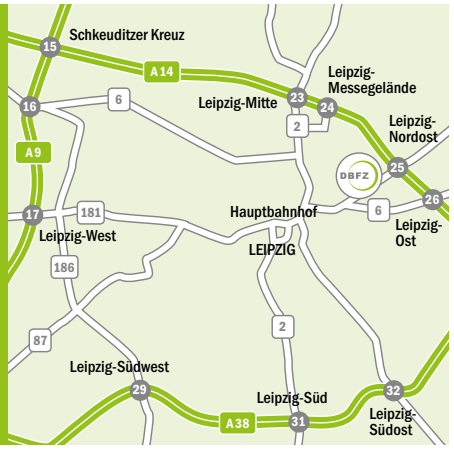
Deutsches Biomasseforschungszentrum
gemeinnützige GmbH

DBFZ

ANNUAL REPORT 2017



DIRECTIONS

By train: to Leipzig main station. Take tram line 3/3E (towards Taucha/Sommerfeld) as far as the Bautzner Strasse stop. Cross over the road, passing the car park on the right, and turn right through gate number 116, after approximately 100 metres turn left, the DBFZ entrance is 60 metres further along on the left-hand side.

By car: on the A14 motorway. Exit at Leipzig Nord-Ost; follow signs for Taucha; then follow signs for Leipzig; then follow signs for Zentrum, Innenstadt. Turn off left after the "bft" filling station (see "By train" for further directions).

By tram: line 3/3E towards Taucha/Sommerfeld; Bautzner Strasse stop (see "By train" for further directions).

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PREFACE BY THE MANAGEMENT

Dear Reader,

2017 was used to intensively sharpen the profile of the DBFZ and to further expand our research activities in the energetic and integrated use of biomass as a material. Against this background, we were able to complete our R&D roadmap, in which the milestones of our scientific development are defined. After a long evaluation phase, we received a very good report in October 2017 from the German Council of Science and Humanities (WR) regarding the implementation of its recommendations. Together, these confirm that we are on the right track in the tenth year of our existence.

Our involvement in national and international expert committees was also further expanded. One example is the German Renewable Energy Research Association (FVEE), in which the DBFZ will take on the role of spokesperson for the Executive Board in 2018. In addition, our partnership with the University of Rostock has been strengthened through a long-term cooperation agreement. On the international stage, highlights included important collaborations, joint research projects, committee work and the co-organisation of major conferences.

One special highlight was the visit by the Dutch royal couple, who were welcomed in February 2017 by us and the Helmholtz Centre for Environmental Research in Leipzig. Another important milestone was the topping-out ceremony for our new building, which we celebrated on 12 September 2017 in the presence of various ministry representatives and numerous people involved in the construction work. You will find this and much more in this year's annual report.

As every year, we would like to thank our numerous supporters (shareholders, supervisory board, research advisory council, ministries, project sponsors and all project partners). We are very grateful for the fruitful cooperation and your many suggestions, which help us improve day by day even after ten years!

Prof. Dr. mont. Michael Nelles
Scientific Managing Director

Daniel Mayer
Administrative Managing Director

2
GREETING: TEN YEARS OF BIOMASS RESEARCH AT THE DBFZ


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Fig. 1 Bernt Farcke, Chairman of the DBFZ Supervisory Board

Energy from biomass plays a central role within the framework of the energy transition. It makes an important contribution to reducing greenhouse gas emissions and thus to protecting the climate. Unlike other renewable energies, it is available regardless of the time of day, the season, or the weather. It can also be easily stored. Idleness, of course, means a step backwards. Therefore, continuous, professionally conducted research in the field of bioenergy is necessary in order to take advantages of and develop the potentials inherent in biomass. Since 2008, the federal government has had a highly efficient research institution in the form of the DBFZ, and its ministries have considerably benefited from the expertise of its qualified specialists. For example, the DBFZ has actively and expertly contributed to the drafting of the various amendments to the Renewable Energy Sources Act (EEG).

