# Strategies for a sustainable mobilization of agricultural bioenergy potentials
# (“ALPot”)

## Summary


**Project leader**

*Vienna University of Technology,*
*Energy Economics Group*

Gerald Kalt

Lukas Kranzl

**Partners**

*Austrian Energy Agency*

Heidelinde Adensam

*Im-plan-tat Reinberg und Partner*

Matthias Zawichowski

*University of Natural Resources and Life Sciences Vienna,*
*Institute for Sustainable Economic Development*

Bernhard Stürmer

Erwin Schmid



Vienna 2010

## Objective

With a share of about 15% of the total primary energy consumption (2008), biomass is the most important source of renewable energy in Austria. In recent years, there has been a significant increase in biomass use for energy, partly due to the growing use agricultural resources (such as rapeseed for biodiesel and wheat for bioethanol production). With regard to energy policy objectives in the field of greenhouse gas mitigation and renewable energy sources (Kyoto Protocol, Renewable Energy Action Plan, "2020 targets" etc.), it is expected that the importance of renewable energy will continue to rise in the coming years and decades. Regarding the future role of agricultural bioenergy production, however, several aspects demand close examination. In this project the following key questions are examined:

- What are the potentials of agricultural biomass in Austria, taking into account bio-physical and economic framework conditions?
- To what extent do decision-making structures of agricultural enterprises or farmers, farm types and various driving and restraining factors have an impact on the feasibility of potentials for agricultural biomass production?
- What is the achievable contribution of agricultural biomass to the Austrian energy system up to 2030 and to the fulfilment of energy and climate policy objectives?

## Methodology

The methodological approaches include economic analyses as well as simulations of decision-making structures with an agent-based model (the input data are based on interviews with farmers and agricultural stakeholders) and a spatially explicit modelling approach, based on geographical information systems.

In a first step, data on the current state and structure of agricultural biomass use as well as the utilization paths and technologies applied are analyzed. The current importance for the Austrian energy supply is discussed. Consecutively, consistent scenarios for the future of agro- and energy-economic framework conditions are derived. These scenarios are a common database for the following modelling approaches.

The willingness and initiative of farmers is a precondition for increasing energy production from agricultural biomass. Therefore, decision-making structures which are derived from interviews with farmers and stakeholders are analyzed with the use of the **agent-based model** *AGRIEN*. Basically, agent-based models simulate the operations and interactions of agents (farmers, in this case), in an attempt to assess the effects of individual actions, which are based on specific rules for decision-making, on an aggregated level. The decision-making structures of the farmers in *AGRIEN* depend on the farm type and size, their available agricultural land, regional characteristics etc. These parameters determine, to what extent and under which conditions each agent is willing to use agricultural land for biomass production. Exogenous scenario assumptions (primarily agro- and energy economic framework conditions) are varied in order to derive different scenarios and gain insight into the effect of different scenario settings. The core results of the model are the share of agricultural land (including arable land and grassland) which is used for biomass production on a regional and national level as well as the number of agricultural enterprises involved.

The natural conditions (soil, radiation, precipitation etc.) of agricultural land in Austria, together with the requirements of the different crop species are a major determining factor for an enhanced energy crop production. A **spatially explicit modelling approach, based on geographic information data** (GIS-model) is used to analyze the constraints which arise from the natural conditions and to derive scenarios for the arable land use in Austria. The core model assumption is that each area element is occupied with the crop species which is suited best according to the natural conditions of the area and the requirements of crops. Crop rotation is also taken into account. The model results are dynamic, spatially explicit scenarios of arable land use, as well as according production volumes. Different scenarios are derived by applying variations in crop rotation rules and other setting.

In contrast, the **agro-economic model cluster** (consisting of the models *CropRota*, *EPIC* and *BiomAT*) is used to analyze the economic potentials of energy crops. Again, natural conditions like soil, precipitation etc. are taken into account as well as crop rotation. However, in this modelling approach, economic framework conditions (market prices, variable costs, subsidies etc.) determine the choice of crops and the resulting production volumes. Supply curves for energy crops are derived from different simulation runs with varying producer prices.

