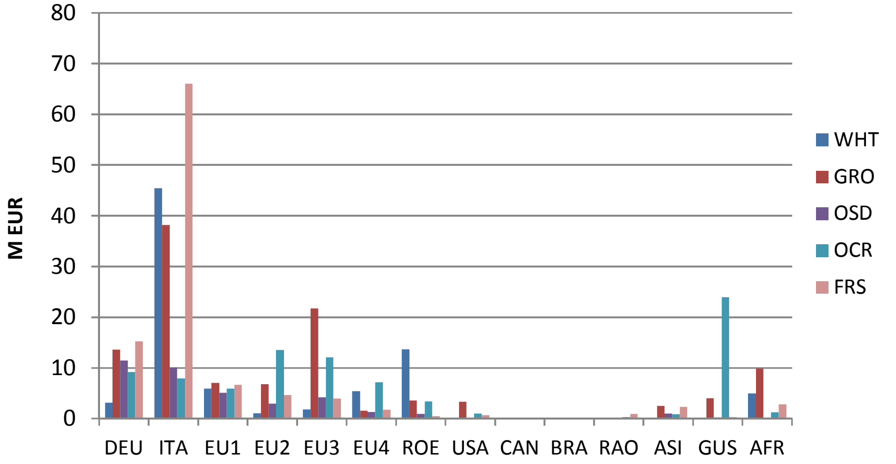

Figure 5: Exports from Austria to other countries and regions for selected economic sectors; Source: GTAP 7 database (GTAP 2007), own illustration

Austria is a net importer of OCR and FRS (see *Table 4*). AUT is a major importer of OCR from Germany (DEU, 29% of total OCR imports), the Netherlands (NLD, 25%, within EU1 in *Figure 6*) and Africa (AFR). AUT imports forestry products from DEU (44%), the Czech Republic (CZE, 25%, within EU3), Poland (POL, 6%, within EU3), Slovakia (SVK, 6%, within EU2) and Switzerland (CHE, 5%, within EU2).

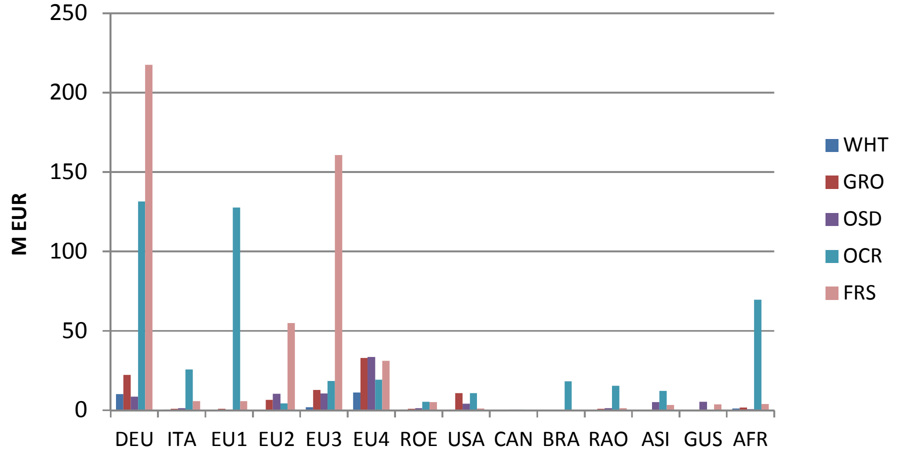

Figure 6: Imports to Austria from other countries and regions for selected economic sectors; Source: GTAP 7 database (GTAP 2007), own illustration

While the GTAP database is a reliable source of information for foreign trade flows and in particular for regionally consistent trade linkages, there are also national data sources that contain information on bio-energy trade flows for Austria (see e.g. KALT and KRANZL 2012). The authors report on the methodological challenges that arise in assessing these foreign trade streams. In particular, *indirect* bio-energy trade flows are hard to capture.

3. Scenario: Opportunities and challenges of enhanced biomass production

The Austrian forestry and wood processing sector is already well utilized and well studied (cf. KRANZL et al. 2008), and the wood processing industry seems reasonably established (cf. JUNGINGER 2011b). Therefore, we concentrate on the *agricultural* potential for biomass production as an emerging sector. Additional supply might more likely arise from developments in the bio-energy market of agriculturally based products. TRINK et al. (2010) compared the costs of various biomass technologies and quantified their labor market and welfare effects for a NUTS 3 region in Austria. According to their results, pellets made from SRF such as poplar or willows plantations are among the most efficient technologies and similar results have been achieved by other authors as well (compare results of section B). SRF is considered as agricultural activity due to its rotation periods of a few years between each harvest as well as recultivation of the site to cropland after its use (i.e. about 15-20 yrs.). Starting from these results, we will thus be very specific and investigate the potential and consequences of bio-energy provision based on poplar pellets for Austria. A focus is put on the provision of *heat* through biomass products (thus neglecting electricity generation and biofuels in the transportation sector).

