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First UFZ Energy Days 2012 | Book of Abstracts

Uwe-Jens Görke, Daniela Thrän, Frank Messner, Olaf Kolditz (Eds.)

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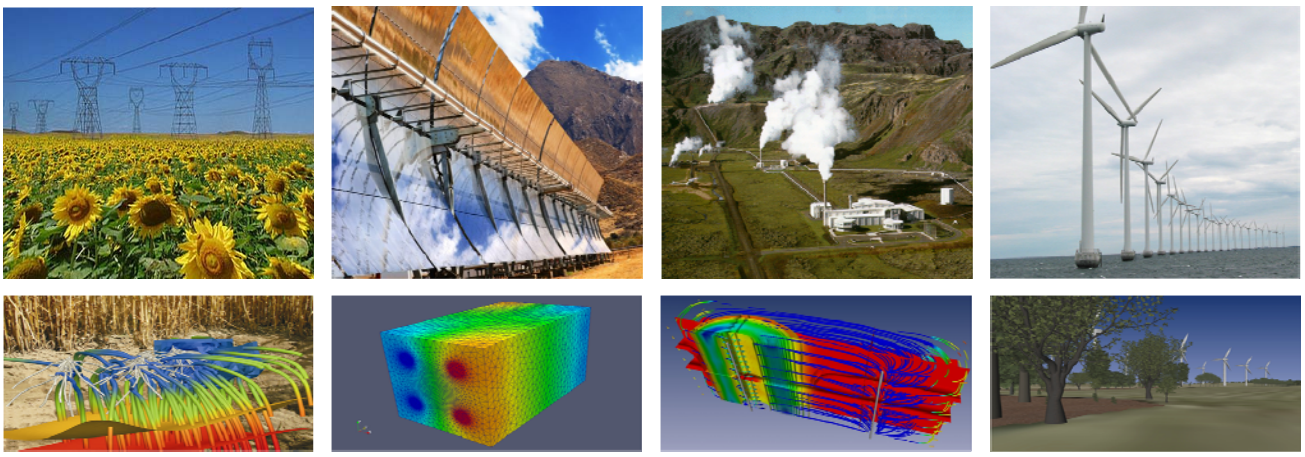
1st UFZ Energy Days 2012



4-5 April 2012, Leipziger KUBUS

Book of Abstracts

Uwe-Jens Görke, Daniela Thrän, Frank Messner, Olaf Kolditz (Eds.)

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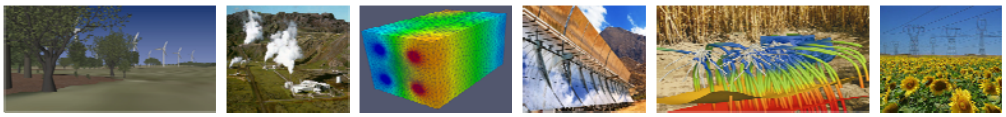

Introduction

Research on energy-related topics became increasingly important, particularly since last year's political decisions in Germany to move away from fossil and nuclear sources of energy in order to design a transition process towards sustainable energy generation and provision in Germany. This energy transition process requires an acceleration of knowledge generation in numerous research fields, e.g., development of technologies and instruments to foster energy efficiency and renewable energies, realization of energy transition options including the analysis of their environmental effects, storage of energy and waste from energy production processes, intelligent and regionalized energy supply as well as flexible and context-specific political instruments and governance structures to manage the transition process. In particular, the expansion of renewable energies and the increase of energy efficiency are most important aspects of the sustainable German policy on energy and climate, which has been established in the 6th Energy Research Program of the Federal Government in August 2011. Within this context, the European and German research funding are currently essentially shaped by energy-related topics.

At the UFZ, energy-related research topics have been officially established some years ago. However, unlike energy research in traditional engineering research centers, UFZ energy research is not oriented towards "hardware" technology development. UFZ research rather relates to environmental and geological aspects of energy generation or provision and to biological processes which either might advance the generation of biologically-based energy sources or contribute to the remediation of areas contaminated by coproducts of the energy value-added chain. The first pieces of UFZ research which became part of the Helmholtz research energy programs in 2009 were research on bioenergy and geothermal energy sources and their environmental impacts. Since then UFZ energy research grew, especially triggered by the successful cooperation with the Deutsche Biomasseforschungszentrum (DBFZ), which was founded in 2008 next to the UFZ headquarter in Leipzig, leading to increased acquisition of third party projects. Moreover, energy-related research also gained in importance in UFZ's environmental research in recent years due to, among others, land-use impacts of energy policy and new ways and technologies to exploit new unconventional energy resources like shale gas, oil sands and old waste dumps – all with unknown environmental implications and risks. Today a wide diversity of energy-related research exists at the UFZ and it is no longer transparent, which group is participating and who is doing what. In order to bunch the resources of UFZ´s energy research, it is necessary to structure and network the variety of research activities. Collecting the knowledge about existing initiatives and revealing synergies of cooperation provides a necessary precondition to accomplish an improved efficacy of energy-related UFZ research. This could strengthen the ability to acquire new national and international research grants, to better give political advice for the national and regional implementation of the energy transition, and to deepen the links to important regional networks such as The Power & Environment Network of the City of Leipzig, which features strong links to industry.

Having these efficacy and cooperation gains in mind, the 1st UFZ Energy Days have been organized in April 2012 in the Leipziger KUBUS, analogous to the Climate Days at the UFZ in 2010. The major aim of this energy workshop is the exchange of information as well as the fostering of networking of existing research activities on energy-related topics – in order to subsequently generate synergy effects and to sharpen the energy research profile of the UFZ. Additionally, the 1st UFZ Energy Days are meant to contribute to the UFZ's positioning within the framework of the third program-oriented funding period (POF III) of the Helmholtz Association. These days have been arranged by researchers of the UFZ, presenting more than 40 contributions from 21 departments, which are – to a greater or to a lesser extent – linked to energy research. This book of abstracts combines one-page summaries of the given presentations, and represents a comprehensive overview of the present state of energy-related research at the UFZ. Contact information below each abstract is provided in order to alleviate the initiation of coordinated activities in the future.

Leipzig, April 2012

Uwe-Jens Görke, Daniela Thrän, Frank Messner and Olaf Kolditz

Biogas Processes

The potential of calorespirometry for control and analysis of biogas processes

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Abstract

Biomass is a readily available renewable energy source which has received increasing attention due to rising prices of fossil fuels and the urgent need to mitigate anthropogenic global warming. The conversion of biomass into gaseous and liquid biofuels by microorganisms can be considered as a way to gain safe and sustainable energy which does not contribute to a further build up of carbon dioxide in the atmosphere (McKendry 2002). The most biological processes converting biomass into liquid biofuels, hydrogen or biogas are anaerobic.

Changes in stoichiometry and kinetic of anaerobic digestion processes are reflected by heat production rates in real-time. The combination with other monitoring tools either on-line (e.g. gas emmisions, pH etc.) or off-line (intermediates) allows the separation of stoichiometric and kinetic information using thermokinetic models.

Forming the enthalpy balance of a reactor allows the determination of the metabolic heat production rate in an easy way. This approach was already successfully demonstrated at different scales for aerobic bioprocesses [1] and the principle should also be applicable to anaerobic digestion processes. Since with any scale-up the ratio of the heat producing volume to the heat exchanging surfaces increases and therefore the accuracy of the heat measurement improves this calorimetric principle might be particularly advantageous for anaerobic digestion processes as they are typically performed in large tanks. The gas production is a further easily on-line monitored variable.

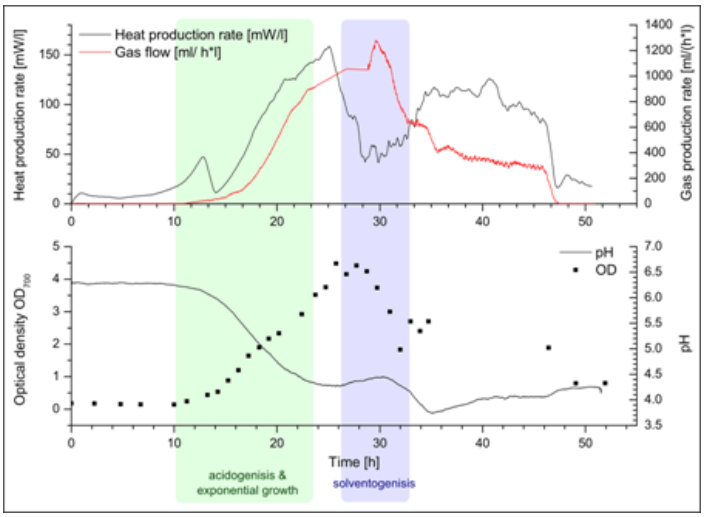

Figure 1: Growth pattern of *Clostridium acetobutylicum* (ATTC 824) on glucose at 37 centigrade. Heat production rate, gas flow and pH are on-line variables and suggested to control the process.

For exploring the information content of the calorimetric signal the heat production rate as well as the gas emission (calorespirometry) of *Clostridium acetobutylicum* was monitored in real time. This test system was chosen because *Clostridia* contribute to the complex biogas process and *Clostridium acetobutylicum* has been used for production of butanol for decades. Butanol may be used as a fuel alternative to ethanol in combustion engines. Thus, *Clostridium acetobutylicum* being a well-studied bacterium some information on kinetics, stoichiometry, genetics, and proteomics are available from literature. The ratio of the on-line signals heat production rate to gas evolution shows clearly differences between different productions states (e.g. acetogenisis and solventogenisis). Thermodynamic calculations show some similarities to other anaerobic processes. This opens opportunities to monitor and control such processes. However, the recently available calorimeter types are not perfectly suited for controlling anaerobic processes at technical scale. This challenges the development of tailor-made calorimeter. The recent achievements and potential development directions will be discussed.

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Fungal pre-treatment of lignocellulosic feedstock to improve biogas production

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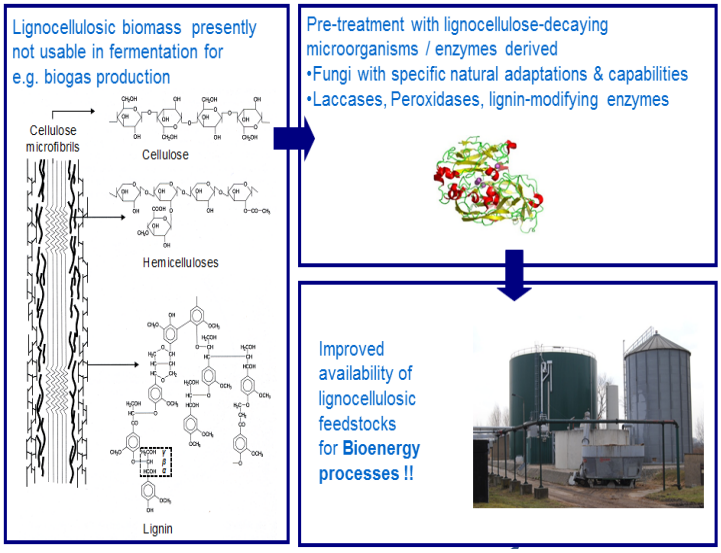
Abstract

Pretreatment altering chemical structures are of central importance due to its impacts on process efficacy, regardless of whether a digestive process in human beings or the bioconversion of lignocellulosic biomass for biogas production is considered. Pretreatment strategies play a vital role in lignocellulosic biomass (Wheat straw) processing to yield biofuels (biogas). Many investigations have being conducted on methods for pretreatment and enzymatic hydrolysis of lignocellulosic substrates but the lignin barrier accommodates most of the void in this process and obstructs the biogas production. Hence, pretreatment is a "must" step for subsequent enzymatic hydrolysis. Thus we focus upon the potential of biological pre- and post-treatment of a lignocellulosic feedstock (wheat straw) and digestates (remaining from biogas fermentation) with fungi originating from less investigated environments such as various aquatic ones, whereas terrestrial basidiomycetes representing white-rot, litter-decay, and brown-rot fungi were included for comparison as biocatalysts targeting improvement of biogas yields.



Within this bio-pretreatment approach we have screened more than 100 fungal strains (more than 90 were aquatic isolates). The most promising strains were grown on either wheat straw or digestates (applied as solid substrates, respectively) to investigate their substrate colonization and saccharification ability along with the potential for lignin degradation. Furthermore, we have monitored the production of oxidative enzymes such as laccase, manganese-dependent, and manganese-independent peroxidase; which potentially contribute to lignin decomposition. The effects of fungal treatments on aromatic water soluble high molecular weight compounds (lignin constituents and humic substance-like compounds) were assessed using gel permeation chromatography (GPC).

The remaining lignin content of the solid substrates and their total mass loss after fungal treatment was determined with Fourier transform mid-infrared (FT-mIR) spectroscopy and gravimetrically, respectively.

A considerable lignin removal at moderate total mass loss of wheat straw was observed for some of the tested strains. On digestates, the aquatic ascomycete *Phoma* sp. led to very high laccase activities: hereby offering an interesting option in using a waste product for the production of an active biocatalyst that can also be employed for bioremediation purposes. The parameters evaluated so far are of potential importance for the accessibility of the treated substrates for subsequent efficient biogas fermentation, which will be exemplified and discussed. Testing of the biogas potential of the substrates after (pre)treatment with the most promising fungal strains is currently in progress.

From the single cell to the improvement of renewable energy production - Monitoring microbial population dynamics using flow cytometry

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Abstract

The use of biomass as a renewable energy resource is becoming increasingly important in the substitution of fossil fuels. Over 5000 biogas plants of different scales are already installed in Germany and cover already about 1.5% of our total energy demand. An upward trend is found worldwide.

Biogas reactors contain a highly divers microbial community comprising of bacteria and archaea. They are able to degrade complex substrates, ranging from energy crops to organic wastes and distillers grains, to biogas mainly composed of methane and carbon dioxide. Substrate choice, temperature, retention time, pH and the presence of trace metals or noxious compounds are just some factors influencing the community composition and the total reactor performance. So far, most studies only focused on the microbial composition at certain time points using molecular fingerprinting techniques. Differences were found but distinct correlations to total reactor performance could hardly be made. Monitoring these complex communities can be challenging and costly when using molecular techniques. Therefore many biogas systems are still regarded as black box. An alternative approach based on single cell characteristics and optical measurements using flow cytometry was established.

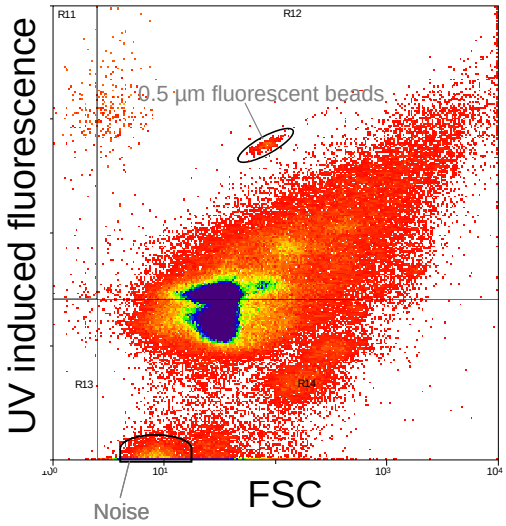

Figure 1: Cytometric pattern displaying DAPI stained cells from a biogas reactor sample.

Using a MoFlo cell sorter morphological cell features can be analyzed by forward scattering behaviour (FSC) and the DNA content, measured using the AT specific fluorescent dye DAPI (Fig.1). Cytometric analyses of these parameters result in distinct, fingerprint like, patterns. These patterns are highly reproducible and represent the composition of the microbial community at a certain point of time. The combination with cell sorting of interesting subcommunities (either very stable or very fluctuating) and their molecular characterisation can help to identify the key organisms behind a stable or unstable process performance.

The microbial community in a biogas reactor, run at the German Biomass Research Centre (DBFZ), was investigated over a period of nine months and first results on the question “How stable is stable – community dynamics in a biogas reactor” will be presented with the aim of understanding the dynamics behind functional stability.

Analysis of carbon fluxes and syntrophic interactions in the biogas process using the Stable Isotope Probing

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Abstract

Since 2011 the long-standing discussions about the energy policy in the future turned up. For sustainable and renewable energies is asked. Biogas is such a sustainable and renewable energy source. It can easily be stored and maintained and thus is able to balance fluctuating power generation by wind or solar power. However, today's biogas plants are not optimal in terms of efficiency. Imbalances in the chemical process lead to a lower amount of produced biogas. To solve such problems foremost a precise insight and understanding of the complex microbial processes in a biogas plant is needed. This is a prerequisite for an early detection of errors (disturbances) and an improved process design. The microbial investigation of the anaerobic degradation processes is still on their beginning. Other processes of the biotechnology like the wastewater purification based on the usage of the knowledge about the microbiology, but this is not yet the case for biogas plants.

The aim of this project is to generate fundamental knowledge about the microbial system in a (disturbed) biogas plant. This can enhance existing models and may improve the process control of biogas generation. Disturbances and their underlying microbial mechanisms will be analyzed with a focus on the syntrophic degradation steps of the biogas process (secondary fermentation, acetogenesis, methanogenesis). Two small scale wet lab reactors will be run in parallel with equal treatment in the beginning but later on under different conditions. This makes it possible to analyze the effects of an artificially induced disturbance on the microbial community. Especially the activity of metabolic key functions is of interest. The induced process disturbance will be the absence of vital mineral nutrients as this is a common problem in commercially use biogas plants. The carbon flux of the specific process step will be analyzed using the *Stable Isotope Probing* (SIP) techniques to get insights into the metabolism and to indentify and quantify degradation steps. Furthermore, active key microorganisms and microbial processes shall be characterized with molecular biological methods. Such results can be used to establish phylogenetic and functional marker of the acetogenic step as indicators for the process stability. Determined indicators could be used in the process monitoring to contribute to an efficient and stable operation of biogas plants.

Radio-wave-supported biogas treatment for the substitution of natural gas as energy carrier

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Abstract

In contrast to other regenerative energy sources like wind or solar energy, biogas has some unique advantages leading to a great potential as "bioenergy carrier". Beside the fact that, due to intelligent fermenter feeding, biogas production is predictable, the ability to transport and store biogas in the national natural gas grid usually is pointed out to emphasize the potential of biogas.

In order to use the already available gas transport system, the biogas has to achieve a quality being comparable to that of natural gas. In addition to sulphurous compounds, maximum contents are primarily defined for water and carbon dioxide. However, water and CO_2 are immanent products of the fermentation process and therefore they cannot be avoided which leads to the necessity of adequate biogas treatment. This handling of raw biogas includes a number of physical and chemical processing steps. In spite of many technical innovations in the last years, the gas treatment is still relatively inefficient and energy-consuming. Therefore, optimization can be seen as a key challenge to establish biogas as transportable, storable and economic renewable energy carrier.

In the field of biogas treatment described above, especially fine drying of biogas is not yet optimized with respect to the energy efficiency. One state-of-the-art technology for biogas drying is adsorption on porous materials such as hydrophilic zeolites mostly realized as temperature swing (TSA) adsorption-desorption process. There, the challenge consists in enhancing the efficiency of the regeneration step after the actual drying procedure. In the working group an innovative technique based on radio-frequency heating is being investigated. This dielectric method allows achieving volumetric heating of the zeolite adsorbent bed and therefore establishing homogeneous temperature profiles independent of the gas flow. This leads to an efficient heating reducing energy losses due to inhomogeneous temperature profiles (as with conventional heating via hot surfaces) or hot air in the outlet (conventional heating via pre-heated gas stream). RF heating also allows using vacuum techniques for more-efficient thermal regeneration of the drying agent.

Currently the concept pointed out above is proved for various adsorber materials and geometries in lab and technical scale.

Enrichment of lignocellulose-degrading microorganisms from natural habitats and their potential to enhance the biogas process

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Abstract

In order to reduce the negative effects of the production of energy crops for the generation of biogas as a renewable energy source, there is the general aim to increase the amount of organic wastes and agricultural residues as substrates for biogas production. However, agricultural residues such as straw have a high lignocellulose content and hence are difficult to degrade under anoxic conditions. On the other hand, microbial degradation of lignocellulose under anoxic, methanogenic conditions can be found in various natural environments. In our project we aim to make this natural potential of anaerobic lignocellulose degradation available for the biogas process. The goals are i) to obtain efficient and stable lignocellulose-degrading microbial cultures, ii) to identify the key players and iii) to determine their potential to enhance the biogas production from lignocellulose-containing substrates by bioaugmentation.

Plant material decaying sediments of thermal and soda lakes in Hungary were sampled. Enrichment cultures with cellulose and wheat straw were established at neutral and alcaliphilic and at mesophilic and thermophilic conditions. The degradation of the cellulose-containing substrates was followed by measuring the produced gas volume, the gas composition, the medium pH and the produced organic acids. The microbial composition of the enrichment cultures and its changes during the enrichment process was followed by T-RFLP analysis of the 16S rRNA gene diversity coupled with cloning and sequencing.

All enrichment cultures were able to grow on cellulose and wheat straw. In general most of the gas was produced within the first two weeks and was mainly composed of CO_2 and H_2. Methane was mainly detected in alcaliphilic cultures. The gas production was accompanied by the formation of organic acids, especially acetate, and a decrease in the pH indicating the hydrolysis of the substrate. Neutrophilic, thermophilic enrichment cultures on straw were more diverse and were composed of microorganisms only distantly related to cultivated members of Clostridiales, while predominant microbes in cellulose cultures were affiliated to the genus *Caloramator* and *Clostridium*.

Bioaugmentation experiments are currently performed either in batch systems used for quantification of the biogas potential of organic substrates or in lab scale batch systems used for solid state fermentation. Microorganisms from straw-degrading enrichment cultures were added to both systems containing wheat straw as substrate. First results indicate that the amendment of neutrophilic, thermophilic microorganisms to the biogas potential test system led to a faster and up to several percent higher methane production in comparison to the control without added microorganisms. The first experiment to enhance the biogas production from straw in a solid state fermentation batch system by addition of alcaliphilic, mesophilic lignocellulose-degrading enrichment cultures did not show any positive effect.

Biogas stable isotopic fingerprinting for the process control of anaerobic digestion

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Abstract

Molecular biological techniques have revolutionized our knowledge about biogas process but they are still impractical for process monitoring at industrial scale due to their cost and time requirements. As an alternative approach, determination of stable isotope characteristics of the produced CH_4 and CO_2 may allow a rough estimation on the predominant methanogenic pathway in anaerobic digesters with potential industrial applicability [1]. To investigate this possibility, laboratory-scale continuous stirred tank reactors were run under various conditions using either dried distillers grains with solubles (DDGS), a by-product from bioethanol industry, maize silage or chicken manure as substrate. In addition to the standard process parameters the stable hydrogen and carbon isotopic composition of the produced biogas (methane and CO_2) was also analysed to estimate the predominant methanogenic pathways (acetotrophic vs. hydrogenotrophic).

The methanogenic communities in the reactors were also investigated for their phylogenetic composition by terminal restriction fragment length polymorphism (T-RFLP) analysis and sequencing of the *mcrA* genes coding methyl coenzyme M reductase. In addition, the expression of the gene was also studied as a better indicator of the metabolic activity. The carbon isotopic values ($\delta^{13}C$) of methane ranged between -68‰ and -31‰. This latter value of the maize silage reactor was probably influenced by the original high value (-12‰) of this C_4 plant substrate. The hydrogen isotopic values (δD) of methane were very low (-364 to -339‰) except for the samples from the maize silage reactor ranging from -291‰ to -280‰.