Consecutively, the economics of various utilization paths for generating heat and/or electricity as well as transport fuels from agricultural biomass are analyzed. Scenarios for the development of bioenergy use in Austria with a focus on the utilization of agricultural biomass resources are derived with a **simulation tool for the bioenergy sector** (*SimBioSe*). The basic modelling approach is to simulate the future deployment of bioenergy plants (up to 2030), based on profitability analyses. The implications of different economic framework conditions (primarily fossil fuel price scenarios) as well as subsidies for bioenergy on the development of the bioenergy sector, greenhouse gas mitigation and other parameters are assessed. Furthermore, cost-benefit analyses for different focuses concerning energy crop species (conventional crops, biogas plants, lingo-cellulosic plants) and applications (heat and/or electricity generation or mobility) are carried out.

### Decision-making structures and agent-based model

With regard to the decision-making structures of agricultural enterprises, three different decision types are identified: innovative, traditional and utilitarian enterprises / farmers. According to the results of the survey, innovative famers are the smallest group (5 to 10% of agricultural enterprises in Austria). They are characterized by a high willingness to “try something new”, even if it is risky. They are motivated by personal attitudes rather than economic incentives.

Traditional enterprises are the biggest group (75 to 80%). Their decision-making structures depend on parameters like income situation or production characteristics. For example, enterprises with livestock often do not have the opportunity to change their production at short notice or such who have forest land are most likely to establish short rotation plantations. The decisions of utilitarian farmers or enterprises are highly based on prices and market expectations. In contrast to traditional farmers, their decisions are not easily influenced by subsidies.

The interviews reveal a multitude of inhibitory as well as supporting factors for agricultural energy production. These influencing factors are subdivided into the following categories: personal, internal, external and natural factors. Examples for personal factors are personal preferences, attitudes or the readiness to take risks. Internal factors include the characteristics of the agricultural enterprise, such as income situation or recent investments and forthcoming investment needs. External factors comprise subsidies, market prices or contract conditions. Natural conditions and the requirements of energy crops are summarized in the category “natural factors”.

The main result of the agent-based mode *AGRIEN* are the shares of agricultural land (including arable land and grassland) which are used for biomass production in different scenarios. These scenarios differ with regard to the agro- and energy economic framework conditions, which are characterized by indicators ("favourable"/"pro", "trend" or "adverse"/ "contra"). The simulation results show that the agricultural land which is used for biomass production in 2030 varies from 4 to 30%, depending on the framework conditions (Table 1). The highest share is reached in a scenario with adverse agro-economic conditions and favourable conditions for bioenergy.

Due to the geographical conditions as well as the distribution of farm types and sizes, areas in the North-East of Austria make the most significant contribution. In regions with a high importance of livestock breeding (primarily around the Alps), the share of land used for biomass production is low, even under favourable conditions for bioenergy.

*Table 1: Summary of the simulation results from the model AGRIEN: agricultural land used for biomass production in 2030*[1]

| Area used for bio-energy production as share of total agricultural land | | Agriculture | | |
|---|---|---|---|---|
| | | Pro | Trend | Contra |
| Bioenergy | Pro | 21 % | 28 % | 30 % |
| | Trend | 8 % | 10 % | 12 % |
| | Contra | 4 % | 5 % | 6 % |

| Area used for bioenergy production in ha | | Agriculture | | |
|---|---|---|---|---|
| | | Pro | Trend | Contra |
| Bioenergie | Pro | 444,211 | 582,596 | 630,242 |
| | Trend | 175,058 | 214,713 | 238,963 |
| | Contra | 81,402 | 107,133 | 128,401 |

**GIS-Model**

The GIS-model is used to derive scenarios for arable land use. The core assumption for this modelling approach is that each of the approximately 46.000 area elements representing the total arable land in Austria is occupied with the plant species which is most suitable according to the natural conditions of the area element and the specific requirements of each plant species. Furthermore, it is assumed that the natural conditions are not modified, for example with the use of chemical fertilizers. The core results are the production volumes and regional distributions of crops. Therefore, conclusions about the suitability of energy crops on arable land in Austria can be derived. Variations in the restrictions for crop rotation and other parameters result in different outcomes and provide closer insight. The following figure shows the aggregated results under default settings and in the different variants.

