

# Research activities in polygeneration in Germany within the BMU-funding programme - Status and prospects

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## Background and projects

The challenges in the context of worldwide climatic protection efforts can only be realised with sustainable energy provision. Biomass is the most important and versatile renewable energy source in Germany. For this reason, the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) has drawn up a programme for "Promoting projects to optimise biomass energy use" in the framework of the German Climate Initiative. The programme supports further development of the current discourse on the generation of power, heat and fuels from biomass, up to the preparation of a sustainable and supportable biomass strategy. Furthermore, the promotion programme will focus on the development and optimisation of climate-friendly and energy-efficient technologies for the utilisation of biomass for energy, taking into consideration their sustainability and climatic protection aspects. The programme was adopted for a period of three years (2009 – 2012). Detailed information about the programme and the participating projects can be found at [www.energetische-biomassenutzung.de](http://www.energetische-biomassenutzung.de).

Since the programme has been launched in April 2009, several research projects, partially grouped in joint research projects, are following the design and testing of improved biomass utilisation technologies. Projects for utilisation of residues, for the drawing up of regionally integrated and optimised local concepts as well as the development and demonstration of biomass gasification technologies have particular significance. Questions of knowledge, education and consultation and the social acceptability of biomass are also part of the programme. First of all, the practical work of the Phase I projects includes the creation of a reliable data base, optimisation approaches, concepts, biomass potential (by-products, waste, landscape management residues, agriculture and forestry) and feasibility studies. Additionally, further projects will be funded in a second phase of the programme from the end of 2010 on. Pilot and demonstration projects are at the centre of interest in this case.

With regard to polygeneration strategies, projects with focus on the following thematic areas are funded within in the programme:

### Utilisation of residues:

Improvement and further development of parameters and technologies for the efficient harnessing and utilisation of biogenic residues, e.g. through "best practices" for the different material flows.

### Biomass gasification:

Development and demonstration of biomass gasification technologies to support efficient production of electricity and heat from combined heat and power generation (CHP).

#### Bioenergy strategy:

Further development of the sustainable bioenergy strategy by resolving current problems in the biofuels sector and electricity/heat production, e.g. through scientific monitoring of the forthcoming implementation of European criteria to safeguard sustainability in biomass use and pilot projects for the use of climate-gas-efficient fuels and bioenergy carriers.

#### Regional bioenergy:

Optimisation of regional biomass use in terms of regional value added, security of supply and climate protection in Germany.

#### **First results of the programme and scientific coordination**

The BMU has appointed the Project management Jülich (PtJ) with the technical and administrative coordination of the programme. On behalf of the BMU the German Biomass Research Centre (DBFZ) is responsible for the scientific support and public relations presentation of the entire programme with the "Service and Support Project". The tasks include the coordination of methodologies and strategic networking of the projects within the programme, as well as with the external specialist publicity.

As a result of the networking process within the programme, several working groups were established. They are sustainable platforms to discuss essential methodical and technical issues between the projects to improve the quality of the research results and to assure a proper integration of the results in the framework of the national climate initiative. So far, knowledge and information transfer on utilization of residues, measurements on climate relevant emissions and particulate matter, utilization of ash originated from gasification processes, social acceptance and value creation have been promoted and questions of data and method comparability, networking potentials and use of synergy effects were discussed.

Especially, due to the increasing energetic use of solid biofuels, the question of the utilisation of the remaining ashes is an important topic discussed within the programme. One possible path considered is the utilisation of ashes as fertilizer. In this regard, participants of the programme and external experts discussed whether the common classification of ashes as waste should be upheld, especially with a view to their origin from natural wood. Among others, advantages of the use of ashes as a fertilizer are the self-interest in a high quality of the produced ashes since they can be sold as secondary raw materials, closed material cycles and saved expenses since there is no need for landfilling.

Needs for further research and implementation measures were identified as a base for the ongoing discussion process. Furthermore the inauguration of demonstration plants is planned for the end of the year 2010 which will be accompanied by the public relations team of the Service- and Support team.

