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AMARA – Adequacy of Mitigation and Adaptation Options for a Case Study Region in Austria

The Example of Biomass as Climate Change Response Strategy

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AUSTRIAN INSTITUTE OF ECONOMIC RESEARCH

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Abstract

The project analyses the inter-relationship between adaptation and mitigation strategies for a study region in South-Austria. In a first step, we estimate the socio-economic impacts of fostering a shift in agricultural output from food to bioenergy production. In a second step, we analyse how future climatic conditions (around 2050) will affect the biomass production capacity. The analysis is, i.a., carried out using a regional computable general equilibrium model. It shows options of mitigation and adaptation strategies. It turns out, that they have to be combined given the specific regional setting in order to minimise the overall economic costs of climate change. Fostering the use of biomass to substitute fossil energy resources is a viable mitigation strategy. Adaptation to altered future conditions therefore is a central element of an overall strategy to cope with climate change.

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Outline

Activity Report

In this research project a scheme of mitigation and adaptation strategies for Austria is derived and assessed. In particular, the project aims to answer the question on how mitigation and adaptation strategies can be successfully interlinked. Hereby, the focus is on fostering the use of biomass to substitute fossil energy resources.

An Austrian case study is carried out to that end. As a first step, an attempt is made to estimate the socio-economic impacts of a bio-energy supply extension in the selected region. This includes the determination of the potential of biomass production in a regional context. It also requires a detailed analysis of biomass technologies for alternative energy production with respect to their competitiveness with fossil technologies.

In a second step, it is analysed how future climatic conditions (around 2045) will affect the biomass production capacity. An attempt is made to analyse how much locally consumed energy can be substituted by locally produced biomass, thereby determining the mitigative potential of biomass. This includes the estimation of the additional biomass potential in the study region. Furthermore, the adaptation needs to the regional impacts of climate change will be determined given the arising implications for the potential output of biomass for energy purposes. Finally it will be evaluated how mitigation and adaptations strategies have to be combined in order to minimize the overall economic costs of climate change.

Within the first project year, work package 1 analysed and summarised in brief the state of the art in mitigation and adaptation options to climate change taking a focal perspective towards biomass as a feedstock of energy production in Austria. The inter-relationship of adaptation measures in the agricultural sector with the potential of bioenergy as mitigative response to climate change was delineated.

In work package 2, as a first step towards the determination of the mitigative potential of regional biomass supply, the (additional) regional biomass potential for the future was estimated under specific assumptions on structural, legal and political conditions. Together with the regional energy demand by households for space heating, which was estimated for 2030 and 2045, the fraction of additional bio-energy in total regional energy demand could be assessed (section 2 of this report).

A multi-regional CGE model was developed for the assessment of the options and effects of mitigating climate change and adapting to its impacts in a regional setting. The model was first built in stylised form and then calibrated to the selected Austrian study region in South-Eastern Styria. The year 2003 was taken as a reference. Then, a Business As Usual scenario for 2045 (as representative for the 2040ies) was developed, in its first approach without considering climate change impacts so far (section 4).

A quantitative assessment of a biomass extension by technology for the reference year 2003 was carried out (section 5). It reports on regional GDP and employment effects and tests the model in its scope and sensitivity, preparing the CGE framework for the subsequent policy analysis. Then, based on the cost analysis of biomass technologies, which investigated the cost effectiveness of different single home heating systems (section 3), two technologies were selected and tested for the arising economic performance and labour market effects of a biomass expansion in the future target period in the 2040ies.

1 Mitigation and adaptation as response strategies to climate change

With climate change already happening, societies worldwide have to adapt to its impacts as a certain degree of climate change is inevitable throughout this century and beyond, even if global mitigation efforts will prove successful. Adaptation, however, has its limits. Once certain climate thresholds are exceeded, climate impacts, e.g. social disruptions, are expected to become severe and irreversible. Therefore, adaptation and mitigation are an indispensable complement to each other. Article 2 of the UNFCCC therefore applies: "The ultimate objective of this convention [United Framework Convention on Climate Change] ...is to achieve ... stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should b e achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure food production is not threatened and to enable economic development to proceed in a sustainable manner" (UNFCCC, 1992).

The aim of the subsequent sections is to draw a synopsis of the state of the art in mitigation and adaptation strategies towards climate change with a focal perspective towards biomass as energy feedstock.

1.1 Mitigation

The reduction of greenhouse gas emissions (mitigation[1]) in order to ensure a stabilisation of the concentration of carbon, methane and others in the atmosphere and limit the progress of global warming is currently a central environmental policy target on the domestic and international agendas. Emissions abatement can be achieved through a variety of measures that are to be applied in all areas of the economy and society. The main drivers for emissions are the level and development of economic activity, the energy intensity (energy use per unit GDP) and the carbon intensity of the energy employed. Key approaches to influencing energy use and related carbon emissions hence include technological improvements and innovations as well as changes in production and consumptions patterns. Mitigation is closely interrelated with broader socio-economic policies and trends and must therefore be analysed in a wider context, taking into account other policy objectives, possible synergies and non-climate change impacts (see for example *Krupnick et al*., 2000, *IPCC*, 2001, *Jochem – Madlehner*, 2003). These include economic issues like the security of energy supply and the reduction of the dependency on imported fossil fuels or growth and employment potentials through an ecological tax shift and the increased use of domestic renewable energy sources or. Besides, other (non-monetary) ancillary benefits have been increasingly discussed in

[1] Anthropogenic intervention to reduce the sources of greenhouse gases or enhance their sinks.

climate policy literature. These regard positive health effects and improvements in environmental quality due to the simultaneous reduction in conventional air pollutants (e.g. particulate matter), protection of forests, soils and water sheds that also serve as recreational areas or the reduction in congestion and road-use related fatalities.

Fig. 2 summarises the portfolio of available mitigation options for the main sources of greenhouse gas (GHG) emissions. In 2005 industry and transport each had a share of 26% in total emissions in Austria, energy generation (electricity, heat, refineries) and space heating by households and businesses each contributed around 17%[2].

The sectoral mitigation options can largely be classified in three categories:

- changes in energy inputs used (fuel switching),
- behavioural changes,
- development and deployment of efficiency technologies.

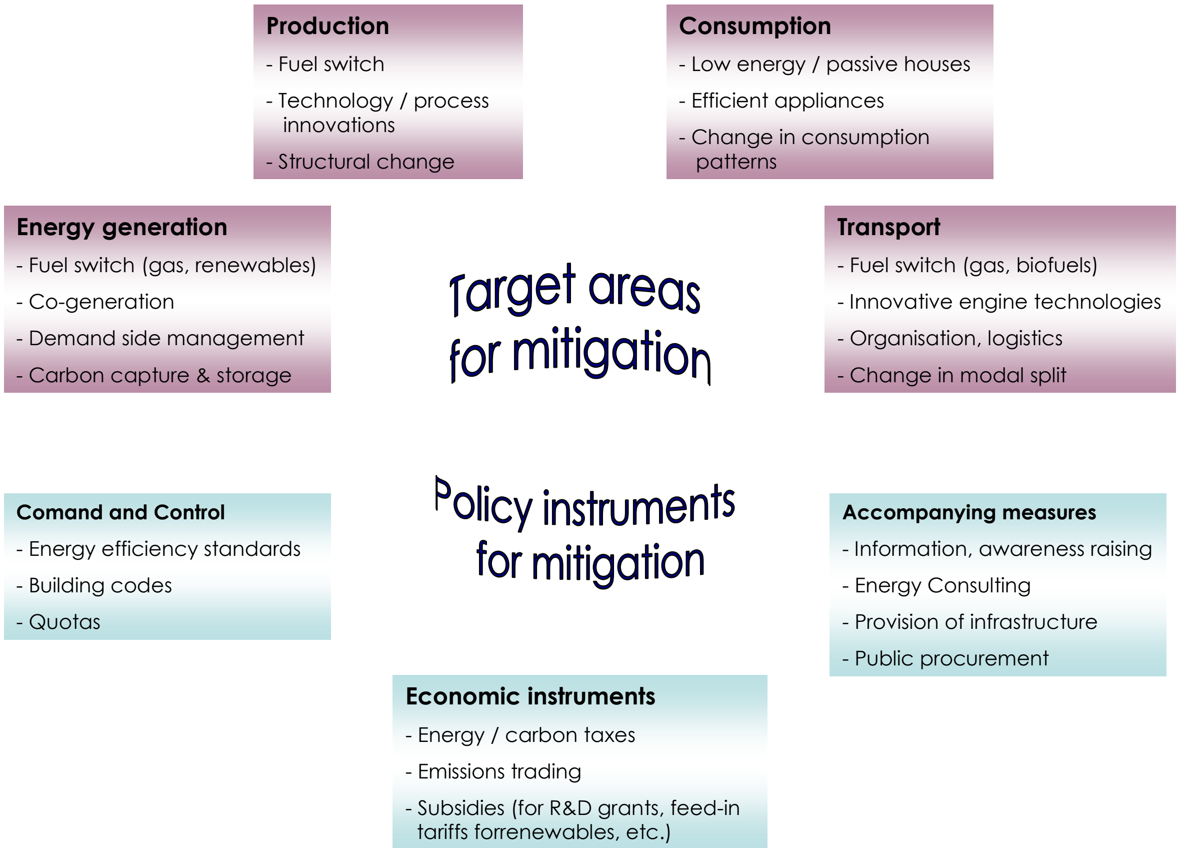
One obvious mitigation option is to switch from emission intensive energy sources to low or zero carbon alternatives. Examples are the substitution of coal and oil by natural gas, the increasing use of renewable energy sources[3] for the generation of heat and electricity and also the blending of biofuels with diesel and petrol. The emissions from natural gas for example are 40% lower than those from burning coal and conversion efficiency is generally higher in gas-fired power plants (*Netherlands Environmental Assessment Agency*, 2006). This approach can generate substantial emission reductions in the short to medium term and represent a relatively low cost mitigation option until other efficiency technologies become available at competitive prices. However, natural gas is still an exhaustible resource and does not contribute to improving the security of supply as do renewable energy sources. In this context the role of biomass as energy source for heat, electricity and transport has been intensively discussed recently (for an economic impact analysis see *Kletzan et al., 2008*; for an overview on the potential of biomass in the mobility sector see *Meyer and Scheffran, 2008* and *Weizsäcker, 2008*). Biomass has a huge potential for substituting other fuels and reduce emissions, but still the realistic contribution has to be assessed and resources have to be used in a cost-efficient way. This concerns the limited availability of land (competition with food production), the production of biomass for energy use in an environmentally compatible way and the consideration of other environmental needs (e.g. conservation areas, biodiversity, etc.). Given these limitations for supply of bio-energy, resources should be distributed to cost-efficient uses. Research results (see for example *Sachverständigenrat für Umweltfragen*, 2007) suggest that the stationary use of biomass for power and heat generation (especially in co-generation plants) is preferable to its use as transport fuel as the conversion efficiency is

