

Regional Economic Impacts of Biomass Based Energy Service Use: A Comparison Across Crops and Technologies for East Styria, Austria

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ABSTRACT:

Biomass action plans in many European countries seek to expand biomass heat and fuel supply, mainly to be supplied by peripheral, agricultural regions. We develop a three-region energy-focused computable general equilibrium (CGE) model that acknowledges land competition in analysing the regional economic implications of such a strategy. Our model is based on a full cost analysis of selected biomass technologies covering a range of agricultural and forestry crops, as well as thermal insulation. The regional macroeconomic effects differ significantly across technologies and are governed by factors such as net labour intensity in crop production. The high land intensity of agricultural biomass products crowds out conventional agriculture, and thus lowers employment and drives up land prices and the consumer price index. The regional economic results show that net employment effects are positive for all forestry based biomass energy, and also show for which agriculture based biomass systems this is true, even when accounting for land competition. When regional consumer price development governs regional wages, positive employment impacts vanish fully for agriculture based bio-energy.

KEY WORDS: biomass energy, CGE regional analysis, land competition

JEL: D58, R13, Q43

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1 INTRODUCTION

Stimulated by the strategic biomass energy goals of the EU¹, member states, including Austria, have adopted an ambitious biomass strategy. Supply security, environmental criteria, and economic aspects such as the creation of jobs and value added are crucial arguments. More recently the role of biomass in combination with carbon capture and storage (CCS) is highlighted as one of the few potentially reasonable technologies to decrease greenhouse gas concentrations in the atmosphere, after allowing for overshooting the ultimate stabilisation level.²

Economic impact analyses of biomass energy use have mainly been carried out for the national level and generally result in proving net positive job market effects (for a recent overview of studies on this issue see e.g. Berndes and Hansson, 2007). For the case of Austria, Haas and Kranzl (2002), Madlener and Koller (2007), and Ökocluster Oststeiermark (2007) reach similar conclusions. When thermal insulation is expanded in parallel with biomass, employment effects are slowed down due to reduced demand for heat (Haas and Kranzl, 2002). For gross national income, predominantly positive net effects are also observed. These reach a maximum in the case of wood biomass. Especially rural areas, often economically underdeveloped, benefit from additionally generated income. Further, the more biomass is used, the higher is the direct effect on value added in an input-output analysis (Madlener and Koller, 2007; Ökocluster Oststeiermark, 2007). However, positive direct effects on value added and employment do not necessarily result in positive net economic overall impacts. Steininger and Voraberger (2003) show that biomass energy use could also have negative impacts on GDP in cases where high public subsidies are required to initiate biomass use.³

The majority of *economic* studies on biomass energy use are based on input-output analysis (e.g. Madlener and Koller, 2007; Clement et al., 1998; Kaltschmitt et al., 2000) and focus on the national (or an even more aggregated) level (Haas and Kranzl, 2002; Clement et al., 1998; Kaltschmitt et al., 2000; Pichl et al. 1999). Input-output analysis allows for intersectoral interdependencies to be investigated using linear homogeneous production coefficients. However, as this method does not allow for endogenous, price-dependent input coefficients, it is impossible to study the impacts of different policies on e.g. prices of biomass pre-products, (biomass) technology and factor prices. In the case of biomass energy, such feedbacks on input

¹ In its *Action Plan for Biomass* (European Commission, 2005) the European Union asks for an increase in biomass use from the 2005 level of 69 mtoe to 150 mtoe by 2010. The *Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources* (European Commission, 2008) gives detailed suggestions on how to reach the objective of a 20% share of renewables (including biomass) in energy supply by 2020. For an overview of the development of bio-energy for the EU-15, policy instruments used by country and technological options see Faaij (2006).

² While the Stern Review (Stern, 2007) asks for a stabilisation level of greenhouse gases in the range of 450 to 550 ppmv CO₂e, there are more recent initiatives to ultimately reduce concentration further to 350 ppmv, acknowledging our present 430 ppmv. For such a stricter objective biomass with CCS plays an important role.

³ The potential trade-off across biomass technologies between the objectives of climate change mitigation, employment and reduced dependency on imported fuels has also been shown by Berndes and Hansson (2007), albeit by means of a pure energy system model, without linking up to a fully fledged depiction of the whole economy.

and factor prices e.g. due to land competition among food and energy production, are however crucial, as Ignaciuk et al. (2006) have shown in a partial equilibrium analysis.

It is thus necessary to consider a different and more comprehensive method for analysing the economic effects of biomass energy use. Computable *general* equilibrium analysis (CGE) is just such an analysis. It not only captures the economywide feedback effects of energy policy, but also the complex interactions between economic actors (government, enterprises and households) triggered by endogenous (relative) price changes. Steininger and Voraberger (2003), for example, have provided a comprehensive analysis of intensified biomass energy use (for heat, power and fuel production) and its implications for selected economic indicators (GDP, employment, public budget) in Austria using a CGE approach. As mentioned above, the results of such an analysis may differ significantly from those obtained using pure input-output methods.

Of particular interest are the local-regional effects of increased biomass energy supply; particularly in rural areas characterised by a high share of agriculture, low income and job scarcity. The expectation is that “rural regions in particular can benefit from the establishment of bioenergy industries and the related production of biomass” (Berndes and Hansson, 2007: 5974). The impacts on such regions and the regions they are embedded in can be quantified by means of a multiregional CGE approach. Multiregional CGE models for the analysis of energy policy are not new, but to date have almost exclusively focussed on a global scale, with “regions” implying world regions (e.g. Reilly and Paltsev, 2007; Jacoby et al., 2006; or taken the many models based on GTAP, such as Kuester et al., 2007). There is a lack of endogenous multiregional analysis at the local, i.e. sub-national scale. We seek to close this gap here and provide an extensive analysis of macro-economic effects at the local-regional level.

This poses a different methodological challenge than that found on the global scale, since inter-regional trade specifications are no longer endogenously closed. We apply our analysis to East Styria in Austria. The area is characterised by a high biomass potential and therefore considered a promising region for further biomass energy development.

The focus is on the macro-economic effects resulting from intensified, but demand-oriented biomass energy production used for household space heating. Taking into account regional energy demand and private costs of biomass energy we analyse macro-economic effects, especially employment, sectoral production level, prices, value added and public budgets at the regional level. We designed a three-region energy-focused CGE model. While we use specific cost data for biomass energy and regional economic data from East Styria in order to determine macro-economic effects, one can generalize the results for similarly structured and embedded regions.

The structure of this paper is as follows. Section 2 presents the costs of biomass energy supply by technology as well as the cost of thermal insulation measures. Section 3 describes economic modelling, while section 4 briefly summarizes the regional economic database. In Section 5 the regional macroeconomic effects of expanded biomass use and increased thermal insulation are presented including a sensitivity analysis of these results. A final section concludes, summarising the main results.

2 ECONOMIC ASSESSMENT OF COSTS OF ENERGY SERVICES

Agricultural energy crop production

The economic appraisal of agricultural products is difficult because there are deviations between actual product costs and market prices. A sustainable energy crop production can only be ensured if the market prices cover the actual production costs. For that reason, we here give energy crop production costs based on absorption costing. This method of full cost accounting is designed for the long-term perspective and considers variable (e.g. seed, fertilizer, drying, transport) as well as fixed (e.g. land rent, wages, machinery) costs. The aim of the economic calculation of crop production costs is to identify those energy crops providing for sustainable economic production in the long run. Figure 1 illustrates total crop production costs and their underlying cost factors.