With regard to polygeneration strategies in Germany, the status of related projects within the programme will be described in short project descriptions in the following [1]:

#### Gasification technologies and concepts:

Project title:	Research and Development Platform "BtG" (Biomass-to-Gas) – Decentralised utilisation of biomass residues with AER-technology (Absorption Enhanced Reforming)
Funding period:	04 / 2009 - 12 / 2012
Project coordination:	Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW) (Centre for Solar Energy and Hydrogen

	Research), Department: Renewable Fuels and Processes
Partners:	DVGW-research division of the Engler-Bunte-Institute of the Karlsruhe University (TH), Department gas technology and University Stuttgart, Institute of Combustion and Power Plant Technology
Project goals:	<ul style="list-style-type: none"> <li>- Establishment of R&amp;D-Platform “BtG“ for future projects</li> <li>- Further development of AER Technology</li> <li>- Polygeneration: Power, Heat, “Renewable Substitute Natural Gas (SNG)“ and “Green Hydrogen“ from AER-Gas</li> <li>- Networking with partners from R&amp;D, Industry, NGOs, etc.</li> </ul>
Interim research results:	<ul style="list-style-type: none"> <li>- Fuel Flexibilisation: characterisation and suitability of new biomass sources (residues from forest, landscaping etc.)</li> <li>- CO2 sorbent bed material: selection, characterisation, and analysis of potential materials with focus on mechanical stability, CO2 sorption reactions as well as tar removal</li> <li>- Interaction between biomass ash and bed material: identification of critical reaction conditions by means of ash melting and bed deactivation</li> <li>- Hot gas cleaning: Development of hot gas cleaning concept to increase product gas quality for downstream SNG production</li> <li>- Pressurised AER gasification: feasibility study for up-scaling of future gasification plants</li> </ul>

Project title:	Closure of regional material circuits at decentralized generation of electricity and heat with a bubbling fluidized bed gasification – RegioSWS
Funding period:	07 / 2009 – 12 / 2010
Project coordination:	Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT
Project goal:	<ul style="list-style-type: none"> <li>- Further development of the concept of CHP-plants on the basis of a stationary fluidized bed</li> <li>- Optimization of ecologic and economic features by using regional biomasses</li> </ul>
Interim research results:	<ul style="list-style-type: none"> <li>- Laboratory gasifier with fuel input of 100 kW put into operation to quantify gas yield and gas quality for different biomass feedstock</li> <li>- Design study for demonstration and commercial scale underway</li> </ul>

Project title:	National monitoring program for further development of small-scale biomass gasification plants
Funding period:	08 / 2009 – 01 / 2012
Project coordination:	German BiomassResearchCentre (DBFZ)
Partners:	University Zittau/Görlitz (FH), Fraunhofer Institute for Factory Operation and Automation (IFF) Magdeburg and The Bavarian Centre for Applied Energy Research (ZAE Bayern)
Project goal:	<ul style="list-style-type: none"> <li>- Scientific support of small-scale biomass gasification plants</li> <li>Technical, economic and ecological optimization of existing plants</li> <li>- Providing proofed information for users and investors</li> <li>- Development and implementation of optimized components and plant concepts (2nd Phase)</li> </ul>
Interim research	- Database of small-scale gasifier is under development

results:	<ul style="list-style-type: none"> <li>- Survey of interested small-scale gasifier manufacturers/operators has been completed</li> <li>- Measurement campaigns of 8 different gasification systems in planning stage</li> <li>- Verification of measuring methods is scheduled (for July 2010)</li> </ul>
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Project title:	Feasibility study for a decentralized wood chip gasification plant with CHP in the bioenergy region Achentel
Funding period:	10 / 2009 – 09 / 2010
Project coordination:	ATZ Development Centre
Project goal:	Investigation of the technical and economic feasibility of a wood chip gasification plant with CHP (probably SNG-provision) and its integration in the overall concept of using renewable energy resources
Interim research results:	<ul style="list-style-type: none"> <li>- Analysis of regional demand for heating and potential technological heat consumers and deduction of time variation curves for the heat demand</li> <li>- Conception of the gasification technology with heat-pipe reformer, gas cleaning and gas engine for production of heat and power</li> <li>- Implementation of the gasifier in the regional heat supply structure including existing biomass plant and district heating grid</li> <li>- Technical and economical analysis of different operation options with combined heat and power production</li> <li>- Sensitivity analysis of the main influencing parameters regarding the economics of the plant (including investment and fuel costs, hours of annual operation)</li> <li>- Reduction potential of greenhouse gases</li> <li>- Development of reliable recommendations for the operation of the demonstration plant</li> </ul>