As chairman of the Supervisory Board, I am pleased to have the opportunity to provide a brief look back at ten years of successful bioenergy research at the DBFZ. Bioenergy research at the institute began in 2008 with a team of 56 employees. The ongoing projects of the Institute of Energy and Environment (IE), which had been in existence since 1953, were continued using the existing research infrastructure. The early days of the DBFZ under its first scientific managing director, Prof Martin Kaltschmitt, were characterised by a high degree of entrepreneurial spirit, scientific optimism and personal commitment on the part of those involved. Leipzig has proven to be an excellent location to this day, in part due to the existing research landscape here. Under the institute's subsequent leadership of Prof Frank Scholwin from 2011 to 2012, the research biogas plant was completed

and the work-life balance of the institute's employees was improved, which we expressly welcome on the part of the ministry.

The years since 2012 have been marked not only by a large number of new scientific research topics and an evaluation by the German Council of Science and Humanities (WR) but also by the expansion and modernisation of the infrastructure at the DBFZ. In this context, we would particularly like to thank the administrative managing director, Mr Daniel Mayer, for his unflagging and continuous efforts. As part of the second economic stimulus package, older parts of the building were demolished or renovated from the ground up to improve energy efficiency and working conditions for the growing workforce. Since August 2016, a new state-of-the-art building has been under construction on the site, which should be ready for occupation in spring 2019.

In the summer of 2012, Prof. Michael Nelles took over the scientific management and since then the DBFZ has developed in an excellent direction from the perspective of the Supervisory Board. The German Council of Science and Humanities recommended narrowing the focus of our research and since 2015 research has been conducted in five core research areas under the name "Smart Bioenergy Strategy". Prof. Nelles has not only further strengthened the role of the DBFZ as a central federal research institution in the field of energetic biomass use, he has also steadily expanded its international activities. His numerous university contacts to research institutions as far away as China have contributed to disseminating the DBFZ's excellent scientific expertise and to establishing and consolidating numerous new research contacts.

As chairman of the Supervisory Board, I can state after ten years that the DBFZ has developed very well from the point of view of the Federal Ministry of Food and Agriculture and has more than fulfilled expectations. We would like to thank all DBFZ employees for their dedicated work and to express our hope for continued successful development and cooperation, as well as numerous scientific stimuli for a sustainable and "smart" bioenergy supply in the future.

Bernt Farcke
Federal Ministry of Food and Agriculture

3
BIOGAS AND THE EEG: AN INDUSTRY IN SEARCH OF NEW CONCEPTS

Against the backdrop of national climate protection targets, the conversion of the current system of energy to a system based on renewable energies faces numerous challenges. Since the introduction of the Renewable Energy Sources Act (EEG), the number of biogas plants in Germany has grown continuously and has been exposed to a changing regulatory and market environment as a result of the amendments to the EEG. After a boom in the years 2009 to 2011, expansion significantly slowed down as a result of the restructuring and reductions in remuneration in the EEG in 2012 and 2014. Due to changes in the legal framework conditions (EEG 2012 and 2014), capacity expansion in the biogas sector now mainly comprises plant expansions, conversions to flexible plant operation, the expansion of small liquid manure plants and plants in the waste sector.

In view of the fact that the 20-year fixed EEG payment for a large number of plants expires in 2030, and the share of fluctuating renewable energies in the energy system is increasing, new requirements and challenges are arising for biogas plants. In order to continue the operation of their plants, operators are looking for lucrative alternatives for marketing the products that are created from biogas production. If there is no prospect of continued, economically efficient operation of existing plants after the EEG remuneration expires, no investments will foreseeably be made in existing plants. These are necessary for further operation of these plants and current plant outputs will decrease as a result.

Fig. 2 Biogas plant owned by Naturgas Quesitz GmbH near Leipzig

3.1 INTERVIEW WITH DR. JAN LIEBETRAU

Dr. Liebetrau, what was the development of the biogas sector like in 2017?