[2] The remaining 13% could be attributed mainly to agriculture and waste management.

[3] The EU has set a target to increase the share of renewables in primary energy use to 20% in 2020.

higher and negative effects from biomass production are lower[4]. However, it is not adequate to give generalised recommendations as the production and use of bioenergy and/or biofuels is energy- und cost-efficient in some countries/regions but may not be so in other regions and under different institutional settings (*Worldwatch Institute*, 2007; *Rosillo-Calle*, 2007). Hence region-specific conditions under which to produce and employ biomass to generate low-carbon electricity, heat and mobility services need to be analysed in detail on a case-study basis.

Fig. 1 : Target areas and policy instruments for mitigation measures



The role that can be played by other renewable energy sources like hydropower, wind or solar and geothermal energy depends on which time frame is considered and which assumptions on future economic and market conditions are made. Although these renewable sources are currently still among the more expensive mitigation options, substantial reductions in costs are predicted and have already been observed (e.g. in wind turbines). The competitiveness of these energy sources also depends on the price differential

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[4] For electricity and heat generation mostly wood biomass or wood waste are used. Transport fuel production in comparison is largely based on crops like rapeseed and corn that entail negative environmental effects (fertiliser use, irrigation, etc.) and are expected to compete for land for food production.

with respect to fossil fuels and on research and development efforts in this technological area.

However, the resulting decline in carbon intensity of energy use through fuel switching will not be sufficient to reach the defined climate policy targets, especially if energy consumption continues to rise. Between 1990 and 2005 final energy consumption increased by 44%, with the most considerable growth in transport (+76%) which currently has the largest share in energy use of nearly one third.

Thus, further interventions are needed that, on the one hand side, improve the energy efficiency of production and consumption activities and, on the other hand side, affect the level of activities or their structure. In certain areas a reduction in the activity level, i.e. in redundant energy services consumed, will be feasible. For example, in goods traffic the number of empty runs can be minimised by enhanced organisation and logistics, traffic and congestion in urban areas can be reduced by telecommuting or improved public transport. But as (voluntary) behavioural changes will presumably only bring about small emissions reductions and limiting economic activity is not a possible mitigation option, energy efficient technologies and innovation will have to play a major role. Examples include highly efficient co-generation plants for the joint production of heat and electricity or low energy and passive houses that can reduce the energy demand for heating by as much as 90% compared to the average building stock in Austria[5]. These technologies are already available but have not yet been widely used due to their higher costs relative to conventional alternatives. Other technological mitigation options are still in the phase of research, development and demonstration. These include innovative propulsion technologies on the basis of fuel cells or electric motors, zero emission processes for industry or clean coal electricity generation with carbon capture and storage. These options are not ready for market penetration and in some cases – e.g. carbon capture and storage – connected with a high degree of uncertainty, i.e. regarding the amount of CO_2 that can be stored in reservoirs (e.g. depleted oil or gas fields), the period of storage, i.e. how long it would stay trapped or whether the CO_2 would leak to other formations. The uncertainty about leakage and environmental effects as well as the currently high costs suggest (*Newell et al.,* 2006) that carbon capture and storage might only be a medium-term option and represent a temporary storage until other means of permanent mitigation technologies are being developed.

In general research and development in technologies that improve the efficiency of end use devices and energy conversion technologies are of great importance. As the IPCC stated already in 2001 "...*known technological options could achieve a broad range of atmospheric CO_2 stabilisation levels*...", i.e. technologies that exist in operation or pilot plant stage. But in order to affect emissions considerably not only the average efficiency of new

[5] The average dwelling in Austria has an energy demand for heating of around 180 kWh/m2/a. Low Energy houses require at most 40 kWh/m2/a, passive houses 15kWh/m2/a.

technologies has to increase, also the diffusion of these innovations and the stock turnover has to accelerate since emissions are mainly driven by the existing stock of capital combined with the intensity of use (*Newell et al.*, 2006).

The necessary technological and behavioural changes to obtain the required substantial decrease in emissions have to be incentivised by climate policy. And as a variety of mitigation measures will have to be applied, climate change policy will be most effective if a portfolio of policy instruments is deployed.

The portfolio of national policy approaches includes economic instruments like carbon/energy taxes, tradable permits and the introduction or removal of subsidies[6]. A second category of policy instruments are command and control type instruments like technology or performance standards, zoning regulations or energy mix requirements. In addition, other approaches include information and awareness raising campaigns, energy audits, public or publicly funded research and development, the provision of infrastructure (e.g. for public transport) and the exemplary function of public procurement. Standards and regulations are widely used, but in recent years the introduction of market-based instruments like the EU emissions trading scheme or ecological taxes or tax reforms has increased. Alternative types of policy instruments will have different effects on various target groups or on the rate and direction of technological change[7]. Empirical analyses typically show that economic instruments are more efficient in providing incentives and changing behaviour than conventional regulation (*Newell et al.*, 2006). In addition, taxes and auctioned tradable permits generate revenues that can be used to lower other taxes (usually on labour) and thus reduce market distortions and negative tax interaction effects (*Krupnick et al.*, 2000) or can be recycled through energy efficiency or R&D subsidies. The latter offer the possibility to shape technological change in coherence with climate policy and sustainable development objectives, which can be further supported by a combination with incentives for a premature retirement of the existing capital stock in all areas of the economy (e.g. carbon pricing or regulations). A comprehensive policy approach regarding research, development and diffusion of environmental technologies can generate positive ancillary effects not only in terms of reducing energy costs and thus enhancing firms' competitiveness, but also regarding fist-mover advantages for the innovating firms and possibilities for exporting the technologies.

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[6] For a discussion of environmentally harmful subsidies in Energy see Kletzan – Köppl, 2004.

[7] For an extensive discussion of climate policy instruments and their impacts see the Stern Review (2007).

1.2 Adaptation

Societies have long been adapting to the impacts of weather and climate impacts, for instance, through crop diversification, irrigation, water management, disaster risk management, and insurance. But climate change potentially leads to risks that are outside the range of experience, such as impacts related to drought, heat waves, accelerated glacier retreat and hurricane intensity (*Adger et al.,* 2007). These climate related stimuli are possibly not limited to changes in average annual conditions, they include variability and associated extremes, sometimes referred to as "climate hazards" (*Smit et al.,* 2001).

Adaptation concerns the adjustments in ecological, social, or economic systems in response to climate change and correlated impacts (*Smit et al.*, 2001). The purpose of adaptation to observed or expected changes in climate is to reduce vulnerability and to enhance resilience. Vulnerability is the state of susceptibility to harm from exposure to stresses associated with climate impacts and from the absence of capacity to adapt (*Adger,* 2006). Resilience, by contrast, refers to the magnitude or disturbance that can be absorbed before a system (social, natural) changes to a radically different state as well as the capacity to self-organise and the capacity for adaptation to emerging circumstances.

Adaptations are dependent upon the system in which they occur, who undertakes them, the climatic stimuli that prompts them, and their timing, functions, and effects. In natural systems, adaptation is autonomous and reactive, it is the process by which species and ecosystems respond to changed conditions (*Smit et al.,* 2001). Adaptation to climate change, yet, is often referred to as consciously undertaken by humans with respect to actual or expected climate change and with reference to economic sectors, managed ecosystems, urban settlements, undertaken by private and public agents.