The scenario *(ScenBIOM)* is constructed to show the opportunities and challenges of enhanced domestic biomass production for the economy and international trade. For the baseline in 2020 (no change in biomass supply), we assumed expected reforms of the Common Agricultural Policy (CAP) such as the abolition of milk quotas, the transition towards a regional system of decoupled direct payments, greening of the 1st pillar and premium reductions in the 2nd pillar. Furthermore, we take losses in agricultural land for infrastructure development into account. Data on productivity and price developments are drawn from OECD-FAO (2011) forecasts and other literature.

ScenBIOM is based on the literature review presented in section B of this report, which shows comparative advantages of ligno-cellulosic crops such as straw and wood compared to other energy crops. Consequently, we model short rotation forestry (SRF) production in the year 2020. SRF may become even more attractive once 2nd generation conversion technologies become available at industrial scales, which may be assumed for the year 2020. However, in this study, we assume traditional utilization for heat production. ScenBIOM is driven by PASMA and its effects are transmitted to the CGE via an upward linkage. In PASMA we introduce a subsidy on SRF based on the physical biomass output to promote its production to a target level. According to the literature, more than 200,000 ha of arable land may be available for agro-fuel production in Austria in the next decades (cf. section B). However, values vary due to assumptions on market development, agricultural policies or consideration of set-aside land. In ScenBIOM, we strive for an area of 250,000 ha without including set-aside land, which is fixed to 7% of total arable land in each NUTS 3 region in 2020. Due to current negotiations on the CAP reform concerning “greening” European agriculture, it appears unlikely that set-aside land is released for biomass production.

4. Simulation Results and Discussion

4.1 Opportunities and challenges of enhanced biomass production: Effects for agriculture and cropland

The biomass premium for the scenario (ScenBIOM, Euros per ton dry matter (€ (tDM)$^{-1}$) is included in PASMA as top-up to the market price for wood chips. The latter is assumed at 49€ (tDM)$^{-1}$ based on Stürmer and Schmid (2007). Consequently, this price is consistent to the base year prices in PASMA (average 2006-2008), from which prices for 2020 are estimated based on the OECD-FAO market outlook (OECD-FAO, 2011). In order to attain an additional level of 250,000 ha of SRF on arable land in Austria compared to the baseline in 2020 (BAU), a biomass premium of 65€/tDM is required in ScenBIOM (see *Figure 7*). Most of the resulting SRF sites are in the arable regions of Eastern Austria consistent to Stürmer et al. (2013) and Asamer et al. (2011).

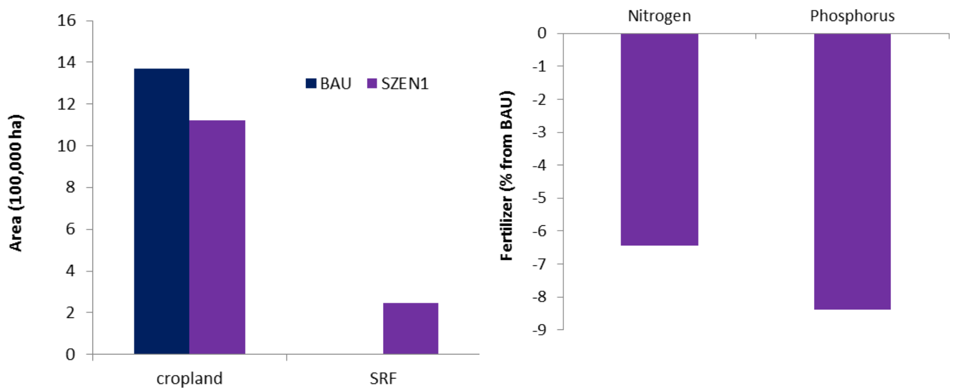

Figure 7: Cropland and short rotation forestry (SRF) area (left) and effects of ScenBIOM on fertilizer application (right)

With respect to environmental effects, increasing SRF areas reduce total fertilizer application rates in the model due to the lower nutrient demand of SRF compared to annual field crops. However, we did not model changes in intensity on the remaining cropland, which has been stated by Stürmer et al. (2013) and may reduce fertilizer reduction effects.