Jan Liebetrau: In 2016, Germany had around 8,700 biogas production plants, which produced a total of 32.3 TWh_{el} of electricity and 16.9 TWh_{th} of heat. An estimated 200 new plants were added in 2017 – especially in the small plant sector, which does not require tendering. Overall, the share of renewable energies has been rising continuously; in 2016, renewables accounted for 31.7 % of total gross electricity consumption at 188.3 TWh_{el} – a significant proportion in the national energy mix. However, the political framework conditions and the current Renewable Energy Sources Act (EEG) are not exactly causing the plant operators to rejoice, especially in the bioenergy sector.

According to EEG 2017, the fixed remuneration for existing plants will be discontinued; new plants must apply in a tendering process. What effect does this have on the biogas market?

Jan Liebetrau: We at the DBFZ have already made clear in various statements, studies and background papers that the number of plants and the amount of electricity generated from biomass will significantly decrease in the future as a result of the EEG. The effects have been noticeable since the amendment of the EEG in 2012. Unfortunately, subsequent amendments have done away with important control tools so that now only costs are relevant; the focus is no longer on important, above all, environmentally relevant criteria. We currently expect electricity generation to fall from 33 TWh (2017) to under 40 % in 2035. However, there are great uncertainties surrounding the development of the biogas market, as no one can yet estimate how it will develop until then. This process is also tied to the currently unresolved question of how the quantities of electricity and heat that are lost as a result will be replaced.

How can and/or must plant operators adapt to this development?

Fig. 3 DBFZ Report No. 30 "Existing biogas and biomethane plants – biogas production and use in Germany"

Jan Liebetrau: The political framework conditions have caused some unrest in the biogas industry and of course this also has very concrete effects on the way operators will have to market their plants and products in the future. If energy is no longer sufficiently remunerated to cover the costs of operation in the future, new marketing concepts and technical adjustments to existing plants are inevitable. Some approaches are already working, such as the production of fuel or basic chemicals, the provision of heat or electricity for private use or as a service provider. However, there is, as of yet, no silver bullet. Thanks to the EEG, current discussion revolves around the issue of flexibility as an important measure, which is increasingly being implemented.

How can flexibility contribute to the electricity system of the future?

Jan Liebetrau: Bioenergy has a decisive competitive advantage over other renewable energies: it can compensate for fluctuations in wind and solar energy. However, this requires systems that can react flexibly to fluctuations in the system. The demand for flexible systems is growing continuously and if you are making your system flexible today there is a good chance that it will be able to meet the required demands in the future as well. I firmly believe that flexibilisation will be unavoidable in the future, in other words, only systems that can provide flexible electricity and heat will be able to make a meaningful contribution to energy supply in the future.

Since autumn 2017, the level of remuneration has been awarded by means of a competitive tendering model. What is the background of the new model?

Jan Liebetrau: The primary goal is to reduce production costs, because biogas is still quite expensive compared to other renewable energies. Whoever offers their electricity at the lowest price during the EEG remuneration period is awarded the contract. Under certain conditions, existing plants may also participate in a follow-up subsidy at the end of their 20-year EEG remuneration period. The plant can then receive another ten years of EEG compensation. However, the first round of tenders has shown that participation was not particularly high and that competition has been lower than anticipated. I am curious to see how things will develop. However, based on the design, I am rather sceptical as to whether it will have the desired effect on costs.

The operators of smaller biogas plants are afraid that they will no longer have a chance to compete in the new tendering system. Is their concern justified?

Jan Liebetrau: The effort and financial risk involved in participating in the tendering process are high and smaller plants tend to be at a disadvantage. On the whole, the current structure of the EEG only does limited justice to the special conditions in the biogas sector. Smaller plants often use liquid manure and therefore play a particularly important role in reducing greenhouse gas emissions. In my opinion, the regulation exempting 75 kW plants from the tendering process falls short if further progress is to be made in this area.

The expiration of the twenty-year funding period not only preoccupies plant operators, it also preoccupies you as a scientist. What future scenarios are you developing at DBFZ?