Adaptation to climate change has the potential to significantly lessen many of the adverse impacts of climate change, for example, threats to food supply, infrastructure, public health, and the availability of water resources etc. Adaptation is dependent upon the adaptive capacity of an affected system, region, or community to cope with the impacts and risks of climate change. Adaptive capacity is the potential or ability of a system, region or community to adapt to the impacts of climate change. Enhancement of adaptive capacity reduces vulnerabilities and promotes resilience. The determinants of adaptive capacity are *inter alia* economic, social, institutional, and technological conditions that facilitate or constrain the development and deployment of adaptive measures (*Smit et al.*, 2001).

Adaptation in the context of climate change is important in two instances, one relating to the assessment of impacts and vulnerabilities, the other to the development and evaluation of response options (*Smit et al*., 2001). Assessing adaptation options, cost-benefits analysis are applied in order to elicit the efficiency of adaptation measures. In this context, adaptation costs are usually expressed in monetary terms, while benefits are typically quantified in terms of avoided climate impacts, and expressed in monetary as well as non-monetary terms.

Much of the literature on adaptation costs and benefits is focused on sea-level rise and agriculture (*Rosenzweig und Parry*, 1994; *Yohe and Schlesinger, 1998; Hartje et al.,* 2002). However, the literature on adaptation costs and benefits remains quite limited and fragmented in terms of sectoral and regional coverage.

Comprehensive risk management strategies at the city, regional and national level have been developed, e.g. France, Finland and the United Kingdom have developed national strategies and frameworks to adapt to climate change (*Adger et al.*, 2007) and the EU has produced a Green Paper on adaptation in Europe (*CEC*, 2007). At the city level, climate scenarios are being considered by New York City as part of the review of its water supply system. For Austria there exists a national communication of the Austrian Federal Government (*Austrian Federal Government,* 2006). According to this, Austria is expected to be very vulnerable to a climatic change. This is due to the fact that mountainous regions are highly sensitive to changing climatic patterns and 70% of Austria's surface area is situated higher than 500 m above sea level and 40% higher than 1,000 m. The report reckons that a significant climate change can already be observed, i.e. the mean annual temperature has increased, snowfall has decreased, and glacier inventories show losses. Based on the insight that projections of climate change are difficult to obtain and rather uncertain, especially for mountain environments, the report draws the following conclusions concerning climatic changes in Austria:

The length of time that snow cover remains will be reduced due to changed precipitation regimes. This will alter the timing and amplitude of runoff from snow, increase evaporation, decrease soil moisture and groundwater recharge. Flat areas in the east of Austria will experience hydrological conditions more severe than those in the mountains. Changes in the natural water balance would have a serious impact on run-of-river power stations, which have a considerable share in electricity production in Austria. Reduced snow cover will have negative impacts on Austria's winter tourism and with that considerable socio-economic disruption in communities that have invested heavily in the skiing industry can be expected. Further, temperature increase, changes in intensity and frequency of precipitation, glacier retreat and loss of mountain permafrost could alter the frequency of natural hazards such as landslides, mudslides and avalanches. Currently, Austrian adaptation measures are either induced by impacts of observed climate change or are serving the reduction of natural hazards, having climate change adaptation co-benefits, e.g. irrigation channels, insurance instruments in agriculture, artificial snow making, erosion and torrent control measures in forests, and risk management in flood hazards (*Sinabell and Url, 2007*).

But there is not a comprehensive scheme on adaptation options in different Austrian regions. Nevertheless governements have a role to play in making adaptation happen, e.g. by providing policy guidelines and economic and institutional support to the private sector and civil society (*Stern, 2007*). This is because market forces are unlikely to lead to efficient adaptation. In particular, governments shall help to provide high-quality climate information, i.e. improved regional climate predictions with respect to rainfall and storm patterns. The scale and complexity of climate information will make it unlikely that individuals and frims will undertake basic research into future changes. Therefore, high-quality information on impacts of climate change in space and time must be considered a public good. Information about climate change and its impacts should not be to complex and should provide practical pointers such that climate change will be integrated into project appraisal and decision-making by private investors and civil society. Climate information is, thus, an important starting point for adaptation because it will drive efficient markets for adaptation.

The agricultural sector has to be considered a key sector in adaptation because agriculture is not only central in food production but will as well become ever more important in the energy supply sector. Hence, there is a strong inter-relationship between successful agricultural adaptation measures and the scope of bioenergy as a reliable mitigation and energy supply strategy. Agricultural and, thus, feedstock production for bioenergy need to take into account climate impacts and effects on water availability and quality. "While moderate warming benefits crop and pasture yields in mid- to high-latitude regions, even slight warming decreases yields in seasonally dry and low-latitude regions " (*Easterling et al., 2007, 300*).

Bioenergy crops are susceptible to natural and human-caused disasters, including crop failures, irregular weather patterns and droughts, which could increase with climate change. Adaptation strategies to be investigated therefore incorporate changes in the topography of land, the use of artificial systems to improve water use or availability and protection schemes against soil erosion, changed farming practices, changes in the time of farm operations, use of different crop varieties, research into new technologies, governmental and institutional policies and programs (*Smit et al,* 2001).

2 The biomass potential in a regional context

2.1 The regional potential of biomass production

2.1.1 Agriculture and forestry in the study region

The wider Feldbach region in South-Eastern Styria (SE Styria) comprises five political districts (Feldbach, Fuerstenfeld, Hartberg, Radkersburg and Weiz) as shown in Fig. 2. The study region is among the most productive agricultural production regions in Austria, since it allows for a large variety of agricultural crops at a comparatively small regional scale. In this way, it provides a selection of adaptation options to climate change. Moreover, SE Styria is characterised by a high biomass potential and thus promising for bio-energy development. However, because of its location in the shade of the Alps, SE Styria is characterised by little precipitation.

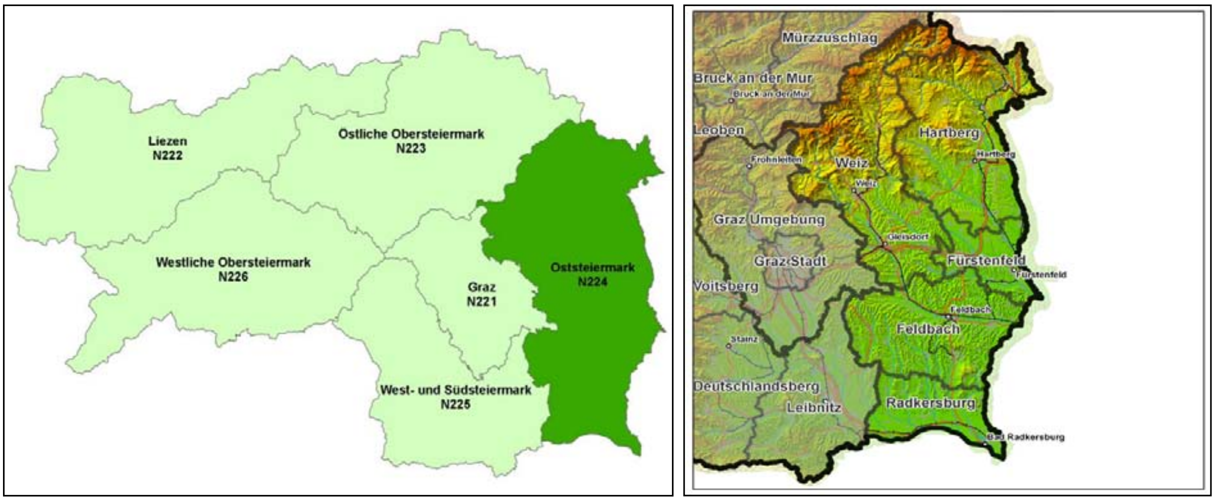


Fig. 2 : The study region in South-Eastern Styria in Austria.

In the study region, two thirds of agricultural area is farmland. While grassland amounts to some 43.700 ha, farmland corresponds to an area of some 86.600 ha. The main crop cultivated in SE styria is maize, which accounts for 47% of total farmland in the region. Forestry biomass used for energetic purposes in the study region is of minor importance in that the South-Eastern woodland (151,000 ha) makes up some 15% of the total Styrian woodland. Still, bio-energy based on wood plays a central role in mitigating emissions (in terms of cost-efficiency of the technology as well as economic performance and labour market effects in a regional context) as we will see in later sections of this report.

At the national level, in 2007 some 5.000 ha land were used for energetic purposes; this is 1% of the total agricultural area in Austria. According to IACS[8] (2007), 2.100 ha out of these 5.000

[8] Integrated Administration and Control System of the European Union.

are situated in South-Eastern Styria, making up some 1.5% of agricultural area in this region. In terms of energy sources, in SE Styria mainly maize (silage maize, grain maize) is used for energy production (78%), followed by rape-seed (15%) (see Fig. 3). For pure energy crops such as miscanthus, short rotation woods and sorghum there is effort to foster their cultivation in the study region.