Compared to the statistical data on arable land use in Austria, this approach basically leads to a pronounced extensification with high shares of grasses. By applying restrictions for the cultivation of grasses on arable land, higher outputs of conventional crops like wheat or maize are achieved (scenarios "enhanced intensification" and "enhanced crop rotation" I to III). Apart from that, the simulation results reveal that the requirements of "new" energy crops (especially short rotation coppice) are often better suited for the natural conditions than those of conventional crops. Hence, the results indicate that an enhanced production of energy crops can basically be brought in line with environmental aspects and does not necessarily result in an intensification of land use.

[1] The agricultural land considered here includes the total arable land and grassland, except for the region "Hochalpengebiet" (Alps region).

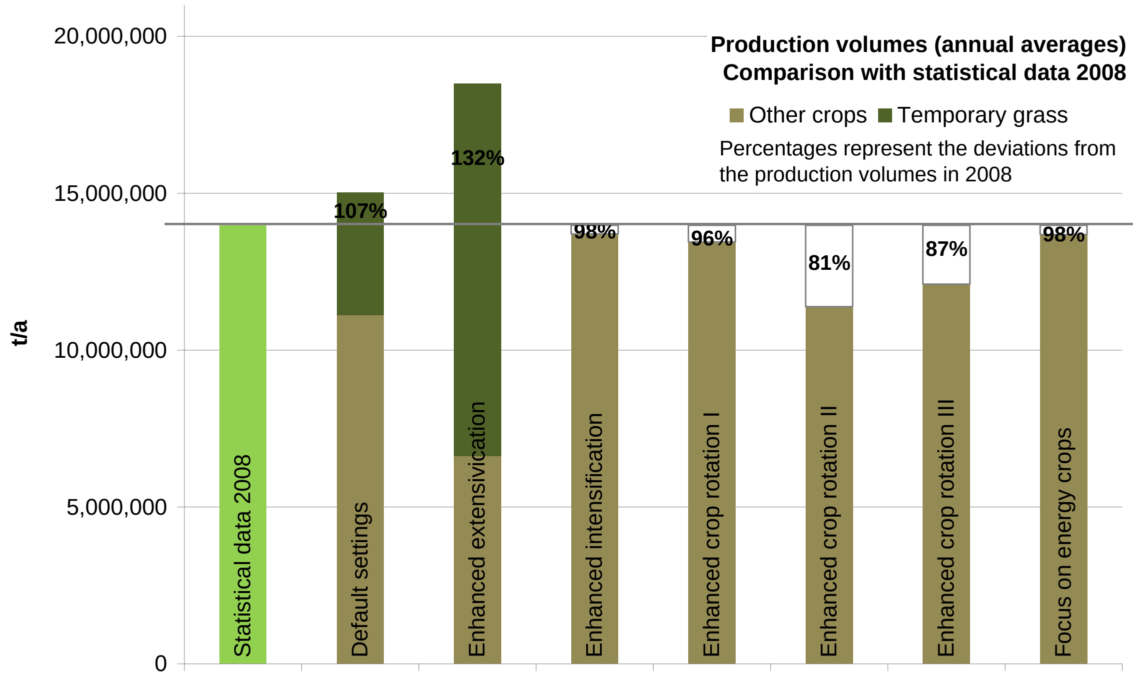


*Figure 1: Aggregated simulation results of the GIS-model: Comparison of the production volumes (annual averages) in the different variants with statistical data 2008*

## Agro-economic modelling

For the assessment of the economic potential of energy crops in Austria, the following aspects are taken into account: (1) the influence of regional conditions on crop yields, simulated with the bio-physical process model *EPIC*, (2) regionally specific crop rotation schemes, determined with the model *CropRota* and (3) specific opportunity costs and alternatives which are assessed with the model *BiomAT*. More precisely, *BiomAT* is a land-use optimization model which identifies the most profitable option for each municipality, taking into account natural conditions (soil, precipitation and topography). In order to determine relations between prices and production volumes, prices for energy crops are varied and the reactions in production volumes observed. Increasing prices generally result in an intensification of land use. However, to some extent this is counterbalanced by the Austrian program for environmental agriculture (ÖPUL). Hence, financial incentives (price signals) required to enhance energy crop production are relatively high.

