Research on Biomass for Energy Production in Europe – the German BEST-Project as an Example

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ABSTRACT

Bioenergy results from transformation of biomass resources such as energy crops, forest and agricultural residues and organic waste into energy carriers including heat, electricity and fuels. In its "Renewable Energy Road Map", the European Union committed itself to a mandatory target of 20% for the share of renewable energies in total energy consumption by 2020 and a compulsory minimum target of 10% for biofuels. Much research has been devoted subsequently to the important question if and how these target lines may be achieved.
In Germany, the broad interdisciplinary and integrated project BEST ("Boosting bioenergy-regions: New system solutions in the divergence of ecological, economic and social demands") investigates how wood biomass can be supplied in in a sustainable way and an ecologically as well as economically attuned approach in example regions. Results show that there are good potentials of enhanced bioenergy utilization, however, also limitations arising from competitions and trade-offs in land use strategies have to be duly considered.

Keywords: bioenergy, Europe, Germany, interdisciplinary research, woody biomass

INTRODUCTION

Energy provision is and has always been a key issue to mankind throughout civilization, and is turning ever more acute, the more industrialized and energy-hungry human societies develop. Among the different primary energy sources, fossil fuels still play a most important role all around the globe, although their reserves are definitely limited and at the same time exploited in an ever increasing pace. Therefore, it is vital for mankind to find substitutes for fossil energy carriers rather quickly, and those substitutes should be provided in a sustainable and environmentally compatible modus, they should not entail high technological risks, and they should be economically acceptable.

The "Renewable Energy Directive" of the European Union established the relevant framework for the promotion of renewable energy in Europe, setting mandatory national renewable energy targets for achieving a 20% share of renewable energy in the final energy consumption and a 10% share of energy from renewable sources in transport by 2020. These goals are headline targets of the European 2020 strategy for growth, since they contribute to Europe's industrial innovation and technological strength as well as reducing emissions, improving the security of energy supply, and reducing the dependence on energy imports. The Directive also involves the simplification of administrative regimes faced by renewable energy, together with improvements to the electricity network, to improve access for electricity from renewable energy into those networks. It established a wide-ranging sustainability scheme for biofuels and bio-liquids with compulsory monitoring and reporting requirements. All biofuels used for compliance with the 10% target which benefit from national support are required to comply with

the scheme.
A report issued by the EU (EU-COM 2013) states that with respect to renewable energies, overall a substantial initial start at EU level has already been achieved, but with slower than expected removal of key barriers to a growth of the sector, which makes additional efforts by the member states necessary. According to the report, at EU and member states level, further efforts are needed in terms of administrative simplification and clarity of planning and permitting procedures and for infrastructure development and operation. And further efforts beyond that are needed regarding the treatment and inclusion of renewable energy production within the electricity system.

Energy supply is one of the big actual challenges to modern industrialized societies. Their energy demand is high, and besides of that, it is a generally accepted claim today that energy should be produced as much as possible in a sustainable manner and with controlled or minimized environmental risks. This awareness is a consequence of various past and present environmental crises which came along with our exploitation of energy sources (e.g., air pollution, acidification of rain, water bodies and soils, emission of greenhouse gases, hazards from nuclear waste etc.).
Because fossil fuel reserves are finite, new innovative approaches to the production of energy are required. Ideally, these should offer sustainably produced energy with minimal transport losses along the way to the place of consumption. Utilization of bioenergy (i.e. energy generated from biomass) can make an important contribution to a sustainable and climate-neutral energy supply. Biomass contributes already more than 90 % to renewable energy sources for heat supply in Germany, and wood biomass delivers the biggest share of that. Wood from forest is under steadily increasing demand during recent years, and a strong competition evolved between the energetic and material uses of forest wood. In this context it is particularly noteworthy that the energetic use of forest wood exceeded the material use for the first time ever recorded in Germany in 2010 (Mantau, 2012). Therefore, also prices for fire wood are strongly increasing and a "wood supply gap" of more than 30 million m^3 is predicted for the year 2020 (Thrän et al. 2009).
Furthermore, bioenergy production is also confronted with diverse user interests based on limited land resources and rising competition for space. Additionally, environmental consequences of bioenergy production still have to be fully assessed.