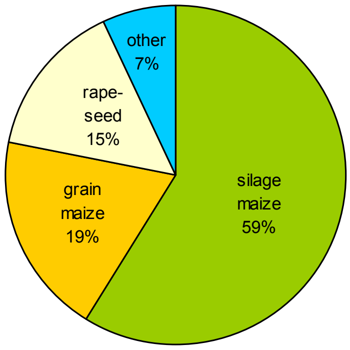


Fig. 3 : Regional energy crop production in SE Styria in 2007.

Other crops: miscanthus, short rotation woods, corn, sunflower, grasses, sorghum. Source: IACS (2007).

2.1.2 Additional biomass potential

The additional potential of forestry based biomass in SE Styria for a time horizon of 2030 is estimated in coordination with the Styrian Agricultural Chamber and amounts to 135.638 solid cubic metres.

Agricultural based biomass includes the complete variety of crops cultivated on farmland and grassland which can be used for energetic purposes. We estimate the additional potential of agricultural biomass under consideration of the dynamics of land use change, i.e. the changing partitioning of farm-, grass- and woodland with a national widely observed decline in farm- and grassland since the 1960ies. In order to determine the potential of biomass production in a regional context the future development of the following factors are of relevance (Haas et al., 2007):

- the Common Agricultural Policy within the European Union
- scope of cattle ranching and grazing land
- subsidies for landscape preservation
- demand for agricultural output
- legal and institutional conditions

Following *Haas et al.* (2007) we define three scenarios (low, medium, high) which differ by assumptions on the distribution of crops, potential area, development of livestock and the share of agricultural by-products which can be used for energetic proposes. By defining different scenarios, we also consider a specific mix of energy crops. Moreover, we take into consideration the gain in energy crop yields due to breeding progress (1% p.a.).

Thus, under the very specific assumptions on structural, legal and political future conditions, we find the following development for SE Styria up to 2030 compared to 2006 (see Tab. 1):

- reduction of farmland by 2%
- reduction of grassland by 6%
- increase in relative and absolute share of energy crop production in farm- and grassland

In the high scenario, 28% of farmland and 29% of grassland are cultivated by energy crops in 2030; in the low scenario 20% of farmland and 20% of grassland is potential energy land at that time in the future.

Tab. 1 : Estimation of additional biomass potential in the study region by 2030.
Source: own calculations based on Haas et al. (2007).

	2006 reference		2030 high scenario	2030 low scenario
***distribution of crops* [ha]**				
farmland	86,613		84,558	84,558
		Δ reference	*-2%*	*-2%*
grassland	43,737		41186	41186
		Δ reference	*-6%*	*-6%*
***potential energy areas* [ha]**				
farmland			23,676	16,912
		share in farmland	*28%*	*20%*
grassland			11,944	8,237
		share in grassland	*29%*	*20%*

2.2 The mitigative potential of regional biomass supply

2.2.1 Regional energy demand for space heating

In this section we determine the regional energy demand for space heating by households for different time horizons and under different assumptions on expanded insulation. These calculations do not include impacts from climate change.

Energy consumption by households is calculated using the concept of energy services, which are „actual services for which energy is used: heating a given amount of space to a standard temperature for a period of time" (*IEA*, 1997, p. 35). As a first step, based on data of the household and population census 2001 (*Statistics Austria*, 2004a, 2004b) and on population statistics of *Statistics Austria* (2007a), an energy service of heated 10.6 million m^2 living space is calculated for the base year 2003. This living space implies a heat demand of 9.54 million GJ in SE Styria and of 45.38 million GJ in Styria. In addition, it is assumed that all new buildings after 2003 fulfill low energy standard, with an energy demand not higher than 0.15 GJ per m^2. In existing buildings energy demand is reduced with insulation by 0.26 (small reconstruction) and 0.33 GJ (big reconstruction) per m^2 (see *Jakob et al.*, 2002).

Then, in order to assess the heat demand for different points in time up to 2045, the development of living space (*Statistics Austria*, 2008) and the projected number and size of households (*Landesstatistik Steiermark*, 2007) are included.

This procedure allows modelling the energy sector for a Business as Usual scenario in the future (see also section 4.3, where the future scenario is developed). Recall that the future heat demand by households is quantified leaving out any effect from altered climatic conditions.

Tab. 2 presents the final demand for heat by households in the study region SE styria for different reconstruction rates and under the assumption that all new dwellings are built in low energy house standard. Tab. 3 does the same calculation for Styria. Four different reconstruction rates are simulated (1%, 1.5%, 2% and 3%), with 1% being the baseline.

Tab. 2 : Final demand for heat by households by 2030 and 2045 in SE Styria for different reconstruction rates and under the assumption that all new dwellings are built in low energy house standard.

Source: own calculations based on Statistics Austria (2004a, 2004b, 2008) and Landesstatistik Steiermark (2007).

	final heat demand in SE Styria (new dwellings as low energy houses) [TJ]					
reconstruction rate	2003	2010	2020	2030	2040	2045
1%	9,540	9,352	9,103	8,877	8,675	8,585
1.5%	9,540	9,243	8,841	8,461	8,105	7,938
2%	9,540	9,134	8,578	8,045	7,536	7,291
3%	9,540	8,916	8,053	7,212	6,396	6,162

Tab. 3 : Final demand for heat by households by 2030 and 2045 in Styria for different reconstruction rates and under the assumption that all new dwellings are built in low energy house standard.

Source: own calculations based on Statistics Austria (2004a, 2004b, 2008) and Landesstatistik Steiermark (2007).

	final heat demand in Styria (new dwellings as low energy houses) [TJ]					
reconstruction rate	2003	2010	2020	2030	2040	2045
1%	45,375	44,228	42,639	41,076	39,508	38,736
1.5%	45,375	43,594	41,114	38,660	36,201	34,983
2%	45,375	42,961	39,590	36,244	32,894	31,231
3%	45,375	41,694	36,541	31,413	26,281	25,108

Depending on the reconstruction rate, the demand for heating energy makes up between 6.16 million GJ (3%) and 8.59 million GJ (1%) for SE Styria (see Tab. 2) and between 25.1 million GJ (3%) and 38.7 million GJ (1%) for Styria (see Tab. 3) in 2045.

2.2.2 Application of the additional biomass potential

Once the additional regional biomass potential under future conditions (section 2.1.2) and the regional energy demand of households (section 2.2.1) are estimated, the mitigative potential in terms of bioenergy can be assessed. We will thus determine how much of the energy consumed by households in 2045 can be substituted by locally produced biomass once its output has reached the anticipated targets.

In order to assess how much of energy demand in 2045 can be supplied by the additional biomass potential, we choose a specific mix of energy crops which is cultivated on the potential farmland available for energy purposes (see Tab. 1). In particular, it is assumed that the following crops take up each 20% of the potential farmland and that their utilization is as follows:

- maize (for the production of bio-gas)
- rape-seed (for bio-diesel)
- miscanthus (for heat)
- whole plant corn (for heat)
- poplar (for heat)

Based on the additional agricultural and forestry biomass potential estimated in section 2.1.2., we calculate with an agricultural potential of 23,676 ha in SE Styria and 40,544 ha in Styria in the high scenario in 2030 and of 16,912 ha in SE Styria and 28,960 in Styria in the low case. The same values are assumed for the year 2045, since estimates are getting increasingly uncertain in the further future.

As for forestry biomass, it is assumed that the additional potential is used in the following manner:

- 10% wood chips
- 50% wood logs
- 40% pellets heating systems

We calculate with an additional forestry potential of 135,638 solid cubic meters in SE Styria and of 900,000 solid cubic meters in Styria in both the low and the high scenario in 2030.

Moreover, for the future energy demand by households, we take the assumption of new houses to be built uniformly in low energy standard. Thus, under a reconstruction rate of 1%, for example, the demand for heating energy makes up 8.9 million GJ in 2030 and 8.6 million GJ in 2045 for SE Styria; the demand for Styria amounts to 41.1 million GJ in 2030 and 38.7 million GJ in 2045.

In order to guarantee that the regional biomass potential can be fully exploited, we introduce tailored subsidies for those technologies which are not able to compete with the reference technology (oil) yet.

We are now in the position to show the increase in the households' future energy demand for space heating than can be served by exploiting the region's biomass potential. The fraction of additional bio-energy is calculated for 2030 and 2045. Fig. 4 shows the results for the study region (SE Styria) and for the region of Styria. What can be seen as well is the different initial shares in agricultural and forestry biomass in Styria and SE Styria, with forestry biomass dominating in Styria and vice versa in SE Styria.

Depending on the assumed potential (low, base, high), between 21 and 23% of regional energy demand by households can be supplied by additional biomass in SE Styria by 2030 (10% forestry, 13% agricultural). These values rise to some 27 to 30% by 2045 (10% forestry, 23% agricultural). In Styria some additional 18% of Styria's energy demand can be produced by 2030 by the additional biomass potential (14% forestry, 4% agricultural), increasing to some 20 to 22% by 2045 (13% forestry, 9% agricultural).