Apparent fractionation factors (αCO_2-CH_4) suggested a hydrogenotrophic pathway in the chicken manure reactor, while probably both pathways influenced the isotopic signal of derived methane in the other reactors. The isotope data-set mainly agreed with the molecular biological results. According to the T-RFLP analysis the reactors were dominated by hydrogenotrophic *Methanomicrobiales* with *Methanoculleus* as the predominant genus. Sequences affiliated to the acetotrophic *Methanoseta* genus were predominant only in one DDGS reactor with low organic loading rate, while sequences affiliated to *Methanosarcinaceae* were frequently found in reactors with higher organic loading rate.

At RNA level, major changes in the relative abundance of the amplified sequences were observed compared to the results obtained from the isolated DNA. Furthermore short-term changes in the isotopic composition were followed in two reactors as a function of substrate feeding. Significant decrease in both $\delta^{13}C$ and $\delta^{13}D$ values of methane was observed in the reactor fed with maize silage half an hour after feeding whereas no significant changes were observed in the chicken manure reactor. This ability of the stable isotope fingerprinting to follow short-term activity changes shows also potential for indicating process failures.

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Aquatic neophytes as a substrate for biogas plants?

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Abstract

There have been rapid growths of Western waterweed (*Elodea nuttallii*) in waters in Germany over the past decades. The fresh mass produced during an *Elodea* plague in the Goitzsche lake in the German state of Saxony-Anhalt in 2004 has been estimated to amount to about 26,000 metric tons. Elsewhere in Germany, *Elodea* plagues have occurred in 2004 in the Ruhr reservoirs in North Rhine-Westphalia and in 2002 in the Steinhuder Meer lake in Lower Saxony. In the Steinhuder Meer lake, *Elodea* covered up to two thirds of the entire lake area (about 1600 ha) during the second half of the year. Such massive occurrences of *Elodea* impede the use water bodies for recreational purposes. For this reason, this aquatic macrophyte is now often harvested and usually disposed of as organic waste.

A possible alternative is the use of the harvested *Elodea* biomass as a substrate in biogas plants [1]. Mono-fermentation of freshly harvested *Elodea* in a laboratory-scale biogas plant produced a biogas yield that was reduced by 50% compared to maize silage, however. A mix of 30% *Elodea* and 70% maize silage was therefore used, which produced a biogas yield of 580 standard liters per kilogram of organic dry mass. In comparison, mono-fermentation of maize silage produces an average gas yield of 650 L_S/kg_{oDM}. In order to ensure the availability of *Elodea* over a long period of time, it was ensiled in combination with maize, which resulted in good quality and suitability for storage [2].

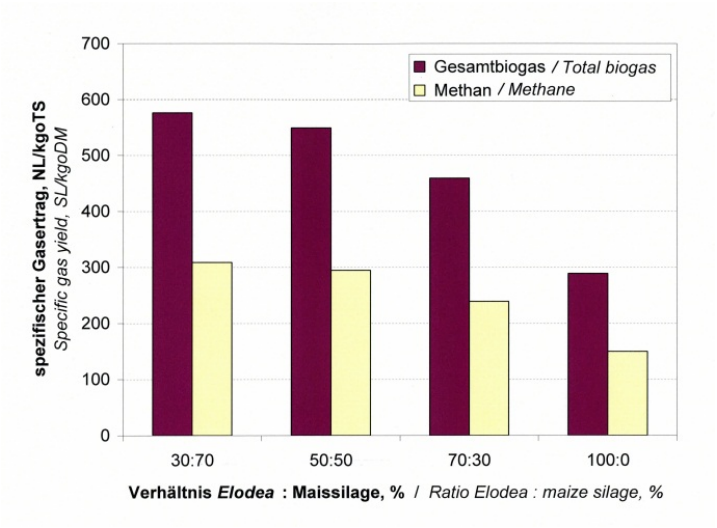

Figure 1: Application of different mixture ratios of *Elodea* biomass and maize silage in a laboratory-scale biogas reactor.

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Foam formation in biogas plants

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Abstract

A great number of biogas plants have been commissioned in Germany in the last decade as part of the promotion of renewable energies. As biogas production is independent of weather conditions and diurnal cycles, it is a very attractive component in the energy mix of renewable energy sources. Nevertheless, the immense potential of biogas production can only be fully realized if continuous biological processes within anaerobic digestors effectively run. One of the most common process problems is foam formation in biogas reactors [1]. This troublesome issue may have negative impact on the economics of the biogas plants. The problem of extensive foam production especially concerns those biogas plants which utilize biogenic waste for methane production. A survey of operators of waste treating biogas plants from Saxony, Saxony-Anhalt and Thuringia, was undertaken by scientists from the Centre for Environmental Biotechnology of the Helmholtz Centre for Environmental Research (UFZ), showed that at least two thirds of operators had experience with extensive foaming in their biogas plants [2].

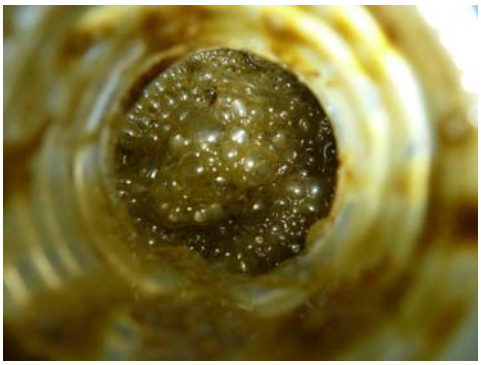

Figure 1: Foam in biogas reactor.

The causes of the foam formation are not well understood by operators. The experience of the operators of biogas plants shows that problems with foam formation are often caused by using inadequate substrates in high amounts (e.g. sugar beets, tensides, protein-rich or low-grade substrates). Also suboptimal process control (regarding mainly feeding and stirring periods) has been identified as a cause foam generation in biogas reactors.

Scientists at the UFZ are researching the formation and removal of foam in biogas plants in order to identify the contributing factors to foam production and to find effective foam control strategies. This means the testing of antifoam agents and their efficiency as well as searching for early warning signs for foam formation in the process of anaerobic digestion.

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Modeling of Geotechnical Energy-Related Processes

OpenGeoSys – An open-source finite element multiphysics community project for the simulation of energy-related geotechnical applications

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Abstract

The OpenGeoSys (OGS) project is a scientific open source initiative for numerical simulation of thermo-hydro-mechanical-chemical processes in porous media. The basic concept is to provide a flexible numerical framework (using primarily the Finite Element Method) for solving multi-field problems in porous and fractured media for applications in geosciences and hydrology. To this purpose OGS is based on an object-oriented concept including a broad spectrum of interfaces for pre- and post-processing [1]. The OGS idea has been in development since the mid eighties. The idea behind OGS is to provide an open platform to the community, outfitted with professional software engineering tools such as platform-independent compiling and automated benchmarking. A comprehensive benchmarking book has been published recently [1]. Benchmarking has been proven to be a valuable tool for cooperation between different developer teams, e.g., for code comparison and validation purposes (DEVOVALEX and CO2BENCH projects). Object-orientation provides a suitable framework for distributed code development; however the parallelization of object-oriented codes still lacks efficiency. High-performance-computing (HPC) efficiency of such codes is subject to future research.

Coupled process modeling has been considered in various engineering problems and geoscientific applications since the computation method was introduced for problems of soil consolidation, dam construction and oil/gas field exploration in early 1970. However, substantial progress in experimental and theoretical studies regarding the fully coupled effects of temperature, hydraulics and mechanics, as well as chemistry, in fractured porous media was just made in the last two decades.

Physical coupling phenomena of thermal (T), hydraulic (H), and mechanical (M) processes are fundamental for the analysis of deep geosystems under high temperature, pressure and stress conditions. The strong degree of coupling between the different processes requires adequate numerical methods for coupling partial differential equations. Sound understanding and predictability of THM processes including chemical reactions (C process) are important to a large variety of geotechnical applications such as nuclear and chemo-toxic waste disposal, geothermal energy, carbon capture and storage as well as gas and oil production. These geoscientific applications all share the same physico-chemical basics which emphasizes the importance of reliable THM/C codes.

A very recent research area for THM/C modeling has become energy storage. The economy and feasibility of renewable energy sources will depend at a large degree on efficient energy storage systems. Within this context, the long term stability and efficiency of those energy storage devices can be optimized using THM/C modeling (i.e., solving the inverse geothermal problem). In addition to thermal storage, thermo-chemical concepts are under development, i.e., storing thermal energy by triggering endothermic reactions and gaining thermal energy back on demand with the reverse reaction (exothermic).

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Scientific 3D visualization – representing complex data sets in a comprehensive way

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Abstract

Often data sets that involve complex geometries, multiple parameters and time-dependent processes need to be visualized. One such data set is the reservoir in Ketzin that is used as a pilot site for testing the feasibility of CCS (Carbon Capture and Storage) technology. The aim is to show the geophysical measurements that are the basis for the interpretation and construction of the geometrical model together with the resulting model, its parameterization and the simulation results. Visualizing these kinds of data sets in a comprehensible way can be a challenge. This is especially true if the visualization of diverse results needs to be explained intuitively to the public, politicians or stake-holders for planning or decision-making purposes. The viewers can quickly lose their orientation when they move into the 3D scene and it becomes difficult to focus on specific simulation results within a given context. For this reason the Helmholtz Centre for Environmental Research – UFZ uses a projection-based visualization centre (TESSIN-VISLab) that shows the 3D scenery on a large rear screen using stereoscopic rendering. This can be augmented with 2D visualizations, such as maps and linked views, using two additional side screens. The combined 2D/3D representation allows the use of synoptic views of complicated data that are easy to navigate and comprehend [1] and has been already applied to the visualization of a large scale groundwater study [2]. As an alternative the whole display can be used as a virtual environment.

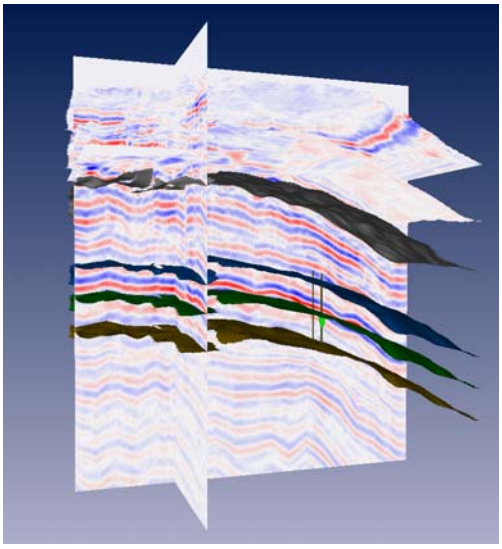

Figure 1: Visualization of geophysical data and the interpreted stratigraphic interfaces of the Ketzin pilot site together with the simulated CO_2 propagation (source for data: GFZ Potsdam, 2011).

To generate this visualization, it was necessary to implement or extend several software modules in order to establish the interfaces required between the software systems used by the domain scientists and the software used in the VISLab for the visualization. In order to be able to work with data that are typical for the Oil & Gas industry we have extended the commercial software GOCAD to incorporate it into our workflow [3]. Further we have another tool, the OGS 3D Data Explorer, to preprocess a wide range of data which come from the GIS and related domains [4].

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Two-phase flow in deformable porous media under deep geological conditions

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Abstract

All engineering projects in the upper crust are influenced by the interaction of fluids with their surrounding medium. The feedback between pressure and temperature changes with deformation of both fluids and the solids that contain them influence the rate and safety of CO_2 propagation in CCS projects, the viability of profitable energy recovery and potential for induced seismicity in geothermal reservoirs, the safety of radioactive waste disposal, profitability of enhanced gas recovery, and many others. Understanding these feedbacks requires cooperation between laboratory and field scale experimentation, large scale numerical modeling, and targeted scientific examination of micro- and macro-scale processes that influence overall behavior.

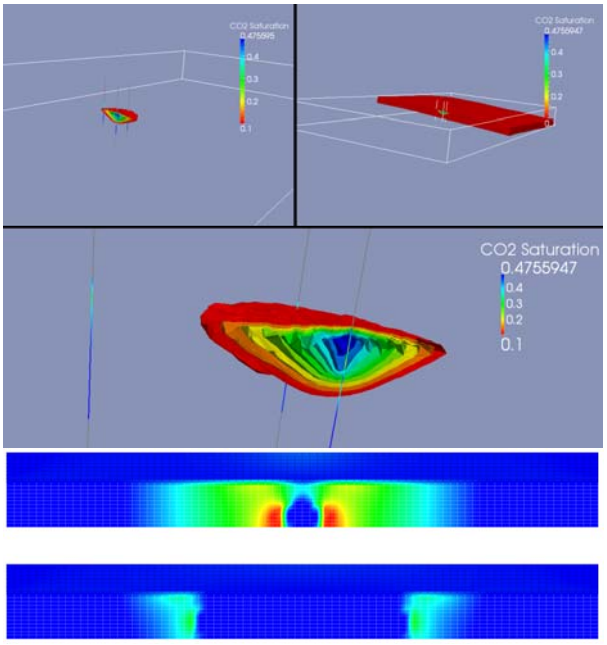

Figure 1: Top: CO_2 migration in the Ketzin basin after 100 days of simulation. Monitoring wells have recorded the real arrival times. Bottom: Propensity for mechanical failure in a mock saline reservoir, with the advance of CO_2 and the resulting evolution of gas pressure.

The viability of carbon dioxide sequestration as a strategy for the reduction of greenhouse gases depends not only on storage capacity of the medium (itself a function of complex fluid thermodynamics and solid deformability) but also the rate of propagation of injected CO_2 and the potential for mechanical alteration to modify what we understand about permeable pathways in target geological formations.

The images on the left are produced by the open source scientific software OpenGeoSys [1]. On the top we observe the expanse of CO_2 following injection into the Ketzin basin in Germany. Through cooperation with GFZ Potsdam we are able to compare these numerical results with field scale data of CO_2 injection which has been conducted there for nearly two years.

The lower image focuses on smaller scale behaviors. CO_2 is injected into a mock reservoir beneath an impermeable "caprock" in the center of this image, and by considering feedbacks between the fluid and mechanical system (fluid mass and momentum balance coupled with solid mass and momentum balance) we plot the potential for mechanical failure in this reservoir (red areas are under higher potential of failing mechanically and inducing new fractures that can serve as permeability pathways for the escape of CO_2).

Through studies such as these we are attempting to better understand the processes that are taking place during CO_2 injection and provide insight into how to reduce the potential for CO_2 release. The recent availability of field scale data allows us to proceed with greater confidence that such models can in fact be valuable tools for the prediction of CO_2 behavior.

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Non-isothermal compositional gas flow in porous media with geotechnical applications

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Abstract

Flow of a gaseous mixture composed of two or more pure gases is termed as compositional gas flow. Variations in the mole-fraction of the components with time and space affect the flow and transport processes significantly. Non-isothermal compositional gas flow module is developed for solving multi-field (thermo-hydro-componential THC^n) problems applicable in various geotechnical areas. Particularly, using this module, the open-source scientific finite element code OpenGeoSys (OGS) simulates problems considering several important physical phenomena such as molecular interaction, molecular diffusion and mixing. Components utilized in this module for the gas phase are numbered as CO_2 (0), H_2O (1), CH_4 (2) and N_2 (3). OGS uses van der Waals mixing rule to calculate the average value of material parameters for the composition. Pure gases are mixed at the molecular level, and they share the same seepage velocity, pressure and temperature calculated for composition, and mass transfer takes place by advection and diffusion-dispersion.

The mixture mass balance equation for porous media with fixed porosity is solved for mixture pressure. With assumption of local thermodynamical equilibrium, heat transport equation for the porous medium (which pores are filled with a mixture of compressible gases) is obtained by combining the solid and gas phase's heat transport equations. The mass transport equation in terms of mole-fraction, i.e., fractional mass transport equation, is solved for mole-fraction of each component in the mixture. To close the system of governing equations, additional relations termed as equations of state (EoS) are required for material parameters. The so-called super-compressibility factor '*z*' is frequently used to get other parameters with the constants of the components. This module uses Peng-Robinson (PR) EoS, for the calculation of the super-compressibility factor as PR-EoS is simple and it uses only two parameters (attraction '*a(T)*' as well as repulsion '*b*'), and it calculates the super-compressibility factor of the real gaseous mixture with a high decree of accuracy. Compared to Soave-Redlich-Kwong, PR-EoS performs slightly better around the critical region, thus the PR-EoS is best suited to natural gas systems in the petroleum industry.

Benchmarks represent well-defined examples for process simulation under simplified conditions keeping the necessary physics of the problem under consideration [1]. Finite element solutions for particular and coupled processes are verified, and analyzed the complexity occurred either due to process couplings or due to variations of the material parameters. Four different test benchmarks are solved: (1) Gas flow through porous media; (2) Joule-Thomson cooling; (3) Tracer test and (4) CO_2 storage. The method of weighted residuals is applied to derive the weak formulations of all the governing equations. The governing equations are discretized spatially within the context of a Galerkin approach, whereas the temporal discretization is performed using a generalized single step method. The system of non-linear equations is solved iteratively using the Picard linearization. A staggered scheme for coupling the mass transport with flow and heat transport is adapted [2]. The numerical module for non-isothermal compositional gas flow has been implemented into the scientific object-oriented finite element code OGS.

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Numerical simulation of coupled processes for thermo-chemical energy storage systems

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Abstract

As a carbon-free energy supply technology, the operation time and final energy output of thermal solar power plants can be greatly extended if efficient thermal storage systems are applied. One of the proposed design of such system is to utilize reversible thermochemical reactions and its embedded reaction enthalpy, e.g. the $Ca(OH)_2$/CaO hydration circle, in a fixed-bed gas-solid reactor [1].

The modeling of such a storage system involves multiple strongly-coupled physical and chemical processes in porous media. Gas velocity is calculated by the Darcy's law, with permeability influenced by particle size. Gas phase density and viscosity are temperature, pressure and composition dependent. Also, heat transfer between gas and solid phases is largely influenced by the exothermal heat produced by the hydration of calcium oxide. Four governing partial differential equations (PDEs) including the mass balance, reactive transport, heat balance equations for gas and solid phases, are implemented in the open source scientific software OpenGeoSys [2] and solved in a monolithic way. Based on it, a 1D domain representing the fixed bed reactor was set up to simulate its energy-storage and release circle of the reactor.

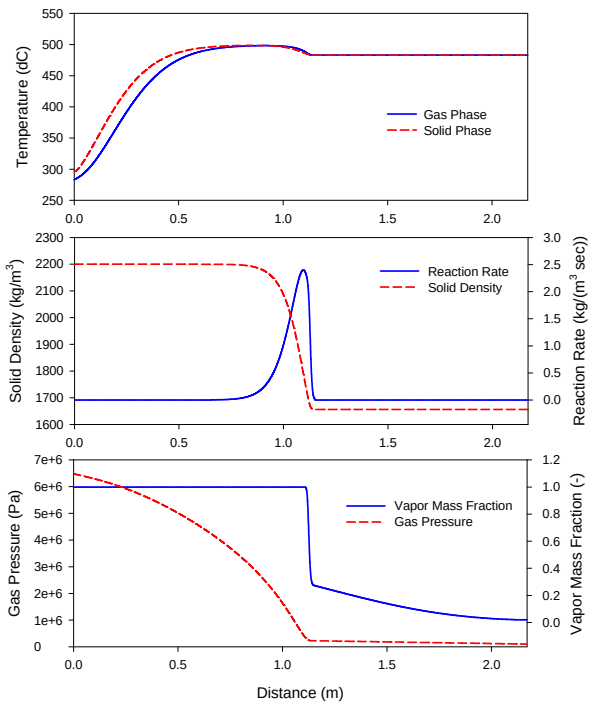

Figure 1: Simulated profile of the fixed bed reactor after 30 min hydration operation. From top to bottom are the gas and solid phase temperature, reaction rate and solid phase density, gas phase vapour mass fraction and pressure distribution.

Fig. 1 illustrates the hydration process of the fixed bed reactor. The cold carrying gas saturated with water vapor was pumped into the column from the left-hand-side inlet. Since temperature/pressure values are suited for a hydration reaction, water molecules react with the solid grain with an initial composition of CaO and a density of 1656 kg/m^3. The reaction gradually transformed the solid phase to $Ca(OH)_2$ with a density of 2200 kg/m^3. During this process, the exothermal heat produced by the reaction first elevated the solid phase temperature, and then heated up the gas phase as well. At the water vapor front, the reaction rate was the highest, while it decreased down to zero where no CaO was available for reaction.

The next step of this work is to extend the model to include non-linear Forchheimer flow rule, and calibrate the model against experimental results. The final calibrated model could be further integrated in the process control of the solar power plant in the future, to predict the gas/solid phase temperature of the system and the amount of heat stored in the system.

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Bioenergy and Land Use

Optimization of land use and management pattern in the context of bioenergy production, food production and ecohydrology - first working concept

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Abstract

Bioenergy is currently one of the major renewable energy resources worldwide, but it also poses several challenges as the production and utilization of energy from biomass has complex environmental and societal interactions. The spatial configuration of land use and management patterns, which most likely alters under bioenergy production, is relevant for most of the trade-offs between the yield of bioenergy crops and food production, but also a number of other ecosystem goods and services like e.g. water quality, water availability and biodiversity. Depending on the specific production methods and regional conditions the possible effects of biomass cultivation may have positive or negative impacts. To develop strategies for environmentally sound bioenergy production and sustainable land use a comprehensive understanding of biophysical interactions between bioenergy plant cultivation, spatial configurations and ecosystem processes and services is required.

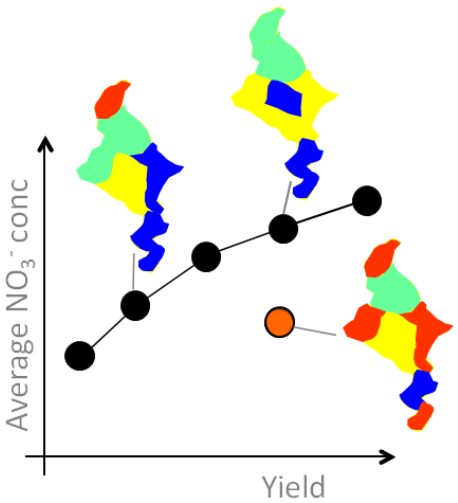

Figure 1: Spatial multi-objective optimization on the regional scale.

The overall objective of the study is to give cultivation recommendations for bioenergy plants (suitability maps based on trade-off curves) based on landscape analysis, biophysical model simulations and optimization procedures. Suitable means in this regard that i) the cultivation does not impair soil loss, ground- and river water quality and quantity, but ii) does also not impair the food production. In this approach the integrated modelling system Soil and Water Assessment Tool (SWAT) [1] will be used to predict biomass yield and selected environmental impacts on the level of large river basins (Saale, Mulde) and their subbasins. SWAT is a widely-used, (semi-) distributed, ecohydrological river basin scale model developed to quantify the impact of land management practices on water, sediment, nutrient and pesticide yields. It simulates by both physically-based and conceptual model approaches using spatially distributed data on landscape characteristics (geomorphology, soil, climate, current land use situation), river networks and land management-related components such as land use pattern, cultivation practices and intensity and yield. During the simulations the hydrological response units of SWAT will be assigned to predefined crop rotation and management schemes. Numerous simulations and land use and management combinations enable the generation of a pool of potential land use and land management configurations.