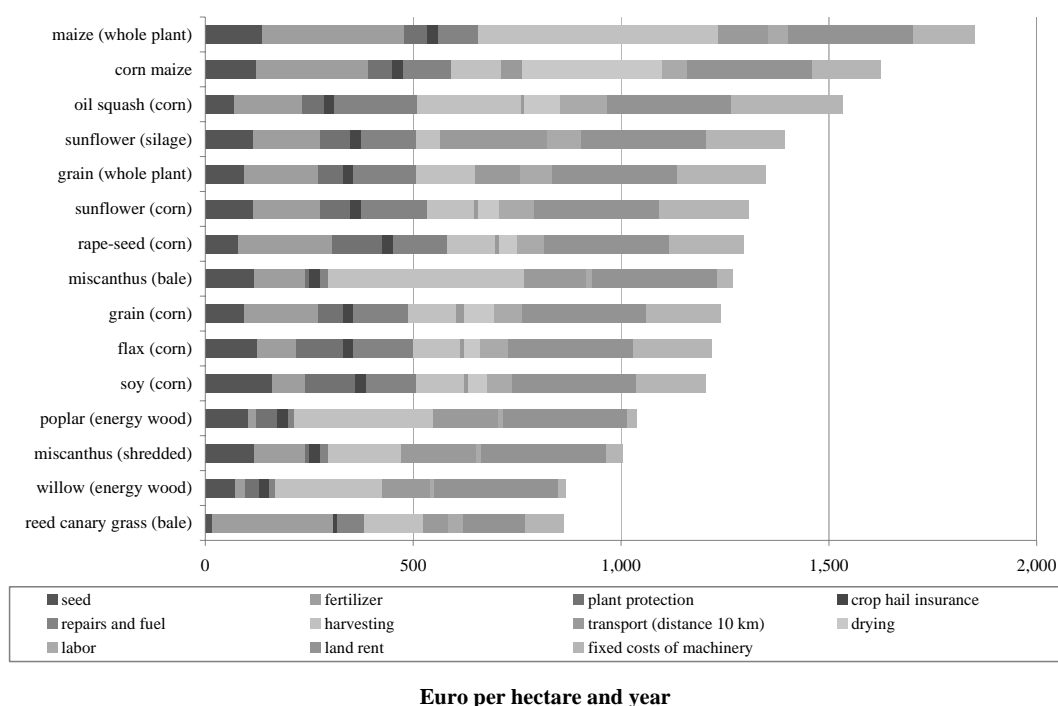


Figure 1. Detailed production costs of energy crops

In Figure 1 we find that lower costs per hectare and year arise from cultivating perennial crops like willow, poplar, miscanthus, lucerne or reed canary grass since their production costs are allocated over several years. The shares of single expense factors in total production costs differ across crops. Crops like rye grass or reed canary grass show, for example, low seed costs but a high share in fertilizer costs. Other crops like poplar and willow have low fertilizer costs but relatively high costs for harvesting. It is important to note that labour costs are generally low due to the high degree of mechanization. Irrespective of their relative distribution, single expense factors are very inflexible (i.e. they can hardly be influenced), and also in general do not change with yield rates per hectare. Since for most crops cultivation costs are in the range of €1,000 to €1,500 per hectare and year, the efficiency of energy crop production is crucially determined by yield-rates per hectare, which differ across plants. Ecological aspects are not considered here, but see e.g. Fraser and Hubacek (2007) for sustainable land use management.

Transport costs

The costs of biomass transport are dependent on several factors: energy-density of transported material, transport distance, level of mechanization and also mode of transport. High transport costs are a specific problem in energy crop production for the majority of crops with a low energy density (e.g. willow/poplar chips, wood chips, miscanthus chips). For example, the bulk density of miscanthus chips and poplar chips amounts to 110 and 350 kilograms per cubic meter respectively. We find that transport distances beyond roughly 10 km are not economically feasible for chips. There are only a few biomass products where longer distances are in fact feasible. Granular or baled agriculture products show a high density (approx. 650 kilograms per cubic meter), and are thus suited for longer transport distances. Although increasing the capacity of producing energy from biomass crops involves economies of scale, this would also imply longer transport distances and increasing transport costs. Therefore, a main challenge is the trade-off between rising transport costs from increased centralization and scale effects originating from production in ever larger energy plants.

Costs of energy contained in biomass

The relevant factor in determining the cost-efficiency of biomass products used for energy production is not production costs per hectare, but costs per unit of effective energy (e.g. cents per kWh).

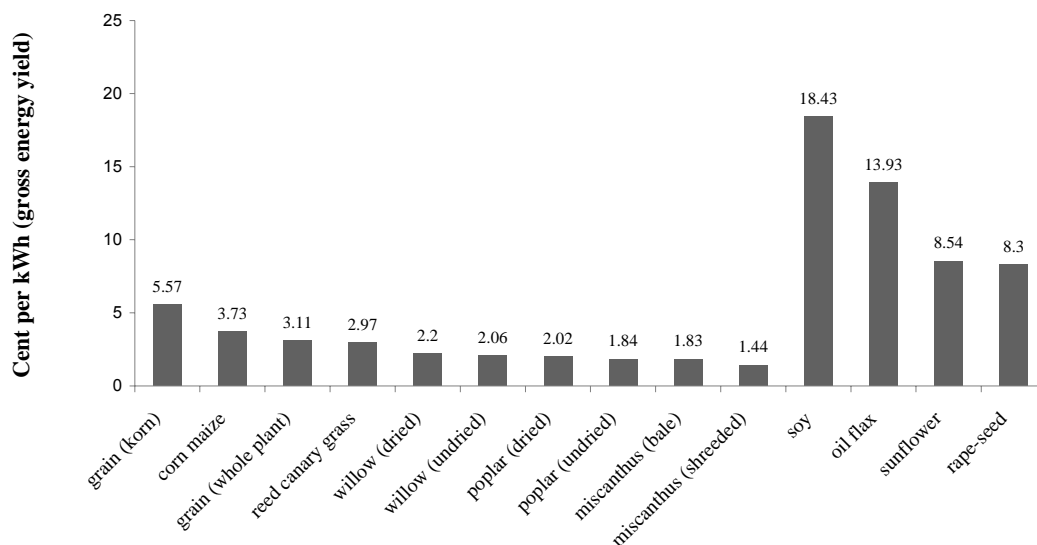


Figure 2. Specific energy costs

Figure 2 shows the specific costs of energy contained in biomass. The use of land for biomass energy production will be of prime importance for the region of East Stryia in the future, especially in the energetic utilization of fast growing tree species like poplar and willow. Figure 2 illustrates that supply of energy via perennials such as miscanthus, willow or poplar is cost-efficient. Since wet (not dried) chips can not be used in single heating systems, we differentiate for poplar and willow between dried (water content about 25 %) and wet (water content about 50 %) chips. Costs for drying amount to €270 per hectare and year.