These shares can be increased when insulation measures are expanded. With a reconstruction rate of e.g. 1%, the fraction of additional bio-energy in total regional energy demand can be increased by up to 5% for SE Styria by 2045 and up to 4% for the region of Styria (both values for the high scenario).

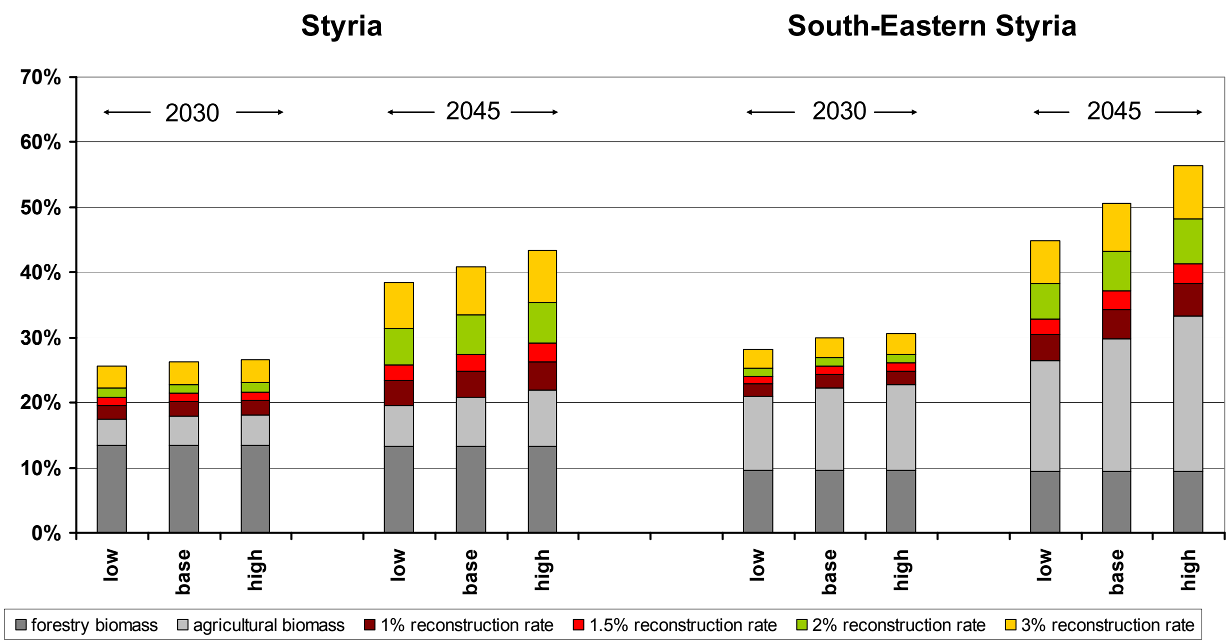


Fig. 4 : Fraction of additional bio-energy in total regional energy demand by households for Styria and SE Styria in 2030 and 2045 under different reconstruction rates.

3 Cost analysis of biomass energy production

3.1 Cost factors in energy production from biomass technologies

The cost efficiency of biomass technologies is a decisive factor that determines to what extent energy services are provided from biomass resources. *Bentzen et al.* (1997), for example, show that although wood based heating systems are generally cheaper than the fossil alternative, the substitution process of biomass for fossil fuels is slow. High investment and low operating costs, e.g. cheap fuel costs, imply that a high level of energy consumption is necessary to make biomass technologies profitable. Furthermore, risk aversion of consumers might be a barrier in that it prevents investments in biomass based heating systems.

The costs of energy services provided by the use of biomass are determined by various factors. In general, total expenditures can be split up into single expense factors such as fuel costs (i.e. the cost of biomass products), costs of capital and costs of operation and maintenance. In the present approach, land use rent is only considered for agricultural crops. Moreover, the calculations include the cost of processing and transporting. For the case of pellets, namely agro pellets or wood pellets, given biomass production costs have to be adjusted by adding costs of producing pellets.

3.1.1 Costs of energy crop production

Fuel costs, i.e. the costs of biomass pre-products form the basis for an estimation of energy supply costs. Fuel costs are predominantly determined by yearly energy costs (such as costs for oil, pellets or wood chips). They include additional costs of heat and electricity that occur in system operation. The costs of electricity are included by taking conventional household prices (16 Cents per kWh) (*E-Control,* 2007) into account. In order to guarantee the comparability of results, agricultural and other subsidies are not included. Since here fuel costs equal regional production costs, the calculated costs of biomass pre-products used for energetic purpose could possibly differ from current market prices. Tab. 4 compares the costs of biomass supply by biomass pre-product for different solid biomass resources.

Tab. 4 : Cost of biomass supply by biomass pre-product.

Biomass energy pre-product	unit	**production costs [€]**
solid biomass resources		
wood chips	Srm[1]	20.17
wood logs	rm[2]	54.90
wood pellets	kg	0.19
poplar pellets	kg	0.30
Miscanthuspellets	kg	0.34
grain pellets	kg	0.33
straw pellets	kg	0.14
Miscanthus (whole plant)	Srm	16.10
energy corn (whole plant)	kg	0.19

[1] amount of a cube full of loosely poured wood chips with a side length of one metre

[2] cubic metre

The costs of energy crops (miscanthus, straw, grain, poplar, energy corn) are calculated by using a full cost accounting method (for details on the method see *Steininger et al.*, 2008). This approach is designed for the medium and long-term perspective and considers both variable costs (seeds, labour, fertilizer, pest management, insurance, variable costs of machinery, harvesting, transport, drying) and fixed costs (lease, fixed costs of machinery).

3.1.2 Capital costs and costs of operation & maintenance

The costs of capital per year are calculated by using the method used by *Kaltschmitt – Hartmann* (2002). It splits up total costs of ownership and allocates them to single years of the assumed service life of the heating system (the planning horizon covers 20 years). This results in the annuity, which can be interpreted as yearly payment for redemption of capital. Thus, total yearly costs of capital are calculated by adding all required capital investments split up according to the method used here.

The costs of operation and maintenance per year include the costs for repair, service and maintenance. It is assumed that the yearly costs of maintenance vary between 0.5% and 1% of total capital expenditure. Furthermore, the costs of operation and maintenance take account of administrative costs, risk costs, costs of insurance and labour costs. With heating systems that have a capacity range below 100 kW, theses costs can be neglected, however.

3.1.3 Costs of production and distribution of pellets

The usage of pellets is quite convenient and therefore very popular in private households. Hence, if heating systems are based on pellets, given costs structures have to be adjusted by the costs of producing and distributing pellets to final consumers.

The cost structure shown in Tab. 5 is based on the work of *Eder* (2007) and estimates costs for the production of 10,000 t pellets per year. The costs of resource inputs (agricultural crops, wood) are excluded here. Both agro pellets (pellets made of agricultural crops) and wood pellets are considered.

Wood pellets are currently widely used inputs in single home heating systems. Although the production of agro pellets is – from a technological point of view –, feasible and cost-efficient, the usage of agro pellets not ready yet for widely spread usage. One reason is the negative combustion features of agro pellets, namely the high emissions of nitrogen oxides and particular matter, the high ash content and the low fusibility of fuel ash which occur to their usage in heating systems.

Tab. 5 : Costs of pellets production and distribution

Calculations excluding resource cost and considering a yearly production of 10,000 t. Source: own calculations based on Eder (2007).

Costs of pellets production and distribution	agro pellets	wood pellets
costs of capital	172,764 €	194,422 €
fuel costs	640,000 €	506,396 €
costs of operation and maintenance	291,825 €	291,825 €
total costs	1,104,589 €	992,643 €
total investement costs	1,570,000 €	1,753,000 €
costs of pelleting	76 € per t	64 € per t
costs of distribution (incl. risk loading)	3 € per t	34 € per t

3.2 Cost effectiveness of biomass technologies

This section compares the cost effectiveness of selected biomass technologies. The overall cost calculation for biomass energy supply is based on the method as in *Steininger et al.* (2008). It considers the demand for heat, which is calculated by the building's space heat load and the yearly full load hours (1500 h/a). More specifically, the technologies analysed here are single home heating systems with a space heat load of 15 kW. 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, yields total annual mean costs by technology as well as total costs per kilowatt hour. Moreover, the calculations are based on real values, i.e. values (costs, prices) are adjusted for differences in price levels over a specific period of time (inflation rate). We assume that investments of private households are subject to a real interest rate of 2.2%.[9]

Summing up over all cost factors mentioned in section 3.1, Tab. 6 gives an overview of the cost of biomass energy production for 9 different single home heating options. In particular, the single home heating systems given in Tab. 6 are based on wood chips, wood logs, wood pellets, poplar pellets, miscanthus pellets, grain pellets, straw pellets, miscanthus (whole plant) and energy corn (whole plant). In addition, the single home heating system based on oil is listed as a reference fossil fuel technology.

[9] The real interest rate of 2.2% is calculated by the inflation-adjusted geometric mean of the Secondary Market Yield between the years 1997 and 2006 in Austria (Austrian Central Bank, 2007, Statistics Austria, 2007b).

Tab. 6 : The cost of biomass energy supply by technology.