Jan Liebetrau: We are currently working on two research projects on post-EEG scenarios that are looking into which business models could still be worthwhile for operators of biogas plants once the EEG remuneration expires. In the research project “BE20plus” we are identifying new business models and developing reference scenarios for using bioenergy in the context of the energy transition. An-

Fig. 4 Energy maize is still widely used as a substrate for biogas plants

other project, “Biogas2030”, is investigating which alternative plant concepts are particularly valuable for the changing energy system. It seeks to understand what the obstacles impeding the implementation of alternative plant concepts are, and how they can be overcome. In addition, we are investigating options for coupling biogas plants with plants for the material use of biomass. The aim is to improve the value added from the substrates.

Speaking of substrates: the new funding criteria provide for increased support for residual and waste materials. Has maize served its day as a traditional energy plant?

Jan Liebetrau: Not necessarily. Maize is justified when it can provide advantages for the region and for plant design. In agricultural practice, care must be taken not to increase the pressure on land in problem regions where a lot of maize is already being cultivated. When maize can contribute to the reproduction of crop rotation in arable regions, it makes sense as a substrate. However, in order to defuse the issue of competing uses, we at the DBFZ have for some time also been concentrating on substrates that do not fall under the term “cultivated biomass”.

Fig. 5 Leak detection at a biogas plant

Can you give any concrete examples?

Jan Liebetrau: First and foremost, of course, are animal excrement, such as liquid manure, dung, dried chicken manure, as well as agricultural residues and organic waste. Straw is something that has great potential. In cooperation with the Helmholtz Centre for Environmental Research and the Thuringian State Institute of Agriculture, we calculated in 2013 that, of the 30 million tonnes of straw produced annually in Germany, between eight and 13 million tonnes can be used sustainably for electricity or fuel production. This would supply 1.7 to 2.8 million average households with electricity while providing 2.8 to 4.5 million households with heat. The use of biomass from so-called greening measures, e. g. the cultivation of wild plants, is also a sensible supplementary measure. This creates new natural spaces and reduces the effect of monocultures. However, this is a challenge facing the entire agricultural sector. Energy crops only play a minor role in this regard.

How can biogas contribute to achieving national climate protection targets?

Jan Liebetrau: Climate protection means, first and foremost, reducing greenhouse gas emissions. Biogas makes a significant contribution in this regard. This can be increased further by measures such as emission reduction and the increased use of residual and waste materials. The agricultural utilisation of fermentation residues also supports the circular economy. But it is also true that biogas plants are not “ecologically valuable” per se. Inflexible plants, the non-utilisation of heat,

and high emissions should no longer exist in the industry in the future. We need clear criteria here on how the sector is to develop. We are currently working on “MetHarmo” (more on page 30), a research project dealing with the detection and quantification of greenhouse gas emissions from various sources at biogas plants. The aim of our research is to devise a scientific and well-founded classification of the environmental effects of energy generation plants, such as biogas plants, and to develop appropriate GHG avoidance strategies.

What would such avoidance strategies look like in concrete terms?

Jan Liebetrau: Well-known sources of emissions from biogas plants include leaks, overpressure and underpressure safety valves, gas utilisation facilities and open storage facilities for fermentation residue. The easiest way to reduce avoidable emissions is to implement changes in operation. Proper gas management can thus reduce emissions from overpressure incidents. Structural changes are usually more complex, but can be viable if the measures result in a high reduction in emissions. When it comes to the measurement methodology, there is currently no uniform European directive on how to determine total methane emissions from biogas plants. We are trying to develop comparable and reproducible measurement methods that can then be incorporated into a standardisation process.

Whether feeding it into the natural gas grid, using it as a fuel or as a way to supply heat: there are many ways to use biomethane made from biogas. Where do you see the greatest potential?

Jan Liebetrau: That’s a difficult question. It is clear that biomethane can be used in all sectors, but it is unable to cover a significant proportion of the total demand in any of them. In the past, the focus was on electricity production because this was where the greatest potential for GHG savings could be achieved. At present, however, politicians prefer to shift biomass to the transport and heating sectors because there are few alternatives there. I think that the greatest potential of biomethane is that it can be used flexibly. Usage can be adapted based on requirements and the state of development without having to change the supply chain. That is why I regard biomethane as a high-quality energy source of the future.