At sectoral level, production values shift among agricultural sectors, while the total agricultural sector output decreases by 2% from BAU (*Figure 8*). Considerable effects such as in the oil seeds and rest of agriculture sectors (OSD, RAGR) contribute little to total changes due to its small absolute size. Losses in some sectors such as the important grains sector (WHO) are compensated by increases in OCR, of which SRF is part of. The forestry sector (FRS) is not impacted by this policy in the model. However, one has to acknowledge likely impacts of agricultural biomass policies on forest product markets especially wood for industry and energy purposes. With respect to the livestock sector, the model does not show significant impacts. Reasons are the high relative competitiveness of Austrian livestock production, the dominance of ruminants on grasslands as well as the option to substitute feed production on arable land by feed imports. In general, SRF sites are hardly established in livestock intensive production regions of Austria according to the model. Feed imports increase in order to compensate for losses in land.

Figure 8: Effects of ScenBIOM on production values of agricultural and forestry sectors

Figure 9 shows the impacts of ScenBIOM on the output of major crop categories in order to assess its impacts on domestic food and feed supply. Despite rather stable supply in livestock products - Austria has been net exporter for milk, beef and pork in 2010 (BMFLUW 2012) - self-sufficiency decreases in ScenBIOM for major plant products, which decrease their trade balance.

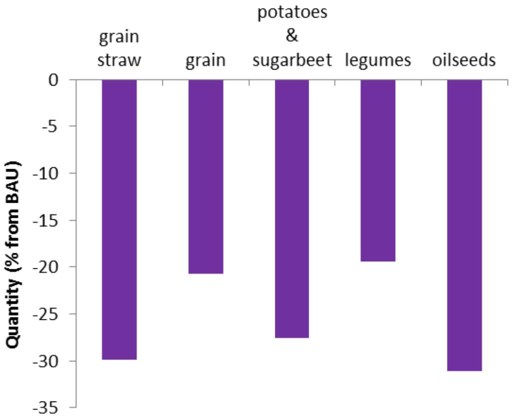

Figure 9: Effects of ScenBIOM on production of major food and feed crops (Note: classification not equal to sectors)

In the economic model, without a subsidy the heat technology based on poplar-pellets is not attractive compared to the fossil fuel technology. While the pure cost spread based on the energy content provided per EUR paid for the heating technology is some 7% (cf. TRINK et al. 2010), we find that feedback effects in the economy lead to an increased subsidy required to activate the technology of some 11% of heat service value. This is in line with the biomass premium necessary to produce the required amount of SRF as pre-product for heat generation in the sector model PASMA and validate both model results.

The biomass supply extension of ScenBIOM permits the provision of poplar-pellets worth some 157 million EUR, and biomass heat services worth some 740 million EUR. Bio-heat covers some 33,000 TJ of heat energy demand (see *Table 5*). As a consequence, the fossil heat demand and the remaining heat demand (other than biomass energy) decrease (*Figure 10* shows the corresponding level decrease).

Table 5: Level of biomass and bioheat supply based on short rotation forestry extension in ScenBIOM

Results from biomass extension	
biomass production in Mio EUR	156.7
bioheat supply in Mio EUR	743.2
bioheat demand in TJ	32,815.4

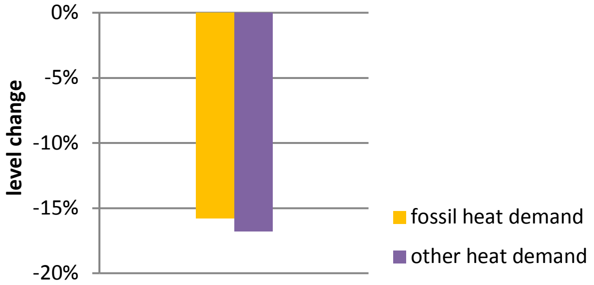

Figure 10: Change in heat demand in AUT relative to base, ScenBIOM

As an additional central result in terms of domestic biomass potential, *Figure 9* shows a decline in grain *straw quantities* (as an outcome of ScenBIOM). According to the literature review on biomass production potentials (section B), straw appears as promising option for agro-fuel production in the future. 2nd generation agro-fuel technologies may allow conversion to transport fuels despite the current use of grain straw for heat production. Availability of straw is considered as sufficiently for alternative purposes (compare to results of section B). As it is a side product of grain production, one major advantage of straw is its limited competition to food and feed production. However, there are other competitive uses of straw as fertilizer, feed, and in animal housing, that limit its availability for the energy sector. For this study a straw balance has been included in PASMA in order to take these alternative uses into account and assess available quantities for bio-energy production. In ScenBIOM, the reduction of grain production reduces straw availability significantly. Assuming a rate of 40% remaining at the field to stabilize soil carbon contents as well as considering demand from livestock sector, a surplus of 300,000 t a^{-1} in BAU turns to a deficit of about 100,000 t a^{-1} in ScenBIOM indicating a limited availability of this resource.