On this background and with a specific focus on woody biomass, the BEST project consortium was composed of scientists from Göttingen University together with nine further research institutions and regional energy management bodies, who together responded to the call for proposals of the German Federal Ministry of Research and Education (BMBF) entitled "Sustainable Land Management" in 2009. After success of the proposal, BEST commenced its work in September 2010 and continued until August 2014. Core motivation of the consortium was to investigate and to demonstrate

- how wood biomass production for energetic and (cascaded) material use can be boosted in example regions which are representative of the central German intermediate mountain ranges
- how such production can be accomplished in a sustainable and environmentally compatible manner
- how wood biomass sources both from existing forest land and (newly established) fast growing plantations could contribute to the overall regional yield
- which economic gains may be facilitated by such production and which economic risks may be involved, an finally
- which ecological consequences the new avenues of wood biomass production may entail.

In order to test and to demonstrate the practical applicability of project results from the beginning on, the research activities were located in two German "Bioenergy Regions": the Göttingen county and the Thuringian field plain. Their development represents ongoing processes in similar regions throughout Germany.

In the present paper, we first examine the general state of affairs and the perspectives regarding bioenergy utilization in Europe, so that this can be put in a perspective with the respective situation in Southeast Asia in general, and in Thailand in particular. Then we turn to current research on bioenergy in Europe and show the variety of topics covered. Finally and as an example, we report from the German "BEST" joint project, which has a focus on wood-based bioenergy, primarily for thermal use, but also for cascaded utilization chains from material use to finally thermal use, which may involve a much higher creation of value than energy wood alone would provide. We end with conclusions on the potentials but also on the apparent limitations of the contributions of bioenergy to a future energy mix.

BIO-ENERGY RESEARCH IN EUROPE AND THE GERMAN "BEST"-PROJECT

Bioenergy use in Europe

The trend of growth in renewable energy supply (stratified by the different sectors of origin and as averaged total) is shown in Fig. 1 (from EU-COM 2013), expressed as the share of renewables in each category over the recent years. In Europe, bioenergy is contributing to all three sectors (heating, electricity, and transport), prominently as energy from wood in the heating sector and as energy from biomass-based liquid fuels in the transport sector, and to a moderate part in the electricity sector, where energy from wind-driven generators prevails.

However, a deeper analysis which considers current policy initiatives and various barriers to renewable energy advance reveals a less optimistic outlook on European and national levels for 2020. The analysis, which relies on a conservative estimate of renewables growth compared to other sources, limits policies to those which are already in place, and additionally reflects the economic crisis, ongoing administrative and infrastructure barriers and policy and support schemes disruption. This suggests future investment may decline or be delayed unless further measures are taken by member states to achieve their targets.

An example of the possible lack of achievement of target lines is given in Fig. 2 for the biomass energy sector, which is in the focus of our consideration here. For biofuels (biomass consumed in the transport sector), the prognosis is pretty much like that of biomass in general: a slight surplus over the planned trajectory in the initial years will decline and, unless further measures are taken, will result in a lagging behind planned production rates. In addition, the EU-Commission has proposed an amendment to the 10% target for renewable energy in the transport sector, requiring greater use of non-food feedstock to contribute towards the target. Greater reliance on advanced feedstock (which produces higher greenhouse gas savings than food-related feedstock) clearly requires additional measures for the target to be reached.

With respect to biofuels, it is also important to note that the EU is not completely self-subsistent, but only to a degree of ca. 80 %, both with respect to bio-diesel and to bio-ethanol (Table 1). So Europe may be partly exporting the problem of competition and trade-off of fuels for food crops to other countries and regions of the world as listed in the table.

From all of the above it can be concluded that overall, by sector and across technology, there has been a compelling initial start in EU renewables growth under the new regime of the EU's Renewable Energy Directive. However, as we look at the further development to be expected, it seems that the economic crisis is now affecting the renewable energy sector, particularly its cost of capital, as it has all other sectors of the economy. This, combined with ongoing administrative barriers, delayed investment in infrastructure and disruptive changes to support schemes, means that without doubt further efforts are needed to achieve the 2020 targets for renewable energy in Europe.