Technology	**Supply costs [€/MWh heat]**
single home heating systems (15 kW)	
wood chips	10.6
wood logs	8.5
wood pellets	9.9
poplar pellets	9.8
agro pellets (Miscanthus)	12.0
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

[1] assumption: fuel oil price of 69 Cents per litre (mean price in 2006 excl. tax)

The calculations in Tab. 6 show that using current oil prices as reference, biomass technologies based on wood (chips, logs or pellets) are cost efficient. We find cost savings between € 1.1 (chips) and € 3.2 (logs). Furthermore, technologies based on miscanthus (whole plant) show lower costs than the fossil fuel oil system. On the other hand, costs of heating systems based on agro pellets exceed fossil fuel costs between € 0.3 (miscanthus) and € 2.5 (grain) per megawatt hour; the costs of a heating system based on energy corn do so by € 2.6.

Thus, heating systems based on wood biomass are generally cost efficient relative to the fossil alternative. While wood based heating systems are cost efficient in buildings with a low space heat load, systems based on agricultural biomass are only profitable with high levels of energy consumption (i.e. with a space heat load beyond 30 kW) due to high investment costs.

4 The regional economic model

4.1 Model structure

4.1.1 The basic set-up

The present project employs a comparative static three region CGE model, which is developed within GAMS (*Brooke et al.*, 1998) using the modelling framework MPSGE (*Rutherford*, 1998). The core region, Region 1, is fully embedded within Region 2, and both Region 1 and 2 are surrounded by Region 3 (see Fig. 5).

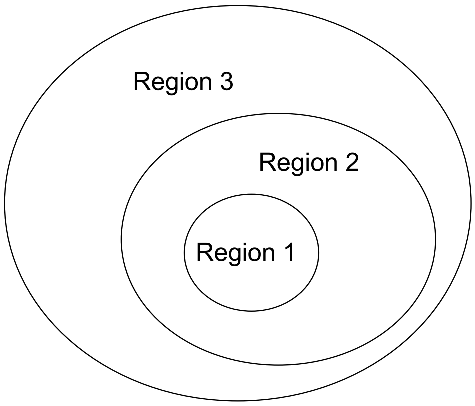


Fig. 5 : The 3 stylized regions of the model.

In terms of empirical implementation, SE Styria forms the core region (Region 1) in the three-region economic model, embedded within the rest of Styria (Region 2) and the "rest of the world" (Region 3) including the rest of Austria and abroad. While Region 1 and Region 2 are fully modelled, Region 3 is connected to them via trade flows.

The modelled economy comprises 41 sectors, whereof six are energy producing (coal, diesel, other oil products including gasoline and fuel oil, electricity, gas), and three factors of production (labour, capital, land). Goods and services are thus produced by the use of the primary factors labour, capital and land (for agricultural crops) and by intermediate inputs from other sectors.

Furthermore, in the biomass energy sector, the model is extended for a technological process-specific analysis. I.e. discrete biomass energy technologies are specified that allow for the substitution of fossil-based ones.

The factor land is only used in agricultural production and for biomass intermediate products. It is assumed that land available for crop production is limited in each region such that producing agricultural biomass displaces the conventional agricultural sector that is scarcely able to substitute land against other productive factors.

The labour supply is exogenously given and dependent on the demographic trend in the study region. While capital and land are fully employed, the labour market does not clear, so there is unemployment. In addition, the model captures the potential labour demand shift since labour intensities vary among sectors and technologies, respectively.

4.1.2 Consumption

Households demand goods and services and supply labour, capital and land. The representative household derives utility from the consumption of a bundle of n goods and services. This bundle involves private consumption, investments and stock changes. The household maximizes utility (1) subject to the budget constraint (2):

$$U = \prod_{i=1}^{n} X_i^{\alpha_i} \qquad \sum_i \alpha_i = 1 \tag{1}$$

$$Y \geq \sum_{i=1}^{n} p_i X_i \, , \tag{2}$$

where Y represents household income and p_i the price of consumption good i, $i = 1,...,n$. The utility function is modelled by a Cobb Douglas function, incorporating fixed expenditure shares α_i for each good. Income is made up of wages wL (where w is the wage rate and L labour), returns on capital rK (where r is the interest rate and K capital), land rents vKL (where v is the land rent and KL agricultural crop land) and transfers T:

$$Y = wL + rK + vKL + T \tag{3}$$

The demand functions resulting from households' maximisation problem can be written as

$$X_i = \frac{\alpha_i Y}{p_i} \tag{4}$$

Expressing the households' utility as a function of income and prices yields the indirect utility function

$$U = Y \prod_i \left(\alpha_i / p_i \right)^{\alpha_i} \tag{5}$$

Note that a different bundle for space heating service is specified. This allows for the substitution of biomass technologies for fossil heating systems. The consumer demands heat services rather than just energy for the production of heat.

Furthermore, there is final demand for goods and services by the government. Public revenues accrue from taxes from households and firms on goods and factors (e.g. income tax, value-added tax, land tax). These revenues are spent on public demand or investment, or they are passed on to households via social transfer payments T (e.g. unemployment benefit).

4.1.3 Production

Firms produce goods and services and demand intermediate products from each other. They are assumed to maximise profits. Production in each sector follows a nested CES (constant elasticity of substitution) structure and involves primary inputs (labour, capital, land) and intermediate inputs from other sectors. On the top level of the production structure intermediate inputs are combined with an aggregate of land, labour, capital and energy, involving fixed input coefficients (i.e. the elasticity of substitution equals zero). One level below, a small elasticity between land and other inputs is assumed to highlight the importance of the factor land in agricultural production. The exact values for the respective production elasticities are given in Tab. 7.

In particular, heat services can be either provided by fossil technologies or by biomass energy. Another possibility is found in improving the thermal efficiency of buildings through investments, modelled by a given level of the reconstruction rate. In particular, the higher the reconstruction rate, the higher the demand for insulation material and the lower the demand for heat products.

4.1.4 Trade

Commodities can be traded across the three regions, modelled under the Armington assumption (see Fig. 6).

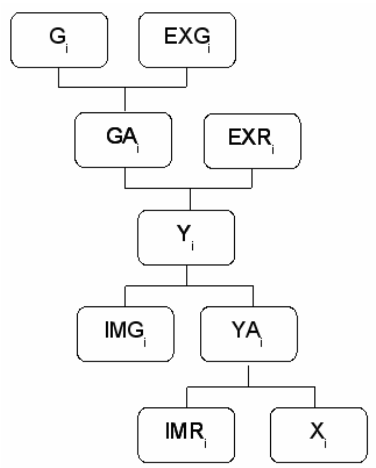


Fig. 6 : The structure of foreign trade under the Armington assumption.

Domestically produced commodities (X_i) in Region 1 combined with imports from Region 2 (IMR_i) and imports from the ROW (IMG_i) constitute the total available commodities in Region 1. These are either consumed locally or exported to Region 2 (EXR_i) or ROW (EXG_i). G_i therefore denotes commodities which can be consumed or used as intermediate input in Region 1. The same structure holds for Region 2. In sum, EXR_i for Region 1 must equal IMR_i for Region 2 and vice versa. The quantities traded depend on the relative price of domestic and foreign goods and on trade elasticities of substitution (for exact values see Tab. 8).

4.2 Reference specification

The model is calibrated to the year 2003. As a first step, the exogenous parameters and initial variables are specified in order to calibrate the reference equilibrium, thereby reproducing the economic data of 2003.

The elasticities of substitution in production and the trade elasticities of substitution, i.e. the Armington elasticities, are listed in Tab. 7 and Tab. 8. The Armington elasticities vary between sectors and by kind of trade, i.e. regional or global trade. In particular, higher preferences for goods produced regionally within Styria are reflected by higher elasticities for regional trade flows, i.e. trade between Region 1 and Region 2, than for global ones, i.e. flows to and from Region 3.

Tab. 7 : Elasticities of substitution in production.

Elasticities start from the highest nesting level. Source: own assumptions for the two upper levels; in the lower nesting levels, the elasticities are in the range of those from Wissema and Dellink (2007); Rutherford and Paltsev (2000).

elasticities of substitution in production	value
between intermediate inputs and aggregate land-labour-capital-energy	0.00
between land and other inputs (labour, capital, energy)	0.10
between labour and aggregate capital-energy	0.85
between capital and energy	0.65
between elecricity and fossil fuels	0.20
between coal and aggregate oil-gas	0.50
between gas and oil	2.00
between other oil products and diesel	0.01

Tab. 8 : Armington elasticities per sector.

Source: Welsh (2008).