You head the research focus area “Anaerobic Processes” at the DBFZ. What do your employees investigate?

Jan Liebetrau: In our research focus area, we are developing efficient and flexible processes for biogas production that can meet the requirements of the future energy system. A higher added value should also be achieved by linking this to material recycling processes. We are also developing tools to monitor and control processes, concepts for flexible, low-emission plants and operating regimes, as well as methods for evaluating and optimizing efficiency. Methods for monitoring and minimising emissions as well as for maximising material conversion, especially for difficult substrates, are further focal points of our research.

Thank you for the interview.

Additional information:
www.dbfz.de/en/focus-areas/anaerobic-processes

In profile:

Dr.-Ing. Jan Liebetrau has been working at the DBFZ since 2008 and has been head of the Biochemical Conversion department and the research focus area “Anaerobic Processes” since 2011. After studying civil engineering with an emphasis on urban water management and waste management at the Bauhaus University in Weimar, he successfully completed his doctorate on the subject of “Control procedures for the anaerobic treatment of organic waste”. After a fellowship at the German Federal Environmental Foundation (DBU), he was a visiting scientist in the field of biogas technology at the Alberta Research Council in Alberta, Canada from 2006 to 2007.

4
REFERENCES OF THE RESEARCH FOCUS AREAS

The DBFZ conducts research on the energetic and integrated material use of biomass in five main research focus areas. This ensures that important questions and aspects of bioenergy can be mapped at the depth necessary for excellent research. The priorities are oriented towards future developments as well as the challenges and framework conditions of research policies (e. g. the strategies of the German government such as the national BioEconomy Research Strategy 2030, the national Bioeconomy Policy Strategy, the Mobility and Fuel Strategy and the Biorefineries Roadmap). Important cornerstones for the scientific orientation of the research focus areas include the funding policy framework, unique selling points within the research landscape and the good infrastructure at the DBFZ.