European research efforts to support bioenergy

The European Union (EU) consists currently of 28 member states, and the wider geographic area of the sub-continent comprises even many more countries, which all support research on national level. Hence, there is an overwhelming number of research projects going on in Europe on the sector of renewable energies in general and also on bioenergy in particular. While it is unachievable to summarize or synthesize all those research projects in a short review paper such as the present one, we can get an impression of current research efforts in Europe by looking at the big joint projects which are funded on EU level. The EU organizes its research funding in so-called "Framework Programmes" (FPs) of usually five years duration, and the last one of those was the seventh Framework Programme (FP7) which ran from 2007 until 2013. We present here very condensed summaries of the approaches of the most relevant joint EU projects from FP7 which are of significance to our topic. More information can be found on the web pages of those projects.

One larger group of FP7 projects focuses on improved and more efficient production of liquid fuels. Examples are the BIOCORE project, which will create and demonstrate a lignocellulosic biorefinery for sustainable processing of agricultural residues (wheat and rice straws), short rotation coppice (SRC) wood from poplar, and hardwood forestry

residues into second generation biofuels, bulk chemicals, polymers, speciality molecules, heat and power. (http://www.biocore-europe.org/)
Likewise, the BABETHANOL project proposes solutions for a more sustainable approach of 2nd generation renewable ethanol. The new process, called CES - Combined Extrusion-Saccharification, will be an alternative to the costly processes of the current state-of-the-art. CES will be developed and tested from laboratory up to semi-industrial pilot scale with different new feedstock: Blue Agave Bagass, Palm Oil Empty Fruit Bunches and Olive oil milled husks. A Europe-Latin America lignocellullosic biomass catalogue will also be developed as a further contribution to the expansion of feedstocks. (http://babethanol.com/project.html)
The big joint project OPTFUEL undertakes a first large scale demonstration of the biomass to liquid (BtL) production chain from biomass via gasification and fuel synthesis to the final fuel in the consumer car. BtL production will be demonstrated in an industrial size plant environment (15000 t/a). All production chain components from biomass provision up to market introduction of final consumer fuels containing BtL will be optimized and demonstrated. Well to Wheel (WTW) analysis of this pathway with different parameter studies, dissemination of biomass supply concepts and the demonstration of BtL blend fuel in show cars are included. (http://www.optfuel.eu/)
The HYPE project will approach developing a new process concept which integrates the most relevant achievements in the field of lignocellulosic ethanol and focuses on the reduction of the production costs of bioethanol. The overall aim is to accelerate the implementation of new second generation biofuels from lignocellulosic raw materials. (http://blogs.helsinki.fi/hype-project/)
The objective of the DirectFuel project is to develop photosynthetic microorganisms that catalyze direct conversion of solar energy and carbon dioxide to engine-ready fuels. Through this project new metabolic pathways are constructed which catalyze "direct" production of gaseous fuels for transport "directly from solar radiation". (http://www.uni-freiburg.de/news/news_011010_02)
Finally, in the group of liquid fuel oriented projects, the SUNLIBB projects brings together key researchers and industrial innovators working to overcome technical barriers all along the pipeline for second generation bioethanol production. The range of research spans from feedstock improvement, through innovations in pretreatment and saccharification, the generation of added value products, especially from lignin, and innovations in fermentation. (http://www.york.ac.uk/org/cnap/SUNLIBB/)

A further cluster of projects is focused on improved pathways of biogas production and provision, including the aspects of using algae directly as a resource or as a catalyzer in biogas creation, thus avoiding the frequently criticized employment of potential food crops for the biogas generation.
The project "Biowalk4Biofuels - Biowaste and Algae Knowledge for the Production of 2nd Generation Biofuels" has the aims of developing an alternative, innovative system for the treatment of biowaste and use of greenhouse gas (GHG) emissions to produce biofuels, by using macroalgae as a catalyser. Objectives are the production of a cost-efficient biogas without using cereal crops, to optimise production of biogas per amount of biowaste and CO_2 used, and to broaden the spectrum of types of biowaste which may be used for biogas production. (http://www.biowalk4biofuels.eu/)
The project "AquaFUELS - Alage and aquatic biomass for a sustainable production of 2nd generation biofuels" focuses on research, technological development and demonstration activities of various algal and other suitable non-food aquatic biomasses for 2nd generation biofuels production and its place in the present and future renewable energy sources portfolio of the EU. (http://www.aquafuels.eu/)
"VALORGAS - Valorisation of food waste to biogas" is dedicated to identify optimal ways of gaining biogas from food residues, which are a surprisingly abundant resource. Because of the high water content of food waste, energy can only effectively be gained through biochemical conversion. The research explores the ways in which this energy potential can be realised through effective collection, pre-processing and optimisation of the fuel conversion technology, and considers how integration of these aspects with improving conversion efficiencies can maximise net energy gains. (http://www.valorgas.soton.ac.uk/)