The lowest specific energy costs can be reached by cultivating miscanthus, however the resulting raw biomass has a rather low energy density, implying high transport and storage costs. The energy crops grain (corn or whole plant) and corn maize show the highest energy costs in cents per kWh. This stems from high production costs in combination with relatively low yields per hectare.

Forestry biomass

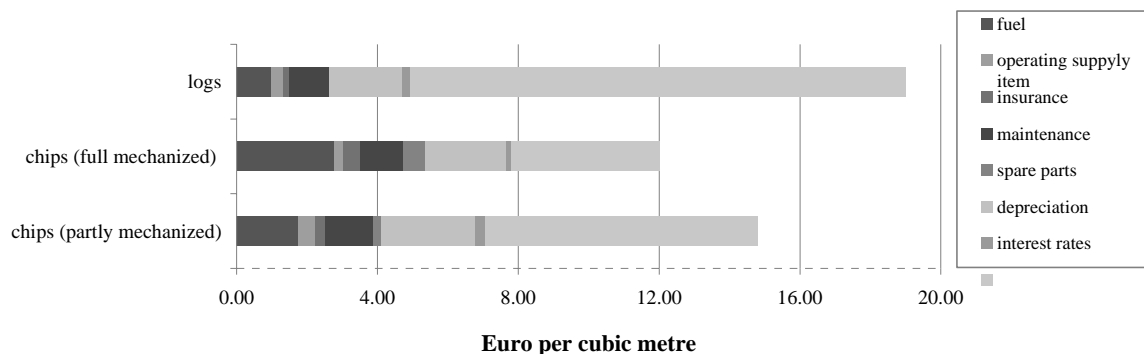


Figure 3. Production costs of wood logs and wood chips (own calculation based on Stampfer (2007))

Apart from agricultural crops, forestry based products (wood logs, wood chips) also play a major role in heat (and power) production. For forestry products all costs of processing and transportation are included, but no land rent. For harvesting, the costs for partly mechanized harvesting are about 20 % higher than those for full mechanized harvesting. Since most forests in East Styria are privately owned and relatively small (< 200 hectares) the partly mechanized method dominates. It is interesting to see that the specific energetic costs of wood chips based on this harvesting method (1.83 cents per kWh) are almost the same as that of poplar chips (1.84 cents per kWh). Nevertheless, wood chips are preferable for energetic utilization, since they occur as a byproduct and are not in competition with food production. Wood log production is more costly than wood chip production.

Assessment of energy conversion technologies

The cost efficiency of biomass technologies is a decisive factor in determining the extent to which energy services are provided from biomass resources, although not the only one. Bentzen et al. (1997) show that although wood based heating systems and the services they supply are cheaper than the fossil alternative in many cases, the substitution process of biomass for fossil fuels is slow. High investment and low operating costs (cheap fuel costs) imply that a high level of energy consumption is necessary to make biomass technologies profitable. Further, consumer risk aversion appears to be a barrier to investment in biomass based heating systems.

Costs of energy services provided by the use of biomass are determined by both the costs of biomass products (agriculture crops and wood biomass) and technology costs. In particular we look at twelve different options for supplying heat and liquid fuels (see Table 1). Among the single home heating systems, those based on wood chips, wood logs, wood pellets, poplar

pellets, miscanthus pellets, grain pellets, straw pellets, miscanthus (whole plant) and energy corn are analysed. The single home heating system based on oil is used as a reference fossil fuel technology. Alternatively, heat can be supplied by district heating (station based, capacity of 1000 kW).

Energy supply costs by biomass technology are shown in Table 1. In order to allow for cost comparability, costs are expressed in cents per kilowatt hour use energy (cent/kWh). The cost calculation is based on the demand for heat, which is calculated for a building's space heat load of 15 kW and yearly full load hours of 1500 h/a. Considering the net-energy demand and taking into account grid losses as well as specific fuel characteristics, the yearly demand for fuel is calculated. Including system costs of effective energy supply and taking into account a service life of 20 years, we obtain total annual mean costs by technology as well as total costs per kilowatt hour.

Table 1. Costs of biomass energy supply by technology

	supply cost cent/kWh heat	supply cost euro/liter
single home heating systems (15 kW)		
wood chips	10.6	
wood logs	8.5	
wood pellets	9.9	
wood pellets incl. stirling motor	12.2	
poplar pellets	9.8	
agro pellets (Miscanthus)	13.0	
agro pellets (grain)	14.2	
agro pellets (straw)	12.3	
Miscanthus (whole plant)	11.3	
energy corn (whole plant)	14.3	
fuel oil ¹	11.7	
district heating (1.000 kW), based on		
wood chips	7.4	
biofuels		
biodiesel (RME) ²		0.72

¹a fuel oil price of 69 Cent per litre is assumed (mean price of the year 2006 excl. tax;

see also sensitivity analysis in section 5.6)

²assumption: regional biodiesel plant with a yearly production capacity of 17,600 t

Note: For the technological details of the specified biomass reference technologies and for details concerning the cost calculation methods see Steining et al. (2008).

Concentrating on single home heating systems (including district heating) Table 1 depicts that using current oil prices as reference, common biomass technologies based on e.g. wood (chips, logs or pellets) are cost efficient. Furthermore, technologies based on miscanthus (whole plant) as well as district heating also show lower costs than fossil fuel oil systems. Costs of heating systems based on agro pellets exceed fossil fuel costs between 0.6 (straw) and 2.6 (energy corn) cents per kilowatt hour.

To sum up, we come to the result that in many cases heating systems based on biomass are cost efficient relative to the fossil alternative. We find that wood based heating systems are also cost efficient in buildings with a low space heat load, whereas systems based on agricultural biomass are only profitable as energy consumption increases (space heat load > 30 kW), again due to the relatively high investment costs involved.

Assessment of thermal insulation measures

A necessary requirement for reaching the goal of a sustainable energy system is to reduce total energy use by increasing efficiency, which in our case implies reducing space heating through thermal insulation of buildings. High investment costs in biomass technologies may create a trade-off with insulation. Further details are provided below. Overall, private households can lower their heating costs through reducing demand for heat. Materials used for insulation can either be synthetic such as EPS (Expanded Polystyrene), mineral wool and glass wool or renewable, such as flax, hemp and straw. Renewable resources have an advantage over synthetic material: the use of renewable insulation material provides a new income source for farmers and generates additional gross value added within the region (Strasser et al., 2006). In practice, however, renewable resources used as insulation material play only a minor role so far (GDI, 2005). We thus focus on traditional materials in the following.

Cost structures of thermal insulation measures are adopted from Jakob et al. (2002), who calculate costs of energy efficiency measures in households, comparing marginal costs of energy efficiency measures with non-efficiency measures and applying both to buildings constructed earlier than 1960. The authors reach the conclusion that the improvement of the insulation of roofs, cellars and facades are the most cost-efficient measures, more so than other costly measures like modernization of windows, ventilation systems or building services. For that reason the following cost calculation is restricted to insulation measures taken on facades, roofs and cellars. For our purpose we adjusted the results of Jakob et al. (2002) to the differences in price level and interest rates between Switzerland and Austria (see Table 2).