4.2 Opportunities and challenges of enhanced biomass production: Effects for the national economy and international trade

Economy-wide and cross-sector effects of impacts in the agricultural and biomass markets are subject to inter-industry dependencies and relative prices on factor and product markets. We compare economic and trade effects to the base case 2004. We choose parameters in the CGE model such that the relative differences between the sectors with respect to their likely developments until 2020 are accounted for.

Figure 11 shows the impacts of ScenBIOM on the remaining sectors of the economy. Effects for the agricultural sectors have been described above. The impacts of ScenBIOM on these crop outputs are transferred to the FOOD sector, which is strongly linked to the agricultural sector up (agricultural intermediary inputs) and down (animal feed) the value chain. Domestic production of non-meat products (FOOV) falls by 1.3% as a reaction to the output decrease in crop sectors. Production of meat products (FOOM) profits from the now higher availability of production inputs from the LIV (livestock) sector and increases its domestic production (+1.8%, see *Figure 11*). In absolute terms, the shift in the FOOV sector is about three times that of FOOM and 10 times that of RAGR (see *Figure 12*). The remaining sectors of the economy (industry and service sectors, primary energy carriers) are not affected remarkably (see the Appendix for domestic production levels in the base case 2004). Summing up over all agricultural sectors, the agricultural output has decreased by some 150 M EUR compared to the base case.

Figure 11: Relative change in domestic production value in AUT relative to the base case in ScenBIOM (in %)

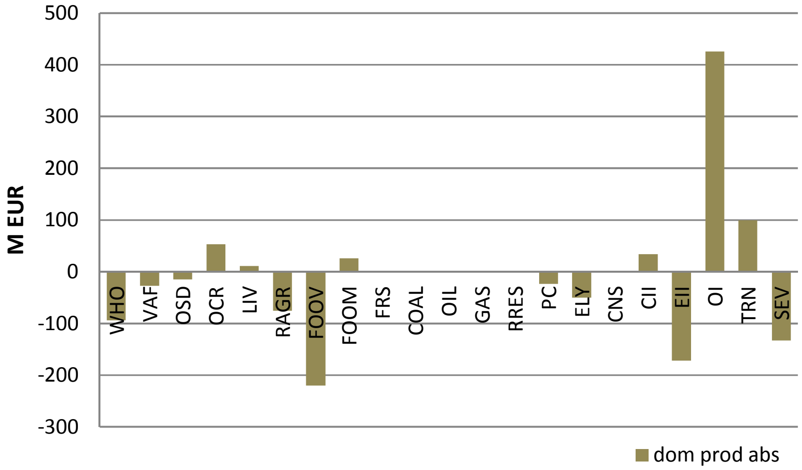

Figure 12: Absolute change in domestic production value in AUT relative to the base case in ScenBIOM (in M EUR)

Effects on domestic output price are most significant for agricultural goods. The three largest sectors respond by +1.3% (vegetables and fruits, VAF), -0.8% (bio-energy and fodder crops, OCR) and -1.4% (livestock industry, LIV) price changes. Price effects on the food market are moderate, while compared to prices of other consumption goods, domestic prices of non-meat food rise (FOOV) while those of meat products (FOOM) fall.

Increased biomass production levels as in ScenBIOM impact not only on the other agricultural (land using) sectors in the home market, but they also affect exports and imports of agricultural goods from and to Austria. Export and import intensities depend on the terms of trade (relative prices of home to foreign). Furthermore, the food sector responds to these changes in reaction to the relative prices of the inputs needed in its production. To maintain food security, imports in food products increase when domestic food production is lower than its demand. However, if part of the food production is relocated abroad, value added along the production chain flows to other countries and may have negative welfare implications (leakage) - and vice versa for an export oriented food industry.

The implications of ScenBIOM for foreign trade of Austria differ across sectors. The food industry has diverging impacts for meat (FOOM) and non-meat products (FOOV) in accordance to the effects on domestic production levels. FOOM exports rise (+3%), while imports slow down (-1%). FOOV sees a decrease in exports (-2.8%) and an increase in imports (+1.2%). In absolute terms, the change in FOOV exports is about twice the FOOM exports (and 10 times that of RAGR). As for imports, the change in the FOOV sector is seven times that of FOOM (in absolute terms, see *Table 6*). The trade balance changes for the sectors according to *Table 7*. FOOV increases its imports yet stays a net exporter. FOOM raises its net exports thus remaining a slight net exporter. For the OCR sector the trade balance remains negative.