Project title:	Evaluation of concepts for small plants with thermo chemical gasification of woody biomass as well as the development of recommendations for private and public investors
Funding period:	04 / 2009 – 06 / 2011
Project coordination:	C.A.R.M.E.N. e.V.
Project goal:	<ul style="list-style-type: none"> <li>- Collection and evaluation of the newest developments in the sector of small plants with thermo-chemical gasification of woody biomass</li> <li>- Development of recommendations for action for potential private and public investors to avoid misinvestments, to reduce environmental impacts and to facilitate the technical evaluation of implemented advancements</li> </ul>
Interim research results:	<ul style="list-style-type: none"> <li>- Compilation of experiences and characteristics for the optimisation of biomass heating plants for small plants with thermo chemical gasification of woody biomass and compilation of a database</li> <li>- Creation of a checklist for investors, including the following topics: property, investor, general information, technical conception (supply of wood chips, gasification system, gas treatment, gas utilization), operation of the plant, investment costs, heat utilization, total revenue)</li> <li>- Following aspects have been determined as particularly relevant for the assessment of the economic conception: user adapted available references for the plant concept taking into account the dimension and used quality of wood chips, to be calculated costs for maintenance and repair costs are elements of uncertainty due to the</li> </ul>

	lack of the data basis (long-term data sets), fuel costs
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Gas cleaning:

Project title:	Biosyn: Novel biomass gasification process for the production of a tar-free synthesis gas
Funding period:	04 / 2009 – 03 / 2012
Project coordination:	Fraunhofer Institute for Solar Energy Systems ISE, Freiburg
Project goal and aspects:	Demonstration of a novel process for biomass gasification on pilot plant scale: - for the production of a tar-free, hydrogen and carbon monoxide rich synthesis gas - with a planned downstream multi-stage gasifier - based on the Wamsler Thermoprozessor with constructional improvements made and patented by Fraunhofer ISE
Interim research results:	- Commissioning of the 50 kW reactor, feeding system and other balance of plant components will be completed by August 2010 - Pyrolysis of various kinds of wood and its components, with varying moisture content, has been successfully tested in a lab-scale reactor - Product gas composition was analyzed to predict the heating value of the gas, depending on the feedstock, in order to control engine performance

Biofuels:

Project title:	Optimization of the Downstream-Processing within the fermentative production of biofuels
Funding period:	10 / 2009 – 03 / 2011
Project coordination:	University of Bremen, Institute of Environmental Process Engineering
Project goal:	As many organic liquids (alcohols) form an azeotropic mixture with water, this separation process is technically very demanding and energy consuming, therefore the project aims to present an alternative process to reduce or avoid the use of the rectification, as it is technically very demanding and energy consuming by taking advantage of the osmotic pressure of a highly concentrated salt solution to achieve a dehydration of the organic phase.
Interim research results:	- The principle of the phase separation of water and butanol could be proved several times in batch mode in the laboratory. - The time span from beginning of the experiments until phase separation appears varies between one and three days. This period is similar to the periods used in fermentation processes so it means no limitation for the whole production process. - Right now the transfer from the batch process in laboratory scale to a semi-batch process in pilot plant scale is in progress. First experiments seem to be very promising.