Table 2. Heat energy savings and marginal costs⁴ of effective energy savings in Austria by measure taken for non-insulated buildings constructed before 1960

insulation measures	savings of heat energy	marginal costs of effective energy savings in Austria caused by insulation measures ¹
<i>unit</i>	<i>kWh/m²/a</i>	<i>Cent/kWh</i>
facades: 12 cm	41.6	4.3
roof: 14 cm	23.6	3.4
cellar: 8 cm	7.5	5.2
average marginal costs in Cent/kWh effective energy²		4.1

¹ Cost calculations consider an exchange rate of CHF 1 = € 0.66 (2002) and a real interest rate of 2.2%. The prices in Switzerland and Austria are adjusted at a ratio of 1: 0.84.

² It is assumed that measures taken at the roof, the building facade and the cellar contribute to energy savings to 32%, 57% and 10%, respectively.

Source: Own calculation based on Jakob et al. (2002).

In addition to the case where moderate thermal insulation measures are taken for old, non-insulated buildings, we have considered two further scenarios: comprehensive insulation measures taken on old, non-insulated buildings, and upgrading buildings of moderate insulation to comprehensive insulation. The comprehensive insulation includes the exchange of windows and the extension of the insulation layer (building facade: 20 cm, cellar: 12 cm, roof 20 cm). In the comprehensive insulation case marginal costs of effective energy savings amount to 5.4

⁴ Cost calculation assumes that thermal insulation measures are coupled with general maintenance and retrofit measures. Therefore, the costs exclude regular retrofit expenses for e.g. the scaffold.

cents per kWh, whereas insulation upgrading costs around 10.4 cents per kWh. Taking into account a yearly refurbishment rate of 1.5%, we assume that 4/9 of refurbished buildings are insulated moderately, 4/9 comprehensive and 1/9 are upgrades from moderate to comprehensive insulation.

Avoided and marginal costs of thermal insulation measures

For the comparison of thermal insulation costs with saved heating costs (by technology) two different approaches are provided: in the first approach savings of heating costs include only fuel costs saved (avoidable costs in the short run) due to lower energy demand. Beyond the avoidance of fuel costs, the dimension of the heating system can also be reduced in the long term, which is considered in the second approach (avoidable costs in the long run). Figure 4 compares the short run and long run avoidable costs of different heating systems when thermal insulation measures are taken. As long as the marginal costs of thermal insulation are smaller than fuel cost savings (Figure 4, left panel) and cost savings due to smaller heating systems (Figure 4, right panel), thermal insulation measures are cost efficient in the short and long run, respectively.

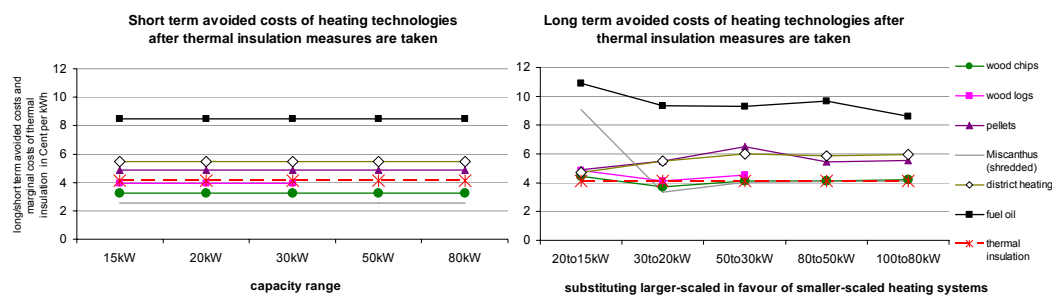


Figure 4. Short term (left panel) and long term (right panel) avoided costs of heating technologies after thermal insulation measures are taken (own calculation)

Considering only the avoided fuel costs (Figure 4, left panel), the cost efficiency of thermal insulation measures differs significantly across heating technologies. While the avoided fuel costs for biomass technologies (excluding pellets, however) are below the marginal costs of thermal insulation, the avoided fuel costs for oil, district heating and pellets are above. In the short run it is only the use of these latter heating technologies for which insulation pays off.

On using the second approach, which acknowledges the fact that thermal insulation measures provide an incentive to modernize old heating systems in favour of new, smaller systems, we arrive at somewhat different results. Once again, cost savings for heating systems using oil, pellets or district heating are above marginal costs of thermal insulation, implying that insulation pays off in combination with their use. However, considering the biomass technologies wood logs and miscanthus (whole plant), long term savings as a result of scaling down the heating system are now also in the range of marginal costs of thermal insulation (+/- 1 Cent per kWh). Only small scaled biomass heating systems are an exception: Exchanging a 20 kW heating system (based on miscanthus or corn) in favour of a 15 kW system still places marginal costs of thermal insulation below long term costs of down-scaling the heating system.

Note, as investment costs do not proportionally decrease with the size of the heating system, long term avoided costs summarized in Figure 4 are lower than the average heating costs presented in the economic analysis above. Thus, costs of 10 kW heating systems are not half of those of 20 kW systems.

To sum up, thermal insulation measures on building facades, roofs and cellars are predominantly cost-efficient. In particular, this is the case if thermal insulation measures are taken in the course of indispensable maintenance works of the house. Extra expenses for the scaffold, for example, can be saved by combining general facade renovation with thermal insulation measures. Furthermore, a discrepancy is found to exist between heating systems with low fuel costs (wood logs, wood chips) and systems with high fuel costs (oil, district heating, pellets). Considering the latter, thermal insulation measures are more efficient, especially in the short run.

3. METHODOLOGY OF REGIONAL ECONOMIC IMPACT ASSESSMENT

The present study employs a comparative static three region computable general equilibrium (CGE) model. Region 1 (East Styria) and region 2 (rest of Styria) are fully modelled, connected with region 3 (rest of the world) by trade flows, modelled under the assumption of a small open economy. The model is calibrated for the year 2003 using the data described in section 4. Simulations are performed as counterfactuals in the base year, such that we assume the use of bio-energy has taken off early enough to show all effects and feedback effects by 2003. The model structure is described below, emphasizing consumption, production and trade specifications.

Consumption

Market clearance must hold for all commodities, meaning all goods produced must be consumed. Each commodity can either be used as an intermediate input in production sectors, can be traded abroad or consumed by one of two agents: the household or government.

Household consumption is modelled by taking one representative consumer. Her consumption bundle involves private consumption, investments and stock changes. For our purpose a separate consumption bundle for space heating service is modelled. This specification allows for substitution of new biomass technologies for fossil heating systems. The present mix of energy for space heating is taken from Steininger et al. (2008). Consumption is financed by factor rewards (wages, interest) and by public transfers.

Capital and agricultural crop land are primary production inputs and assumed to be fully employed. By contrast, the labour market does not clear; there is unemployment in the reference scenario. This modelling scheme enables us to show how the labour market responds to increased biomass energy use. The real wage rate is assumed to be rigid to below the level that initially implies the reference rate of unemployment. In the policy simulations the real wage rate of each region is assumed to be bound to the developments of the corresponding consumer price index in order to reflect medium term wage negotiations. To slow down reactions we assumed that only half of the price index changes are transferred to immediate wage rate adjustment.