Table 6: Import and export changes, ScenBIOM

	2004 in M EUR	ScenBIOM in M EUR	% change		2004 in M EUR	ScenBIOM in M EUR	% change
Imports				**Exports**			
WHO	110	123	11.3%	WHO	197	133	-32.5%
VAF	801	804	0.4%	VAF	106	103	-3.2%
OSD	82	86	5.1%	OSD	38	31	-18.2%
OCR	453	486	7.3%	OCR	86	94	8.8%
LIV	318	308	-2.9%	LIV	157	162	3.1%
RAGR	43	97	126.7%	RAGR	8	3	-65.3%
FOOV	3,496	3,539	1.2%	FOOV	3,911	3,801	-2.8%
FOOM	571	566	-1.0%	FOOM	632	651	3.0%
FRS	489	490	0.1%	FRS	106	106	-0.1%
COAL	211	209	-0.9%	COAL	0	0	-0.7%
OIL	1,598	1,585	-0.9%	OIL	0	0	-0.7%
GAS	712	696	-2.2%	GAS	25	24	-1.1%
RRES	553	551	-0.3%	RRES	228	228	0.1%
PC	1,815	1,800	-0.8%	PC	227	225	-0.7%
ELY	854	844	-1.1%	ELY	651	646	-0.8%
CNS	940	939	-0.1%	CNS	957	958	0.1%
CII	8,970	8,966	0.0%	CII	11,284	11,308	0.2%
EII	17,468	17,354	-0.7%	EII	17,400	17,327	-0.4%
OI	45,855	46,004	0.3%	OI	43,581	43,833	0.6%
TRN	4,747	4,757	0.2%	TRN	8,685	8,718	0.4%
SEV	27,602	27,558	-0.2%	SEV	23,852	23,854	0.0%
Total	120,114	120,190	0.1%	Total	117,982	118,060	0.1%

Table 7: Change in the trade balance, ScenBIOM

	2004 in M EUR	ScenBIOM in M EUR
trade balance		
WHO	87	10
VAF	-695	-702
OSD	-44	-55
OCR	-367	-392
LIV	-160	-147
RAGR	-35	-94
FOOV	415	262
FOOM	61	85
FRS	-383	-384
COAL	-210	-209
OIL	-1,598	-1,585
GAS	-687	-671
RRES	-326	-324
PC	-1,588	-1,575
ELY	-202	-198
CNS	17	19
CII	2,314	2,343
EII	-69	-27
OI	-2,274	-2,171
TRN	3,938	3,961
SEV	-3,749	-3,704

In terms of trade intensities, the export intensity (exports relative to domestic production) of FOOM rises by 0.5 percentage points, its import intensity (imports relative to domestic production) falls by 0.6 percentage points. FOOV now exports less intensively (-0.3 percentage points) and imports more relative to domestic production (+0.4 percentage points, see *Table 8*). The sharp rise in import intensity of RAGR has no strong impact due to the small size of the RAGR sector in terms of domestic production (see the Appendix, *Table 10*, for base year values of domestic sectoral production).

Table 8: Change in export and import intensities (in % points), ScenBIOM

	2004	**ScenBIOM**	change (% points)		**2004**	**ScenBIOM**	change (% points)
export intensity				**import intensity**			
WHO	32%	26%	-6.5%	WHO	18%	24%	5.7%
VAF	6%	6%	-0.1%	VAF	47%	47%	1.0%
OSD	25%	23%	-2.3%	OSD	54%	63%	8.9%
OCR	8%	8%	0.3%	OCR	42%	43%	1.0%
LIV	5%	6%	0.1%	LIV	11%	11%	-0.4%
RAGR	3%	1%	-1.5%	RAGR	16%	51%	35.0%
FOOV	18%	18%	-0.3%	FOOV	16%	17%	0.4%
FOOM	31%	32%	0.5%	FOOM	28%	27%	-0.6%
FRS	5%	5%	0.0%	FRS	23%	23%	0.0%
COAL	0%	0%	0.0%	COAL	90%	90%	-0.8%
OIL	0%	0%	0.0%	OIL	88%	87%	-0.8%
GAS	3%	3%	0.0%	GAS	74%	73%	-1.7%
RRES	11%	11%	0.0%	RRES	27%	27%	-0.1%
PC	5%	5%	0.0%	PC	37%	37%	-0.1%
ELY	10%	10%	0.0%	ELY	14%	14%	0.0%
CNS	4%	4%	0.0%	CNS	4%	4%	0.0%
CII	30%	30%	0.0%	CII	24%	24%	0.0%
EII	32%	32%	0.0%	EII	32%	32%	-0.1%
OI	34%	34%	0.1%	OI	36%	36%	0.0%
TRN	24%	24%	0.0%	TRN	13%	13%	0.0%
SEV	10%	10%	0.0%	SEV	12%	12%	0.0%

4.3 Sparing land for biomass production in Austria – some qualitative considerations

Additional bio-heat production based on SRF requires production resources and is particularly dependent on the availability of land. One way of increasing domestic biomass-supply might be by setting appropriate incentives (premiums), as shown within ScenBIOM. In such a situation, farmers are incentivized to switch from crop production to SRF. Another way of releasing land for alternative uses is on the demand side. Considering the fact that 84% of agricultural land is needed for animal products (cf. Zessner et al. 2011), a reduction in overall consumption of livestock products could help to release land resources. Thus, here we discuss the likely consequences of a change in eating habits of the Austrian population. One possible example of such a change could e.g. be in line with the dietary recommendations issued by the German nutrition society and applied to Austria (cf. Zessner et al. 2011).