In order to assess and optimize impacts of different land use and management patterns on regional ecosystem-services, the analysis of trade-offs between the different aspects is based on optimization techniques. The SWAT model will be coupled with a multi-objective genetic algorithm (e.g. NSGA II [2]) to find solutions (spatial configurations) which are pareto optimal. Pareto optimal solutions are solutions in which none of the objectives can be improved without decreasing another objective. The results are the best compromising options achievable in the considered model framework.

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Transregional land-use dynamics of bioenergy policies – An agent-based approach

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Abstract

The increasing use of bioenergy promotion policies can influence land-use decisions in production regions around the world via international markets, creating conflicts with the environment, food production, and social interests. Governance instruments aimed at ensuring the sustainability of bioenergy production, therefore, need to be based on knowledge about these potential transregional dynamics, in order to be effective and avoid unintended consequences, such as leakage effects.

Currently, a common approach to produce this knowledge is the use of computable general and partial equilibrium models, which can simulate impacts of bioenergy policies on a global scale. In order to do so, these commonly assume the homogeneity of all agricultural producers. However, differences between different types of agricultural producers and their local circumstances could have a significant effect on how agricultural demand and the incentives created by governance instruments are translated into land-use patterns. Especially, smallholders and large commercial farms, both important actors in the agricultural sectors of some of the most important bioenergy production regions, are known to differ in their behavior. Therefore, the homogeneity assumption underlying most of the current predictions about the transregional effects of bioenergy policies could cause them to be systematically biased.

The work presented investigates the role of producer heterogeneity with regards to the transregional effects of bioenergy promotion policies and governance instruments on land-use decisions. In order to incorporate heterogeneity between different types of agricultural producers into a simulation of these transregional effects, a model is created, which operates on two levels. On the local level, agent-based models based on artificially generated landscapes provide the framework for the introduction of heterogeneity between agricultural producers. Two different production regions are simulated, which are characterized by different compositions of smallholders and large commercial farms, representing stylized versions of regional differences in the structure of the agricultural sector. Agents of the two producer types decide between various land-use options, based on different sets of decision rules and optimization functions. On the transregional level, a simulation of markets for bioenergy and food products links the two production regions with each other. This creates a situation where the structures of the agricultural sector in the different regions are pitted against each other.

The model is used to analyze the effects of various combinations of bioenergy promotion, climate and land-use policy instruments in contrast to a baseline. Evaluation functions in the model allow for assessments of the economic welfare effects, the environmental impacts on climate, soils, and ecosystems, and the social consequences of these policy mixes. The analysis aims at providing a better assessment of the reliability of the predictions on which current decisions about bioenergy policies are commonly based and new insights into phenomena such as leakage effects and indirect land-use change (iLUC).

Spatially Dependent LCA of bioenergy systems for the Region "Mitteldeutschland"

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Abstract

Due to the decentralized nature of biomass production, bioenergy systems will greatly affect regional sustainability and socio-economics, as well as altering the ecosystems services provided by the landscape [1, 2]. In this context regional energy policies will play a significant role in the implementation of Germany's climate and energy policy targets [3]. Therefore, decision making tools are needed to make choices among the various bioenergy alternatives. Life cycle analysis (LCA) is one of the most important assessment tools used for the promotion of bioenergy [4], as it can generate a suite of environmental impact indicators, making it useful for communicating to stakeholders from a spectrum of disciplines [5].

The use of LCA as an assessment tool for identifying the potential impacts of decentralized biofuel production is diverse and complex. The inclusion of spatial heterogeneity within a Life cycle assessment (LCA), particularly in relation to land use options and bioenergy production will be a crucial methodological advancement to determine the sustainability of decentralized bioenergy options. One of the aims of the bioenergy assessment project (BEN) is to produce a spatially dependent LCA for bioenergy production within the case study region of "Mitteldeutschland", to assess the potential environmental impacts associated with decentralized bioenergy production systems.

The inclusion of spatial and temporal heterogeneity within the LCA methodology, involves the integration of the LCA method with GIS and other modeling approaches. The LCI (Life Cycle Inventory) phase, in progress, is the accumulation and organization of all relevant data streams in relation to the various steps along the bioenergy conversion pathway, with a particular emphasis on technological, spatial and temporal data. The technical conversion data is being generated through collaborations with the DBFZ and the spatial and temporal data through literature, modelling and collaborations within the BEN project. The inventory data will be used to first, generate a classical LCA, which will then be expanded further through explorative spatial analysis with other regional models e.g. land use and hydrology models. This approach allows the identification of technological feasible and sustainable biomass production potentials for the specific region. At a later stage, advantageous combinations of the modeled technologies will be evaluated in regard to different ecosystem services such as biodiversity or soil and water quality.

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Modelling bioenergy and land-use dynamics for Mitteldeutschland

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Abstract

Landscape patterns and bioenergy production are intrinsically linked and bioenergy is considered as one of the drivers of land-use change. To enable optimal planning for sustainable bioenergy production, it is essential to estimate future potentials and to develop an understanding of structural changes in the landscape associated with biomass based energy production.

This study aims at quantifying total potential of energy production based on biomass from energy crops, spatial allocation of energy crops in the future and estimating land-use change up to 2050 in the "Mitteldeutschland" region of Germany. Mitteldeutschland comprises of the three states of Saxony, Saxony-Anhalt and Thuringia and has a total area of ~ 55,000 km^2. The central method consists of the development and implementation of a land-use model using the SITE (SImulation of Terrestrial Environments) framework [1]. The SITE framework is a platform for the development of regional land-use change models with variable thematic focus. The SITE-MD (Fig. 1) model is currently being developed to simulate spatial allocation of land for fulfillment of demands on land for living space, food, and energy production and forest produce which are the primary drivers of the model. Using a high resolution grid (500m x 500 m) SITE-MD simulates land-use patterns in annual time-steps. Crop growth in the model is simulated by the process model DayCent. Land suitability is assessed by multi-criteria analysis while demand driven land allocation is based on transition rules and constraints. Simulations run up to 2050 using scenarios developed at the UFZ- NaBü (Nachhaltig und Bürgernah) and RaMa (Radikale Marktkräfte) [2].

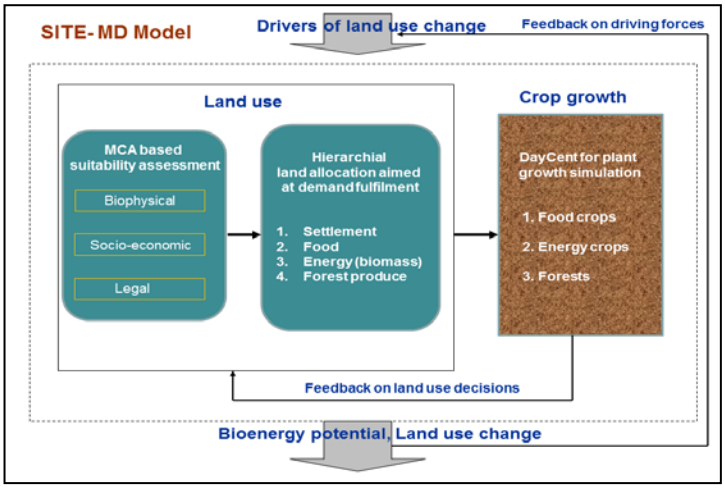

Figure 1: Structure of the SITE-MD model.

The expected outputs from the project are the spatial allocation of future bioenergy feedstock, total potential of energy generation from crops, land-use patterns up to 2050 and land-use change quantification. The scenario outputs have further scope of integration with Life Cycle Analysis (LCA) to generate spatially explicit indicators for sustainable bioenergy in the region.

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Bioenergy and Ecosystems

Transregional effects of the European Renewable Energy Directive on land use in Brazil

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Abstract

To meet the future energy demand coupled with a reduction of Greenhouse Gas Emissions (GHG), the European policy makers decided on a 10% goal for renewable energies in the transport sector till 2020 (Renewable Energy Directive 2009, RED). This target will not be met through the use of European arable land for energy crops alone. The term *transregional* focuses on the capture of reciprocal effects in between different regions in different parts of the world. Aim of the project is to answer the question, if and how the European demand for exported ethanol – coupled with the sustainability standards and certification schemes – is affecting land use in Brazil, one of the biggest global ethanol producing countries. In Germany in the year 2011, this question was also reflected in the public discourse about the blending of gasoline with ethanol (E10) and its effects on the Brazilian Amazon. Especially the issue of indirect land use change (ILUC) effects due to energy crops is a highly contested research area. These effects are not yet included into the European sustainability criteria on biofuels. The ILUC-hypothesis is based on the assumption that mechanized agriculture displaces cattle herds from existing pasture lands into the agricultural frontier of the Amazonian forest. Due to conceptual difficulties in linking distal land cover drivers to the point of impact, the measurability of ILUC-effects is connected to high scientific uncertainties.

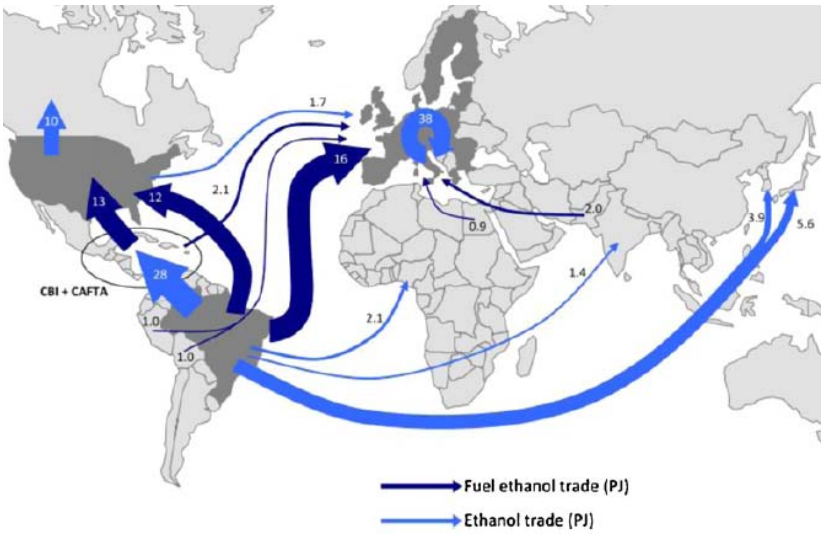

Figure 1: Global (fuel)ethanol trade streams of minimum 1PJ in 2008. Source: Lamers et al. 2011.

The aim of this project is to outline and understand the mechanism, which is initiated by a regionally introduced policy (RED) but which is affecting national and local levels as well as socio-ecologic scales in the producing country Brazil in terms of land use. The process will be interpreted in the light of the theoretical approach of Political Ecology and Politics of Scale. In order to comply with these aims, a mixed method approach will be followed. (1) The analyses of the market impulse of the RED, the ethanol trade in between Europe and Brazil as well as land use dynamics within Brazil will be based on secondary literature and data. (2) In Brazil, current trends in land use management and aims of implementation of certification schemes aiming at exportation possibilities to Europe are explored through expert interviews with key informants. (3) To capture concrete social and ecological developments and impacts as well as possible connections in between different regions, two in-depth case studies will be carried out in the states of São Paulo and Mato Grosso. Finally, it will be discussed and outlined, which positive and negative implications on land use the RED has in Brazil.

Landscape generators as tool for integrated regional environmental impact assessment of bioenergy activities

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Abstract

Biomass from renewable resources for bioenergy uses offers a great opportunity for the replacement of fossil fuels, especially for future energy demand scenarios. However, modified land use change may lead to new or increased environmental impacts, additionally modulated by climate change. For the assessment of bioenergy impacts on the environment, there is need for regional studies, which integrate a variety of impacts, and which go further than classical Life-cycle-assessments (LCAs), e.g. by including effects on biodiversity, or on river and streams. Especially it is important to include the effects on biodiversity, as such studies are at its beginning.

To tackle these questions, we develop a landscape generator, which aims to understand the environmental impacts of bioenergy use on the environment including future climate change at the landscape level. This approach will include exemplary studies of bioenergy impacts on biodiversity, aspects of spatial effects of the landscape on populations, and is planned to include the effect of cropping systems on rivers and streams.

The landscape generator will vary systematically spatial structures of model-landscapes, e.g. landscape configuration and composition, and relative distribution of cropping systems. It generates a set of model-landscapes, which can be investigated consistently by several collaborating projects with specific questions related to the bioenergy impact on the environment. The use of the same model-landscapes for all collaborating projects ensures a consistent multi-criterial impact analysis.

The results of the specific modelling studies will be used for the analysis of the environmental bioenergy impacts at the landscape and the regional scale.

Estimating the impact of energy crop cultivation on aquatic ecosystems on a landscape level: focusing on pesticide use in Central Germany

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Abstract

Agriculture is responsible for a large share of the pollution of surface waters and biodiversity loss in Europe, according to the European Environment Agency. An estimated 17% of total arable land in Germany in 2009 was used for cultivation of crops, such as silage corn, rape seed, wheat and sugar beets, used for biogas and biofuel production. The cultivation of crops for energy and with it the impact of agriculture on aquatic ecosystems is expected to increase. Pesticide runoff is one of the strongest stress factors for aquatic ecosystems in agricultural areas. For example, it has been shown that pesticides cause changes in macroinvertebrate communities by removing sensitive species at environmentally relevant concentrations [1]. Despite many concerns raised, large scale studies on more than one water body remain relatively scarce, the latest field study in Germany being over a decade old [2].

Most of the arable land in Central Germany is used for conventional and large scale cereal, rape seed, sugar beet and corn cultivation, which provides an excellent opportunity to study the potential impacts of biomass production. The overall goals of our working group are: 1) to determine the acute and the long-term effects of current pesticide use on macroinvertebrate communities in streams of Central Germany and 2) to evaluate the positive influences of forests and riparian buffer strips on agriculturally impacted communities.

Thirty water bodies in Central Germany are selected for the field study. Pesticide exposure will be measured using passive samplers and event-triggered samplers, whereas pesticide impacts will be detected using the macroinvertebrate-based indicator system SPEARpesticides. The potential of forest fragments and riparian buffer strips to enhance the recovery of sensitive species in agricultural streams will be investigated. Modeling studies using the SPEARpesticides system, GIS tools and the empirical Runoff potential model are carried out in parallel to determine hot spots of pesticide contamination on a regional scale. The modeling tools will further evaluate the effectiveness of riparian buffer strips and forest fragments as measures to reduce agricultural impacts on aquatic ecosystems in Central Germany. The possibility of combining these measures with benefits for biomass production, e.g. using fast-growing tree plantations as buffer strips, will be investigated.

Previous studies of the department of system-ecotoxicology with the abovementioned field and modeling methods have successfully detected pesticide impacts in real multi-stressor ecosystems [3]. Considering that some of the high yield biomass crops, like rape seed and silage corn require relatively high inputs of pesticides, the effects of biomass crop cultivation on aquatic ecosystems are important to consider for evaluating the overall environmental impact of bioenergy.

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Impact of bioenergy production on carbon storage and soil functions

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Abstract

With the German Renewable Energies Act 2009 began the expansion of biogas production. In 2010 Germany-wide were 5900 biogas plants which use not only plant biomass but also lifestock and biogenic waste. Such a big demand in the agriculture leads to changes inter alia of crop rotation with a higher rate of energy crops and reduced recycling of by-products (straw and beet leaves) into soil. Thereby new management systems and material cycles establish. For example digested biogas slurries are used as new organic amendment on the arable land. Predictions of the impact and consequences of new management systems on soil organic matter are important for sustainable soil use and maintenance of soil functions and fertility.

For that we are using two models. The mathematical model CANDY (Carbon and Nitrogen Dynamics) simulates carbon and nitrogen dynamics, soil temperature and soil water balance as one dimensional process in an agriculturally used soils. Simulation results are produced in one day steps. The model requires site-specific description of the soil profile (texture, wilting point, water capacity, saturated conductivity, bulk and substrate density), meteorological data (air temperature, precipitation, global radiation or sunshine duration) and management information (tillage, emergence, fertilizer, org. amendments, irrigation, harvest) [1].

Another model is CCB (CANDY Carbon Balance) which is a simplified version of the carbon dynamic model in CANDY. It describes the turnover of decomposable carbon in annual time steps for average site conditions depending on crop yields and input rates of fresh organic matter. Less data input (crop yields, applied OM amount, soil physical parameters, average rainfall, air temperature and initial organic carbon content) are needed [2].

One example for site-specific soil characteristics on the carbon turnover is simulation with CANDY on a farm-scale in Saxony-Anhalt. On that farm a biogas plant was built in 2005 and usage of biogas residues were established in 2006. We have an opportunity to evaluate with CANDY real management data from 1973 till now to predict the change of soil organic matter until 2050. Data preparation and right parameterization of biogas residues are one of challenges for realistic results.

Simulation results for district Teltow-Flämming in Brandenburg is one example for CCB use. Real data management from 2005 to 2009 and three additional land uses (cross compliance, 100% remove of by-products, 100% maize cultivation) were created and applied on two sites with fertile soil and poor soil. Results of simulations allow first statements on biomass potentials.

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Renewable Energies and Sustainability

Legal and economic instruments to govern bioenergy use

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Abstract

Being regarded as a promising tool for a sustainable development, bioenergy plays an important role in achieving Germany's ambitious climate protection goals and has been promoted intensely over the last years. Not only is it expected to be a climate neutral energy source helping to mitigate greenhouse gas emissions, but also to be a means to reduce the dependency on fossil fuels, thus increasing supply diversity and energy security. Especially feed-in tariffs under the Renewable Energy Sources Act (EEG) provide a supplementary income for farmers and may add regional value. However, critics hold that the promotion of bioenergy leads to competing uses of biomass, land use changes and an intensified arable production. So far, approximately 7,000 biogas facilities have been established in Germany. Even though possible negative effects cannot be generalised, there are some regions where the cultivation of maize as the currently most efficient energy crop has in fact increased significantly, also entailing the conversion of grassland, the displacement of other crop production and the intense utilisation of land which was only managed extensively before. This development bears the ecological risks of large-scale monocultures affecting biodiversity and soil functions as well as the spatial effects of a changing landscape. Whereas some of these effects may not only be due to biomass production, but also to structural changes in agriculture as a whole, others can clearly be attributed to bioenergy use, for example the application of fermentation residues which can serve as a valuable fertiliser, but accumulate in typical biogas regions and may thus affect water quality when applied in large amounts. Furthermore, the cultivation of new energy crops may change existing agricultural patterns.

With regard to this development, a reliable legal framework is needed. The project "Spatially relevant bioenergy policy as a legal problem" aims at analysing the prevailing legal provisions in the national and European context with regards to the effects of bioenergy use, pointing out available instruments to face the challenges of the politically required promotion of bioenergy use while taking into account the environmental and spatial aspects at the same time. Necessary legal amendments are to be identified and formulated.

Approaching bioenergy governance from an economic perspective, the project "Policies and instruments for sustainable bioenergy use – a new institutional economics approach" seeks to determine what changes to the existing institutional framework would be necessary to provide adequate incentives for an efficient and sustainable use and production of bioenergy. For this purpose, concepts, objectives and problems of bioenergy policy are examined, with special regard to the question of how energetic biomass use in Germany could be optimized, given the existence of multiple competing uses for biomass and land resources. In order to develop policy recommendations, the project analyses what kind of policy mix could be suitable to address the challenges of bioenergy governance. The analysis' methodological approach is based on new institutional economics, which, using more realistic assumptions than standard neoclassical economic theory, can generate insights of high practical relevance. To that effect, it is examined what implications uncertainty, information asymmetries, transaction costs, institutional and infrastructural path dependencies and political feasibility have for a bioenergy governance between market and government failures. Results are contrasted with recommendations based on neoclassical economics, to draw conclusions for a more realistic economic policy advice.

Carbon lock-out: Advancing renewable energy policy in Europe

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Abstract

An important pillar of the EU's climate strategy is the increased use of renewable energy sources (RES). In 2020, at least 20% of final energy consumption in the EU shall be provided by RES. This implies a RES share in electricity generation of at least 37%. Attaining this target (and even more ambitious future targets) may be a challenging task as the energy sector has been "locked" into a carbon-intensive system which hampers the adoption of RES technologies. An effective strategy for carbon lock-out requires a set of well-designed and coordinated policy instruments. These have to address the entire energy supply chain as well as energy demand, and account for the spatial and temporal dimensions of the energy system. We examine to what extent the existing EU policy framework for supporting RES use in the electricity sector actually satisfies these requirements.

As a first step, the characteristics of the carbon lock-in in the electricity sector are specified. We argue that supply and demand are subject to important path dependencies which put existing, non-renewable energy sources at an advantage. Path dependencies can be attributed to increasing returns, external effects, sunk costs and the long time horizons which are associated with the adoption of energy technologies. They are reinforced by the institutions which co-evolve with technologies.

Subsequently, the measures taken by the EU and its Member States to overcome this carbon lock-in are critically reviewed. So far, the policy focus has clearly been on promoting electricity generation from RES by remuneration schemes. The implementation of these schemes has been fragmented though, and their performance in terms of target achievement and cost-effectiveness has been mixed. More importantly, only limited efforts have been undertaken to address obstacles related to electricity transmission and distribution, storage and demand management. In general, a spatially integrated EU-wide management of the energy system seems to be lacking.

In the light of the deficits of the existing policy framework, we highlight and specify three policy advances which are decisive for attaining RES deployment targets in the electricity sector. (1) An integrated and spatially explicit EU-wide planning has to be introduced for the electricity sector. (2) The rules for remunerating electricity generation from RES have to be improved and harmonized throughout the EU. Inter alia, we argue here in favor of implementing improved feed-in tariffs instead of quotas. (3) We strongly plead for introducing additional incentives to promote grid extension and interconnection, to foster the development and adoption of storage technologies and to make electricity demand more flexible.

Finally, we discuss how a transition towards such an improved policy framework can actually be realized. We touch upon the priorities and timing of policy instruments, their political feasibility and options for an ongoing process of policy learning.

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Sustainability and bioenergy

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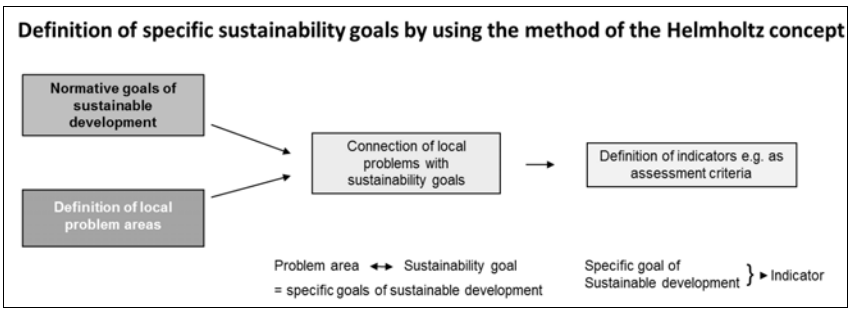
Abstract

The enhancement of biomass for energy use stimulated discussions on negative effects such as increased pollution of soil and groundwater or as regards the competition with land uses e.g. for food production. In reaction to increased criticism of political strategies and instruments that fostered the energetic use of biomass in European countries, in 2009 sustainability criteria for the production of biomass have been defined within the European Union's Renewable Energy Directive 2009/28/EC. To be acknowledged for the EU mandatory targets to obtain at least 20% of total energy from renewables and at least 10 % share of biofuels in transport petrol and diesel by 2020 Biofuel and bioenergy has to fulfill the criteria written therein. In Germany the certification of liquid biomass is obligatory since 2009. Therefore diverse certification systems have been acknowledged.