The second consuming agent is the government sector. The income of the government is generated through taxes. Besides consuming, the government spends funds on supplying unemployment benefits and other social transfers. When policy simulations change the employment level, this also changes unemployment compensation, resulting in public budget variations.

Production

Profit maximization and cost minimization are the basic assumptions used for describing the behaviour of production sectors. The economy is disaggregated into 41 production sectors, of which six sectors are energy producing (coal, gas, electricity, district heating, diesel and other oil products, with the latter including gasoline and fuel oil). In this context, the production of each sector is described by a nested constant elasticity of substitution production function (see Figure 5). The elasticities of substitution (s) are in the range of those taken for the energy-environment CGE Models by Wissema and Dellink (2007) and Rutherford and Paltsev (2000).

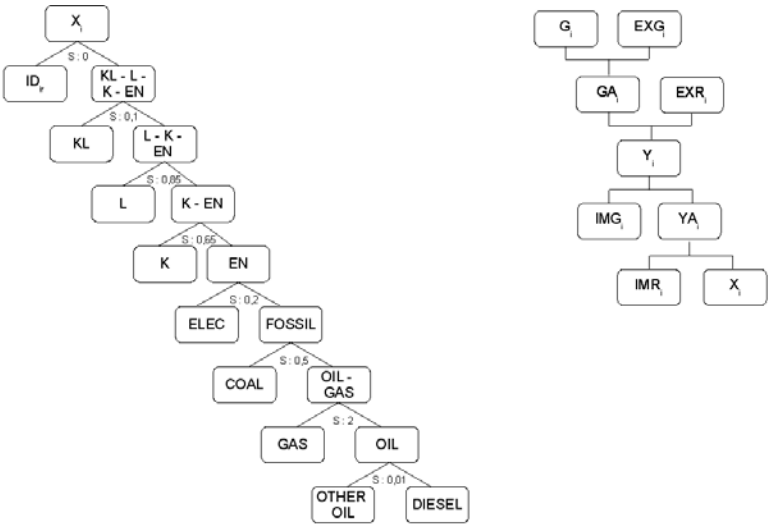


Figure 5. Nesting structure of the production function Structure of Armington trade assumption

Production of heat services

The production of bio-energy is modelled in two steps for each biomass product. In the first step biomass is produced as a preliminary product with a fixed input coefficient production function. Biomass products can only be used for bio-energy production and can not enter other sectors (e.g. wood chips produced for bio-energy can not be used in the paper industry). Concerning biomass, we distinguish between wood biomass, residuals, and biomass produced on agricultural crop land. It is assumed that land available for crop production is limited in each region, such that producing agricultural biomass displaces conventional agriculture, whereby land can hardly be replaced by other production factors. In the second step biomass is converted into use energy, again modelled with a fixed input coefficient production function for each technology available.

Production of RME

Producing rapeseed methylester (RME) follows the same structure taking a fixed coefficient production function: in the first step the preliminary product rapeseed is produced, which is then processed to obtain RME in the second step.

Trade

All commodities produced in the 41 production sectors can be traded among all three regions. The structure employed is depicted in Figure 5 and can be read from the perspective of region 1 as follows: Domestically produced commodities (X_i) combined with imports from region 2 (IMR_i) and imports from ROW (IMG_i), the rest of the world, constitute the total available commodities in region 1. Agents in region 1 either consume these commodities or commodities are exported to region 2 (EXR_i) or to ROW (EXG_i). G_i therefore denotes commodities which can be consumed (C) or used as intermediate input (ID_i) in region 1. The same structure holds for region 2 noting that EXR_i for region 1 must equal IMR_i for region 2 and vice versa. Quantities imported for each region are determined by the price ratio between domestic and foreign prices, and by trade elasticities of substitution. With imports thus determined, this also defines exports for the trade relationships between regions 1 and 2. For exports to ROW, an Armington structure is also employed. For industry sectors trade elasticities of substitution are derived from Welsch (2008) and Reinert and Roland-Holst (1992). Regional trade elasticities are assumed to be 1.5 times higher than global ones. Heat or fuel produced with biomass is not tradable, though it is possible to import biomass preliminary products at an amount fixed by an exogenously set import quota, as stated below.

4. REGIONAL ECONOMIC DATA BASE

The regional Social Accounting Matrices employed in our model were estimated by means of biproportional adjustment based on regional Make and Use tables (most recently available for the year 2003). As these tables do not focus on energy or environment, they had to be adjusted for our purposes using the data of the regional energy balance calculations provided by Statistics Austria (2006a). Statistics Austria (2006b) and Arbeiterkammer (2007) served as database for the macroeconomic framework data (unemployment, transfers, taxes).

5. THE REGIONAL ECONOMIC IMPACTS OF CHANGING THE BASIS OF ENERGY SERVICES

5.1 Overview of Simulations

For a comparative evaluation of the different biomass heat technologies we choose a uniform expansion in terms of energy content across technologies. We analyse the substitution of 2000 TJ use energy supplied to date by fossil fuel heating systems, employing each of the different biomass heating systems introduced in section 2 above. This amount of energy accounts for about 20% of total space heating energy demand in region 1. The subsidies already in place are taken account of in the simulations.

For biodiesel we examine the macroeconomic effects of increasing the rate of compulsory blending of diesel to 5.75%, 10% and 20% respectively.

In the foreign trade of biomass we assume import quotas define the proportion of biomass imported from the rest of the world (ROW), as given in the second column of Table 2. The quotas are 0% for pellets, for which domestic national supply exceeds demand (IEA, 2007), 10% for wood-based biomass products such that national targets can be achieved (Federal Ministry, 2006), and the status quo (8%) for agricultural biomass products (Eurostat, 2007). For each import quota we assume the regional import quota to be in line with the national one. For rapeseed we need to take account of a broader possible range, and use import quotas of 30%, 60% and 90%.

As we are interested in regional effects and their spill over to neighbouring regions, we implement biomass expansion only in region 1, and then analyse its impacts in both regions 1 and 2.

Finally, we analyse the impacts of thermal improvement in the housing stock. By assuming a yearly refurbishment rate of 1.5% as described in section 2 we can compare the effects of investments in biomass technology to those of improving thermal insulation.

5.2 Biomass for space heating

Substituting fossil heat by heat from biomass is expected to trigger positive effects for the region by lowering imports and raising domestic demand. Table 3 and Figure 6 show the effects on regional GDP and employment of an increase in heat energy by 2000 TJ, as supplied by different biomass technologies. Italics are used to indicate those technologies which are more expensive (per kWh) than the reference heating system. For these technologies it is assumed that the consumer is willing to pay the higher costs.