ScenBIOM in section 4.1 assumed 250,000 ha of arable land in Austria available for biomass production. A biomass premium for each produced unit has been introduced to stimulate domestic production. The reviewed studies provide a range of arguments for its availability including utilizing set-aside areas, decreasing market opportunities for traditional crops especially for marginal areas due to increasing competition and structural change, or increasing competitiveness of crops for energy production. Recent market and policy developments, however, challenge these assumptions. During recent years, market prices for major crops increased for several reasons such as adverse weather conditions in major producer countries, increasing demand for agrofuels, as well as souring demand through a world population increasing in number and wealth. Increasing public awareness on the value of remaining natural land and the negative effects of high land use intensities (e.g. agri-environmental policies in the CAP) limit utilization of further land resources.

New strategies of sustainable land use are required under such framework conditions, which may even become tougher in the future (e.g. further increasing of world population in number and affluence, climate change effects). Some authors, such as FOLEY et al. (2011) propose "sustainable intensification" as solution. It includes measures such as closing yield gaps, preventing utilization of land at the margin or bringing new land into production, as well as re-distribution of farm inputs around the globe. At the consumer level, suggestions include a reduction in the consumption of highly resource-demanding food, such as meat, and food wastes. With respect to the former, livestock production demands 70% of agricultural land on earth (STEINFELD et al. 2006), although one has to acknowledge high shares of grassland based livestock production in Austria, which lacks alternative agricultural utilization paths until now. Large scale introduction of 2nd generation agro-fuel production may open production alternatives to permanent grassland. Concerning food wastes, roughly 1/3 of global food production is wasted (GUSTAVSSON et al. 2011). While considerable food waste in developing countries occurs during harvest, storage, and processing (GUSTAVSSON et al. 2011), waste in industrialized countries is high at the level of final consumption, of which a considerable share may be avoidable according to a UK case study (PARFITT et al. 2010). From a sustainability and resource perspective, changes towards vegetarian diets and reducing food waste appear to be high priority measures that may even increase consumer budgets and improve health.

However, for the Austrian economy such changes may have considerable impacts due to the high importance of livestock production, processing and exports. Livestock products accounted for 45% of agricultural production value in 2011. Breeding animals, meat and dairy products account for 29% of agricultural exports, while they are imported at a share of 21% (BMLFUW 2012).

D. SUMMARY AND CONCLUSIONS

We reviewed the scientific literature on agricultural biomass potentials for energy production in Austria to reveal the state of the art in methods, the underlying assumptions and data, and related uncertainties, as well as the most promising biomass crops, range of potentials, and bio-energy conversion pathways. Studies mainly differ by their assumptions, i.e. whether they approach from a technical and natural science perspective providing bio-physical production potentials, or from an economic perspective that take competition among alternative land uses into account. Even at the level of economic analysis, studies can range from a comparison of gross margins among alternatives to integrated market models that take into account linkages among sectors as well as external effects of alternative land uses. The review on potentials supported the definition of the scenario. Despite the current use of forestry biomass for heating, studies show that agricultural biomass production can contribute to significant shares of energy provisioning in Austria. As most competitive appear short rotation forestry for heat supply and the use of crop residues such as straw. With the development of industrial scale 2nd generation biofuel production, its potential may even increase. However, land demand is considerable and there are no substantial free land resources in Austria. Even set-aside land serves purposes such as for nature conservation.

The complexity of the research questions and the need for quantitative assessments to support policy decisions suggest application of a model cluster. We developed and applied an integrated modeling framework in order to overcome limitations of single model components. PASMA depicts the Austrian agricultural sector in detail. This is achieved by its bottom-up structure as well as the integration of bio-physical data and models. Apart from region-internal product flows and resource constraints, PASMA accounts indirectly for changes in other sectors and economies by projections and scenario developments on exogenous price and parameter values. However, this limitation can be partially overcome by linking PASMA to a national small open economy model at the macro level (CGE model). The CGE model works with highly aggregated sectors but well represents interactions among sectors, macro-economic outcomes and trade effects. In this project, we tested a model interface based on relative changes, which turned out to provide reasonable results while at the same time has been manageable concerning data flows and model computations. Using this modeling tool, we develop a detailed scenario for Austria to explore the opportunities and challenges of enhanced domestic biomass production based on short rotation forestry (SRF). In the scenario, a specific focus is laid on biomass heat production from poplar pellets, which are among the most efficient technologies (cf. e.g. TRINK et al 2010). Impacts are observed in agriculture and use of cropland as well as in the wider economy and international trade.