Smaller focus areas of EU research projects are generation of hydrogen as a fuel, and improving the assessment and inventory bioenergy resources, e.g. from remote sensing. The SOLAR-H2 project brings together 12 leading European laboratories to carry out integrated, basic research aimed at achieving renewable hydrogen (H_2) production from environmentally safe resources. The vision is to develop novel routes for the production of a solar-fuel, in our case H_2, from the very abundant, effectively inexhaustible resources, solar energy and water. (http://cordis.europa.eu/project/rcn/85749_en.html)
The objective of "BEE - Biomass Energy Europe" is to harmonize biomass resource assessments, focusing on the

availability of biomass for energy in Europe and its neighboring regions. The major focus will be on methodological and dataset harmonizations and on the opportunities of utilizing both earth observation and terrestrial data for biomass assessments and the integration of multiple data sources. The relevant sectors that will be investigated are forestry, energy crops and residues from traditional agriculture, and waste.
(http://www.iiasa.ac.at/web/home/research/researchPrograms/EcosystemsServicesandManagement/BEE.en.html)

The German BEST project as an example

The main objective of BEST was to develop regional adapted concepts and innovative system solutions for wood biomass production, and to assess their ecological and economic impacts (www.BEST-Forschung.de ; website content in German).
The BEST project is based on a close and interdisciplinary collaboration of researchers from different scientific disciplines ranging from climatology and soil science to wood material science, forestry and resource economics. BEST consists of seven thematic work areas (clusters), which focus on environmental, economic and regional socio-economic consequences of land use concepts:

- Ecological landscape functions
- System solutions for mobilisation of timber reserves
- Innovative wood biomass production systems and techniques
- System solutions for cascade utilisation of materials and energy
- Ecological impact assessment of different cultivation techniques
- Socio-economic assessment of utilisation concepts
- Integration of results, implementation and participation.

Using this approach, utilisation concepts were formulated and comprehensively evaluated. Within the seven thematic clusters, 31 component projects to the overall joint project were in operation. A project coordination team integrated the results gathered from the clusters and individual sub-projects, summarized them, and communicated the outcomes with stakeholders at regional conferences. Opportunities of biomass-based energy systems and material uses for integrated regional development strategies were identified and evaluated jointly with potential users and stakeholders.

In the exercise of communicating the results and really bringing them to the relevant stakeholders in the region of study, the city of Göttingen and its surrounding district, it was an invaluable advantage that one of the partners in the big joint scientific project was the Energy Agency for Göttingen (in German: Energieagentur Region Göttingen, http://www.energieagentur-goettingen.de ; website content in German). They transformed the practically relevant parts of scientific findings and information from the project into hands-on instruction leaflets and brochures, together with an online electronic archive of that information material. Moreover, they organized information meetings for the different target groups of stakeholders involved, such as farmers who were seeking advice on how and where to cultivate short-rotation coppices (SRC) with fast growing wooden species on their land, foresters who were seeking information on how to mobilize additional wood resources for energy supply from their forests, and conservationists who were seeking information on the consequences of the new land use forms investigated by BEST on the local flora and fauna.
Usually, scientists communicate rather among themselves than to the potential users of the scientific knowledge which they generate through their research work. Therefore, it is essential for a big project in applied research such as BEST that a partner is involved who is capable of communicating the results quickly and effectively to the community of stakeholders and practitioners, in order to bring science soundly to application.