Table 3. Impacts on regional GDP and employment by technology, region 1 and region 2

Measures	Importquota ¹	regional GDP		Employment		
		Region 1	Region 2	Region 1	Region 2	
		change in %		change in persons		
single home heating systems (15 kW)						
wood chips	2000 TJ ²	10%	1.39	0.06	1226	178
wood logs	2000 TJ ²	10%	1.59	0.04	1047	167
wood pellets	2000 TJ ²	0%	1.26	0.05	951	194
poplar pellets	2000 TJ ²	8%	0.65	-0.02	-399	-152
<i>agro pellets (Miscanthus)</i>	2000 TJ ²	8%	0.94	0.05	322	112
<i>agro pellets (grain)</i>	2000 TJ ²	8%	0.84	0.02	-81	-5
<i>agro pellets (straw)</i>	2000 TJ ²	8%	1.30	0.11	1222	364
<i>Miscanthus (whole plant)</i>	2000 TJ ²	8%	1.40	0.04	484	81
<i>energy corn (whole plant)</i>	2000 TJ ²	8%	0.56	-0.11	-1721	-581
district heating (1.000 kW), based on						
wood chips	2000 TJ ²	10%	2.18	0.09	1615	320
Thermal insulation						
building facades, roof and cellar	1.5% ³	-	1.73	0.94	1733	3315
biofuels						
biodiesel (RME)	5.75%	30%	0.08	-0.01	-119	-27
biodiesel (RME)	5.75%	60%	0.08	0.00	-57	-12
biodiesel (RME)	5.75%	90%	0.08	0.00	4	2
biodiesel (RME)	10%	30%	0.14	-0.01	-208	-47
biodiesel (RME)	10%	60%	0.14	0.00	-100	-22
biodiesel (RME)	10%	90%	0.14	0.00	7	4
biodiesel (RME)	20%	30%	0.29	-0.02	-425	-97
biodiesel (RME)	20%	60%	0.29	-0.01	-203	-44
biodiesel (RME)	20%	90%	0.29	0.00	13	7

¹percentage of biomass pre-products (e.g. rapeseed) imported from global markets

²additional amount of heat provided by biomass rather than fossil fuels

³refurbishment rate

In general we find positive employment and regional GDP effects for most technologies. Only some biomass technologies based on agricultural energy crops cannot fully link up with the positive economic impacts of the other technologies.

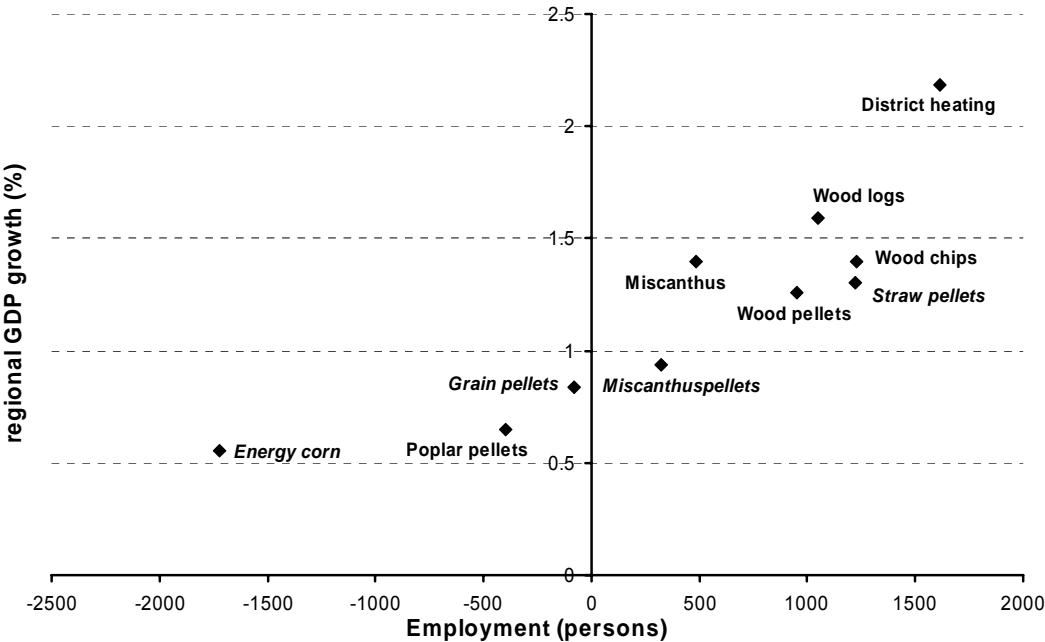


Figure 6. Employment and regional GDP effects resulting from expanded biomass energy use in East Styria

For the macroeconomic impacts on GDP and employment across technologies as denoted in Figure 6 we can point out the core driving forces. Three factors govern the regional macroeconomic results for *wood based* biomass (wood pellets, wood logs, wood chips and district heating): labour demand, investment demand for heating system infrastructure, and production costs. Heat service produced with wood logs has the cheapest production costs per kWh but also the lowest value added since it does not involve any refinement of biomass. For district heating and wood chips, significant investments in infrastructure (e.g. pipes or storage construction) are necessary, which generates a demand in the building and construction sector, characterized by high labour intensity. Relative to wood logs, both technologies increase labour demand, with the investment impact being relatively stronger for district heating, and thus also the impact on GDP. Both technologies are more expensive than the wood log technology, which reduces overall economic impact below what we would otherwise see. For wood pellets this price difference is so strong that the macroeconomic impacts of using this technology are even below those of employing wood logs.

For heat produced with *agricultural* biomass the results diverge more significantly across technologies. In addition to the three factors mentioned above (labour intensity, production costs, and of less importance here, infrastructure investment) agricultural biomass also crucially depends on cropland requirements. This last factor has significant impact on the production level of the agricultural sector since conventional agricultural production is crowded out by the competition for crop land. Further, decreasing conventional agricultural production also implies a decrease in food production. Before continuing our analysis for agricultural biomass energy we need to take a look on labour and land intensity in crop production.

Labour and land intensity in biomass crop production

Labour intensity differs noticeably across biomass products. Relative to conventional agricultural products forestry products show higher labour intensity values, and agricultural biomass products show lower ones. This results from agricultural biomass products requiring advanced machinery rather than labour input. Interviews conducted at the regional chamber of agriculture revealed that agricultural biomass production was considered a chance for the farmers aged 55+ since it lowered labour requirements and retained land as the major source of profit rather than labour.

Table 4. Table 4. Labour- and land intensities in producing biomass products (factor expense shares in production costs)

	Labour-intensity	Land-intensity
Biomass products		
Wood (wood chips)	0.56	0.00
Wood (wood logs)	0.73	0.00
Wood (wood pellets)	0.51	0.00
Wood (poplar pellets)	0.16	0.24
Miscanthus (miscanthus pellets)	0.13	0.21
Grain (grain pellets)	0.11	0.22
Straw (straw pellets)	0.16	0.00
Miscanthus (miscanthus energy corn (energy corn)	0.08 0.22	0.15 0.19
Rape (RME)	0.10	0.22
Conventional agricultural sector		
Region 1	0.28	0.07
Region 2	0.28	0.07

Source: Own calculation based on Steininger et al. 2008.

As agricultural biomass products with high land intensity crowd out conventional agricultural activity, they reduce overall labour demand. Note that values given in Table 4 refer to relative production cost (e.g. 22% of the costs of energy corn are wage payments), hence the land intensity numbers provide no information on yield rates, and labour intensity numbers provide no information on labour demand by energy content.

In analysing the agricultural biomass technologies now in further detail, we find that for heat produced from poplar pellets, both a low amount of labour is needed and almost no investments in infrastructure or machinery are required, resulting in a low net employment effect (see Figure 6). For miscanthus, miscanthus pellets and grain pellets on the other hand, significant investments in infrastructure and machinery are needed (both representing labour intensive intermediate supplies). Across these three technologies, we find different production costs, but also different state-paid subsidy rates. A higher subsidy rate (as for grain pellets) reduces (labour intensive) government consumption.