Additional information:
www.dbfz.de/en/focus-areas

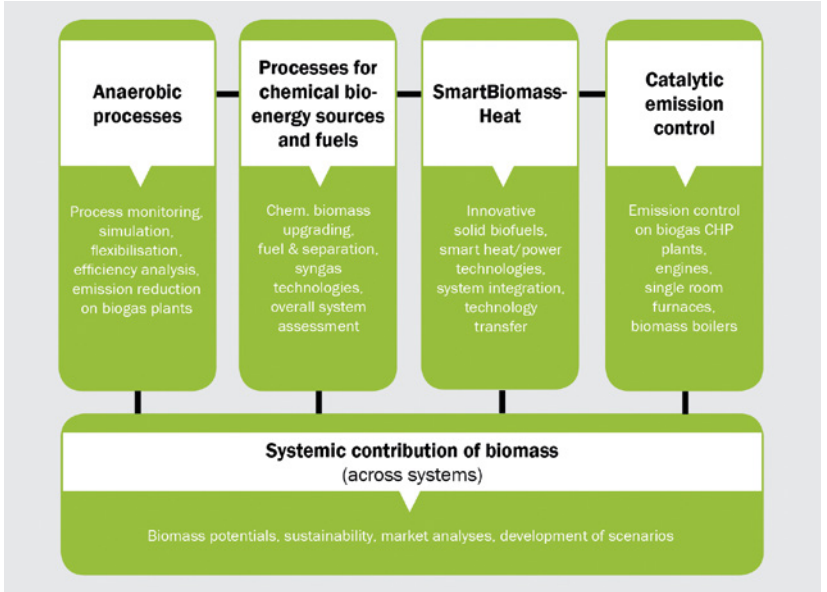


Fig. 6 The five research focus areas of the DBFZ

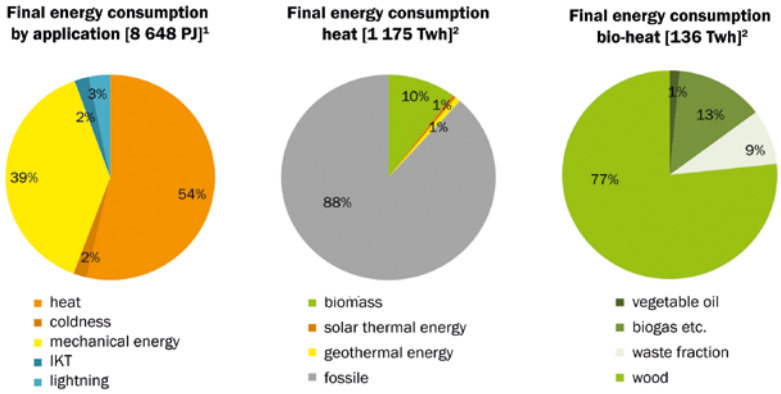
4.1
SYSTEMIC CONTRIBUTION OF BIOMASS

"The 'BioplanW' project systematically assesses the development prospects of generating heat from biomass, taking into account the political objectives and framework conditions in the heating sector as well as the assessment of biomass potential, energy scenarios and information about the technology."

Prof. Dr.-Ing. Daniela Thrän, Project Manager

BIOPLANW – SYSTEM SOLUTIONS FOR BIOENERGY IN THE HEATING SECTOR IN CONTEXT OF FUTURE DEVELOPMENTS

Biomass-based energy is a renewable energy (RE) that contributes to the reliable, affordable and environmentally friendly transformation of the energy system now and in the future, especially when it comes to the provision of heat (see Figure 7) [1,2]. In order to identify cost-effective and environmentally compatible solutions, especially in the heating sector, a number of conditions need to be observed, new technology concepts evaluated and their application and effects in various heating markets analysed. Due to limited resources, acceptance issues and future cost developments, the question arises as to what quantitative and qualitative role biomass, including CHP heat, will play in relation to other renewable energy sources in the heating markets of the future and how these can be implemented as cost-effectively, efficiently and environmentally friendly as possible. The project aims to systematically assess the development prospects of heat gen-



¹ BMWi: Facts and figures energy data. National and international development. Status: 05.04.2016 ²Time series on the development of renewable energies in Germany using data from the Renewable Energy Statistics Working Group (AGEE-Stat). As of February 2016

Fig. 7 Final energy consumption for heat

erated from biomass – taking into account the political objectives and framework conditions in the heating sector as well as the assessment of biomass potential, energy scenarios and information about the technology. This is done with the help of existing modelling and evaluation approaches, which have already been used to derive elements of a bioenergy strategy in the electricity and heating sectors [3]. The technology concepts currently under development are systematised and their competitiveness in various sub-markets is simulated. Then the associated effects on their overall contribution to energy supply and climate protection, as well as their effects on land use, are evaluated and discussed. The data pool developed in this way is combined with information on the prospects of heat supply from biomass (with other renewable energies) and used to support the strategic work in the field of heat and efficiency (policies), e. g. for the platforms and working groups of the BMWi, BMEL or BMUB.[1]

1 Federal Ministry of Economic Affairs and Energy (BMWi)
Federal Ministry of Food and Agriculture (BMEL)
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)

METHODS/MEASURES

Existing models, scenarios and evaluation approaches are used to present the scientifically sound prospects of bioenergy in combination with other renewable energies in the heating sector, providing information, data and analysis for future strategy development. The methods and database, developed as part of the project "Milestones 2030" [3], are further developed with a focus on the heating sector[2]. In order to present and evaluate the prospects for heat supply, 1) differentiated areas of heat application ("sub-markets") were defined and 2) development scenarios were formulated. The following list of questions have been and are being answered in detail:

1. Which technology is currently available or undergoing research and development that produces heat from biomass in an energy efficient way in combination with renewable energies? How can these technologies be classified in terms of efficiency, effectiveness, cost and environmental impact and what is the development potential of these parameters with respect to the individual technologies up until 2050?
2. To what extent can efficient technologies that are based on low-cost biomass establish themselves in different submarkets? How do the constraints impact the competitiveness and implementation of these technologies? Which future technologies for the various sub-markets are competitively robust with respect to one another and to other renewable energy options?
3. How are the technologies classified in terms of their effects on emissions, costs, resource efficiency and land use within the scenarios and in the various submarkets? What is the maximum benefit to climate?
4. Where is there a need for action to effectively integrate highly beneficial technologies? How can these be integrated into the future political processes?