An analysis of those systems and the EU directive shows that sustainability criteria mainly take into account the issue of greenhouse gas emission saving. Further ecological issues are addressed e.g. with reference to land with high biodiversity value, areas protected by law or international agreements and the minimum requirements for good agricultural and environmental conditions defined for agriculture in the EU. Socio-economic criteria are only taken into account with the standard of the International Labor Organization.



If sustainable development should be taken serious in the sense of the Brundtland-definition, which demands to sustain the chances for development of present and future generations, then sustainable development has to be understood as a multidimensional issue. Multidimensionality refers to more than ecological quality or social aspects. Goals of this development should guide action and can be the basis for the assessment of decisions; they have to be defined for each specific (spatially and thematic) context.

In this presentation we will discuss the issue of sustainability and bioenergy with the help of the integrated Helmholtz Concept of Sustainability (the so-called HGF-approach), by contrasting existing criteria with the demand for sustainable development, and by presenting a methodological approach to define sustainability goals.

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EnergyEFFAIR – Efficient and fair allocation of renewable energy production at the national level

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Abstract

As a major measure of its climate policy the Federal Government of Germany intends to increase the share of renewables in gross electricity consumption to at least 30 per cent by 2020, followed by a continuous increase thereafter. At the same time, various studies indicate that both renewables and grid extensions can cause significant externalities. Such externalities comprise non-market effects on humans and the environment (e.g., bird fatalities caused by wind turbines). Failing to consider externalities has been shown to reduce social welfare, or in other words, an efficient allocation of renewables and power transmission lines needs to consider externalities. In addition, externalities indicate to which extent an extension of renewables is acceptable: the larger the externalities the lower the acceptance of renewables by the people.

The overall objective of the project EnergyEFFAIR (2011-2014, funded by BMBF) is to optimise the spatial allocation of renewable energy production activities (REPA) and power lines in Germany, taking into account costs and negative externalities as well as attitudes and fairness considerations regarding the distribution of these costs and externalities over the German population. The project considers three renewables: wind power, solar power and bioenergy. It consists of five work packages.

The objective of the first work package WP 1 is to assess in a spatially explicit manner the *energy potential* and the impacts that can be expected on humans and the environment. The analysis will be carried out on a geographical information system (GIS) considering a spatial resolution of 0.25 km^2.

The main task of work package WP 2 is to calculate the requirements of *additional grid infrastructure* resulting from an increase in the use of electricity from renewable sources, calculated in WP 1. In particular, the costs of the additional grid infrastructure as well as different models of how these costs are distributed will be assessed.

The objective of WP 3 is to assess both *production and opportunity costs* of REPA as well as *externalities* from grid extension and REPA in monetary terms. The production costs include investment and operating costs of the individual REPA and transport of biomass to the next biogas plant. In order to monetise the externalities of REPA a choice experiment (CE) will be used. In a CE, respondents rank different options of how renewable energy can be produced, which allows calculation of a price of the externalities.

The objective of WP 4 is to reveal individuals' *attitudes*, *fairness concerns*, and *willingness to accept financial compensation* for negative externalities from REPA and grid extension as well as to analyse *arguments and attitudes of stakeholders*. Fairness concerns include the acceptance of different principles of distributive justice concerning REPA at the level of households and Federal States. It will be assessed if and to what extent people are willing to accept financial compensation for exposure to REPA and grid extension.

The objective of WP 5 is to *integrate* the results of the work packages 1-4 to determine an *efficient and/or fair spatial allocation* of REPA and network infrastructure. This is done through spatial optimisation of REPA and grid extension. Trade-offs between efficiency and fairness will be evaluated.

Perspektiven der Windenergieplanung in Deutschland (Prospects of wind energy planning in Germany)

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Abstract

Die energiepolitischen Ziele des EEG (2012) sehen eine Steigerung des Anteils erneuerbarer Energien an der Stromversorgung bis spätestens 2020 auf einen Anteil von mindestens 35% vor. Unter Berücksichtigung weiterer Zwischenziele soll der Anteil dann bis spätestens 2050 auf mindestens 80% erhöht werden. Windenergie ist bedeutsam für die Erreichung dieses Ziels, ihr Anteil an der Gesamtstromerzeugung lag im Jahr 2010 bei 6,2%; innerhalb der Stromerzeugung durch erneuerbaren Energien beläuft sich der Anteil der Windenergie auf 36,5%. Zur Realisierung der ehrgeizigen Ziele setzt das Energiekonzept der Bundesregierung u.a. auf das Repowering (dem Ersetzen alter Anlagen durch wenige, aber leistungsstärkere Anlagen) und auf die Erschließung neuer Räume im Onshore-Bereich.

Das Dep. UPR befasst sich bereits seit Längerem mit planungsrechtlichen Fragen zur Flächensicherung für Erneuerbaren Energien im Allgemeinen und Windenergie im Besonderen. Die Notwendigkeit einer räumlichen Steuerung der Windenergie resultiert zum einen aus dem Erfordernis, dem planlosen Errichten von Windenergieanlagen entgegenzuwirken und zum anderen aus dem Erfordernis, Räume für künftige (andere) Raumnutzungsoptionen freizuhalten (Minderung von Landnutzungskonflikten). Durch eine insgesamt großzügige Anerkennung von sog. ‚Tabuzonen' stützt die Rechtsprechung das Verhinderungsinteresse der Planungsträger an einer ambitionierten Flächenausweisung, so dass über gesetzliche Planungspflichten und Mengenziele nachgedacht werden muss.

Die Windenergiebranche versucht teilweise die Bürgerakzeptanz von Windenergieanlagen und Repowering dadurch zu stärken, dass Bürger sich an der Errichtung konkreter Windparks durch Investments beteiligen können (Bürgerwindparks). Ähnliche Strategien werden in einzelnen Kommunen genutzt, die sich eine nachhaltige lokale Energieversorgung auf ihre Fahnen geschrieben haben und in einen Bürgerdialog über die Kommunalentwicklung eingetreten sind. Hier gilt es nachzudenken, welche Anforderungen eine Windenergieplanung erfüllen muss, die neben Effektivität und Rechtsverträglichkeit auch Akzeptanz erzeugen soll.

Mit der sog. Energiewende wird sich zudem die grundsätzliche Frage von Zentralität und Dezentralität der Energieversorgung neu stellen. Einrichtungen der Eigenversorgung werden vermutlich an Bedeutung gewinnen. Neben Fotovoltaikanlagen auf Hausdächern werden mittlerweile u.a. auch „Kleinstwindanlagen" intensiv diskutiert. Das Dep. UPR wird sich dieser Diskussion annehmen und insbesondere den bauplanungsrechtlichen Fragen einer Errichtung solcher Anlagen in Siedlungsgebieten nachgehen.

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Decentralized Energy Systems

Modeling decentralized energy systems to assess the demand of bioenergy in future supply systems

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Abstract

The transformation of the German energy system is the technological and societal challenge of the next decades. Energy saving, energy storage and renewable energy generation are the three pillars of this transformation process. But what does this mean for the future energy system? Could we keep the current institutional structure (centralized system) with few big supply & distribution companies or will we have a completely different system with new, more and smaller players (decentralized system)? Especially, which function will biomass have in future and what amount will be needed for which purpose (electricity, heat, transportation)?

At the Department Bioenergy, a working group deals with the above mentioned questions focusing on renewable energy generation applied on the study region Mitteldeutschland. The main method involves the principles and application of Energy System Modeling and scenario development. The selected Energy System Model (ESM) in the study is the EnergyPlan[1] model. It is a deterministic input-output model that enables the simulation and optimization of an energy system. Based on specific inputs (e.g. energy demands, shares of renewable energies, distribution data, installed capacities and efficiencies, transportation strategies and costs) outputs such as electricity production, fuel consumption and CO_2 emissions for different framing strategies will be estimated. Figure 1 shows an overview of the model structure.

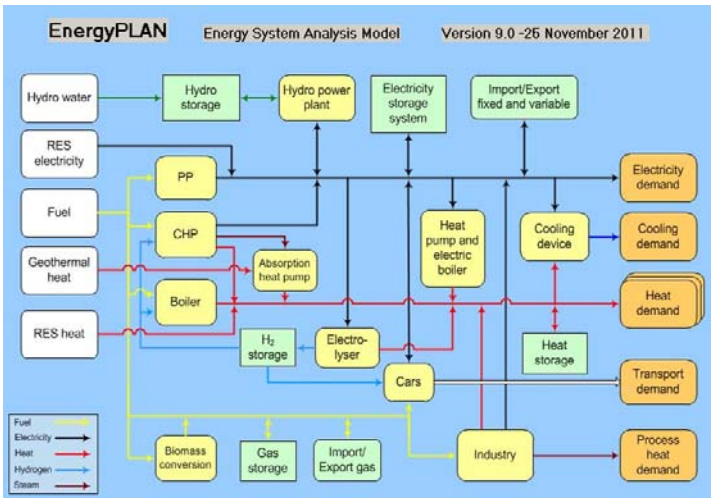

Figure 1: Model overview. *(Source: [1]Lund, H. 2011. EnergyPlan, Manual. Published online from www.EnergyPLAN.eu ©Copyright Henrik Lund, Aalborg University, Denmark.)*

Using the model we aim to investigate possible options for a 100% renewable energy supply for the study region. Since most of renewable energies such as wind power and photovoltaic are characterized by fluctuating availability, certain attention is paid to the demand for regulative energy. Bioenergy could provide such regulative energy. Based on the estimates for regulative energy (calculated with the model), the fractions of future energy demands that have to be fulfilled by bioenergy are deduced.

The expected outputs of this research work are energy scenarios showing possibilities for sustainable future energy supply for the study region. This includes the mix of different conversion technologies, requirements of electricity storage capacities and/or regulative energy. The results of the study are expected to facilitate medium to long-term sustainable regional energy planning. This work is linked with other on-going research at the Department Bioenergy (land-use change), Department CLE (land-use/ energy scenarios) and the DBFZ working group “Biomass in the energy system” (Milestone-Project).

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Energy aspects of regional scenarios

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Abstract

In Germany, our current life style causes emissions of approximately 11 tons of CO2eq. per capita. The main contributing sectors are energy needed (i) for heating/cooling homes, (ii) industrial production, (iii) transportation, and (iv) energy for the mainly agricultural land-use sector. Based on these and other starting conditions, we developed four regional scenarios for Central Germany, which enabled us to address region-specific uncertainties and drivers of change, considered relevant by scientists and regional stakeholders [1].

While the global population continues to increase, probably until the mid-century, causing steeply increasing demands in energy and other resources, one key aspect represented in all of our regional scenarios, is the pronounced decrease of the regional population, expected in the range of -17% to -41% until 2050 [1]. Consequently, in a 1st naïve vision we could assume that this space would become available for the production of renewable resources. However, Table 1 provides a selection of several other factors influencing energy demand and consumption.

Table 1: Energy-related drivers of change.

Type of Driver	Scenario			
	RaMa moderate	**RaMa extreme**	**NaBü moderate**	**NaBü extreme**
GDP growth	high	high	moderate	moderate
Energy demand	moderate; mainly fossil sources	high; fossil sources; some renewabl. due to high prices	low; mix of fossil and renewable sources	very low; almost 100% renewables until 2050
Population	strongly decreasing	extremely decreasing	strongly decreasing	decreasing
Life style	similar as today	similar as today	consumption eco-friendly; regional products appreciated	very eco-friendly consumption; regional products highly appreciated
Nature Protection	lower as now	much lower as now	higher as now	much higher as now

Besides obvious effects on energy demand, such as high vs. moderate GDP-growth in the scenarios, many of the less apparent energy-aspects are linked to our life-style. The sustainability-oriented NaBü scenarios assume for example a reduction in meat-consumption and increasing appreciation of regional (organic) products. The impacts on the energy sector are at least two-fold. Firstly, space needed for feed and fodder production would be reduced, secondly, less energy would be required for the transport of imported feed, food and animals. However, a sustainability-oriented life-style and value system may partly also lead to increasing spatial competition between food and energy production, via growing increasing amounts of organic food or via protecting larger fractions of land from being used for (intensive) agriculture. In the market-oriented RaMa scenarios it is assumed that farmers will continue to produce food-crops, increasingly oriented towards global markets, competing for space potentially available for bioenergy crops.

Furthermore, for decades household-sizes tend to decrease with per capita demands for living space increasing simulataneously [2], causing increasing demands for energy. This development is assumed to continue in the market-oriented RaMa scenarios, whereas in the NaBü scenarios a larger fraction of resource-efficient multi-generational houses and other alternative forms of housing are assumed.

The small set of examples demonstrates that current and potential future regional dynamics are linked within and between sectors, e.g. coupling life-styles and demography with (bio) energy demand and land use change.

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Energy-efficient city of Delitzsch - Simulating future energy use in shrinking urban regions

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Abstract

Shrinking population numbers are a challenge for planning future investments into urban built structures: Declining population can lead to decreasing real estate prices and can even induce vacancies, thus creating uncertainty for returns of investments into the housing stock and public infrastructure. This process is even more critical for municipalities with small budgets. Understanding and estimating future residential mobility is therefore essential for urban development in such regions. In the project "Energy-efficient city Delitzsch" funded by the German Federal Ministry of Education and Research, the effects of population shrinkage on city-wide energy use are investigated. This includes investments in energy-efficient heating systems and insulation of residential buildings. For the city of Delitzsch in Saxony, Germany, simulation models are being built to analyze investments both by private home owners as well as owners of housing estates. For both, investments into existing or new houses are influenced by population scenarios and future housing demand: Only if housing stock is likely to be used in the future, investments into energy efficiency may amortize.

The focus of the talk is on an agent-based model (ABM) for residential mobility that allows for simulating future patterns of population distribution [1]. We build a spatially explicit ABM for two main reasons: ABMs allow for (1) the representation of individual decisions and (2) the inclusion of (spatial) interactions between agents. The agents in the model represent domestic households of different types that decide upon re-locating within the city, to leave the city or to move into the city. The agents consider their housing preferences, the availability of infrastructure as well as the behaviour of other agents in their decision. The decision algorithm will integrate empirical data on residential mobility that is being surveyed especially for this project. This empirical study follows a two-step approach of (a) qualitative, in depth interviews and (b) a quantitative, written questionnaire. The paper describes both the concept of the agent-based model as well as first empirical results. This work will be accompanied by a dialogue with policy makers and residential building cooperatives about future investments into energy-efficient infrastructure in the city of Delitzsch in Saxony, Germany. Later on, this model will be coupled with a second ABM that simulates the investment decisions of private home owners.

The talk presents a model concept and first results of the qualitative part of the accompanying empirical survey that aims at eliciting data for calibrating the model. The process of conceptualizing the model on the one hand and eliciting empirical data on the other hand is a mutual relationship: The general model structure had implications for the questions being asked in the survey that thus includes questions regarding the decision to move or stay, location preferences and the like. Empirical data are not only used to calibrate the model later on, but also influence the model structure. For instance, the importance of storeys for location preferences was a preliminary result of the qualitative survey and has induced the inclusion of the third spatial dimension in the building stock of the model. Such cooperation between modelers and social scientists is essential for building empirically well-founded simulation models.

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Das Recht der Energienetzplanung in Deutschland (The law for planning energy infrastructures in Germany)

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Abstract

Die Energienetzplanung in Deutschland gehört zu den Eckpfeilern der sog. „Energiewende". Die Erneuerung und Erweiterung des Energieleitungsnetzes ist nicht nur im Interesse der Verbesserung des transeuropäischen Energietransports notwendig, sondern wird insbesondere auch für die Einspeisung von Strom aus erneuerbaren Energien gebraucht. Die Bundesregierung geht davon aus, dass bis zum Jahre 2020 mehr als 3600 km Höchstspannungsleitungen errichtet sein müssen, um die Energieziele erreichen zu können.

Die Errichtung von Energiehöchstspannungsleitungen ist raumbedeutsam und unterliegt in Deutschland einem kaskadenförmig ausgestalteten Planungs- und Gestattungsverfahren, das von der Bedarfsermittlung und –feststellung, über die Festlegung von Trassenkorridoren, die Abstimmung mit sonstigen Landnutzungserfordernissen bis hin zur konkreten vorhabenbezogenen Zulassung im Raum reicht.

Das Dep. UPR befasst sich im Rahmen der Helmholtz-Allianz „Zukünftige Infrastrukturen der Energieversorgung. Auf dem Weg zur Nachhaltigkeit und Sozialverträglichkeit" mit den Problemen der Energienetzplanung. Unser Erkenntnisinteresse ist darauf gerichtet, Aussagen darüber zu treffen, wie ein raumbezogenes Planungsrecht beschaffen sein muss, das einerseits dem Beschleunigungs- und Ausbauanliegen gerecht werden soll, andererseits aber auch die Erfordernisse eines hohen Umweltschutzes und die Rechte und Interessen der von Planungen betroffenen Menschen nicht vernachlässigen darf. Einen wichtigen Ansatzpunkt sehen wir in einer nachvollziehbaren Bedarfsplanung und Alternativenprüfung, die den Bürger schon am Anfang der Planungskaskade mitnimmt und gerade durch die Fairness des Verfahrens wichtige Bedingungen für die nötige Akzeptanz setzt.

Der Gesetzgeber hat diesbezüglich schon wichtige Schritte unternommen und beispielsweise ein Energiewirtschaftsgesetz und ein Netzausbaubeschleunigungsgesetz geschaffen, die sich wie eine Antwort auf das Desaster von ‚Stuttgart 21' verstehen lässt: Auf allen Ebenen werden sowohl die Öffentlichkeit, als auch die in ihren Aufgabenbereichen betroffenen Fachbehörden einbezogen, um eine am Gemeinwohl ausgerichtete Entscheidung zu gewährleisten und die Beachtung zwingender fachrechtlicher Erfordernisse, wie beispielsweise Vorgaben des europäischen Artenschutzes, sicherzustellen. Diese neuen Rahmenbedingungen für Planungsprozesse werden wir uns genau anschauen und den Implementationsprozess begleiten, um Beiträge zum Gelingen der Energiewende leisten zu können.

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Unconventional Energy Resources and Fuel Cells

Biotechnological processes for using waste and microbial oils in biodiesel productions

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Abstract

As biodiesel (fatty acid methyl ester, FAME) is mainly produced from edible vegetable oils, crop soils are used for its production, increasing deforestation and producing a fuel more expensive than diesel. The use of waste lipids such as waste frying oils, waste fats and soapstock has been proposed as low-cost alternative to feedstocks. Non-edible oils such as jatropha, pongamia and rubber seed oil are also economically attractive. In addition, microalgae, bacteria, yeast and fungi with 20% or higher lipid content are oleaginous microorganisms known as single cell oil and have been proposed as feedstocks for FAME production. Alternative feedstocks are characterized by their elevated acid value due to the high level of free fatty acid (FFA) content, causing undesirable saponification reactions when an alkaline catalyst is used in the transesterification reaction. The production of soap consumes the conventional catalyst, diminishing FAME production yield and simultaneously preventing the effective separation of the produced FAME from the glycerin phase. These problems could be solved using biological catalysts, such as lipases or whole cell catalysts, avoiding soap production as the FFAs are esterified to FAME. In addition, by-product glycerol can be easily recovered and the purification of FAME is simplified using biological catalysts.

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Methanogenesis in shales, coal and oil reservoirs - a perspective for sustainable exploitation of fossil fuels

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Abstract

Coal and oil account for more than 56% of the current world primary energy supply [1]. And, despite advances in alternative energies, they are expected to continue being an important resource in the near future. It has been estimated that around 3×10^{11} m^3 of normal oil and 8×10^{11} m^3 heavy oil still remain in exploited reservoirs [2], as conventional oil recovery techniques can only extract about 40% at most of the reservoired oil. Consequently, new strategies are under development to try to increase the recovery of the remaining hydrocarbons.

Microbial enhanced oil recovery (MEOR) entails the use of microorganisms to improve extraction of the remaining oil from reservoirs. It has been suggested that anaerobic biodegradation may play a significant role in reservoirs and evidences of *in situ* methanogenic biodegradation of residual oil constituents have been reported [3].

Methane production from oil, coal and shale could be thus a desirable and cost-efficient alternative, because it does not need external electron acceptors unlike other MEOR technologies. In addition, nutrients, water and other amendments could be supplied using the current infrastructure for oil and gas production. In addition, methane has no significant retardation in oil reservoirs, oil shale or coal beads. However, very little is known about the microbiology in these environments. For this reason, the Department of Isotope Biogeochemistry of the UFZ, together with partners from the BGR and the University of Beijing, has focused on the study of indigenous methanogenic hydrocarbon-degrading microbiota and the evaluation of their ability to produce methane from fossil fuels.

Our contribution is to provide analytical tools based on the isotopic composition of reservoir fluids (H_2O, CO_2, CH_4) and GC-MS hydrocarbon fingerprinting techniques to characterize these microbial processes microbial processes in different reservoir geosystems. Geochemical approaches can be nicely combined with microbiological and molecular techniques using ^{13}C-labelled hydrocarbons as substrates.

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Risikostudie "Sicherheit und Umweltverträglichkeit der Fracking-Technologie für die Erdgasgewinnung in Deutschland"

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Abstract

In Teilen Niedersachsens und Nordrhein-Westfalens planen Unternehmen (u.a. ExxonMobil) die Förderung von Erdgas aus sogenannten unkonventionellen Lagerstätten. Als „unkonventionell" werden Lagerstätten bezeichnet, bei denen das Gas so im Gestein gebunden ist, dass es nicht ohne äußere Einwirkung zum Bohrloch strömt und gefördert werden kann.

Erdgas gilt gemeinhin als vergleichsweise wenig die Umwelt belastender fossiler Brennstoff. Es wird in Deutschland als unverzichtbare „Brücke" in eine Zukunft gesehen, in der nur noch erneuerbare Energien genutzt werden. Mit heimischem Erdgas deckt Deutschland derzeit etwa ein Viertel seines Bedarfs. Nach heutigen Erkenntnissen sind mehr als 80% der in Deutschland bestehenden Reserven unkonventioneller Natur.

Um Erdgas aus unkonventionellen Reservoiren fördern zu können, soll das sogenannte Fracking-Verfahren eingesetzt werden. In Teilen der USA wird dieses Verfahren bereits in großem Umfang praktiziert. Berichte über Verunreinigungen von Grundwasser, Methan im Trinkwasser oder auch Erdbeben beunruhigen die Menschen. Anwohner, Politiker und Wasserversorger äußern Besorgnis, dass hierzulande natürliche Ressourcen, vor allem das Trinkwasser, gefährdet werde.

Es sind drei Typen unkonventioneller Lagerstätten zu unterscheiden:

- Schiefergas (shale gas) in etwa 1.000 bis 2.000 Meter Tiefe (erste Probefracks in den Jahren 2009/2010).
- Kohleflözgas (coalbed methane) ebenfalls in etwa 1.000 Meter Tiefe (erste Erkundungsbohrungen).
- Gas im Festgestein (tight gas) in etwa 3.500 bis 5.000 Meter Tiefe (Fracking in der Förderungseit etwa 15 Jahren eingesetzt).