We find high employment effects for straw pellets since straw is a residual product. As no extra crop land is needed it is not in competition with the conventional agricultural sector. Energy corn combines the characteristics of highest cost and lowest area yield rate, resulting in the lowest GDP growth rate and highest loss of employment.

All results presented are sensitive to the assumption concerning the adjustment of the real wage rate. As described in section 3 wage rate development is bound to the development of the price

index. In section 5.6 below we test for sensitivity with respect to other wage rate adjustments. This is relevant especially for agricultural biomass product technologies, since land rent rises in these scenarios by 32% to 137%, implying a (significant) increase in the consumer price index.

5.3 Compulsory Blending for Diesel

Substituting fossil diesel by RME produced in the region decreases the need for import of oil and transfers value added to the region. Producing rapeseed itself, however, triggers the same labour substituting effects as described before, by crowding out conventional agricultural production and reducing food production. Increasing the import quota for rapeseed lowers these negative effects while keeping the positive effects of rapeseed refinement in the region. This can be seen in Figure 7 where positive net employment effects can only be observed for an import quota of 90% (stated in parentheses). We also see that higher substitution rates increase regional value added, as more fuel value added is transferred to the region.

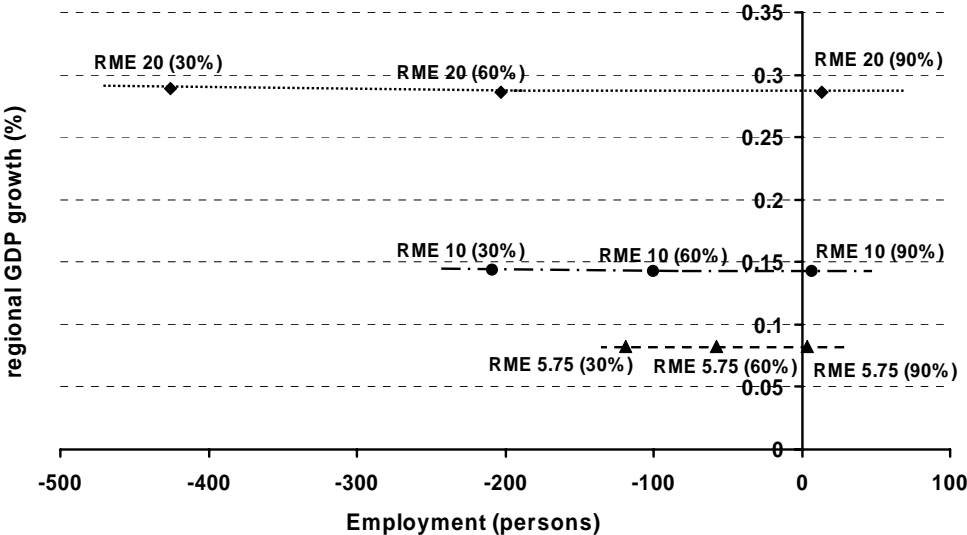


Figure 7. Employment and regional GDP effects resulting from different compulsory blending rates of diesel in East Styria (5.75%, 10% and 20% respectively), with import quotas of 30%, 60% and 90%

5.4 Improving thermal insulation of housing stock

For thermal insulation we need to specify a scenario of how much could be achieved by some future point in time (2030). Let us assume that starting from now all newly built houses are low energy houses. Further, we forecast the increase in housing space per person and come up with a demand for heat service in 2030 12% above that of 2004. For this business as usual scenario we then presume a refurbishment rate of 1.5% (see section 2) which reduces the energy demand for space heating by 29% (to 3500 TJ). The assumed investments in thermal insulation are highly economical since the investment costs are significantly lower than those of providing heat with the reference heating system.

This – in combination with two further aspects given below – leads to a high regional GDP growth (1.73%) as well as to the highest employment growth (some 1700 persons, or +1.4%) (see Table 3). The two further aspects are the associated high investments in the labour intensive building and construction sector, and the fact that improving insulation reduces costs

of heat services, granting the consumer extra funds for other consumption (about 30 mio. euros p.a.), keeping value added within the region.

5.5 Spillover effects to the neighbouring region

Table 3 summarises the effects on regional GDP and employment for regions 1 and 2. For all scenarios which result in positive employment effects in region 1, we also find an increase in regional GDP and employment for region 2. An increase in region 1 in household consumption (increased income) and in government expenditure (with fund becoming available due to reduction in unemployment benefit payment) leads to an increase in demand for goods and services produced in region 2. This is significant for the sectors health service, education and public service. All three are characterised by particularly high labour intensity. This triggers a circular effect enhancing once again an increase in employment, and therefore an increase in consumption of households and government in region 2. Stated more generally, growth in peripheral (agricultural) regions causes increased demand for services, which such regions usually import from neighbouring central regions.

5.6 Sensitivity analysis

First, we test the sensitivity of our results with respect to the parameters for fossil energy prices, interest rate and global trade elasticity for agricultural commodities. Energy price assumptions are crucial. Higher baseline fossil energy prices favour the usage of biomass as an alternative. 50% higher fossil energy prices in our analysis imply about a 40% higher increase in regional GDP (denoted in international prices). The reason is that improved competitiveness of biomass energy systems implies a higher share of consumption budget set free and used for other (domestic) goods after converting one's heating system to biomass. There are no additional impacts on employment, however, as increases in domestic demand also raise the price level, which in turn triggers wage increases. Thus, for higher oil prices, the intensity of some impacts (such as on GDP) changes, impact chains themselves but also the comparison across technologies, however, remain unchanged.

Most biomass technologies show a higher share of investment costs than the reference technology. Changes in interest rate assumptions thus affect the competitiveness of biomass technologies, although the impact remains rather small. A real interest rate of 4.2% (instead of the base case of 2.2%) lowers the regional GDP effect by about 0.1 percentage points.

Assumptions about the global trade elasticity only affect the results of agricultural based technologies. A higher elasticity (threefold of the original value of 3) allows a stronger increase of agricultural imports (triggered by domestic price increases in agricultural commodities as a result of higher biomass production). Land prices also rise to a lesser extent (11% points less). This higher trade elasticity could, for example, reflect a unilateral policy of biomass expansion in region 1, with world agricultural prices remaining unchanged by biomass policy. The lower elasticity of the reference case, on the other hand, can be taken to reflect biomass expansion policy in all trading regions.

Second, the results are sensitive to the assumption of real wage rate adjustment. Binding it to the consumer price index is motivated by the assumption that wage negotiations reflect consumer price developments. Figure 8 shows the results on regional GDP and employment for

two technologies, heat produced with wood pellets and miscanthus pellets (black dots), as well as the spillover effects on region 2 (grey dots). Different wage rate adjustments are indicated by the use of roman numerals. Case I is the base case with results as reported above. Here, the wage adjustment only covers half of the increase in the consumer price within the own region.