The simulation results also illustrate that due to the increasing competition for arable land, an increasing production of energy crops results in a decline of food and feed production (primarily wheat and grain maize; see Figure 2). Apart from that, changes in utilization patterns can be observed, for example wheat is increasingly used as a feedstock for ethanol production or corn silage for biogas plants instead of feed. The most significant changes in arable land use are caused by an increasing cultivation of short rotation coppice.

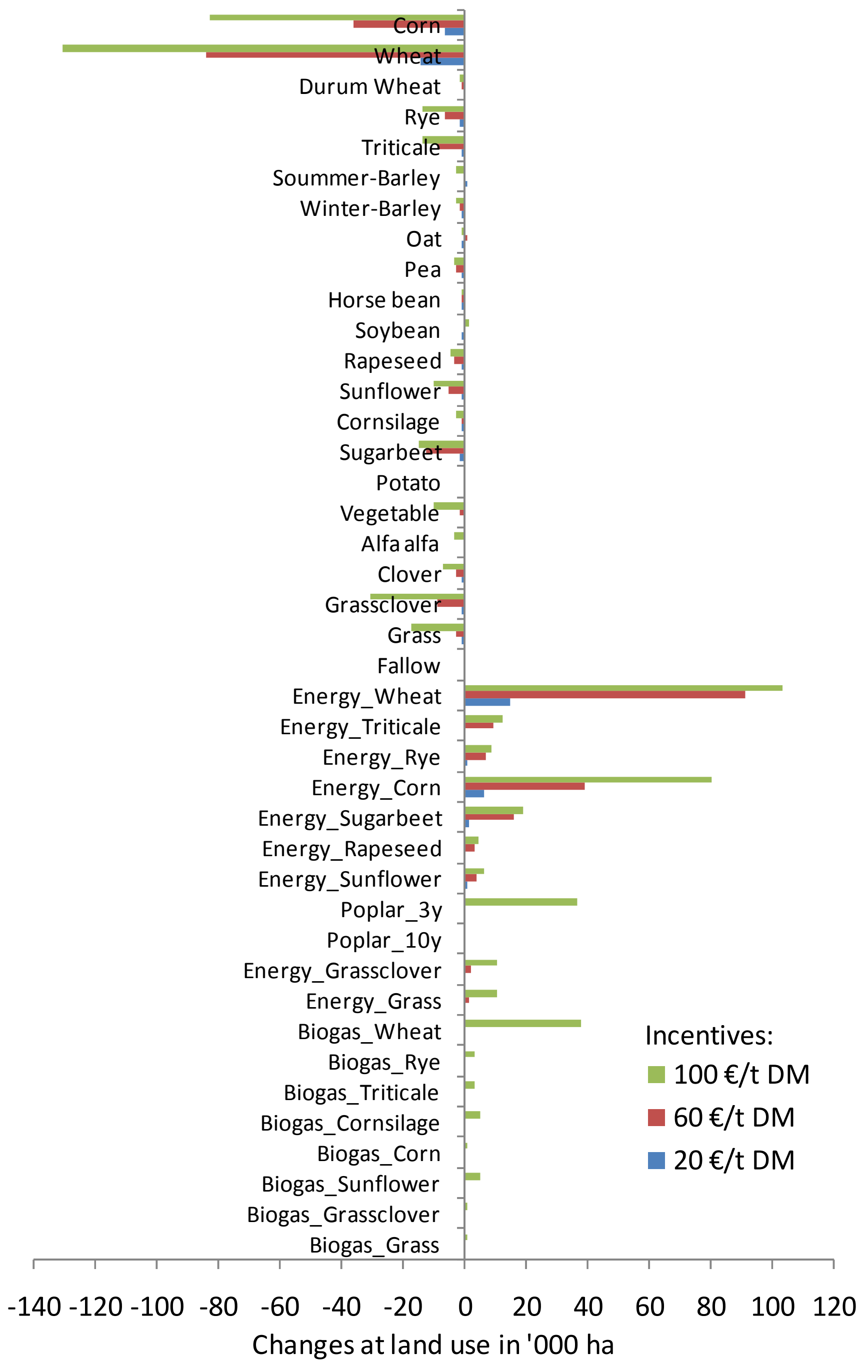


*Figure 2: Changes in arable land use resulting from incentives for the production of energy crops (20 €/$t_{DM}$, 60 €/$t_{DM}$ and 100 €/$t_{DM}$)*

