Optimization of Biomass Utilisation According to Efficiency Criteria

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***Abstract* - Increasing effects of climate change and limited fossil energy resources evoked new policy plans in Germany and the EU for an 'energy transition' process. In this process focus is on reduction of greenhouse gas emissions. Besides other renewable energy sources in Germany efficient bioenergy sources are promoted. An optimized and/or goal-oriented use of available biomass feedstock for energetic conversion requires a detailed analysis of bioenergy production lines according to technical and economic efficiency indicators. Accordingly, relevant parameters of selected production lines supplying heat, electricity and fuel have been studied and used as data base for an optimization model. Most favorable combination of bioenergy lines considering political and economic objectives (presented as different scenarios) are analyzed by applying a specifically designed linear optimization model. Modeling results shall allow deduction of political courses of action.**

Introduction

Increasing pressure due to adverse change of the Earth's climate caused German and the EU's policy to put new regulations for an 'energy transition' (BMWi, 2011; European Commission, 2013). Reduction of greenhouse gases is main focus of the climate policy. Recently, it becomes increasingly clear that limits are set by important unchanged goals of economic growth. Therefore, policy aims a transition to renewable energy sources besides drastic energy savings and, in particular, promotes efficient bioenergy sources with priority.

In the initial phase of renewable energies expansion priority was given to the development of modern technologies. As first generation technologies current sources such as biofuels, biogas, wind turbines and photovoltaic are well developed. In the actual phase, competitive usages of limited biomass resources become visible, both in food security and feed production as well as in various energy sectors (heat, electricity, fuels) due to the versatile character. Optimal usage strategies of limited biomass resources considering food security and climate protection targets are future challenge.

This paper presents partial results of a research project on optimization of biomass usage according to efficiency criteria and food security aspects funded by the German Federal Ministry for Food and Agriculture. Overall objective of the research project is analyzing optimal use of limited agricultural land resources for production of renewable resources and land-related residues (e.g. straw) with regard to highest efficiency of climate protection targets at lowest possible economic costs.

Methodological approach

First of all, available land potentials for production of energy crops of 148 important agrarian nations have been analyzed (see Zeddies et al., 2012). Examining options for energetic biomass conversion (such as biofuels, heat and electricity) and to quantitatively describe effects of policy measures used are objectives of efficiency analyses.

Most favorable combination of bioenergy production sources considering political and economic objectives -presented as different scenarios- are analyzed by applying a specifically designed linear optimization model (LP) for Germany. This model has been developed in order to optimize the allocation of limited available biomass feedstock under consideration of competitive bioenergy production lines. By choice of objective function and configuration of restrictions the LP approach also allows to show availability of biomass over time (2012-2050) as well as different (political) defined strategies; e.g. fuel quotas as maximum or minimum limits, limitations on transfer payments (current limit of electricity rate) and/or restrictions for different energy crops.

Model structure is designed in a way that, firstly, also all available residual and waste materials can be included and, secondly, other new and relevant technologies can be implemented in the model. As new technologies basically compete with first generation techniques for identical biomass feedstock, crop residues and waste materials, the model allows simultaneous optimization of bioenergy techniques of first, second and third generation using (stagnating or increasing) biomass resources that are available over time besides food and feed supply and agricultural exports.

The linear equation system represents technical coefficients ('activities') for each bioenergy production line as well as relevant restrictions on biomass availability. The objective function minimizes additional costs for bioenergy supply compared to fossil energy supply on macroeconomic level. These additional costs can also be considered as subsidies needed for an adequate energy supply based on renewable resources.

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Objective function (Z): $Z = \sum_{j=1}^{n} c_j * x_j \rightarrow Min!$

Restrictions (R_i): $R_i \geq \sum_{j=1}^{n} a_{ij} * x_j$ for all i

$x_j \geq 0$ for all j

Z: value of objective function
R_i: factor capacities for the restrictions
c_j: objective coefficient of the process
x_j: decision variable (volumes of the process)
a_{ij}: factor demands and supplies of the process
i: number of restriction variable
j: number bioenergy production line

Biomass availability of current situation and future date is set by integrating model restrictions. Limitation of land availability in Germany represents maximum restriction. Thus, area of straw residuals can only be seen as a limitation for all types of bioenergy, i.e. combustion, fuels, etc. With consideration of sustainability restrictions available straw potential accounts for approx. 2 million hectares and/or approx. 8 to 13 million tons. Changes in crop ratio lead to decreasing straw potential at increasing silage maize area and/or increasing amounts of straw by extension of rapeseed and grain cultivation in accordance with humus accumulation. Limitation of cultivation area of short rotation coppice (SRC) is given by barriers of acceptance especially by growers who fear long-term fixation in production. Although, SRC, Miscanthus and other permanent crops already could be used efficiently because of economic and climatic reasons, currently, 12,000 ha under cultivation of SRC is much less than expected.

Restricted land and biomass availability can be increased if biofuel production lines are realized. Biomass conversion into biofuels delivers by-products such as valuable animal feed which leads to land release in Germany and import countries. Thus, land productivity of biofuels produced from oilseeds or grain is increasing.

In order to consider non-monetary benefits, which currently are not attained in economic entities, appropriate credit notes are allocated in an additional calculation. It is assumed that credit notes, e.g. credits for greenhouse gas (GHG) mitigation, are implemented by policy instruments in a way (emission trading system, subsidies, tax reduction, etc.) that corporations exactly receive full amount of credit notes.

In order to demonstrate realization of different political and/or economic targets various scenarios have been modeled. LP solutions of selected scenarios are performed with MS Excel Solver. Model results show shares of bioenergy supply on total energy consumption as well as on heating oil consumption, diesel and petrol consumption. Further, efficiency criteria such as total production costs, profits, CO_2 mitigation and mitigation costs, subsidy payments and others are presented.

Results

Besides 'current situation' (i.e. non-optimal use of bioenergy capacities) an 'optimized current situation' scenario has been analyzed. 'Maximization of GHG mitigation' by favoring bioenergy production lines contributing highest GHG mitigation, 'tax exemption of biofuels' and 'political biomass share targets' (see BMELV, 2009) are only some of the investigated scenarios.

Study results are still under review process and will be open to the public soon. In the following some findings in brief:

- Current use of biomass is not efficient and distorted by subsidy. GHG mitigation costs are relatively high.
- Combustion of biomass is from economic perspective most efficient compared to biogas and biofuel conversion.
- Concerning efficiency in land productivity biofuels are in favor due to valuable by products in biomass conversion process.

Discussion and Conclusions

Study results show that there is a lack especially of medium and long-term orientation and continuity of goals in bioenergy policy. Both are indispensable for an 'energy transition' process. At present, the decision-making structures at national and EU level are partly hindering because introduced measures and regulations of both levels are not always consistent.

Further conclusions are given when review process is finished.

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