Research results from BEST with its 31 component projects are of course manifold and far too differentiated to give a complete overview here. A higher-level result of great significance was the finding that in a region such as the Göttingen district, and under realistic assumptions of maximum proportion of cultivation area for energy wood plantations, still only about 5% of total energetic demand for heat could be contributed from that source. Wood-based energy can hence only contribute a modest part to an energy mix of renewables, which has to be combined of many different sources in the future. This is of course not an argument against the usefulness of wood-based renewable energy, because an energy mix is advantageous in regard that one or more parts of the mix could compensate for another if supply of one component in the mix should temporally fall short. However, the results from BEST and further calculations of total projected acquisition of renewable energies strongly suggest that energy savings are indispensable to reach full coverage of energy demand by renewables in the future.

SUMMARY AND CONCLUSION

The European Union (EU) has ambitious goals for the utilization of renewable energies in substitution of fossil and nuclear energy. The goal is currently set at 20% coverage of total energy demand by renewables by the year 2020. After a dynamic start phase on the way to the goal, a slight slowdown has become apparent, and several obstacles are showing up. The relevant EU report concludes that still stronger political and administrative backing measures are needed in order to achieve the goal.

Research on European Union and individual European country level into methods and potentials of renewable energy gain are manifold and currently very dynamic, on all renewable energy sectors in general and also on the sector of bioenergy. Research fields comprise provision of biofuels (with the highest number of EU-funded projects), biogas, other bioenergy carriers such as wood and agricultural and food residues, algae as bioenergy crops and catalyzers, and in general the avoidance of the fuel-for-food tradeoff by converting other biotic resources than food crops into bioenergy.

The German BEST project puts a focus on the role that wood can play as a (mostly thermal) energy carrier in the replacement of fossil fuels. It demonstrated ecologically as well as economically feasible methods and pathways of energy wood production, as part of a workable energy mix. However, it also clearly identified limits to the energy that could be derived from wood in typical German regions of mixed urban and rural composition. Under realistic assumptions of available cultivation area for energy wood plantations, one could expect a contribution in the order of 5-10% of this energy carrier to a future renewable energies mix.

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Table 1**. Origin of biofuels consumed in the EU in 2010 (from EU-COM 2013)**

	Biodiesel		**Bioethanol**		
	Volume (ktoe)	Share		Volume (ktoe)	Share
EU	8,270	83.2%	EU	2,243	80.1%
Argentina	1,003	10.1%	Brazil	234	8.4%
Indonesia	285	2.9%	U.S.	121	4.3%
Malaysia	123	1.2%	Peru	26	0.9%
China	67	0.7%	Kazakhstan	24	0.8%
U.S.	61	0.6%	Bolivia	20	0.7%
Other countries	129	1.3%	Egypt	15	0.5%
			S.Korea	16	0.6%
			Other countries	101	3.6%
Total	9938			2800	

Data Sources: EUROSTAT, COMTRADE.