Project title:	SNG and LPG from bio-based wastes – technical feasibility and application potential
Funding period:	10 / 2009- 11 / 2011
Project coordination:	Fraunhofer-Institute for Environmental, Safety and Energy Technology
Project goal:	While Catalytic cracking of bio-based oils and fats into oxygen-free

	hydrocarbon substances is known as a method of generating liquid biofuels, its potential to generate high-caloric fuel gases is nearly disregarded. Assisted by flow-sheet simulations, this project aims at a first experimental overview of deliberate fuel gas production by catalytic cracking and at first concepts for transferring this method into industrial scale.
Interim research results:	<ul style="list-style-type: none"> <li>- Lab-scale experiments so far indicate a co-generation of liquid and gaseous as an optimum process concept. Fuel gas production turned out to be strongly affected by the ageing stage of the catalyst: while organic liquid product (OLP) formation increases with catalyst usage time, hydrocarbon gas production was found to be high with fresh catalysts.</li> <li>- Experiments covering nearly the whole lifetime of the catalyst led to yields of up to 67 % (based on energy) for the fuel gases (and 31 % for the OLP) when processing Jatropha Curcas-Oil over an activated carbon catalyst.</li> <li>- HZSM-5 zeolites lead to lower gas production rate than activated carbons, but unlike activated carbons, they promote the formation of unsaturated gaseous components that could be used as feedstock for the chemical industry.</li> </ul>

Project title:	Optimization of the regional production of bioethanol from biogenic residues (Re2alko)
Funding period:	08 / 2009 – 07 / 2012
Project coordination:	Münster University of Applied Sciences - Steinfurt division
Partners:	University Hohenheim and Goethe - University Frankfurt
Project goal:	<ul style="list-style-type: none"> <li>- Production of innovative biofuels (2nd/3rd generation)</li> <li>- Optimization of the development and use of biogenic residues as substrate (optimized production of lignocelluloses-ethanol/butanol)</li> <li>- Generation of a reliable concept for gradual conversion of decentralised bioethanol systems in plants for fermentation of regional residues and wastes from agricultural enterprises</li> <li>- Evaluation of the production of biobutanol</li> <li>- Energy optimization of fermentation of the stillage in a biogas plant</li> <li>- Planning of a concept for a pilot plant</li> <li>- Energy efficient distillery with high potential for reduction of GHG</li> </ul>
Interim research results:	<ul style="list-style-type: none"> <li>- The following appropriate substrates were determined: maize silage, grass silage, hay and wheat straw</li> <li>- Crushing tests were conducted with selected substrates</li> <li>- Examination of pretreatment strategies for cellulosic materials</li> <li>- Pretreatment without strong acid-treatment</li> <li>- Optimization of enzymatic hydrolyses using new enzyme combinations</li> <li>- Development of strategies for degradation of pentoses in fermentation</li> <li>- Construction of an optimized metabolic pathway for the utilization of the C5-Sugars D-Xylose and L-Arabinose in industrial yeast strains</li> <li>- Ability to breakdown cellulosic materials to fermentable sugar in mashes with up to 15 % of drymass (procedure takes just about 3 days to reach an 80 % breakdown of cellulose to glucose)</li> <li>- Fermentation tests showed a significant surplus of biogas whereby an increased production of bioethanol can be expected</li> </ul>

Project title:	Monitoring of the influence of the national and international legal framework on the market development in the biofuel sector
Funding period:	07 / 2009 - 03 / 2011
Project coordination:	German BiomassResearchCentre (DBFZ)
Project goal:	<ul style="list-style-type: none"> <li>- Put the legal framework in the context of the practical needs of the biofuels market</li> <li>- Assessment of the market under consideration of purpose expressed by the legislature</li> <li>- Setting up a global database for biofuel plants</li> <li>- Extensive data base for the German biofuels industry and for the impact of laws and regulations effecting it, as well as market influences</li> </ul>
Interim research results:	<ul style="list-style-type: none"> <li>- Evaluation of economic efficiency of producing biofuels</li> <li>- Evaluation of sensitivities and the impact of capacity utilization on costs for biofuel production</li> <li>- Calculation of GHG-Emissions for different biofuel options</li> <li>- Survey of German biofuel producers</li> <li>- Comparison of different models for the calculation of land use by biofuel production</li> <li>- Setting up a global database for biofuel plants, sofar about 1600 plants in 34 countries</li> </ul>