**Simulation of the bioenergy sector**

With the simulation model *SimBioSe*, scenarios for the Austrian bioenergy sector are developed. The simulation algorithm is based on profitability analyses of the different biomass utilization paths. Economic framework conditions like subsidies or prices for fossil fuels as well as supply curves for biomass (which are derived from the results of the agro-economic modelling approach) are the main influencing parameters. In each simulation period (each year throughout the period 2010 to 2030), bioenergy plants (heat generation and combined heat and power plants as well as biofuel production plants) are deployed if they are competitive under the framework conditions of the current simulation period and if there are free demand-side and resource potentials available. Hence, biomass resources are only used if their utilization is economic compared to the respective fossil-fuelled reference system. Hence, with the model it is possible to analyze the effects of different support schemes and price developments on the utilization of (agricultural) biomass resources, and assess the achievable contribution of biomass for the Austrian energy sector.

The following groups of scenarios are analyzed: *No Policy Scenarios* (no subsidies or tax incentives for bioenergy), *Current Policy Scenarios* (current subsidies and tax incentives) und *Specific Support Scenarios* (increasing levels of financial incentives for certain utilization paths). The results of the *No Policy* and *Current Policy Scenarios* are evaluated primarily with regard to the importance of agricultural biomass to the energy supply. The main purpose of the *Specific Support Scenarios* is to illustrate the support costs vs. benefits (greenhouse gas mitigation, substitution of fossil fuels) of different utilization paths and to derive conclusions regarding favourable focal points for funding. With regard to the fossil fuel price developments, two scenarios are distinguished: *Level 2006* (real prices remain constant at the level of the year 2006) and *FAO/Primes* (increasing real prices for fossil fuel with a crude oil price of more than 100 $\$_{2007}$/bbl in 2020).

Under the support scenario *No Policy* and the price scenario *Level 2006* practically no utilization paths of energy crops are competitive. Until 2030, the only notable contribution of agricultural biomass to the energy supply originates from the use of straw and (to a very moderate extent) plant oil in CHP plants. However, in this scenario the bioenergy sector is dominated by the use of forest biomass and wood processing residues for residential and district heating as well as steam generation. The main difference in the price scenario *FAO/Primes* is the clearly higher exploitation of forest biomass potentials for heat generation. Apart from that, electricity generation in large biogas plant (with a power of 500 $kW_{el}$ and more) using maize silage is to some extent competitive. Still, agricultural biomass plays a rather insignificant role.

The *Current Policy Scenarios* illustrate to what extent agricultural biomass could be utilized in a profitable way if the current support schemes and tax incentives are maintained. In contrast to the *No Policy Scenarios*, these scenarios show a substantial increase in the demand for energy crops, and the question of what type of energy crops are preferred, gains in importance. Therefore, three scenarios with different focuses of energy crop production are assessed: *Conventional crops*, *biogas plants* and *ligno-cellulosic feedstocks*. The best cost-benefit ratio as well as the highest expansion of agricultural bioenergy is achieved with a focus on ligno-cellulosic biomass (short rotation coppice). The greenhouse gas reduction from agricultural bioenergy in this scenario accounts for 3 Mt $CO_2$-Equ. in the year 2020 und 5.7 Mt in 2030. The savings of fossil fuel consumptions amount to 15 TWh in 2020 and 27 TWh in 2030. However, the arable land used for energy crop production accounts for about 300,000 ha in 2020 and 600,000 ha in 2030 (close to one fourth/half of the total arable land in Austria). The savings achievable with a focus on *conventional crops* and *biogas plants* are clearly lower. Figure 3 shows a summary of the simulation results: the primary energy consumption of biomass in the *No Policy* and the *Current Policy Scenarios* in 2020 and 2030, subdivided into agricultural and other biomass.