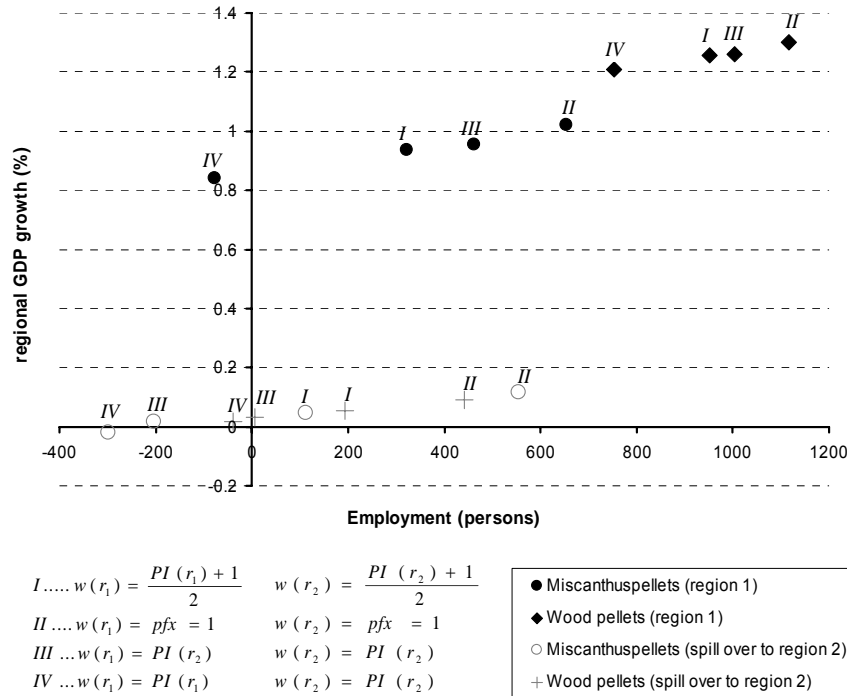


Figure 8. Employment, regional GDP and spill over effects resulting from expanded bioenergy use in East Styria under different wage rate adjustment assumptions

Note: w ... wage rate; PI ... consumer price index; pfx ... price of foreign exchange, which acts as numeraire; r_1 region 1, r_2 region 2.

It can be seen, that the effects on regional GDP are rather robust, irrespective of which wage rate adjustment is used, whereas for the employment effects large differences can occur. Further, the results for agricultural biomass products are more sensitive than those for wood biomass products, as the former imply a higher food price increase (and therefore an increase in the consumer price index).

For assumption II (fixed wage rate) the relatively highest employment effect can be maintained since no negative repercussion on the labour market occurs. Assumption III (“national bargaining”, i.e. consumer price development in the larger region determines wage development in both regions,) leads to slightly more positive effects in region 1, whereas the spillover effects become more negative. The impact on employment is lowest in both regions under assumption IV (“regional bargaining”, i.e. in each region own price developments fully determine wage rate development).

6. DISCUSSION AND CONCLUSIONS

We presented a regional computable general equilibrium model for evaluating the relative effects of three different energy policies: the effects of an increase in heat provided by different biomass based systems, the effects of compulsory blending of diesel, and the effects of investments in thermal insulation. Our specification allows competition for land between the

conventional agricultural sector and agricultural biomass production for energy use to be taken into account. Furthermore, spillover effects on neighbouring regions can be quantified as we use a three-region CGE model.

An expansion of the use of biomass for heating production was found to generate positive effects on employment and regional GDP for almost all investigated technologies. While this is a result frequently found in the literature, we could show here, that this result also holds for most agricultural bio-energy based technologies even when we explicitly accounted for land competition. We showed that a significant increase in land rent occurs when agricultural land is used for producing biomass. As a consequence, for the technologies based on energy corn, grain pellets and poplar pellets the employment impact turns negative.

Prior to our analysis we expected a positive GDP and employment effect, and this was confirmed here for most cases. In our sub-national regional model we quantified this effect. Compared to the nationwide average we expect a more significant impact in agricultural regions. For the particular case of East Styria, Table 5 indicates that this region is responsible for a little more than 2% of value added and employment in Austria, but covers 6% of crop land and 15% of forests and 15% of additional forestry potential. Thus, any nationwide biomass expansion policy will over proportionally impact regions such as East Styria. What we were able to show here, is that this positive impact holds, even when land competition is accounted for. However, when land-price induced consumer price increases in the agricultural region fully translate into wage increases, we found that the additional employment effect disappears (see sensitivity analysis). This is true for all agricultural biomass products.

Table 5. Relative importance of study region in value added, employment and biomass energy potential [shares in Austrian total]

	East Styria	Styria
	[%]	
Share (for Austria) in		
value added (1)	2.13	12.59
employees (2)	2.30	13.36
Share in indicators of biomass potential		
cropland (3)	6.43	10.63
forest (4)	15.07	25.30
additional forestry potential (5)	15.07	22.50

Sources: (1) Arbeiterkammer (2007), (2) Statistics Austria (2005), (3) Statistics Austria (2004), (4) Federal Forest Office (2002), (5) Steininger et al. (2008)

Furthermore, spillover effects on neighbouring regions are found to be primarily triggered by a shift in public spending in region 1, with labour market related public expenditures fluctuating due to changes in unemployment payments.

Positive value added impacts are similarly obtained for blending diesel with RME, with the added restriction that positive employment effects can only be expected when a significant share (some 90%) of rapeseed is imported. When this is not the case, land-intense rapeseed production crowds out too much of the relatively more labour-intensive conventional agriculture.

With respect to the moderate direct employment effects of biomass energy strategies in the agricultural sector, the choice of the reference employment scenario in the agricultural sector needs to be discussed. Clearly, in most industrialized countries, we expect a decline in the

traditional agricultural activities of pig or cattle breeding. These are the most labour intensive agricultural activities per hectare crop land demanded. Thus, the low labour intensity per hectare crop land of biomass energy products may be closer to a more realistic future business as usual scenario than to the current alternatives in agriculture which have been used as reference scenario for the agricultural sector in this paper.

Despite the net overall positive regional economic effects and the relative cost efficiencies of most biomass technologies (compared to the reference fossil system) substitution of fossil fuel for biomass is rather slow. It would appear that apart from costs, several other barriers exist which serve to hinder the substitution process. One of these might be the relatively high investment required for biomass heating systems, necessitating long periods of operation before break even can be reached. In such a situation consumer risk aversion is likely to be a further factor inhibiting investment in biomass systems.

Therefore political measures to increase biomass use seem reasonable. In order to optimize the regional economic benefits of these measures, one should take into account that results such as those shown above depend on:

- cost efficiency of biomass heating systems compared to the reference system
- labour intensity of biomass and heating system production
- land intensity of the agricultural biomass
- amount of technology specific investment required (e.g. storage, piping systems,...) in labour intensive sectors.

The strongest positive employment and GDP effects can be achieved by employing forestry based biomass heating technologies, or – if agricultural based technologies are chosen – by those based on low-cost crops, which are primarily perennial crops such as willow, poplar or miscanthus.

Investments in thermal insulation are highly economical compared to the cost of providing heat by the fossil reference systems (without further improvement in housing stock). For many biomass systems, however, thermal insulation requires either higher housing density (such that the relatively higher investment in this heating system still pays off) or particularly low specific energy demand such that strongly downscaled heating systems can do the job.

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