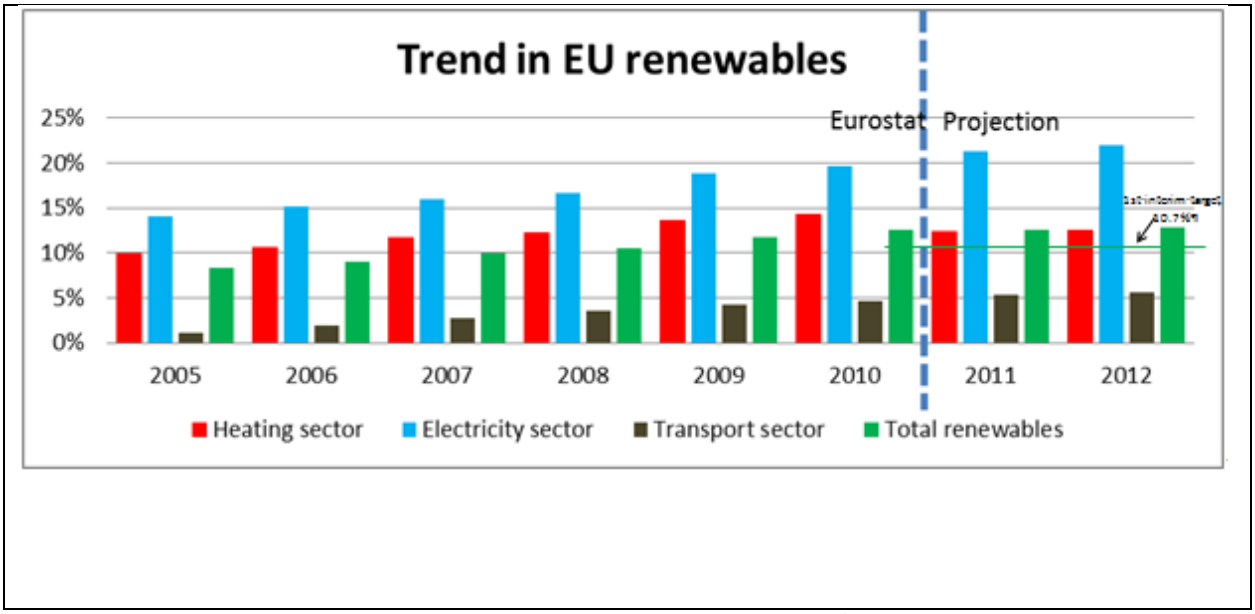

Fig. 1. Trend in renewable energy use in the European Union over the past years (projection for 2011 and 2012, based on data up to 2010); growth rates are considerable, but may have reached a plateau. (reprinted from EU-COM 2012)

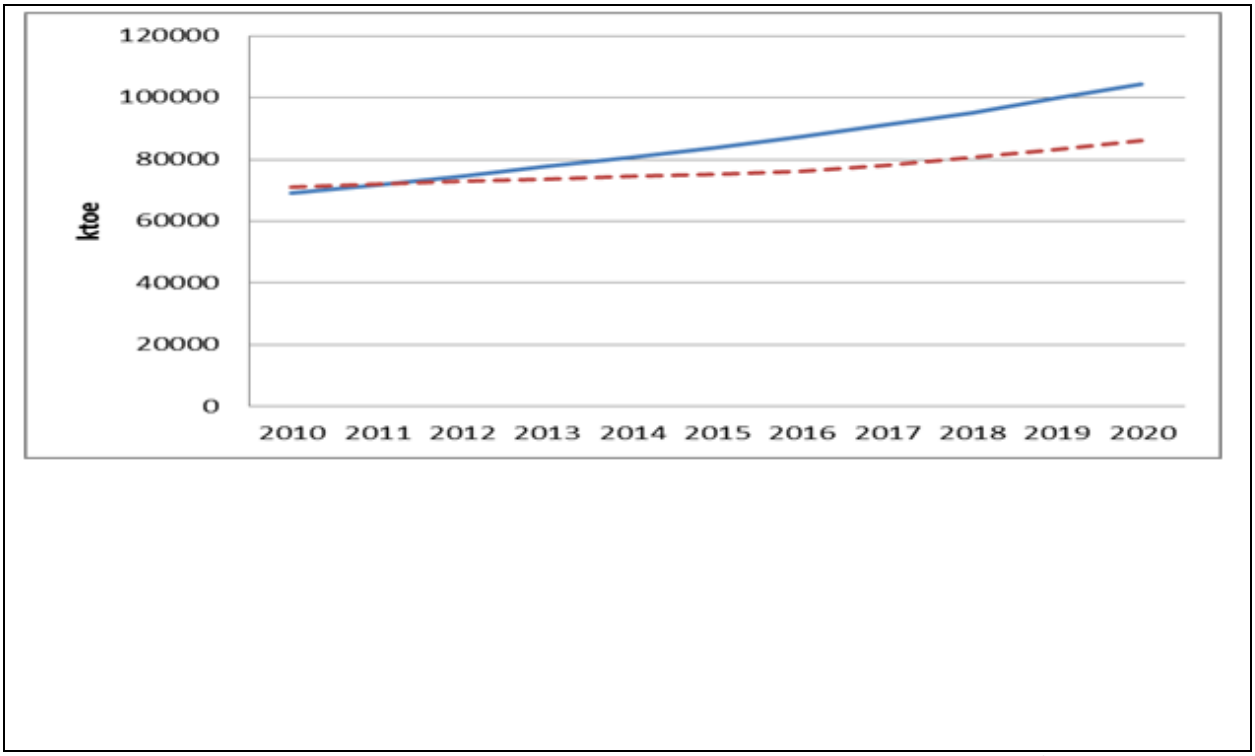

Fig. 2. Planned (blue line) against estimated (red/dotted line) trend in biomass energy production on EU level. (reprinted from EU-COM 2012)