#### Fuel synthesis technology:

Project title:	BioWaste to liquid: Utilisation of biogenic residues and wastes in thermo-chemical systems for the provision of fuels
Funding period:	05 / 2009 – 04 / 2012
Project coordination:	German BiomassResearchCentre (DBFZ)
Partners:	Karlsruhe Institute of Technology - Institute for technical chemistry
Project goal:	<ul style="list-style-type: none"> <li>- Integration of biogenic residues and wastes so far not used in the pyrolysis process for production fuels</li> <li>- Development and standardisation of the products and documentation of the accompanied test and measurement methods</li> <li>- utilisation of the pyrolysis products in engines for the provision of electricity and heat in CHP-plants and further processing of the pyrolysis products to synthetic fuels (e.g. BtL, Bio-SNG)</li> <li>- Setting up a database for improved collection and forecasting of test results</li> </ul>
Interim research results:	<ul style="list-style-type: none"> <li>- Investigation of potentials of several biogenic wastes and residues in Germany for the pyrolysis tests (chosen feedstocks: bark, wastes from the wood industry, oil seed straw, maize straw, green waste, hop residues, beet leaves, residues from wine and beer production, driftwood from different locations)</li> <li>- About half of the materials are already collected and processed this summer 2010</li> <li>- Investigation of the regulatory framework concerning these materials showed that all of these biomasses may be subsidized in several ways when being processed via pyrolysis</li> </ul>

## Biorefinery and overall concepts:

Project title:	BioCouple: Linking of Material and Energetic Use of Biomass: Analysis und Assessment of the Concepts and the Integration into Existing Scenarios of Provision and End-Use
Funding period:	05 / 2009 - 10 / 2010
Project coordination:	Wuppertal Institute for Climate, Environment and Energy (Germany)
Partners:	Fraunhofer-Institute for Environmental, Safety and Energy Technology, Institute for Applied Ecology (Germany)
Project goal:	The aim of the project is to examine, whether the concept is qualified to supply bio energy carrier, energy and biomaterials in a coupled and efficient way and whether it can be optimally integrated into the existing energy systems.
Main aspects:	<ul style="list-style-type: none"> <li>- Analysis of material flows: acquisition of data regarding ecological and economical effects of bio-refinery products (Öko-Institute)</li> <li>- Analysis of conversion technique: technical-economical investigation of current and future bio-refinery concepts (Fraunhofer UMSICHT)</li> <li>- Analysis of energy system: assessment of impacts to climate and energy policies and possibilities of system integration (Wuppertal Institute);</li> <li>- Development of partial strategy: deduction of success factors and integration of concepts for a coupled use of biomass into an overall biomass strategy</li> </ul>
Interim research results:	<ul style="list-style-type: none"> <li>- Analysis of existing energy system and material flows, which could by (partially) replaced by bio refinery products in future.</li> <li>- Generation of those data considering ecological and economical impact on existing energy- and material-systems.</li> <li>- Investigation of rivalry-products (material as well as energetic) data (economical and ecological) now and in the future.</li> <li>- Analysis of chosen conversion techniques (bio refineries) including technical and economical investigation of current and future concepts.</li> <li>- Projection of generated data to the future (2020 and 2030) using the common method of learning curve.</li> </ul>

### Summary

Biomass gasification technologies offer various approaches and possibilities for an efficient use of residues as feedstock.

In the course of the BMU-funding programme different systems and plants are going to be set up and in a timeframe of about two years the efficiency of the concepts generated by the projects will be assessed. Further questions of the suitable legislative and administrative framework (e.g. utilization of ash) are of great importance and discussed in the context of supporting the market introduction of the implemented systems.

### Reference

1. The project descriptions were jointly generated with the project partners of the BMU-funding programme "Promoting projects to optimise biomass energy use". The aid of the project partners is gratefully acknowledged.