Angesichts der Bedenken hat ExxonMobil einen durch Prozessbegleiter moderierten Informations- und Dialogprozess zwischen Öffentlichkeit, gesellschaftlichen Akteuren und dem Unternehmen gestartet. In diesem Zusammenhang wurde ein neutraler Expertenkreis mit der Erarbeitung einer „Risikostudie Fracking" beauftragt. Dieser hat den derzeit verfügbaren wissenschaftlichen Kenntnisstand hinsichtlich der Sicherheit und der Umweltverträglichkeit aufbereitet, interpretiert und weiterentwickelt. Er hat dabei eine Vielzahl von Fragen einbezogen und beantwortet, die von Bürgerinnen und Bürgern, von Politikern, von Kommunen oder auch von Wasserversorgern zum Thema Fracking gestellt wurden. Auf der Basis seiner wissenschaftlichen Studien erarbeitet der Expertenkreis Empfehlungen, ob und wenn ja unter welchen Bedingungen Fracking und die Förderung von Erdgas aus unkonventionellen Lagerstätten mit dem Schutz von Mensch und Umwelt vereinbar sind. Dabei hat er im Blick, dass für die Ausbeutung der unkonventionellen Erdgasreservoire eine Vielzahl an Bohrplätzen und Bohrungen mit der dazugehörigen Infrastruktur erforderlich wären. Der Expertenkreis fokussiert deshalb auf die folgenden Fragen:

- Wie kann die Förderung von Erdgas aus unkonventionellen Lagerstätten konkret aussehen, wenn die **Planungen in den betreffenden Regionen realisiert** werden?
- Erscheinen die für diesen Zustand ermittelten **Risiken beherrschbar**? Welche Vorkehrungen müssten getroffen werden, damit sie beherrschbar sind?
- Gibt es Situationen, in denen **vollständig auf das Fracking zu verzichten** ist?
- Wie schneidet **Erdgas aus unkonventionellen Lagerstätten im Vergleich zu Erdgas anderer Herkunft und anderen Energieträgern** mit Blick auf Umweltauswirkungen ab?
- Zu welchen Aspekten ist das verfügbare **Wissen ausreichend**, um diese Fragen hinreichend fundiert beantworten zu können? Wenn nicht: welche Wissenslücken müssen geschlossen werden, um zu belastbaren Einschätzungen zu gelangen?

Mit diesen Ergebnissen will der Expertenkreis dazu beitragen, dass der notwendige öffentliche Diskurs auf besser abgesicherten Grundlagen geführt und im Ergebnis entsprechend begründete Entscheidungen über den Einsatz dieser Technologie getroffen werden können.

The Helmholtz-Alberta Initiative: UFZ contributions to sustainable oil sands tailings water management

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Abstract

The Helmholtz Alberta Initiative (HAI) is a multidisciplinary international research partnership between the University of Alberta and the Helmholtz Association. It attempts to find solutions to the pressing environmental and sustainability issues facing energy projects, particularly the oil sand mining in Canada.

Canada's oil sand deposits (located in the province Alberta) contain vast amounts of unconventional oil in the form of bitumen. Using current technology, these reserves are estimated to be at least 173 billion barrels, i.e. an amount second only to the reserves of Saudi Arabia. Recovering this energy from the oil sands, however, presents daunting challenges from an environmental perspective: Hundreds of square kilometers of land are disturbed by the mines, subsurface steam extraction and tailings ponds. In addition, large amounts of water are needed for oil sands production, with 2 - 4.5 volumes of water typically needed to extract one volume of oil (80 % of this Oil Sand Process Water (OSPW) are recycled, 20% are stored in tailings ponds). The mining operators thereby face two distinct challenges; the first is to deal with the legacy of accumulated volumes of settled sludge in tailings ponds. The second is to improve the extraction technology in the future in order to minimize the volume of future tailings, to enable sustained development of the resource.

Figure 1: Oil sands are unconventional petroleum deposits and contain naturally occurring mixtures of sand, clay, water, and a dense and extremely viscous form of petroleum (bitumen). *photo: N. Gerner, UFZ*

The contributions of UFZ to HAI are to assess the environmental impacts of oil sands operations and to develop treatment strategies to minimize these impacts through appropriate tailings and water management. In particular, UFZ will contribute to the development of a risk assessment framework for OSPW effects and provide methodologies for evaluation, monitoring, and mitigation of mining water impacts on freshwater ecosystems. The current activities by UFZ cover the (bio-)technological treatment strategies for the decontamination of OSPW, the assessment of the sulfur cycle in tailings ponds and the determination of water quality and evaluation of the toxicological impact of the released treated tailings water on freshwater ecosystems. Future work will also include a socio-economic evaluation and decision support for the oil sands tailings water management.

The UFZ-projects are performed in collaboration with Canadian partners and study the OSPW effects at the microbe- (Project 1), tailings pond- (project 2) and watershed-scale (Project 3):

Project 1: *Effect of electrokinetic treatment on natural attenuation processes of OSPW*: This project investigates the potential of the combination of electrokinetic treatment and bioremediation as a biotechnological approach to stimulate decontamination of OSPW in both waste streams and tailing basins.

Project 2: *Sulfur cycling in an oil sands tailings pond*: This project aims to develop a conceptual model of the sulfur cycle in OSPW tailing ponds and the concomitant microbial communities involved. This research will form the basis for future management of the ponds to reduce the emission of toxic H_2S gas.

Project 3: *Identifying ecological effects of toxic constituents in the oil sand region in Alberta*: This project develops an indicator/monitoring system (SPEAR approach) for retrospective assessment of background contamination and prospective prediction of potential ecological effects of toxic OSPW constituents.

Hydrothermal carbonization: a new/old process for the upgrading of wet biomass

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Abstract

Recently, the hydrothermal carbonization (HTC) has received much attention in the press although actually it is an old process discovered by Bergius in 1913.[1] It is an exothermic process, in which biomass in an aqueous suspension is transformed into a bituminous coal-like material (hydrochar) at temperatures between 180-250°C and under moderate pressure. With these process conditions, the largest part of carbon is obtained as solid char, a fraction of the organic carbon is dissolved in the aqueous phase (5-30%), and little gas (CO_2 and CO) is generated (1-5%). The respective yields and the molecular composition depend on the choice of educts and the process conditions, such as temperature, pH-value, catalyst and reaction time. Experiments by several research groups have shown that HTC is suitable for the processing of wet biomasses with high cellulose and lignine contents. During HTC, the biomass undergoes hydrolysis, dehydration, and decarboxylation reactions, followed by condensation, aromatization and polymerizations. The carbonized hydrochars have an increased carbon content. Thus, they have higher specific heating values as compared to the intial biomass. Due to the loss of water during the carbonization, the chars are easier drainable than their precursor biomass, which is favorable for subsequent incineration processes. Besides their use for energy generation, the hydrochars have also been investigated as soil amendments and are tested at the UFZ for soil amelioration in small scale field experiments over three years using chars from carbonized sewage sludge.

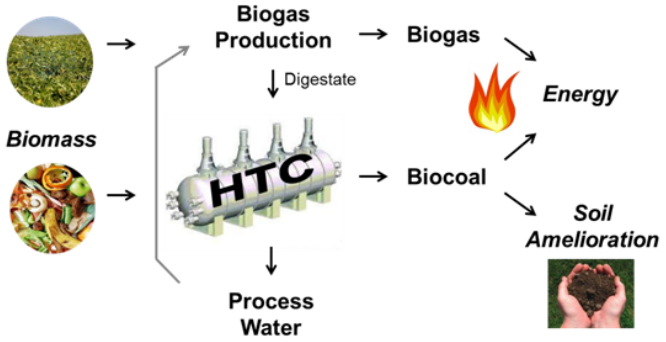

Figure 1: Schematic representation for the use of hydrothermal carbonization for biomass processing.

In our group, various biomass-educts, such as waste materials from agriculture, brewing, wood and paper materials, have been investigated under divers HTC-process conditions, and bulk parameters, such as carbon content in the chars and process waters, have been characterized. The dissolved organic matter (DOM) in the water can have a broad molecular weight distribution, ranging from low molecular weight organic acids to high molecular weight condensation products. In collaboration with the *Deutsches Biomasse Forschungszentrum* (DBFZ) it has been shown that the process water is suitable for methanogenesis. In the employed waste biomass, *e.g.* sewage sludge or organic municipal household waste, trace organic micro-pollutants, such as pesticides, pharmaceuticals and synthetic plastics, can be present. The potential for the degradation of these contaminants under typical HTC conditions is investigated as part of our HTC-project.

Moreover, a concept for the design of a deep well reactor technology based on the Vertech® technology for a continuous HTC process combined with recycling of the process waters has been introduced.[2] Hereby, the feedstock is brought downstream in the reactor as suspension, where reductive HTC conditions aim at high yields of the produced biochar. A subsequent change to oxidative conditions in the upward stream might also favor the decrease of the DOM concentration. Furthermore, oxidative post-treatments of the HTC-suspensions are studied.

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Geochemical processes contributing to electrical currents in microbial fuel cells

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Abstract

Fuel cells are devices with two electrically connected compartments of different potential. The different electrical potentials induce an electrical flow. In both compartments redox reactions occur that supply or consume electrons in the anodic and the cathodic compartment, respectively. In microbial fuel cells microorganisms are used to catalyze one or both of these redox reactions.

We have set up a small, reproducible, parallelizable and continuously monitored microbial fuel cell system and run it with pure and mixed cultures. Also sediment slurries are employed. Apart from energy generation, which is currently too low to be technically useful, the system can be used for sensors, the study of bacterial growth and the study of microbially catalyzed redox processes.

In a second approach, we have set up a flow-through microbial fuel cell which was operated for more than one year with sulfide- and benzene-containing groundwater directly extracted from a BTEX-contaminated field site. Benzene and sulfide were oxidized in the anoxic compartment, as shown by analysis of benzene and sulfide loss and production of oxidation products (CO_2, SO_4^{2-}). Substrate oxidation was accompanied by a low but reproducible production of current, indicating that electrons were channeled from the anodic to the cathodic part of the natural fuel cell system. The results indicate that microbial fuel cell systems can be used to enhance the biodegradation rates of hydrocarbons and sulfide in hydrocarbon-contaminated anoxic habitats.

Summarized, the approach has a wide potential in application and research of microbial process in subsurface environments.

Geothermal Energy

Voyage au chaleur de la Terre: Risk, nonknowledge and geothermal energy

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Abstract

The heat from below the earth's crust can immediately raise primordial fears as well as curious fascination about the unknown. These imaginations have long been supported through medieval illustrations of Hell, reports on the unpredictability of earthquakes, but also through popular fiction stories such as French writer Jules Verne's classical novel on the failed journey to the center of the earth. In this tradition it appears to be wise not to wake any sleeping monsters that may lurk in the deep. This cultural bias on little known things from below may also have influenced public interpretation and judgments on geothermal energy production which, compared to other renewable energy sources, still holds quite a peculiar status in the public perception.

Figure 1: Illustration by Édouard Riou from Jules Verne's novel *Journey to the Center of the Earth* (orig. 1864).

Whereas different types of risk assessments are crucial to enhance public understanding of new technologies and the effectiveness of implementation measures, real world decision making in processes of tapping geothermal energy sources and related areas often necessitate an open acknowledgement that ignorance (here called nonknowledge as a specified form of what is not known) cannot be avoided.

In this presentation some preliminary suggestions via sociological reconstructions and analysis of decision making under situations of nonknowledge are put up for discussion to fathom on how they may be used to (1) better understand strategies used by multiple actors (e.g., scientists, administrators, policy makers) to coping with ongoing situations involving knowledge gaps and (2) how these insights may be used for communication strategies (e.g., informing a concerned public or integrating regional planners into implementation processes of new technologies) as part of successful planning and implementation of geothermal energy technologies.

Recent developments in the sociology of ignorance and organizational psychology indicate that clear communication of what is not known in decision making processes can increase mutual trust among stakeholders as long as the communicated issues are congruent over time. Compared to often misunderstood risk assessments, this may also lead to higher rates of public understanding about the tapping of heat from below the earth's surface.

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Management of geothermal resources – a responsible use of renewable energies as contribution to a sustainable land management

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Abstract

The increasing use of shallow geothermal energy, especially the rising numbers of geothermal ground source heat pumps that are installed to progressively heat entire residential neighborhoods and the increasing use of groundwater to cool residential building and industrial facilities has led to an emerging need to assess possible effects of the use of shallow geothermal energy and to model subsurface heat transport.

Potential effects include the decline of groundwater quality and depletion of ground water ecosystem services. Heat and mass transport by ground water dispersion and convection may lead to a carryover of effects into groundwater dependent ecosystems. Typically, these underground processes are not directly accessible. Conflicting interests between geothermal energy use and groundwater protection as well as conflicts between geothermal energy users are expected to arise especially in densely populated urban areas, where the highest demand for the use of shallow geothermal energy is located but yet exploitation of shallow geothermal energy is limited and, simultaneously, groundwater vulnerability is highest.

In Germany, for example, awareness of possible effects of the use of shallow geothermal energy has been rising over the last few years, in legislation and the scientific community. A variety of statewide guidelines currently exists concerning the use of shallow geothermal energy in Germany, regulating exploration procedures and the installation of ground source heat pumps (e.g. setting minimum distances between ground source heat pumps). However, the high number of statewide guidelines clearly indicates the problems of setting generally applicable standards. Uncertainty in defining standards is primarily due to a lack of available monitoring data and lack of system understanding that is necessary for the formulation of regulations based on scientifically based thresholds rather than on limited operating experience. Hence, a management of geothermal resources is needed that helps contribute to a sustainable land management by mitigation of conflicts that may arise. This can be achieved by: 1) reliable geothermal exploration and monitoring of effects caused by the use of shallow geothermal energy; 2) developing novel measurement and monitoring technologies; and 3) system understanding, modeling, and development of planning tools.

Challenges on measuring and monitoring techniques for shallow geothermal energy

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Abstract

Understanding and quantifying effects that result from the use of shallow geothermal energy is an important prerequisite for developing sustainable management strategies for the near-surface geothermal potential. Until now, relevant literature studies have generally investigated temperature changes and resultant effects based on single point sources, with oversimplification of the (hydro-) geological regime often occurring. A quantitative assessment of potential effects, especially considering the extensive use of shallow geothermal energy, cannot be made based on these approaches. In addition, high resolution information about small scale groundwater flow fields, geology, soil matrix properties, and temperature regime are required. Therefore, exploration and monitoring techniques are necessary for: a) geothermal site characterization under special consideration of site-specific conditions; and b) monitoring and optimized use of near surface geothermal reservoirs.

Geothermal site characterization poses several challenges to measurement techniques, as insufficient site characterization can have a strong impact upon efficient use of geothermal heat systems. Until now, physical sediment characteristics, e.g. thermal conductivity, have been measured as integral values over the installation depths of ground source heat pumps (usually up to depths of 100m). The local hydrogeological regime is often not considered. Thereby, a detailed analysis of sedimentary and hydrogeological site properties could significantly contribute towards planning reliability and towards reducing uncertainties in dimensioning ground source heat pumps.

Once in operation, the use of shallow geothermal reservoirs has direct effects and impacts upon the groundwater. Distinct requirements related to reservoir characteristics, the hydrogeological regime and geology arise based on the intended use. As such, effective and continuous monitoring is required to ensure that an efficient operation of shallow geothermal applications is maintained.

Based on these differentiated requirements, measuring and monitoring techniques must be developed and adapted which are capable of capturing relevant processes and parameters at sufficient spatial and temporal resolutions and increase the reliability, efficiency and sustainability of using shallow geothermal energy.

Advanced numerical techniques for the simulation of thermo-hydro-mechanical (THM) processes in fractured porous media with applications for geothermal reservoir engineering

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Abstract

Numerical analysis of mechanics involved multi-physics problems in fractured porous media is important for various geotechnical applications such as enhanced geothermal systems (EGS), because the EGS reservoirs mostly include enhanced fractures, whose length can be a few hundred meters after hydraulic fracturing. As fractures are mechanical discontinuities, it is difficult to solve the problem using continuity based numerical methods such as the finite element method (FEM). Currently, equivalent porous medium or multiple continuum model approaches are often only the way to model fractured rocks with the FEM [1]. However, explicit modeling of characteristic fractures (i.e. discrete fractures) is still desirable for subsurface systems where a few large fractures dominate the system behavior.

In this study, we present our recent development of the FEM for modeling coupled thermo-hydromechanical (THM) processes in discretely fractured porous media. Flow and heat transport problems in rocks and fractures are solved by assuming no infill materials in fractures and, therefore, continuity of filed variables over the two domains. For mechanical problems, classical zero-thickness interface elements (i.e. joint elements) or lower-dimensional interface elements (LIEs) developed by the authors [2] can be used to model discontinuities. The basic idea of LIEs are (1) representing the fractures with lower-dimensional elements, (2) using fracture relative displacements as additional primary variables and (3) applying a local enrichment only at the fracture elements for a discontinuous displacement function. Unlike joint elements, this method does not require any double-node elements and permits having an identical mesh for all coupled processes. Hence, formulating the problems in a monolithic way is possible for robust computations.

For verification of the method, we have conducted simulations of a 2D fluid injection problem into a single fracture where fracture aperture varies depending on fluid pressure. The study shows that the proposed method can produce very similar results to a semi-analytical solution. Extensions to three- dimensional spaces are ongoing.

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Energy Policy and Environmental Impact

Underground storage of carbon dioxide and hydrogen: current research activities

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Abstract

The capture, transport and storage of carbon dioxide (carbon capture & storage, CCS) is a newly developed technique that may help to reduce anthropogenic carbon dioxide emissions. The pros and cons of CCS are currently discussed. Besides uncertainties in the risk assessment of capture and transport of carbon dioxide, a major current bottleneck in starting up CCS projects is due to gaps in environmental information regarding the risk assessment of storing huge amounts of carbon dioxide in non-engineered underground storage sites [1]. Carbon dioxide leakage from storage sites is one of the main concerns, as the pH can decrease due to high carbon dioxide concentrations, leading e.g. to the mobilization of heavy metals in shallow groundwater systems. In addition, the impact of high carbon dioxide concentrations on microbial communities in shallow and deep groundwater systems is only poorly investigated. The UFZ Departments Monitoring & Exploration Technologies and Isotope Biogeochemistry have recently taken part in a BMBF-funded joint research project in which carbon dioxide was injected into a shallow aquifer, in order to test and develop methods for monitoring carbon dioxide and associated biogeochemical changes in groundwater systems. Furthermore, we investigated the effects of high carbon dioxide concentrations on typical, ecophysiological different groundwater bacteria. In a follow-up project, biogeochemical consequences of carbon dioxide storage in the deep subsurface are currently investigated.

The underground storage of hydrogen may become an important technique in future, as hydrogen is considered an adequate renewable energy source capable of compensating decreasing world oil production rates. Analogously to carbon dioxide underground storage, the current lack of experience in storing huge amounts of hydrogen makes it difficult to assess all possible risks associated with this storage technique. Compared to carbon dioxide, hydrogen is due to its chemical properties more mobile, more reactive and also faster biodegradable, complicating any risk assessment approaches. In my talk, I will present possible biogeochemical effects connected to underground hydrogen storage.

Our team at the ISOBIO consists of A. Schultz, P. Bombach, H. H. Richnow and C. Vogt. We cooperate with the University Kiel, TU Freiberg, Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), and E.ON Gas Storage GmbH.

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Assessing the ecological risks and consequences of alternative energy: a multi-scale perspective, and example from bat mortality at wind turbine sites

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Abstract

The combined effects of climate change and land-use changes pose major threats to biodiversity. While some of the strategies to safeguard biodiversity may facilitate adaptation to climate change, adaptations to climate change may not benefit biodiversity – and in some cases, may even put species at greater risks.

The quest for alternative sources of energy, including renewable energy, facilitates rapid, large scale land-use changes. Associated challenges include *i)* lack of knowledge regarding the impacts, even at the small scale; *ii)* contributions of land-use changes to ongoing homogenization, habitat loss and fragmentation at larger scales; and *iii)* land-use conflicts due to which infrastructures may be located at vulnerable sites even if knowledge suggests otherwise. These challenges pose urgent need to fill gaps in knowledge, across ecological and spatial scales. This can be clearly demonstrated through the effects of wind turbines on bats.

At the **local scale**, direct collision against the rotor blades is known to cause severe causalities to bats, but ongoing analyses suggest that the threats are strongly under-estimated. *i)* Oversampling near turbines and under-sampling at larger distances tends to under-estimate the extent of the impact; *ii)* indirect effects of noise (which for unknown reason seems to attract bats), wind turbulence and sudden air-pressure changes inflict further mortalities that are poorly studied; and *iii)* the use of simple collision models to assess the risks, while neglecting indirect causes of death, likely yields to a vast under-estimation of threats.

At the **landscape scale**, the spatial organization of turbines with respect land-uses is rarely studied; Current analyses show that more than 95% of fatalities occur at turbines at distance of <300 m from woodlands or groves, thus providing new knowledge that can be used for diminishing the impact. On a **wider ecological scope**, one must also consider cascading effects on ecosystem functioning and services: Impacts on bats, as well as raptors, likely releases insects and rodents from predator pressure with potential major damages to agricultural crops in and around such altered environments. Finally, there is an urgent need to assess the large scale, **national- or even continental-scale** consequences of the demand for alternative energy sources, since the development of infrastructure yields landscape homogenization and includes fragmentation due power lines.

Against this background, we need to *i)* generate empirical knowledge of patterns, drivers and impacts; *ii)* take a multi-scale approach which leads not only from local to large-scale but also from individuals and population dynamics to ecosystem functioning and services; and *iii)* consider realistic scenarios, with their associated spatial arrangement, in terms of the potential effects on viability and connectivity. Using empirical data, spatial analyses and simulation models we intend to tackle these questions contribute to assessments at the local to national levels. Thereby, we aim to establish guidelines for planning that minimizes threats, acts in interaction with Green Infrastructure, and potentially even benefits some species or ecosystems.

Quantification of exposure and ecological effect of toxicants in aquatic ecosystems

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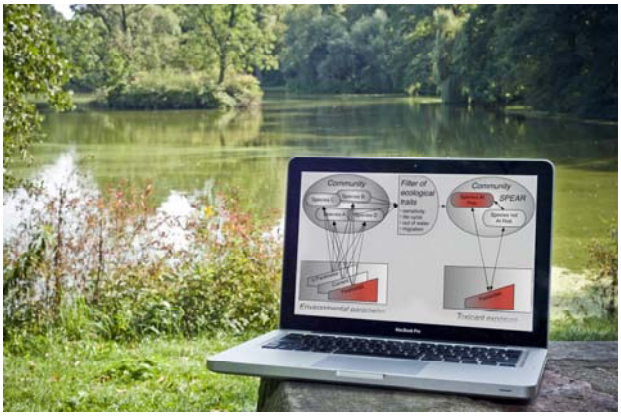
Abstract

A multitude of toxic substances may reach surface waters during the production of energy. This is for example (i) pesticides for agricultural bioenergy production (ii) hydrocarbons and heavy metals for oil sands exploitation and (iii) fracking fluid used in the extraction of tight gas and shale gas wells. A challenge is to 1) identify the toxicity of many of these compounds were so far no information of toxicity tests is existing. Another challenge is 2) to cost-efficiently estimate exposure and ecological effect of these toxicants in aquatic ecosystems. For both tasks we developed efficient tools.