In the scenario, a biomass premium of 65 €$(tDM)^{-1}$ is required to support 250,000 ha of SRF on cropland in Austria in 2020. This leads to shifts among agricultural plant sectors despite a hardly impacted livestock sector. While grain, oil crops, and legumes decrease in production values, the OCR sector including SRF is increasing considerably. Substantial land use changes such as those assumed in the scenario likely impact prices on factor endowments (e.g. land) as well as of other crops even in a small open economy such as Austria. We did not take this into account in the PASMA analysis. However, policies based on our results should take effects on land prices, prices of alternative crops and livestock production into account. It has been shown by our model results as well as other studies (cf. STÜRMER et al. 2013, SCHMIDT et al. 2012) that such substantial land use changes may also be compensated by increases in land use intensity and changes in imports and exports. Leakage of bio-fuel production has been sufficiently documented in the scientific literature and needs to be taken into account whenever land use policies are changing. This is true also for crops already in use for energy purposes, such as wheat for ethanol production or feedstock for biogas plants.

Results from PASMA also show interesting trade-offs between SRF and straw production. Production potentials of straw appear considerable in Austria according to the scientific literature and authors praise its limited land use conflicts as it is considered to be a crop residue. However, straw production is complementary to grain production and thereby is in competition to SRF. Furthermore, straw is already utilized and decreasing grain areas such as in the current scenario may turn the Austrian straw balance negative.

Under the specific scenario assumptions, the biomass supply extension generates poplar-pellets worth some 157 million EUR, and biomass heat services worth some 740 million EUR. The thus provided bio-heat covers some 33 PJ heat energy demand. Taking into account the likely rising of energy prices by 2020, this number may rise to 47 PJ. Assuming that final Austrian energy demand will have increased to 1,400 PJ until 2020 (business as usual assumption), this amount (47 PJ) would serve some 3.4% of final energy demand. If final energy demand can be stabilized at 2005 levels (1,100 PJ, cf. Energy Strategy for Austria, BMLFUW and BMWFJ), some 4.3% of final energy demand could be covered. Taken as shares in final energy demand for household heating and cooling as well hot water boiling, bio-heat would satisfy some 11.1% and 14.1% of energy demand, respectively.

Inter-industry dependencies and relative prices on factor and product markets transfer these impacts in the agricultural and biomass markets to the wider economy. In a global world, goods and services are produced for domestic and export markets, and domestic shortages may be compensated for by imports, both depending on relative prices home and abroad. The food sector is the most important downstream industry of agriculture, but also important upstream (animal feed), and responds naturally to a shift in agricultural supply levels. Adjustments occur in terms of domestic production as well as trade flows.

Scenario results suggest that domestic food production of non-meat commodities (FOOV) falls by 1.3% as a reaction to the output decrease in crop sectors. It translates from a moderate net exporter to a week net exporter. The sector meat products, by contrast, profits from the high competitiveness of Austrian livestock production and responds by a 1.8% increase in domestic production together with a rise in net exports. Leakage of part of the food production, however, may be problematic because it relocates value chains to other countries. By contrast, imports of agricultural goods have not that strong implications for value added. The scenario shows how the food industry reacts differently for meat and non-meat commodities. The competition of land between biomass products and crops for food supply is a key challenge in the discussion of energy and food security, in particular the concern on rising food prices.

In our scenario, compared to prices of other consumption goods, domestic prices of non-meat food rise (FOOV) while those of meat products (FOOM) fall.

Additional public spending is required when domestic biomass potentials are activated by the introduction of biomass premiums per unit of harvested product or by directly subsidizing biomass heating technologies. SRF is not eligible to the current agri-environmental program in Austria. Consequently, considerable funds remain unused in the scenario situation if such large share of eligible cropland is converted to SRF. If earmarked to SRF, these excess funds would account for about 20% of the required premiums to support a production such as in the scenario. With respect to its environmental effects, advantages of SRF such as limited soil disturbance and provision of landscape structure must be contrasted to likely increasing land use intensities in other regions and decreasing aesthetic landscape values in regions with high shares of SRF. Further scientific analyses are required to balance these effects under future energy policies and economic development.