Armington elasticities per sector	value	
	regional trade	**global trade**
ÖNACE sector		
01	1.200	0.900
0205	0.447	0.298
1014	0.039	0.026
1014	0.800	0.533
1516	0.891	0.594
1719	1.200	0.800
20	0.503	0.335
21	0.150	0.100
22	0.469	0.313
23	0.039	0.026
24	0.600	0.400
25	2.250	1.500
26	0.337	0.224
2729	1.200	0.800
3033	0.225	0.150
3435	0.300	0.200
36	0.503	0.335
37	0.300	0.200
40	0.039	0.026
41	0.300	0.200
45	0.503	0.335
5052, 55, 6067, 7074	0.300	0.200
57, 80, 85	1.800	0.200
9095	0.300	0.200

The regional Social Accounting Matrices our model employs are estimated by 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). Tax statistics (*Statistics Austria*, 2006b) and the regional statistics handbook for Styria (*Arbeiterkammer*, 2007) served as database for the macroeconomic framework data (unemployment, transfers, taxes).

4.3 Future scenario without climate change

Building on the base run for the year 2003 (as in section 4.2) the Business As Usual (BAU) scenario for the year 2045 is developed by extrapolating the macroeconomic framework data for the study region. The BAU does not include any climate change. Then, population growth, factor input growth, factor productivity, energy prices and demand for heat, electricity and transport are projected to the future. These values are given in Tab. 9. Moreover, in the housing sector, where a reconstruction rate of 1% is assumed, all new dwellings are low energy houses. The quantities for heat demand of consumers in 2045 under these assumptions are presented in Tab. 10.

Tab. 9 : Parameter values and exogenous and initial values for the development of the BAU scenario 2045.

exogenous and initial values	value		source
	Region 1	Region 2	
GDP growth (initial value)	1.2 % p.a.	1.74 % p.a.	own calculation based on IIASA basis scenario
growth of capital stock	0.9 % p.a.	0.9 % p.a.	EU KLEMS (2007)
change in labour force until 2045	-12.70%	-12.50%	own calculation based on ÖROK (2004)
real price change for energy	+14.5% (coal); +29% (oil products); +29% (gas); +19.3% (electricity)		own calculation
productivity growth	between 0.31 and 2.41 (varying between sectors)		own calculation based on EU KLEMS (2007)
reconstruction rate (initial value)	+ 1.0%	+ 1.0%	own assumption
heating demand of consumers up to 2045 (initial value)	+ 3.71%	+ 1.84%	own calculation
fuel demand of consumers up to 2045 (initial value)	+ 16.87%	+ 26.52%	own calculation
electricity demand of consumers up to 2045 (initial value)	-18.91%	-14.85%	own calculation

Under these assumptions, the BAU for 2045 is characterised by the economic performance presented in Tab. 10, including GDP growth, welfare, consumption price index, the level of agricultural production, factor prices for labour and capital and the agricultural price level. Note that the GDP growth rates are close to the IIASA Baseline Scenario B1, namely for urban growth at 1.76% p.a. and for rural growth at 0.94%.

Tab. 10 : Business as Usual scenario for 2045 (future scenario without climate change).

BAU 2045			
		Region 1	Region 2
Economic Performance			
GDP	[2003 = 100]	163.24	202.75
GDP growth	[% p.a.]	1.20%	1.74%
Welfare	[2003 = 100]	200.0	266.5
Welfare	[% p.a.]	1.7	2.4
Consumption price index	[2003 = 100]	90.6	95.9
Agricultural production level	[2003 = 100]	137.7	136.1
Factor prices			
Labour	[2003 = 100]	282.0	339.5
Capital	[2003 = 100]	124.9	150.4
Price level agriculture	[2003 = 100]	102.2	118.3

5 Quantitative assessment of a biomass expansion by technology

In this section we seek to quantify the economic effects of an increased biomass use by technology. We do so for a reference case (2003) and for a future scenario (for 2045 as representative for the 2040ies), which are based on the reference scenario developed in section 4.2 and the BAU scenario developed in section 4.3.

5.1 Reference case of a biomass expansion

5.1.1 CGE implementation of biomass technologies

For a comparative evaluation of the different biomass heat technologies we choose a uniform expansion in terms of energy content across technologies. We analyse a substitution of 2000 TJ use energy supplied by fossil fuel heating systems by each of the different biomass heating systems introduced in section 3. This represents about 20% of total energy demand for space heating in the study region (Region 1), as estimated in section 2.2. We take account of the subsidies already in place. For those technologies that – even with present subsidies – are more expensive than the fossil ones, households are assumed to take the extra costs.

In foreign trade of biomass we assume import quotas defining the proportion of biomass imported from the rest of the world (Region 3), as given in the second column of Tab. 11. The quotas are 0% for pellets, for which domestic national supply exceeds demand (*IEA*, 2007), 10% for wood bases biomass products (*Federal Ministry of Agriculture, Forestry, Environment and Water Management*, 2006), such that national targets can be achieved, 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. As we are interested in regional effects and their spill over to neighbouring regions, we implement the biomass expansion only in Region 1, and analyse impacts on both Region 1 and Region 2.

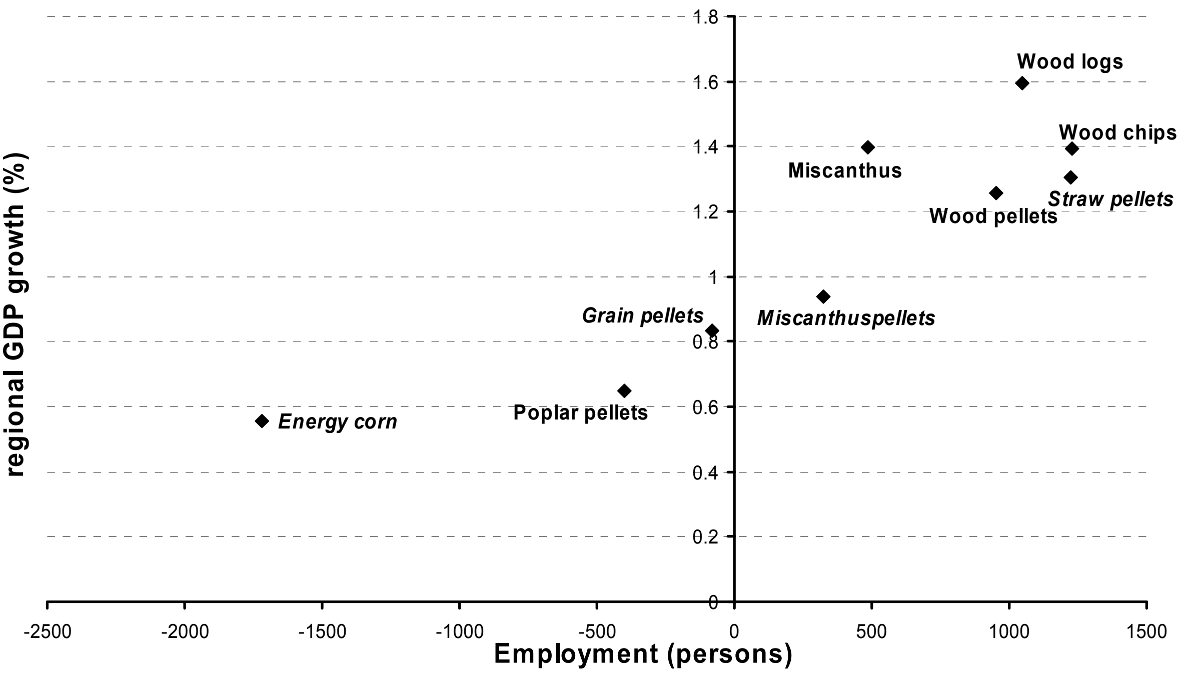
5.1.2 Results on regional GDP and employment by technology

We find positive employment and regional GDP effects from an expanded biomass production based on forestry biomass (see Fig. 7). For wood based biomass (wood pellets, wood logs and wood chip) it is in general three factors that govern the regional macroeconomic results: labour demand, 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. This technology hence shows the highest combination of GDP and employment effects. Effects are similarly positive for the case of wood chips. This result is due to significant investments in infrastructure (e.g. storage construction) which are necessary to install this technology. These investments thus generate demand in the building and construction sector, which are both characterised by a high labour intensity.

We find the highest employment effects for straw pellets, since straw is a residual product, and therefore no extra crop land is needed, which would otherwise place it in competition with the conventional agricultural sector. Furthermore, energy corn combines the characteristics of highest cost and lowest area yield rate, resulting in the lowest GDP growth rate and highest loss in employment.

Fig. 7 : Economic performance and employment effects through expanded biomass use in Region 1.



As for heat produced with agricultural biomass, 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 crucially depends on cropland requirements. This factor has a significant impact on the production level of the agricultural sector since conventional agricultural production is crowded out by the competition for crop land. Furthermore, a decrease in conventional agricultural production implies a decline in food production.

In this context it is interesting to report on the differences in factor intensities across biomass products. In particular, the labour intensity and land intensity differ notably across biomass products. Forestry products show higher values (0.51 to 0.56) than agricultural conventional products (0.28), but agricultural biomass products still show a lower one (0.08 to 0.22)[10]. These values results from the fact that from biomass products require more advanced machinery rather than labour input. Thus, when land intensive products such as agricultural biomass products are crowding out conventional agricultural activities, they reduce the overall labour demand.