1) To identify toxicity read-across enables the interpolation of a property for a target chemical from respective experimental data of sufficiently similar compounds as outlined for example in [1]. A read-across method has been developed that is based on atom-centered fragments (ACFs) for evaluating chemical similarity. The method has the potential to assist in the predictive evaluation of fish toxicity for regulatory purposes.

2) To estimate exposure and ecological effect of toxicants in aquatic ecosystems the SPEAR system has been developed [2]. SPEAR (Species At Risk) is a bioindicator system based on biological traits and focused on various types of contaminants in fresh waters. The traits used are responsive to the effects of particular toxicants (e.g. physiological sensitivity) and associated recovery (e.g. generation time). SPEAR bioindicators are developed to complement existing bioassessment methods and indices in order to assess effects of toxicants. Currently, two SPEAR-indicators exist: SPEARpesticides and SPEARorganic designed to detect and quantify effects of pesticides (insecticide toxicity) and general organic toxicants (e.g. petrochemicals, synthetic surfactants) respectively. An online tool is available to easily use the approach (http://www.systemecology.eu/SPEAR/index.php).

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Sustainable bioenergy governance and the analysis of economic bioenergy strategies

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Abstract

To date, energetic uses of biomass represent the most important renewable energy option in Germany and the EU. Its versatility of use, which enables a wide range of applications in the electricity, heating and transport sectors, and the storability of biomass make bioenergy an important part of renewable energy expansion strategies in many countries. However, both on the European and German level, policies with a strong quantitative focus which emphasise bioenergy expansion across all sectors are increasingly disputed, as the problems of such a strategy become obvious [cf. 1, 2]. Firstly, regional and global bioenergy potentials are limited, given multiple competing uses for biomass and land resources (most notably for food and feed production, material biomass uses, and nature conservation). Also, the growing demand for bioenergy increases pressures on agricultural production systems, which may already have exceeded their sustainable limits, risking undesirable environmental and social consequences. Lastly, the term "bioenergy" encompasses a broad variety of possible pathways, which differ in their choice of substrates, conversion technologies and end use sectors. Depending on the pathway, greenhouse gas balances, costs and other environmental and socio-economic characteristics vary considerably, making a more discriminate approach to policy support necessary.

To take into account the scarcity of available biomass and land resources, but also of private investment capital and public support funds, an optimisation of bioenergy use is necessary. The challenge of bioenergy governance is to establish an institutional framework which promotes those bioenergy pathways contributing the most to the primary policy aim, and effectively safeguards sustainability. This task is complicated by the existence of multiple, conflicting policy aims (climate change mitigation, security of energy supply, rural development), and the complexity and transnationality of bioenergy value chains. Market forces fail to bring about an efficient and sustainable outcome, as prices do not reflect the full environmental and social costs of alternative technologies and land use options. Moreover, in the energy sector, institutional and infrastructural path dependencies favour conventional fossil fuel options. While state intervention is therefore called for, the complexity of the governance problem with its high information requirements and multiplicity of political interests increases the risk of substituting market for government failure.

Economic research on bioenergy governance in the UFZ Departments BEN and ÖKON therefore focusses on the question of how an efficient and sustainable governance of bioenergy between market and government failures can be institutionally implemented. In this context, research topics are the analysis of alternative bioenergy strategies, the balancing of state intervention and markets as governance mechanisms, and the instrumental design of regulation. Research activities are integrated with other modules of the interdisciplinary working group Bioenergy Systems Analysis, the Division Bioenergy Systems of the DBFZ (Deutsches BiomasseForschungsZentrum), and with relevant research at the departments of the Division of Social Sciences and the Department of Ecological Modelling. This integrated approach reflects the wide range of impacts of bioenergy policy, the relevance of energy and land use sector framework conditions, and the importance of scientific knowledge for determining the social desirability of different bioenergy pathways. Building on the results, policy recommendations will be formulated concerning bioenergy strategies, instrument choice and instrument design.

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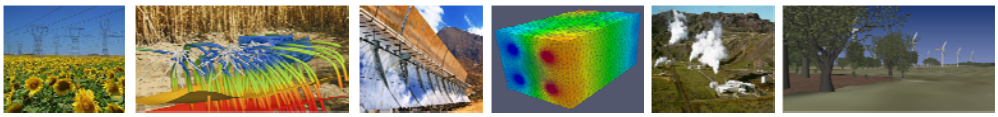
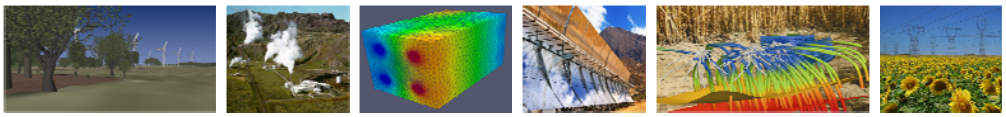


1st UFZ Energy Days 4-5 April 2012, Leipziger KUBUS
Scientific Program

Wednesday, 4 April 2012

09:00 – 09:10	Welcome by Dr. F. Messner (Head of Director's Office – Centre Development and Scientific Controlling) and Prof. O. Kolditz (Head of the Department of Environmental Informatics)
09:10 – 09:20	Introduction by Prof. D. Thrän (Speaker of the Department of Bioenergy)
09:20 – 09:30	Welcoming speech by The Power & Environment Network of the City of Leipzig (Dr. W. Damm, Chairman of the Network Energy and Environment, Stadtwerke Leipzig)
09:30 – 10:00	Guest lecture by Prof. M. Kaltschmitt (Head of the Institute of Environmental Technology and Energy Economy, TU Hamburg-Harburg) Regenerative Energien im Energiesystem – Stand und Herausforderungen im Kontext der sog. Energiewende
10:00 – 11:00	*Biogas Processes I* Chairperson: Prof. D. Thrän (BEN)
	Thomas Maskow, Sven Paufler, Heike Sträuber, Sabine Kleinsteuber (UMB) The potential of calorespirometry for control and analysis of biogas processes Sukhwinder Singh, Dietmar Schlosser (BEN, UMB) Fungal pre-treatment of lignocellulosic feedstock to improve biogas production Christin Koch (BEN, UMB) Prozessüberwachung mittels Einzelzellmessung Babett Arnold (UMB) Analyse von Kohlenstoffflüssen und syntrophen Interaktionen im Biogasprozess mittels Stable Isotope Probing
11:00 – 12:15	*Biogas Processes II* Chairperson: Dr. S. Kleinsteuber (UMB, BEN)
	Markus Kraus, Ulf Roland (TUCHEM, BEN) Radiowellen-gestützte Biogasaufbereitung zur Substitution von Erdgas als Energieträger Katharina Porsch, Marcell Nikolausz (BEN, UMB) Enrichment of lignocellulose-degrading microorganisms from natural habitats and their potential to enhance the biogas process Marcell Nikolausz (UMB, BEN) Biogas stable isotopic fingerprinting for the process control of anaerobic digestion Andreas Zehnsdorf (UBZ) Neophyten aus dem Wasser als Substrat für Biogasanlagen? Lucie Moeller (UBZ) Schaumbildung in Biogasanlagen
12:15 – 13:15	Lunch
13:15 – 14:30	*Modeling of Geotechnical Energy-Related Processes* Chairperson: Dr. F. Messner (ZENCO)
	Olaf Kolditz (ENVINF) OpenGeoSys – An open-source finite element multiphysics community project for the simulation of energy-related geotechnical applications Björn Zehner (ENVINF) Scientific 3D visualization – a way to the comprehensive representation of complex modelling data Joshua Taron (ENVINF) Twophase flow in deformable porous media under deep geological conditions Ashok Kumar Singh (ENVINF) Non-isothermal compositional gas flow in porous media with geotechnical applications Haibing Shao, Norihiro Watanabe, Ashok Kumar Singh, Patrick Schmidt, Olaf Kolditz (ENVINF) Numerical simulation of coupled processes for thermo-chemical energy storage systems

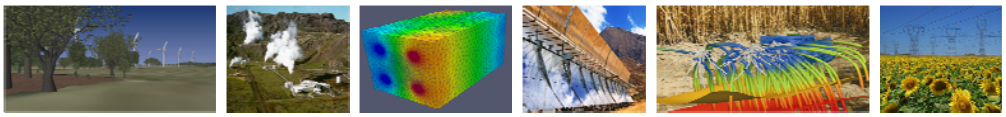


Wednesday, 4 April 2012 (Cont'd.)

14:30 – 15:30	*Bioenergy and Land Use* Chairperson: Dr. P. Lehmann (OEKON)
	Felix Witing (BEN) Optimization of land use and management pattern in the context of bioenergy production, food production and ecohydrology -first working concept Christian Klassert, Erik Gawel (BEN, OEKON) Transregional land-use dynamics of bioenergy policies: An agent-based approach Steffen Schock, Sinéad O' Keeffe (BEN) Area specific LCA of bioenergy systems for the Region "Mitteldeutschland" Subhashree Das (BEN, CLE) Modelling bioenergy and landuse dynamics for Mitteldeutschland
15:30 – 15:45	Coffee break
15:45 – 16:45	*Bioenery and Ecosystems* Chairperson: Dr. J. Bovet (UPR)
	Linda Bausch (BEN, UPOL, NSF) Transregional effects of the European Renewable Energy Directive on land use in Brazil - Cutting down the Brazilian Amazon for ethanol use in Europe? Sandro Pütz, Daniela Thrän, Karin Frank (BEN, OESA) Landscape generators as tool for integrated regional environmental impact assessment of bioenergy activities Polina Khrycheva (BEN, OEKOTOX) Estimating the impact of energy crop cultivation on aquatic ecosystems at a landscape level Nadia Prays (BEN) Impact of bioenergy production on carbon storage and soil functions
16:45 – 18:00	*Renewable Energies and Sustainability* Chairperson: Dr. J. Priess (CLE)
	Vanessa Richarz, Alexandra Purkus (BEN) Legal and economic instruments to govern bioenergy use Paul Lehmann, Erik Gawel (OEKON) Analyse des bestehenden Instrumentenmixes zur Förderung Erneuerbarer Energien Alena Bleicher, Matthias Groß (SUSOZ) Nachhaltigkeit und Bioenergie Martin Drechsler (OESA) EnergyEFFAIR – Efficient and fair allocation of renewable energy production Wolfgang Köck, Jana Bovet (UPR) Perspektiven der Windenergieplanung in Deutschland

Thursday, 5 April 2012

09:30 – 10:30	*Decentralized Energy Systems* Chairperson: Prof. P. Dietrich (MET)
	Marcus Eichhorn (BEN) Modeling decentralized energy systems to assess the demand of bioenergy in future supply systems Jörg Priess, Jennifer Hauck, Marcus Eichhorn, Daniela Thrän (CLE, UPOL, BEN, OESA) Energieaspekte regionaler Szenarien Nina Schwarz, Katrin Großmann (CLE, SUSOZ) Energy-efficient city of Delitzsch – Simulating future energy use in shrinking urban regions Wolfgang Köck, Jana Bovet (UPR) Das Recht der Energienetzplanung in Deutschland
10:30 – 12:00	*Unconventional Energy Resources and Fuel Cells* Chairperson: Dr. Th. Maskow (UMB)
	Laura Azócar, Rodrigo Navia, Hermann J. Heipieper (UBT) Biotechnological processes for using waste and microbial oils in biodiesel production Nuria Jimenez Garcia, Hans-Hermann Richnow (ISOBIO) Methanogenesis in shales, coal and oil reservoirs - a perspective for sustainable exploitation of fossil fuels Dietrich Borchardt (ASAM) Ergebnisse einer Risikostudie zur Gewinnung von unkonventionellem Erdgas in Deutschland Lukas Wick, Matthias Liess, Katrin Wendt-Potthoff, Martha Schattenhofer (UMB, OEKOTOX, SEEFO) The Helmholtz-Alberta Initiative: UFZ contributions to sustainable oil sands tailings water management Igor Baskyr, Barbara Weiner, Juergen Pörschmann, Frank-Dieter Kopinke (TUCHEM), Christoph Fühner (UBZ) Hydrothermale Carbonisierung – ein neuer/alter Prozess zur Veredlung von nassen Biomassen Lorenz Adrian, Carsten Vogt, Hans-Hermann Richnow (ISOBIO) Geochemical processes contributing to electrical currents in microbial fuel cells
12:00 – 13:00	Lunch
13:00 – 14:00	*Geothermal Energy* Chairperson: Prof. K. Frank (OESA)
	Alena Bleicher, Matthias Groß (SUSOZ) Nichtwissen und Geothermie Thomas Vienken, Peter Dietrich (MET) Geothermisches Ressourcenmanagement – ein sicherer Umgang mit Erneuerbaren Energien als Beitrag zu einem nachhaltigen Landmanagement Peter Dietrich, Thomas Vienken (MET) Herausforderungen an die Mess- und Monitoringtechnik für die flache Geothermie Norihiro Watanabe (ENVINF) Advanced numerical techniques for the simulation of thermo-hydro-mechanical (THM) processes in fractured porous media with applications for geothermal reservoir engineering
14:00 – 15:00	*Energy Policy and Environmental Impact* Chairperson: Prof. O. Kolditz (ENVINF)
	Carsten Vogt (ISOBIO) Underground storage of CO_2 and Hydrogen: current research activities Guy Peer, Reinhard Klenke, Klaus Henle (NSF) Assessing the ecological risks and consequences of alternative energy from a broad perspective, and an example from bat mortality at wind turbine sites Matthias Liess, Gerrit Schüürmann (OEKOTOX, OEC) Umweltwirkungen der Energiewende – Erfassung und ökologische Bewertung von Schadstoffen in Gewässern Erik Gawel, Alexandra Purkus (OEKON, BEN) Nachhaltige Bioenergie-Governance und Analyse ökonomischer Bioenergie-Strategien
15:00 – 15:15	Conclusions and outlook: Prof. O. Kolditz (Head of the Department of Environmental Informatics)



Organigram of research at the UFZ related to energy topics

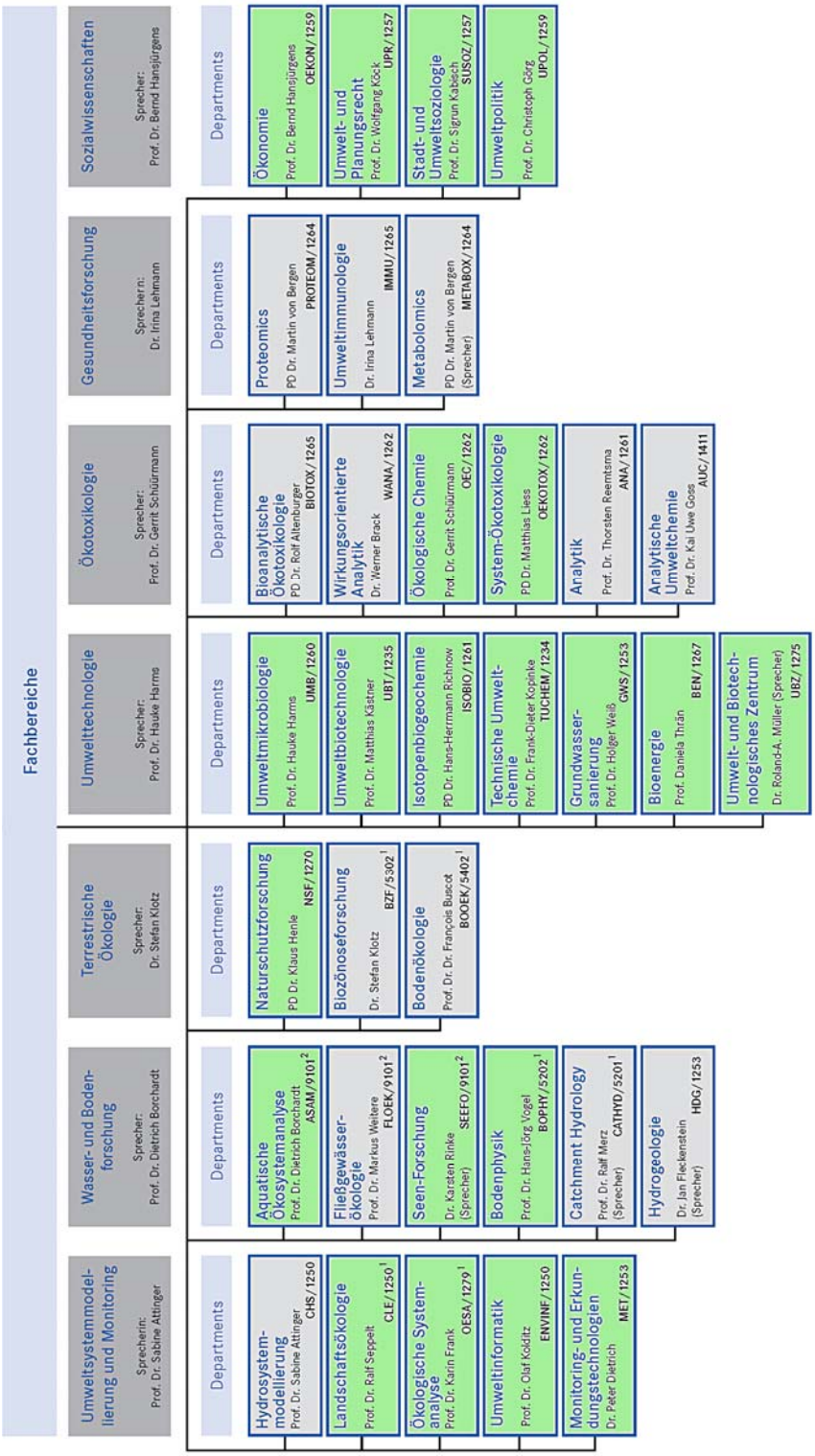
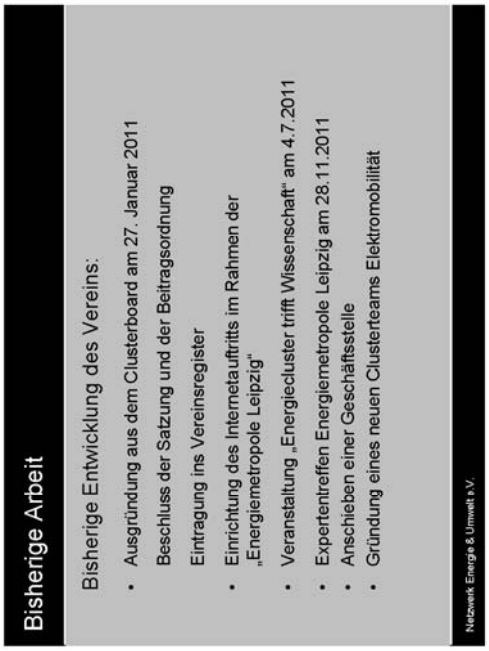
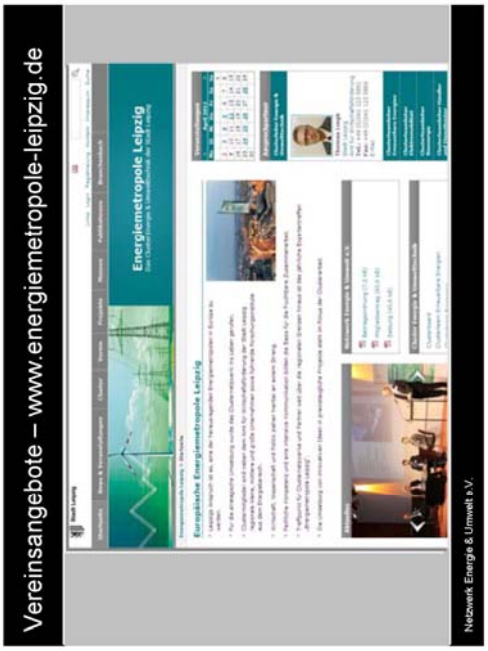
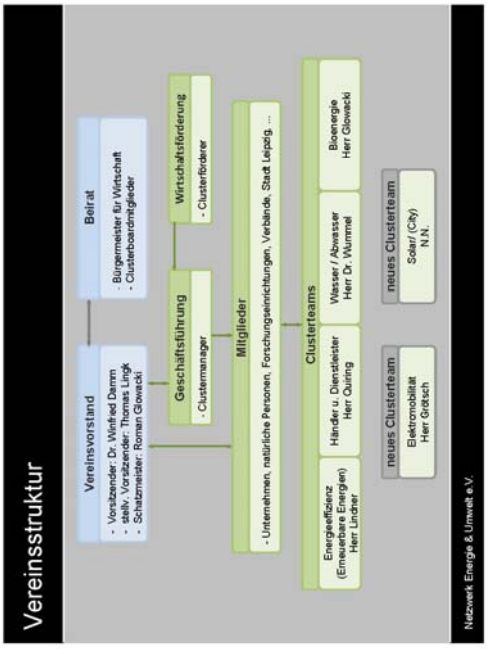


Figure 1: Organigram of the departments of the UFZ. Departments contributing to this book of abstracts dedicated to topics related to energy research are highlighted in green.

Welcoming speech by Dr. W. Damm
(The Power & Environment Network of the City of Leipzig)







Projekte - Beispielhaft

- Spitzencluster „BioEconomy“
- Elektromobilität
- EnergieCity
- Vermarktung von Dächern für Solaranlagen
- Biomassekraftwerk
- Smart Metering
- TREC – Transregional Renewable Energy Cluster (EU-Projekt)
- ZIM-Netzwerk Energieinnovationen
- Potenzialanalyse zur Aus- und Weiterbildung
- SIAG

Netzwerk Energie & Umwelt e.V.

Elektromobilität - Autos

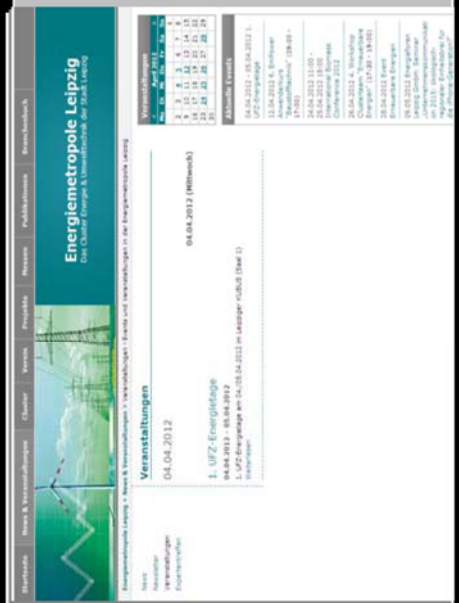
- Stadt Leipzig (10)
- LVB Gruppe (4)
- SW Leipzig (2+1)
- Technische Werke Delitzsch (1)
- S&P GmbH (1)

☛ insgesamt 19 Elektroautos

Fahrzeugtypen:
1 x eAudi A2, 1 x Tazzari,
17 x iMiEV

Netzwerk Energie & Umwelt e.V.

Vereinsangebote – www.energiemetropole-leipzig.de



Netzwerk Energie & Umwelt e.V.