Subsequent to the analysis of a biomass extension on potentially available land, we discuss the opportunity of sparing land through changed nutrition habits of the Austrian population (cf. ZESSNER et al 2011). Changes in diets are often considered as means to more sustainable food systems (FOLEY et al. 2011). However, such changes need to be considered on continental to global scales in order to prevent leakage and rebound effects. Changes of demand for livestock products only in Austria likely will increase exports due to the high competitiveness of Austrian livestock production. Furthermore, the high share of grassland based feeding reduces the environmental burden of Austrian dairy or beef production (cf. WEISS and LEIP 2012). It utilizes a resource, i.e. grassland in mountainous and alpine areas of high ecological and landscape value. Until now, alternative uses such as afforestation may not be a viable option in some regions. Furthermore, utilization of spared land for bio-fuel production needs to be compared to alternative uses such as for nature conservation.

So far, we have considered the challenges and chances for agricultural, biomass and food markets up to the year 2020 (with setting parameters in the CGE model to account for the relative differences in sectoral economic developments from 2004 to 2020 and thus computing simulations in the base year). Further studies should also take into account climate change impacts which are likely to be more severe while regionally heterogenous for Austria by 2050 (cf. SCHÖNHART et al 2013). Finally, a multi-regional model would capture interactions between EU countries and could further take into account climate change impacts in the rest of the world.

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Appendix

Table 9: Sectoral aggregation in the CGE model with correspondence to ÖNACE classification

	TRIOPOL sectors	**model code**	**GTAP sectors (GTAP no.; ÖNACE no.)**
	land using sectors		
1	Wheat and meslin; other cereals (maize, barley, rye, oats)	WHO	wht(2;01.11); gro(3;01.11)
2	Vegetables & fruits	VAF	v_f(4;01.12-01.13&15.33)
3	Oil seeds	OSD	osd(5;01.11)
4	Fodder crops, bioenergy crops, seeds	OCR	ocr(8;01.11-01.13)
5	Livestock (cattle, milk, other animal products, wool)	LIV	ctl(9;01.21), rmk(11;01.21), oap(10;01.22-01.25); wol (12;01.22)
6	Rest of agriculture (sugar cane & beat; vegetable materials; rice)	RAGR	c_b(6;01.11), pfb(7;01.11), pdr(1;01.11)
	food industry		
7	Food (other than meat: vegetarian & beverages)	FOOV	mil(22;15.5), sgr(24;15.83), ofd(25;15.2-15.3&15.6-15.8), b_t(26;15.9&16), pcr(23;15.61), vol(21;15.4)
8	Food (meat)	FOOM	cmt(19;15.1), omt(20;15.1&15.4)
	resource using sectors		
9	Forestry	FRS	frs(13;02)
10	Mining of coal	COAL	coal (15;10.1-10.2)
11	Extraction of crude petroleum	OIL	oil(16;11.1-11.2)
12	Gas extraction; gas manufacture and distribution (heat)	GAS	gas(17;11.1-11.2), gdt(44;40.2-40.3)
13	Rest of resource using sectors (other mining; fishing)	RRES	fsh(14;05&01.5);omn(18;12-14)
	energy, construction and crop intensive industries		
14	Refined oil products (petroleum/fuels, coal products)	PC	p_c(32;23)
15	Electricity	ELY	ely(43;40.1)
16	Construction	CNS	cns(46;45)
17	Energy intensive industries	EII	crp(33;24&25), nmm(34;26), i_s(35;27.1-27.3&27.5), nfm(36;27.4),
18	Crop intensive industries (e.g. wood and paper products)	CII	lum(30;20), ppp(31;21&22.1-22.2), tex(27;17), lea(29;19)
	rest of industries		
19	Transport	TRN	otp(48;60&63), wtp(49;61), atp(50;62)
20	Other industries	OI	wap(28;18), fmp(37;28), mvh(38;34), otn(39;35), ele(40;30&32), ome(41;22.3&29&31&33), omf(42;36&37)
21	Services	SEV	wtr(45;41), trd(47;50-52;55), cmn(51;64), isr(53;66), obs(54;70-74), ofi(52;65&67), osg(56;75&80&85&90&91&99), dwe(57;45.12) , ros(55;92-93&95)

Table 10: GDP and sector outputs in the base year 2004 (Source: GTAP 2007)

	2004 in M EUR
GDP	241,975
thereof	
Consumption	142,931
Investment	55,657
Government	45,519
Trade balance	-2,132
Output	
WHO	613
VAF	1,722
OSD	151
OCR	1,080
LIV	2,923
RAGR	265
FOOV	21,216
FOOM	2,036
FRS	2,108
COAL	233
OIL	1,820
GAS	959
RRES	2,070
PC	4,879
ELY	6,287
CNS	25,121
CII	37,883
EII	53,897
OI	128,816
TRN	36,507
SEV	234,905
Output total	565,490