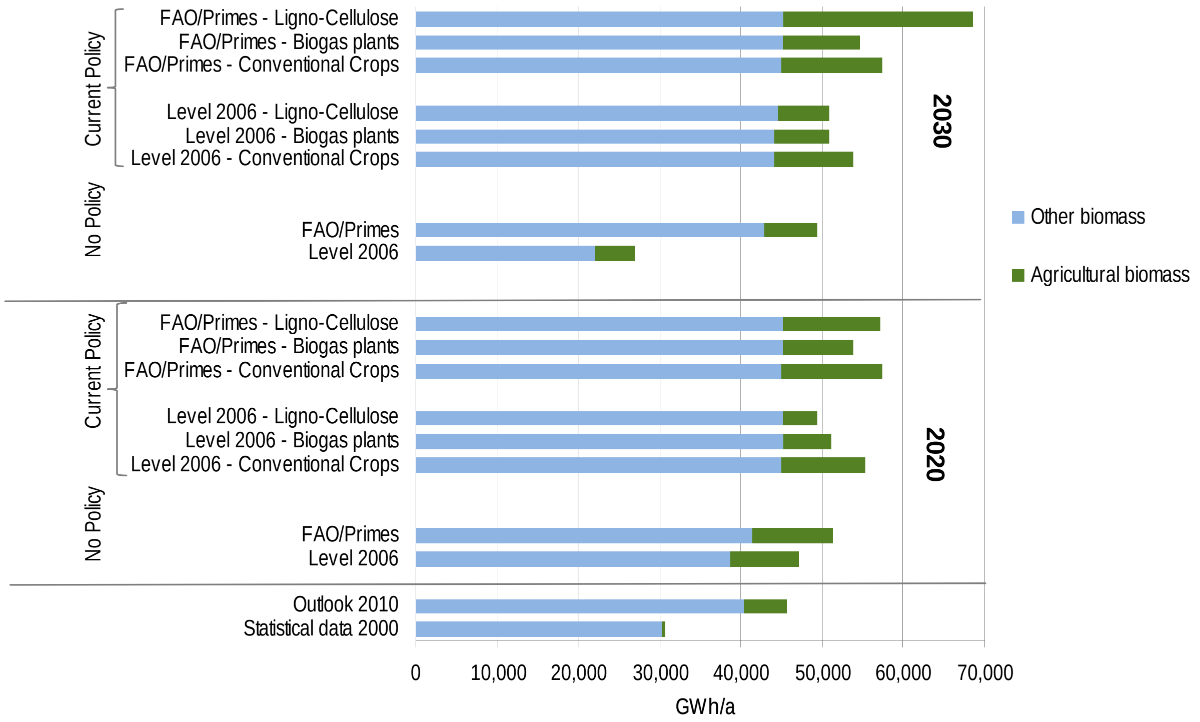


*Figure 3: Summary of simulation results of the model SimBioSe: primary energy consumption of domestic biomass in the No Policy and the Current Policy Scenarios in 2020 and 2030; "FAO/Primes" and "Level 2006" indicate the price scenario assumed, "Conventional crops", "Biogas plants" and "Ligno-cellulose" the focus of energy crop production. Catch crops and biomass from grassland are not considered here.*

**Interpretation and conclusions**

The future importance of agricultural bioenergy does not only depend on agro- and energy economic influencing parameters, but also personal preferences and attitudes of farmers. An increase in energy crop cultivation is associated with different trade-offs, which need to be analyzed and taken into consideration within (bio-)energy strategies. Especially the risks of an increasing competition for agricultural land and likely impacts on food and feed production as well as environmental aspects need to be addressed.

However, there are also clearly positive aspects of agricultural biomass for energy, such as the potential to reduce greenhouse gas emissions and to enhance the competitiveness of the agricultural sector. By creating opportunities for additional income, agricultural bioenergy production can contribute to rural development and landscape conservation. Furthermore, with a diversification of energy sources a (partial) mitigation of fuel price fluctuations may be achieved. Potential risks are that an increasing demand for energy crops may result in a stronger coupling between agricultural and energy markets and put food security in developing countries at risk. With regard to the diverse biomass fractions and utilization paths, regional characteristics should be taken into account in the design of strategies for an efficient use of agricultural biomass potentials.

The achievable contribution of agricultural bioenergy to a future energy supply in Austria highly depends on strategic decisions and energy policy instruments applied. However, the project results indicate that in any case, the economic potentials of agricultural bioenergy are clearly lower than technical potentials stated in literature. (Of course, the economic attractiveness heavily depends on assumed energy price scenarios.) Hence, the results stress the importance of an efficient management and utilization of resources; not only in the field of fossil fuels but also with regard to agricultural land, biogenous resources and food supply.