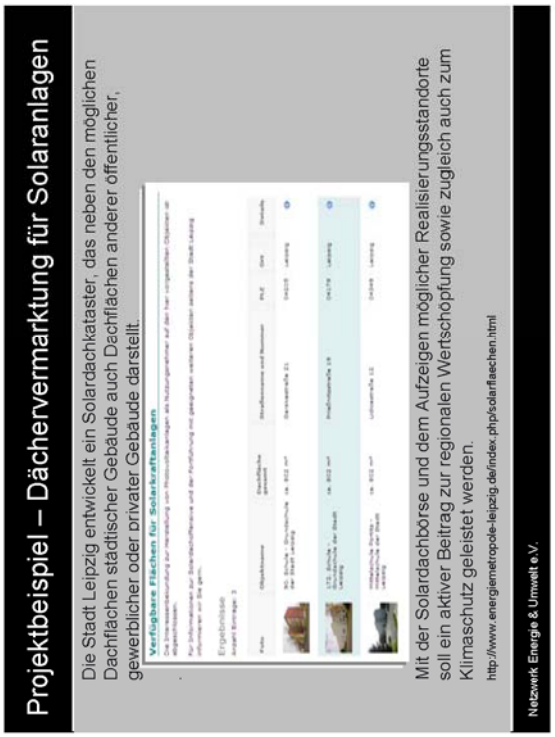
N.E.U - Mitglieder

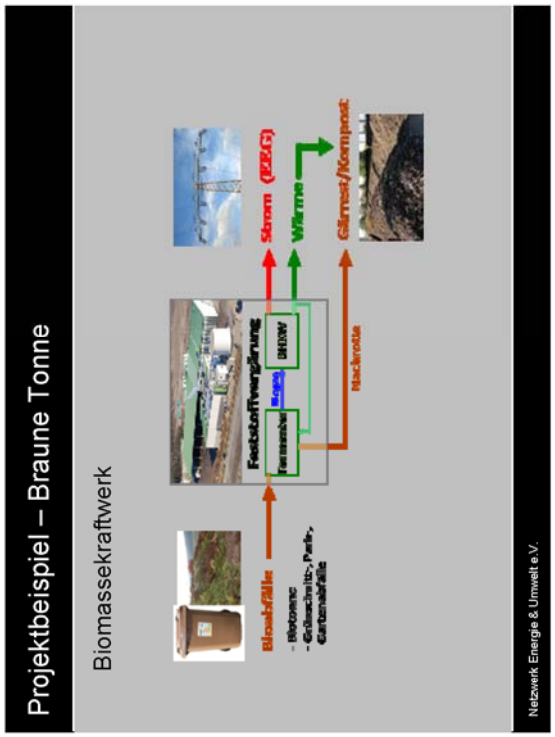
Vereinsmitglieder u.a.:

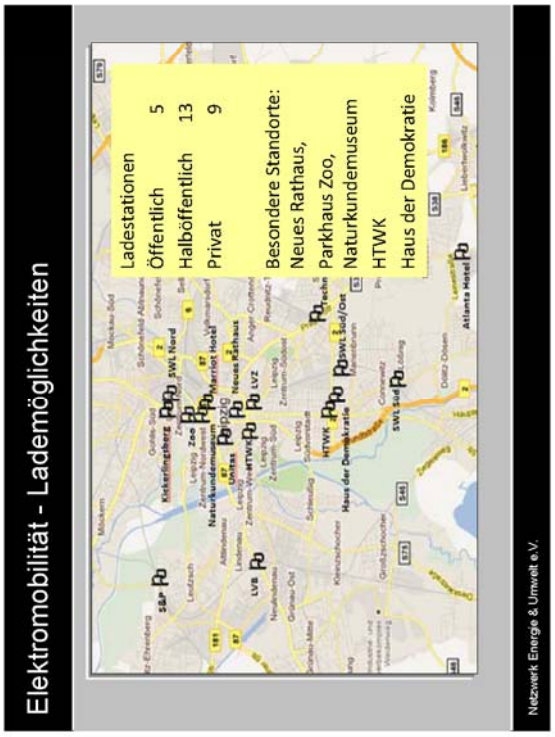
Dr. Födisch Umweltmesstechnik AG
GET AG
Leipziger Institut für Energie GmbH
Sachsen Wasser GmbH
Stadt Leipzig
Stadtwerke Leipzig GmbH
Universität Leipzig
Romann Glowacki
Thomas Hörtinger

Agentur eCONTACT
ALSTOM GRID GmbH
bse Engineering GmbH
CONFORTIS KG
CONOSCOPE GmbH
DBFZ gGmbH
efa Leipzig GmbH
efenco Stefan Lingner
Elektroauto-Center Naunhof
Energieberatungsagentur Enotio
EnergieCity Leipzig GmbH
Energieforen Leipzig GmbH
Europäisches Energie- und Umweltforum e. V.
evermind GmbH
Fraunhofer MOEZ
GICON GmbH
Siegfried Grommek
Helmholtz-Zentrum für Umweltforschung
K. & L. Förster
Robby Leister
Lothar Lindner
Volkmar Müller
R&D Lichtschutzfactory
Gerold Seyfarth
TIQ Solutions GmbH
ZEE GmbH

Netzwerk Energie & Umwelt e.V.


Projektbeispiel – Dächervermarktung für Solaranlagen
Die Stadt Leipzig entwickelt ein Solardachkataster, das neben den möglichen Dachflächen städtischer Gebäude auch Dachflächen anderer öffentlicher, gewerblicher oder privater Gebäude darstellt.
Verfügbare Flächen für Solarkraftanlagen
Ergebnisse
Mit der Solardachbörse und dem Aufzeigen möglicher Realisierungsstandorte soll ein aktiver Beitrag zur regionalen Wertschöpfung sowie zugleich auch zum Klimaschutz geleistet werden.
http://www.energiemetropole-leipzig.de/index.php/solarflaechen.html
Netzwerk Energie & Umwelt e.V.


Projektbeispiel – Braune Tonne
Biomassekraftwerk
Biokräfte
Feststoffvergärung
Strom (EEG)
Wärme
Gärrest/Kompost
Nachrotte
Netzwerk Energie & Umwelt e.V.


Elektromobilität - Lademöglichkeiten
Ladestationen
Öffentlich 5
Halböffentlich 13
Privat 9
Besondere Standorte:
Neues Rathaus,
Parkhaus Zoo,
Naturkundemuseum
HTWK
Haus der Demokratie
Netzwerk Energie & Umwelt e.V.

Projektbeispiel - EnergieCity
Privatwirtschaftliches Projekt der EnergieCity GmbH unter Begleitung des Clusters Energie & Umwelttechnik. Ziel ist die Errichtung eines Ausstellungs- und Demonstrationszentrum sowie einer Bildungsstätte und ein Eventtreffpunkt unter dem Oberbegriff „Fit für den Klimawandel".
Netzwerk Energie & Umwelt e.V.

Energiemetropole Leipzig – Veranstaltungen 2012

Tag der erneuerbaren Energien 28.4.
1. Ostdeutscher Energietag 10/11.5.
Automobil-International (AMI) – 2.-10.6. Probefahrten E-Autos
Veranstaltung „Cluster trifft Wissenschaft" (Jahresmitte)
Workshops (zu von Unternehmen initiierten Themen)
Expertentreffen Energiemetropole Leipzig (3. Dezember)

u. natürlich etliche Clusterteam-Treffen, IBC, iEMS ....

Netzwerk Energie & Umwelt e.V.

Energiemetropole Leipzig – Ihr Beitrag

Sie suchen Partner für
- die Realisierung von Projekten
- die Umsetzung von Ihren Ideen
- den Aufbau von Netzwerken

Sie bieten
- Aufträge
- Ideen
- Dienstleistungen

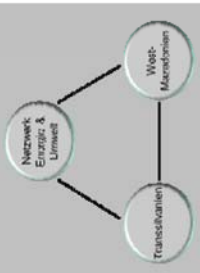
Ziel bleibt immer die Steigerung der Wertschöpfung in der Region

Netzwerk Energie & Umwelt e.V.

Projektbeispiel EU-Projekt

TREC – Transregional Renewable Energy Cluster

TREC



- Aufbau eines internationalen Netzwerkes: **Erneuerbare Energien**
- Partner: - Transsilvanien (Rumänien)
  - West Mazedonien (Griechenl.)

→ **Kontakt- und Geschäftsmöglichkeiten in neuen Regionen**

- Vorbild: Cluster Energie und Umwelt Leipzig
- Sept. 2011 Workshop „Clusteraufbau" in Leipzig

Netzwerk Energie & Umwelt e.V.

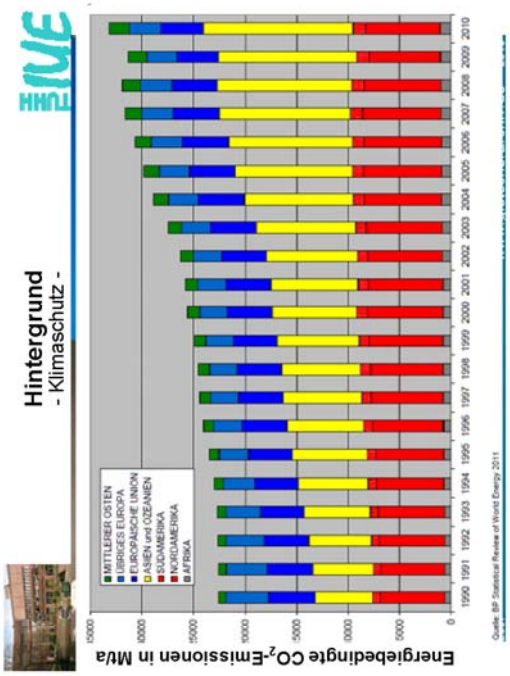
Projektbeispiel SIAG

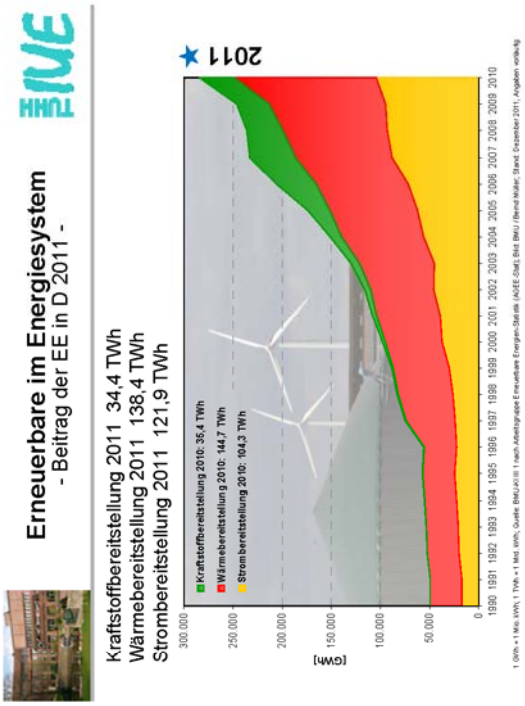
Windkraftürme aus Stahl
200 Mitarbeiter in Leipzig

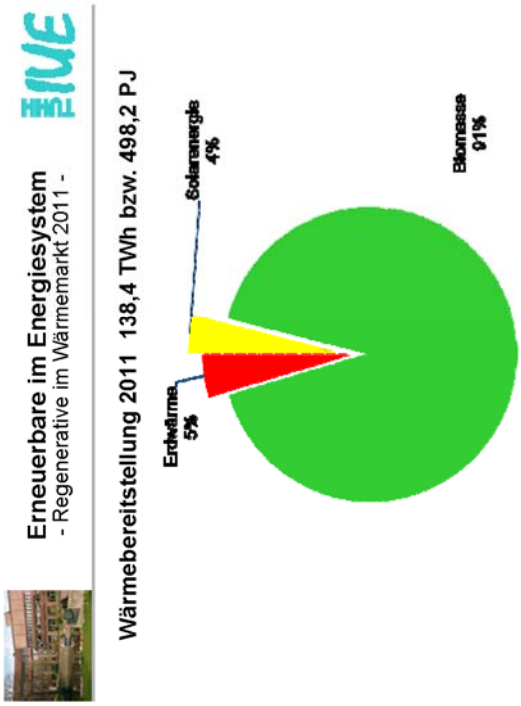
N.E.U.:
Verschiedene Workshops
Ziel: Weitere Produktideen

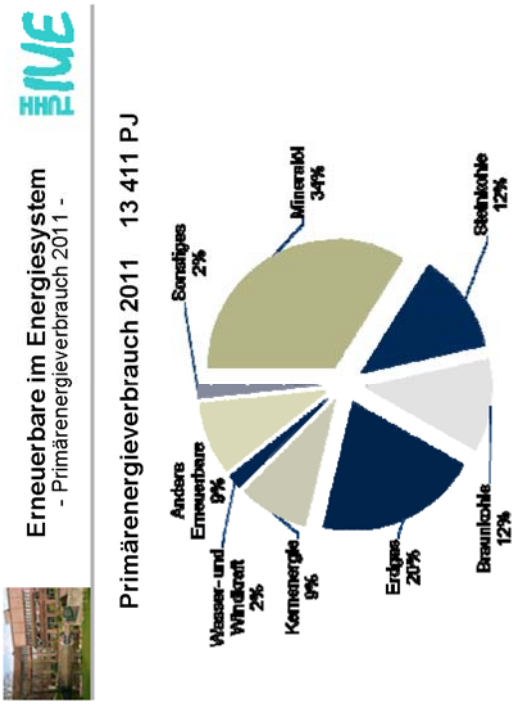
Netzwerk Energie & Umwelt e.V.

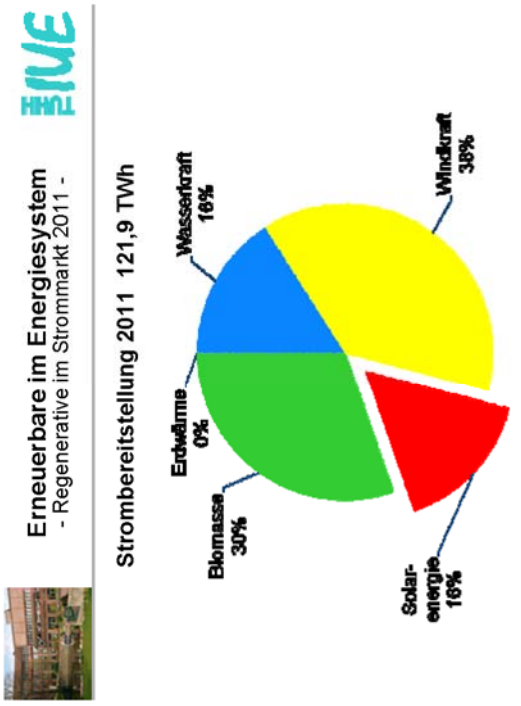
Guest lecture by Prof. M. Kaltschmitt (TU Hamburg-Harburg)




Erneuerbare im Energiesystem
- Beitrag der EE in D 2011 -
Kraftstoffbereitstellung 2011 34,4 TWh
Wärmebereitstellung 2011 138,4 TWh
Strombereitstellung 2011 121,9 TWh
2011
Kraftstoffbereitstellung 2010: 35,4 TWh
Wärmebereitstellung 2010: 144,7 TWh
Strombereitstellung 2010: 104,3 TWh
[GWh]
300 000
250 000
200 000
150 000
100 000
50 000
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010


Erneuerbare im Energiesystem
- Regenerative im Wärmemarkt 2011 -
Wärmebereitstellung 2011 138,4 TWh bzw. 498,2 PJ
Solarenergie
4%
Erdwärme
5%
Biomasse
91%


Erneuerbare im Energiesystem
- Primärenergieverbrauch 2011 -
Primärenergieverbrauch 2011 13 411 PJ
Sonstiges
2%
Mineralöl
34%
Andere
Erneuerbare
9%
Wasser- und
Windkraft
2%
Kernenergie
9%
Erdgas
20%
Braunkohle
12%
Steinkohle
12%

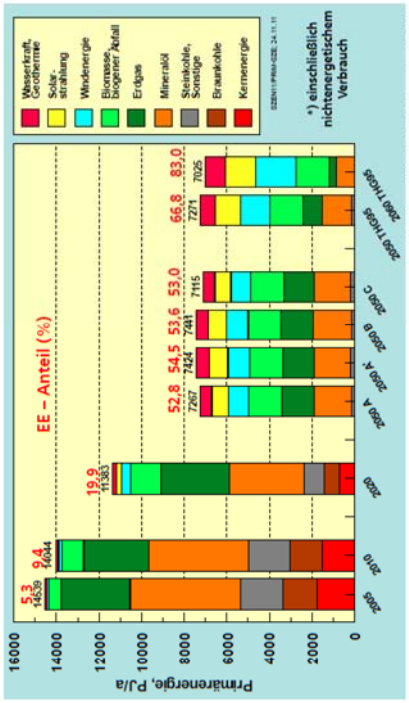

Erneuerbare im Energiesystem
- Regenerative im Strommarkt 2011 -
Strombereitstellung 2011 121,9 TWh
Wasserkraft
16%
Erdwärme
0%
Biomasse
30%
Windkraft
38%
Solar-
energie
16%

Erneuerbare im Energiesystem
- Übersicht 2011 -

Option	Stromerzeugung[1]		Wärmebereit-stellung[b]		Verkehr[c]		Primärenergie[d]	
	in TWh	in %	in PJ	in %	in PJ	in %	in PJ	in %
Wasserkraft	19,5	16,0		0,0			70,2	4,8
Windkraft	46,5	38,2		0,0			167,4	11,5
Solarenergie	19,0	15,6	20,1	4,0			88,6	6,1
Biomasse	36,9[e]	30,2	455,3	91,4	123,9	100,0	1 102,8	76,0
Umgebungs-Erdwärme	0,02	0,02	22,8	4,6			22,8	1,6
Summe	121,9	100,0	498,2	100,0	123,9	100,0	1 451,8	100,0

[a]einschließlich KWK; [b]Brennstoffeinsatz bei Kleinfeuerungsanlagen; einschließlich KWK-Wärme aus Bioenergie; [c]Kraftstoffe; [d]Umrechnung elektrischer Energie aus Wasserkraft, Wind- und Solarenergie sowie Geothermie nach der Wirkungsgradmethode und aus Biomasse gemäß Brennstoffeinsatz; [e]einschließlich Klär- und Deponiegasverstromung und Strombereitstellung aus biogener Müllfraktion

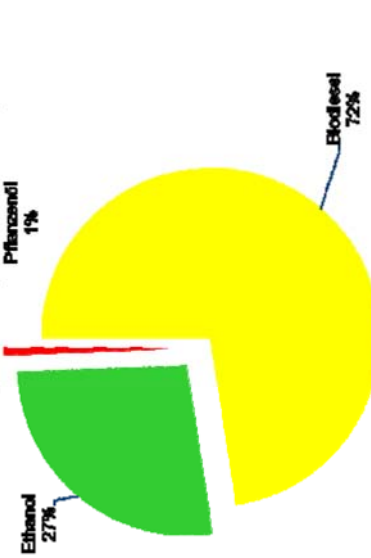
Erneuerbare im Energiesystem
- Entwicklung Primärenergieverbrauch -



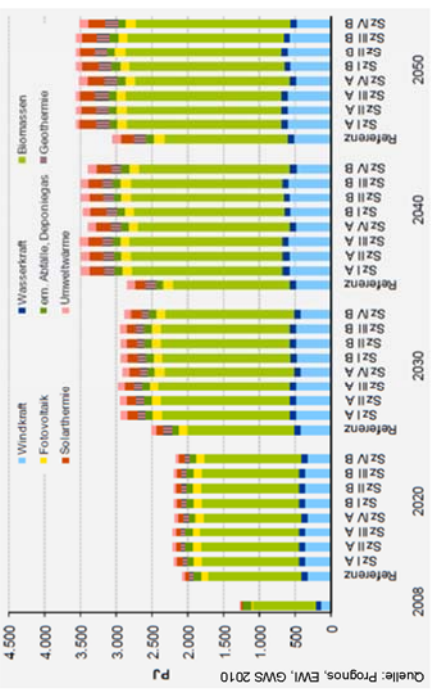
Quelle: Nitsch, Stuttgart, 2011

Erneuerbare im Energiesystem
- Regenerative im Transportmarkt 2011 -

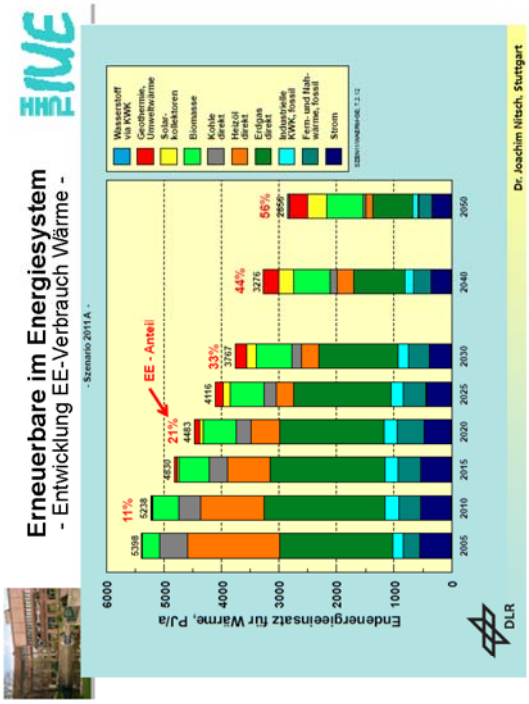
Kraftstoffbereitstellung 2011 34,4 TWh bzw. 123,8 PJ



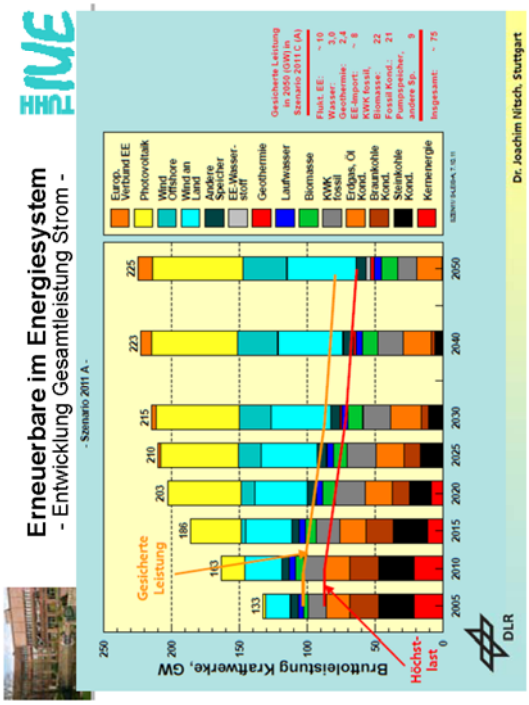
Erneuerbare im Energiesystem
- Zukünftige Entwicklung -