In analysing the agricultural biomass technologies in detail, heat produced from poplar pellets requires both a low amount of labour and almost no investments in infrastructure or machinery, resulting in a low net employment effect. For miscanthus (whole plant), miscanthus pellets and grain pellets on the other hand, significant investments in infrastructure and machinery are needed (both representing labour intensive intermediate supplies). Moreover, these three technologies do involve different production costs, but also different state-paid subsidy rates. A higher subsidy rate (as for e.g. grain pellets) reduces labour intensive government consumption.

5.1.3 Spill-over effects

This section analyses the spill-over effects from a biomass expansion in Region 1 to the surrounding Region 2. Tab. 11 summarises the effects on regional GDP and employment for both regions.

The spill-over effects are obviously highly correlated to the employment effects observed in Region 1. This can be explained by increasing consumption by households (increased income) and by the government (reduction in unemployment benefit payments) in Region 1, leading to an increase in demand for goods and services produced in Region 2. This effect is significant for the sectors health service, education and public service, since they are characterised by a high labour intensity. This in turn triggers a circular effect enhancing again an increase in employment and therefore an increase in consumption of households and government in Region 2.

Stated more generally, peripheral (agricultural) regions in their growth cause increased demand for services, which such regions usually import from neighbouring central regions.

[10] These values for the labour intensity refer to the share in production costs, i.e. a value of e.g. 0.22 indicates that 22% of production costs are wage payments.

Tab. 11 : Effects on regional GDP and employment through expanded use of biomass for energy production in Region 1 and Region 2 in the BAU scenario 2045.

	import quota[1]	regional GDP		Employment	
		Region 1	Region 2	Region 1	Region 2
		change in %		persons	
single home heating systems (15 kW)					
wood chips	10%	1.39	0.06	1226	178
wood logs	10%	1.59	0.04	1047	167
wood pellets	0%	1.26	0.05	951	194
poplar pellets	8%	0.65	-0.02	-399	-152
agro pellets (Miscanthus)	8%	0.94	0.05	322	112
agro pellets (grain)	8%	0.84	0.02	-81	-5
agro pellets (straw)	8%	1.30	0.11	1222	364
Miscanthus (whole plant)	8%	1.40	0.04	484	81
energy corn (whole plant)	8%	0.56	-0.11	-1721	-581

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

5.1.4 Sensitivity of results

We test for the sensitivity of our results (GDP and employment) with respect to changes in various parameters. These include energy prices, the interest rate and the global trade elasticity for agricultural commodities.

First, for the assumption on energy prices we find the following: Higher energy prices favour the usage of biomass since biomass production becomes more attractive. In quantitative terms, some 50% higher energy prices results in some 40% increase in regional GDP.

Second, the level of the real interest rate determines the capital costs of an investment. Compared to fuel oil heating systems, biomass technologies show a very high capital commitment and thus high investment costs. It follows that the level of the real interest rate considerably influences capital costs. The interest rate affects the competitiveness of biomass technologies, simply because they are getting more expensive. Low interest rates favour the use of biomass technologies, whereas high interest rates hinder energy production from biomass due to high capital costs.

Third, assumptions on the global trade elasticity are only affecting the results of agricultural based technologies. A higher elasticity increases the amount of agricultural imports. This is because prices for agricultural commodities from biomass production become relatively high. Another effect is on land prices, which now do not increase that strongly (11% less with an elasticity increased by factor 3).

5.2 Future scenario of a biomass expansion

In order to investigate how economic effects of energy production from biomass change under the possible future economic situation described in section 4.3 we exemplarily show the effects of a 2000 TJ expansion of energy production for

- a forestry based technology (wood pellets) and
- an agricultural based biomass heating technology (agro pellets based on miscanthus).

The use of wood pellets is cost-efficient, while the costs of a heating system based on agro pellets generally exceed fossil fuel costs, with miscanthus ranking best among technologies based on agro pellets (see Tab. 6 for cost efficiency of technologies).

5.2.1 Effects on regional GDP and employment

The observed change in results occurs inter alia due to changing energy prices over time and due to different technical developments across sectors. In addition, the cost per kWh heat is in general changing since price levels in the 2040ies are different from those in the year 2003. For example, labour is getting more expensive and affects production costs according to their labour intensity.

What might happen under future condition are a sharp increase in the cost per kWh heat produced by a fossil based technology and a slight increase in the cost per kWh heat from biomass. Hereby, the change in costs for biomass technologies depends among other things on how much energy they need in production. This implies that the cost of bio-energy gets relatively cheaper.

Comparing the two selected technologies, we find an improvement in the economic performance in the case of both heating systems, yet a stronger development of miscanthus pellets. Results are presented in Tab. 12. Changes are reported relative to the implementation of biomass technologies in the BAU scenario for 2045 (those results are presented in Tab. 11). There are two reasons behind this observation: Firstly, wood pellets, in contrast to miscanthus pellets, are characterised by a high labour intensity. The increase in the wage rate (from 2003 up to 2045) is a multiple of the increase in the price of capital as well as the price of land. Therefore, the production of miscanthus is getting relatively cheaper. Secondly, the production of wood pellets requires a higher amount of diesel, which shows in the BAU scenario of 2045 the second highest price increase of all commodities. It follows that the production costs of wood pellets increase more than do the costs for miscanthus pellets.

Tab. 12 : Effects on regional GDP and employment through expanded use of biomass for energy production in the BAU scenario (low energy price scenario) and a high energy price scenario in 2045.

	import quota[1]	regional GDP		Employment	
		Region 1	Region 2	Region 1	Region 2
		change in %		persons	
single home heating systems (15 kW), Year 2045					
wood pellets	0%	2.72	0.16	957	297
agro pellets (Miscanthus)	8%	3.13	0.14	464	286
single home heating systems (15 kW), Year 2045 - high energy price assumption					
wood pellets	0%	2.83	0.14	899	269
agro pellets (Miscanthus)	8%	3.29	0.13	423	261

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

5.2.2 Sensitivity of results with respect to energy prices

In the recent past we observed a dramatic increase in energy prices, and their future development is very much uncertain. For this reason Tab. 12 also shows the economic performance and employment effects of the two biomass heating technologies under different assumptions on energy prices.

In doing so, we assume the energy price to increase by further 20% compared to the BAU 2045 scenario (see Tab. 9) resulting in an oil price which is about 55% higher compared to that in 2003 (real price increase). Note that with this assumption the BAU scenario changes dramatically indicating the dependence of the economy on cheap energy.

The two lower lines in Tab. 12 present the results for the economic assessment of heat produced with miscanthus pellets and wood pellets under the changed future conditions on energy prices. As for economic performance and employment effects, we get a similar picture than we did before comparing the implementation of biomass technologies in 2003 relative to the 2040ies in the low energy case. The difference is mainly in the magnitude of effects. Again, miscanthus pellets are gaining more from high energy prices than do wood pellets. This result stems from a relative increase in production costs of wood pellets due to a cheaper price of capital relative to the price of labour on the one hand and due to the higher amount of diesel needed for production on the other hand.

6 Summary and outlook

In section 1 of the report, mitigation and adaptation strategies are analysed as a response strategy to climate change, setting a focus on biomass as a feedstock of energy production in Austria. Given that a certain degree of climate change cannot be avoided anymore regardless of the success of global mitigation efforts, societies have to adapt to climate change and its impacts. Adaptation in terms of adjusting practices and processes in response to the threat of climate change can significally reduce negative impacts, e.g. on biomass production. Therefore, adaptation strategies are inter-related to mitigation strategies because the potential of biomass to reduce emissions from energy use depends on the efficiency of adaptation measures implemented.

For the second year of the research project we aim at analysing specific adaptation measures in the agricultural sector, considering adaptation plans from the literature and deriving best practice instruments to be applied in Austria. We investigate into the region's vulnerability to climate change and assess the potential benefits of adaptation with respect to feedstock production as a means of mitigation.

This study reported on the biomass potential in a regional context, both present and as estimation for the future. It set a basis for the determination of the mitigative potential of regional biomass supply in the study region by assessing the fraction of additional bio-energy in total regional energy demand in the future target period (the 2040ies). In order to specify the options and to quantify the effects of mitigating climate change and adapting to its impacts, a CGE model was developed and applied to South-Eastern Styria. A quantitative assessment of a biomass extension by technology both for the reference year and for a future period was carried out, reporting on regional GDP and employment effects and thus preparing the CGE framework for subsequent policy analysis.

The aim for the second year of the present project is to include the impacts of the climate change. This will affect the work carried out so far at different ends. In terms of technology, an extension by the climate component means a change in the cost structure (input structure) for energy production. Moreover, considering the climate component includes the assessment of a shift in agricultural and forestry output under changing climatic conditions. We will thus cooperate with regional climate modellers and combine the data on altering meteorological parameters with agricultural expertise. In doing so, we seek to analyse the consequences of climate change in the study region as well as the arising implications for the potential output of biomass for energy purposes by 2045. This leads us to the CGE model, which will be used to simulate the interlinkage of adaptation and mitigation strategies in such an environment and which will thus be extended to include climate change impacts. An example would be to implement the so far calculated additional biomass potential and its mitigative potential into the CGE model and to study the thereby changed economic performance in the addressed region and its surroundings.

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