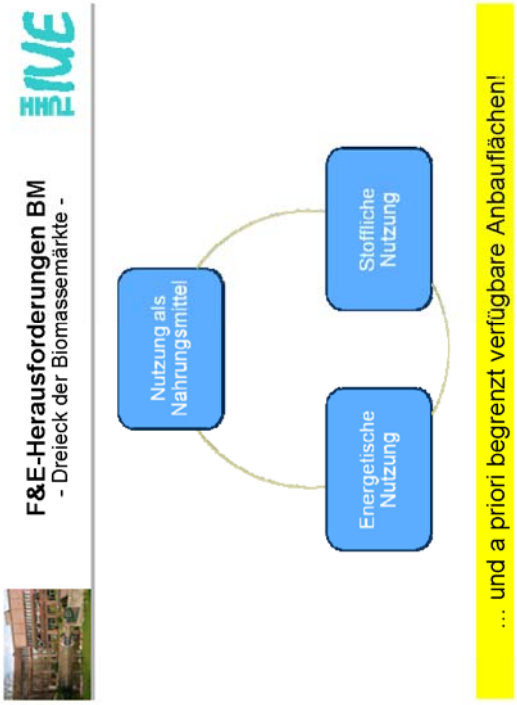
Quelle: Prognos, EWI, GWS 2010

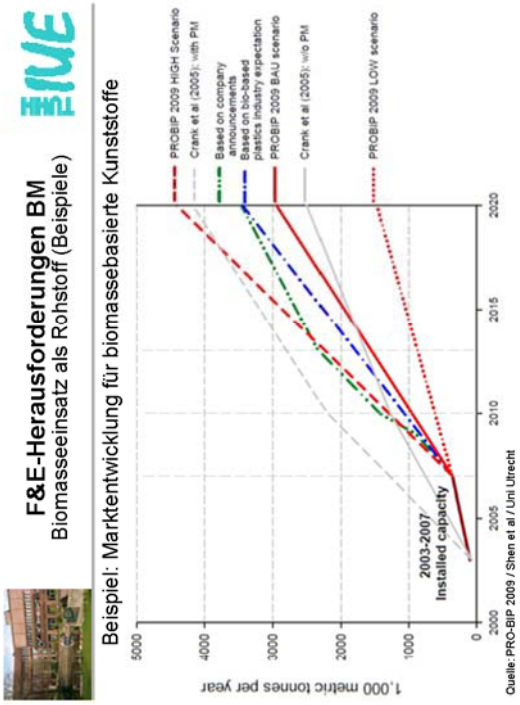

Erneuerbare im Energiesystem
- Entwicklung EE-Verbrauch Wärme -
- Szenario 2011 A -
Endenergieeinsatz für Wärme, PJ/a
EE - Anteil
11%
21%
33%
44%
56%
5398
5238
4830
4483
4116
3767
3276
2556
2005
2010
2015
2020
2025
2030
2040
2050
Wasserstoff via KWK
Geothermie, Umweltwärme
Solar-kollektoren
Biomasse
Kohle direkt
Heizöl direkt
Erdgas direkt
Müll, Abfälle KWK, fossil
Fern- und Nah-wärme, fossil
Strom
DLR
Dr. Joachim Nitsch, Stuttgart

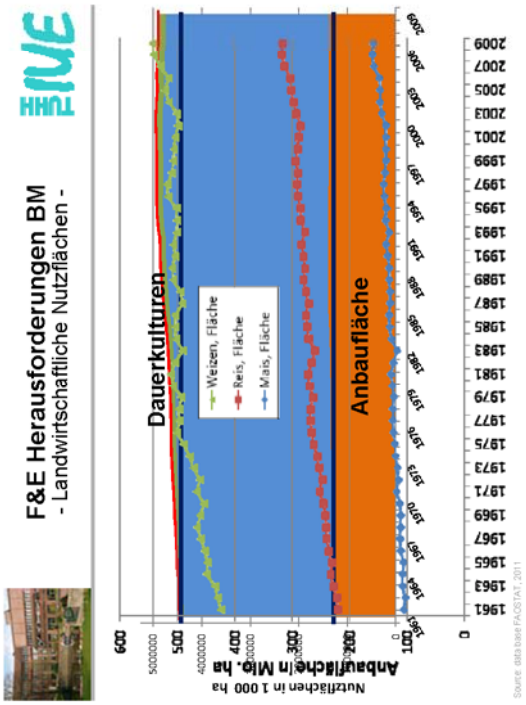
Erneuerbare im Energiesystem
- Zwischenfazit II -
Mit höheren Anteilen einer angebotsorientierten Energiebereitstellung stellt sich die Frage, wie die fluktuierende Erzeugung aus Wasser, Wind & Sonne idealerweise ausgeglichen/gespeichert werden kann, damit die gegebene Nachfrage sicher gedeckt werden kann?
Deshalb werden aus energiewirtschaftlicher Sicht die Optionen zur Nutzung reg. Energien an Bedeutung gewinnen, die nachfrageorientiert die Nachfrage decken können; dies ist bei praktisch allen Biomasse-Optionen und bei der tiefen Geothermie der Fall; deshalb wird ihre Bedeutung im Energiesystem zukünftig weiter zunehmen
Aber es sind viele Fragen offen ...
Wo soll die Biomasse vor dem Hintergrund a priori begrenzter Agrarflächen, steigender Nachhaltigkeitsanforderungen und der wachsenden Nachfrage der konkurrierenden Märkte herkommen?
Ist die Nutzung der tiefen Geothermie standortabhängig technisch und wirtschaftlich zukünftig darstellbar?
Werden diese Optionen (und die damit verbundenen Mehrkosten) auf eine breite Akzeptanz stoßen?

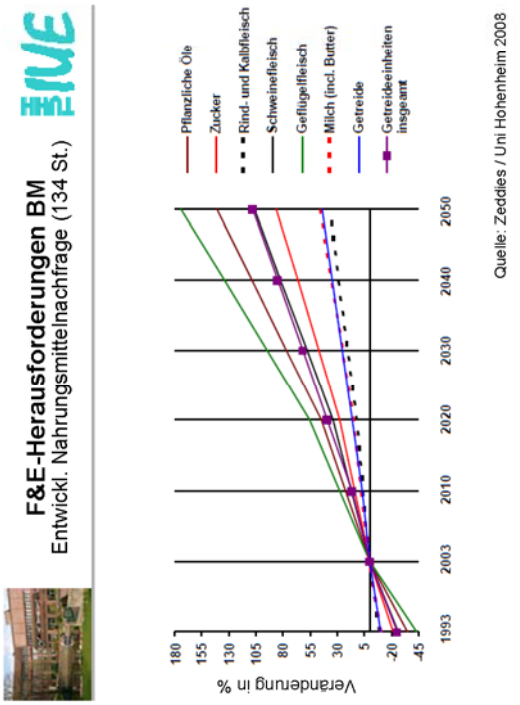

Erneuerbare im Energiesystem
- Entwicklung Gesamtleistung Strom -
- Szenario 2011 A -
Bruttoleistung Kraftwerke, GW
Gesicherte Leistung
Höchst-last
133
163
186
203
210
215
223
225
2005
2010
2015
2020
2025
2030
2040
2050
Europ. Verbund EE
Photovoltaik
Wind Offshore
Wind an Land
Andere Speicher
EE-Wasser-stoff
Geothermie
Laufwasser
Biomasse
KWK fossil
Erdgas, Öl Kond.
Braunkohle Kond.
Fossil Kond.
Pumpspeicher, andere Sp.
Steinkohle Kond.
Kernenergie
Gesicherte Leistung in 2050 (GW) in Szenario 2011 C (A)
Insgesamt: ~ 75
DLR
Dr. Joachim Nitsch, Stuttgart

Erneuerbare im Energiesystem
- Zwischenfazit I -
Erneuerbare Energien sind heute schon ein merklicher Bestandteil des Energiesystem; dieser Anteil wird in den kommenden Jahren (deutlich) weiter zunehmen
Biomasse trägt mit mehr als drei Viertel (76 %) zur Energiebereitstellung aus erneuerbaren Energien bei; auch wenn dieser Anteil relativ zurückgehen sollte, wird er absolut gesehen weiter ansteigen
Weitere wesentliche Beiträge zur Nachfragedeckung kommen von angebotsorientierten Optionen; auch deren Anteile sollen zukünftig (relativ und absolut) weiter zunehmen (u. a. Wind-Offshore)
Erdwärme – und hier insbesondere die tiefe Geothermie – trägt heute in Deutschland nicht nennenswert zur Energieversorgung bei; dies dürfte sich aufgrund der geologischen Herausforderungen auch in den kommenden Jahren nur unwesentlich ändern
Erneuerbare Energien werden immer mehr zum "global player"; es entstehen Handelsströme für regenerative Energien, die sich neben den etalierten Energiemärkten zukünftig verstärkt entwickeln


F&E-Herausforderungen BM
- Dreieck der Biomassemärkte -
Nutzung als Nahrungsmittel
Stoffliche Nutzung
Energetische Nutzung
... und a priori begrenzt verfügbare Anbauflächen!


F&E-Herausforderungen BM
Biomasseeinsatz als Rohstoff (Beispiele)
Beispiel: Marktentwicklung für biomassebasierte Kunststoffe
1.000 metric tonnes per year
2003-2007 Installed capacity
PROBIP 2009 HIGH Scenario
Crank et al (2005): with PM
Based on company announcements
Based on bio-based plastics industry expectation
PROBIP 2009 BAU scenario
Crank et al (2005): w/o PM
PROBIP 2009 LOW scenario
Quelle: PRO-BIP 2009 / Shen et al / Uni Utrecht


F&E Herausforderungen BM
- Landwirtschaftliche Nutzflächen -
Dauerkulturen
Weizen, Fläche
Reis, Fläche
Mais, Fläche
Anbaufläche
Nutzflächen in 1 000 ha
Anbauflächen in Mio. ha
Source: data base FAOSTAT, 2011


F&E-Herausforderungen BM
Entwickl. Nahrungsmittelnachfrage (134 St.)
Pflanzliche Öle
Zucker
Rind- und Kalbfleisch
Schweinefleisch
Geflügelfleisch
Milch (incl. Butter)
Getreide
Getreideeinheiten insgesamt
Veränderung in %
Quelle: Zeddies / Uni Hohenheim 2008

F&E-Herausforderungen
- Biomasse -

- Biomasse wird als Nahrungs- und Futtermittel, als nachwachsender Rohstoff und als Energieträger nachgefragt – mit deutlich steigender Tendenz in allen Märkten und wachsenden Flächenansprüchen
- Konkurrenzen um das begrenzte und schwankende Biomasseaufkommen sind damit möglich; potenziell steigende Preise sind eine Konsequenz
- Damit nimmt die Notwendigkeit zu,
  - neue Ressourcen zu erschließen (u. a. Algen),
  - mehr Biomasse nachhaltig zu erzeugen (d. h. Ausweitung Flächen- und Pflanzenbasis, verbessertes Produktionsmanagement),
  - die land- und forstwirtschaftliche Biomasse möglichst vollständig und hocheffizient zu nutzen (d. h. effizientere Biomassebereitstellung und -nutzung; u. a. Überwindung des naturbedingt dezentralen Biomasseanfalls in der Fläche),
  - möglichst viele (Teil-)Märkte parallel zu bedienen, um mögliche Konkurrenzen zu minimieren (d. h. integrierte und optimierte Produktions- und Nutzungskonzepte; u. a. Bioraffinerie)

F&E-Herausforderungen BM
- Bessere Kulturpflanzen und -produktion -

- Steigerung der Erträge und der Ertragssicherheit der heute primär genutzten landwirtschaftlichen Kulturpflanzen
- Entwicklung und Kommerzialisierung "neuer" und an ungünstigere Bedingungen angepasste Pflanzen, welche die Flexibilität der Produzenten ausweiten und nicht einengen
- Verbessertes, nachhaltiges Produktionsmanagement unter Berücksichtigung u. a. des lokalen Klimas, der Bodengegebenheiten und des Bildungsstandes des Produzenten
- Entwicklung von effizienten, nachhaltigen Produktionsmethoden für die parallele Erzeugung von Nahrungs-, Futter- und Lignocellulosepflanzen auf gleicher Fläche unter Generierung von Synergieeffekten

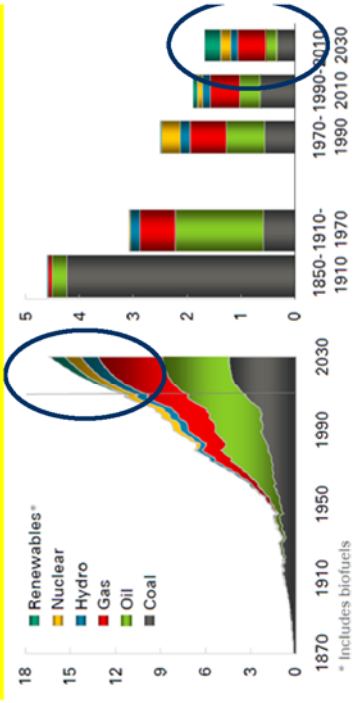
Source: KWS SAAT AG

F6e-Herausforderungen BM
Entwicklung der Energienachfrage

Quelle: BP Energy Outlook 2011

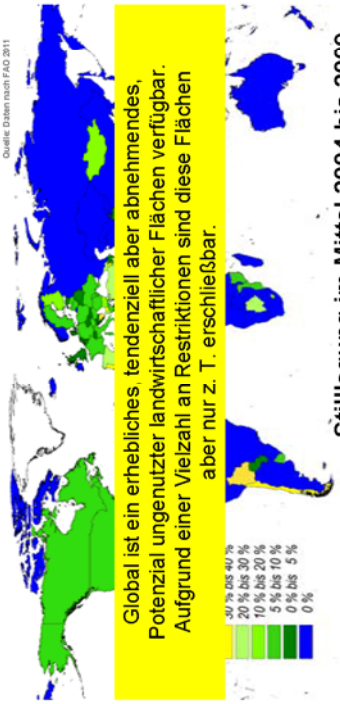
World commercial energy use — Contribution to total energy growth

Keine Berücksichtigung der nicht-kommerziellen Biomasse



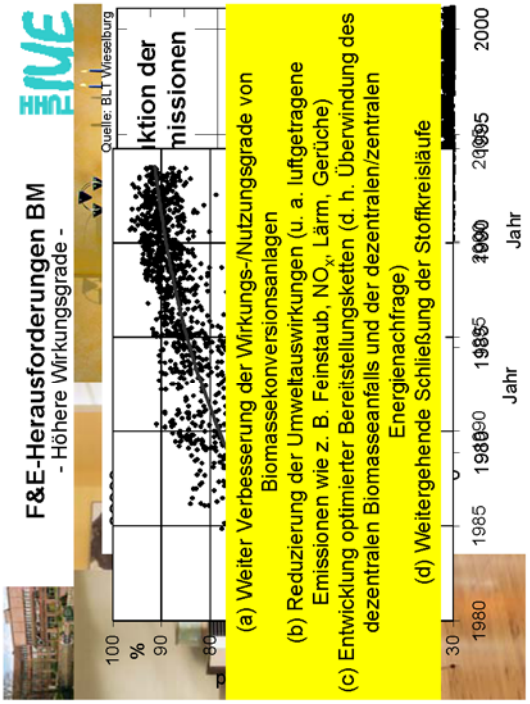
F&E-Herausforderungen
- Bessere Nutzung vorhandenen Landes -

Quelle: Daten nach FAO 2011

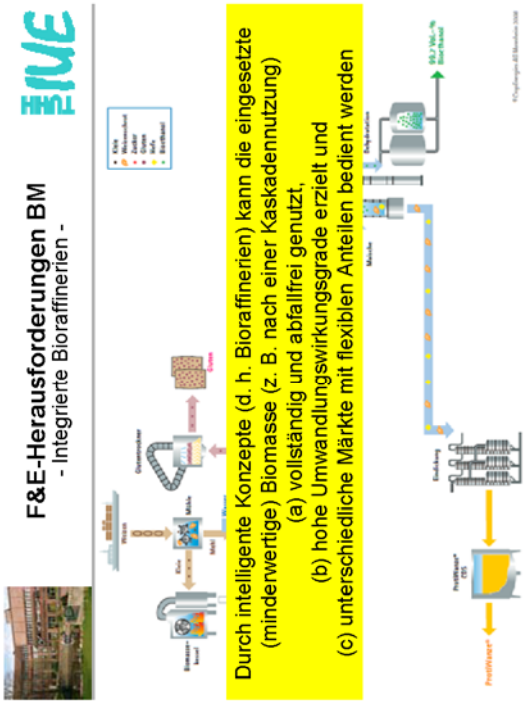


Global ist ein erhebliches, tendenziell aber abnehmendes, Potenzial ungenutzter landwirtschaftlicher Flächen verfügbar. Aufgrund einer Vielzahl an Restriktionen sind diese Flächen aber nur z. T. erschließbar.

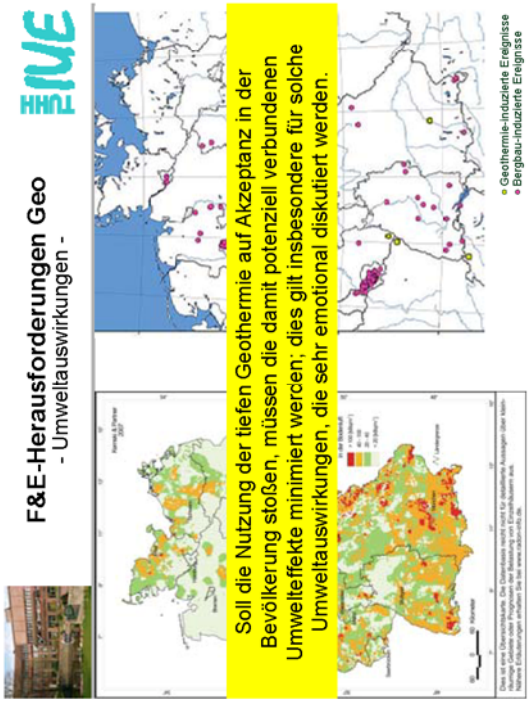
Stilllegung im Mittel 2004 bis 2009

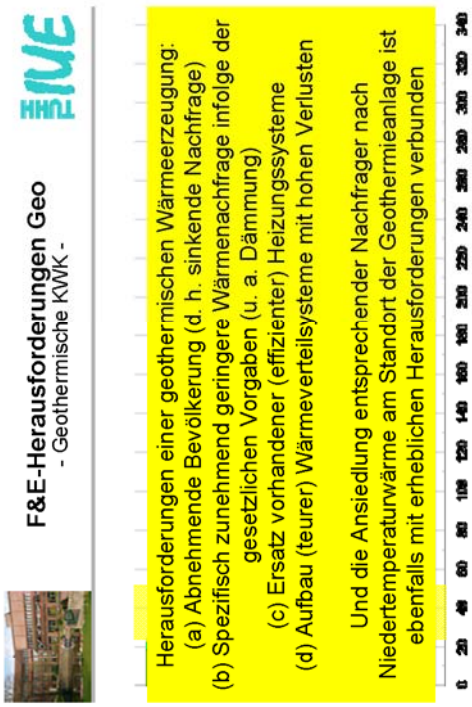

F&E-Herausforderungen BM
- Höhere Wirkungsgrade -
Quelle: BLT Wieselburg
100
%
90
80
ktion der
missionen
(a) Weiter Verbesserung der Wirkungs-/Nutzungsgrade von Biomassekonversionsanlagen
(b) Reduzierung der Umweltauswirkungen (u. a. luftgetragene Emissionen wie z. B. Feinstaub, NO_x, Lärm, Gerüche)
(c) Entwicklung optimierter Bereitstellungsketten (d. h. Überwindung des dezentralen Biomasseanfalls und der dezentralen/zentralen Energienachfrage)
(d) Weitergehende Schließung der Stoffkreisläufe
30
1980
1985
1990
1995
2000
Jahr

Durch eine flexible Polygeneration (d. h. die gekoppelte Erzeugung mehrerer Endenergieträger mit variierenden Anteilen) kann die Brennstoffausnutzung verbessert und das gesamte Energiebereitstellungssystem effizienter gestaltet werden. Auch kann durch die Einbindung der Methanisierung die Dezentralität der Biomasse überwunden werden, da auf eine schon vorhandene Transport- und Speicherinfrastruktur aus dem Erdgasmarkt zurückgegriffen werden kann.


F&E-Herausforderungen BM
- Integrierte Bioraffinerien -
Durch intelligente Konzepte (d. h. Bioraffinerien) kann die eingesetzte (minderwertige) Biomasse (z. B. nach einer Kaskadennutzung)
(a) vollständig und abfallfrei genutzt,
(b) hohe Umwandlungswirkungsgrade erzielt und
(c) unterschiedliche Märkte mit flexiblen Anteilen bedient werden

F&E-Herausforderungen Geo
- Geothermische Ressourcen -
Die geothermischen Ressourcen sind sehr groß und könnten die Energieversorgung für sehr lange Zeit sicherstellen
Die Erschließung des geothermischen Potenzials ist aber bisher anspruchsvoll und aufwändig – und das bei unsicherem Erfolg
Aus Energiesystem-Sicht ist die tiefe Geothermie aber eine wichtige Komponente, der helfen könnte, weitere Herausforderungen zu lösen
Deshalb nimmt die Notwendigkeit zu,
das Verständnis des Aufbaus des Untergrunds an einem bestimmten Standort und dessen sicherer Aufschluss weiter zu verbessern,
die Stimulationstechnik für den Untergrund weiter zu entwickeln und den Erfolg derartiger Maßnahmen vorhersagbar zu machen,
die Nachhaltigkeit der Nutzung des tiefen Untergrunds zu bewerten und Maßnahmen zu deren Gewährleistung zu erarbeiten,
effiziente und integrierte Optionen für die Nutzung der geothermischen Wärme entwickeln und technisch umsetzen,
die systemtechnische Einbindung geoth. Anlagen in das Energiesystem zu optimieren unter Minimierung potenzieller Umwelteffekte


F&E-Herausforderungen Geo
- Umweltauswirkungen -
Soll die Nutzung der tiefen Geothermie auf Akzeptanz in der Bevölkerung stoßen, müssen die damit potenziell verbundenen Umwelteffekte minimiert werden; dies gilt insbesondere für solche Umweltauswirkungen, die sehr emotional diskutiert werden.
Geothermie-induzierte Ereignisse
Bergbau-induzierte Ereignisse


F&E-Herausforderungen Geo
- Geothermische KWK -
Herausforderungen einer geothermischen Wärmeerzeugung:
(a) Abnehmende Bevölkerung (d. h. sinkende Nachfrage)
(b) Spezifisch zunehmend geringere Wärmenachfrage infolge der gesetzlichen Vorgaben (u. a. Dämmung)
(c) Ersatz vorhandener (effizienter) Heizungssysteme
(d) Aufbau (teurer) Wärmeverteilsysteme mit hohen Verlusten
Und die Ansiedlung entsprechender Nachfrager nach Niedertemperaturwärme am Standort der Geothermieanlage ist ebenfalls mit erheblichen Herausforderungen verbunden
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340
Nachfragepotenziale in [TWh/a]

Schlussbetrachtung
Erneuerbare Energien tragen heute schon merklich zur Energieversorgung in Deutschland bei; ihr absoluter und relativer Anteil im Energiesystem wird zukünftig deutlich weiter zunehmen
Dies gilt insbesondere für die Biomasse – und perspektivisch die Geothermie, da beide nachfrageorientiert nutzbar sind und damit die Fluktuationen anderer Optionen ausgleichen können
Dieser absehbare Entwicklungsprozess im Energiesystem muss durch eine verstärkte Energieforschung unterstützt werden, die technische, ökonomische, ökologische und soziale Aspekte – eingebettet in eine übergeordnete Nachhaltigkeitsforschung – beinhaltet
Dies umfasst eine Vielzahl unterschiedlichster Einzelaspekte, die zunehmend gelöst werden müssen; ganz wesentlich dabei ist die Frage der Systemoptimierung (u. a. Synergien, win-win-Situation) unter Berücksichtigung der das Energiesystem (mit-)bestimmenden Aspekte (u. a. Akzeptanz, Umwelt, Klima)
Sollen die politischen Zielvorgaben erreicht werden ("Energiewende"), ist deshalb eine deutlich verstärkte Energieforschung – eingebettet in einer übergeordnete Nachhaltigkeitsforschung – zwingend

Vielen Dank für
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