2 Biogenic heat supply, especially on the basis of wood, should be developed gradually and continuously with respect to future demand structures, combining it with other renewable energies, emission requirements and extending combined heat, power and cooling systems. Regional supply structures, emission requirements and user preferences have to be taken into account. As part of an independent heat strategy, bioenergy in the form of heat networks and CHP plants, for example, should be combined with waste heat recovery from industry and accompanied by efforts to save energy. Cf. [3]

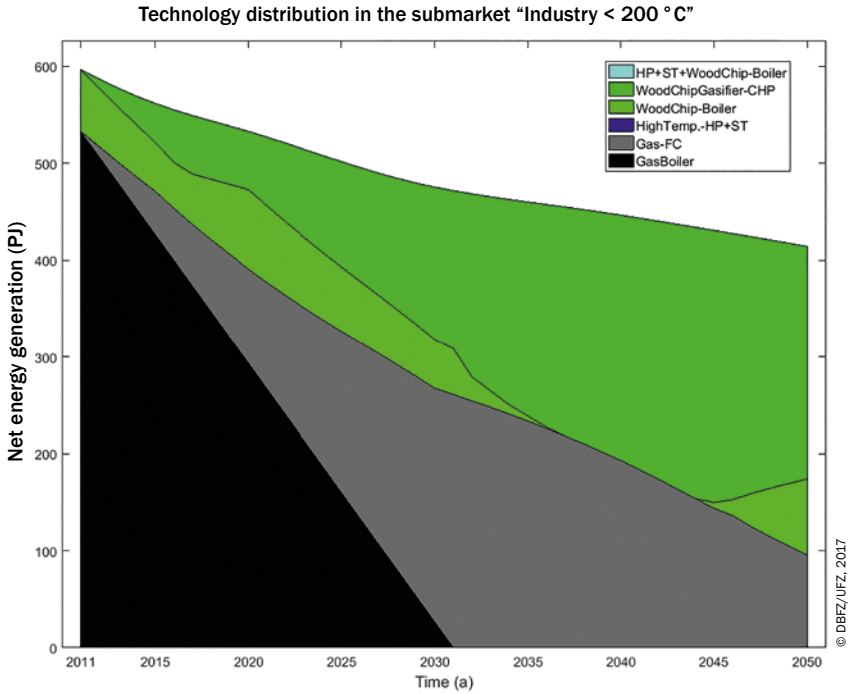


Fig. 8 Example of a preliminary result for an energy scenario in the "Industry < 200 °GradC" sub-market

The following methods and adaptation steps are used:

- The operationalisation of energy scenarios for defined sub-markets
- Fact sheets describing integrated bioenergy concepts for heat generation (incl. CHP and renewables)
- The "BENSIM" bioenergy competition model
- The LandSHIFT land use model and life cycle assessment.

Since a large proportion of the heat supply comes from wood, this material flow receives special consideration. In order to compare the results from the BMWi funding programme "Biomass Energy Use", the approaches are taken from the method handbook where possible, e. g. to define the reference system and to calculate the effects of the concepts.
Figure 8 shows an example of a preliminary result for the "Industry – Temperature Range < 200 °C". This result was simulated in one of the four heat scenarios developed.

MILESTONES/CHALLENGES

Heat and CHP are depicted in different ways in a variety of scenarios (e. g. [4–6]) and there is a wealth of possible technical solutions in the field of renewable energies that can be used to meet the targets of the federal government. The BMWi joint project "Milestones 2030" examined strategic elements to expand electricity and fuel production from biomass. However, there is a lack of comparable results for the provision of biogenic heat. When it comes to necessary system solutions and system integration, as currently being discussed more and more frequently [7] (including various renewable energies in the heating and cooling sector, see [8]), there is also a gap in the concretisation and evaluation of corresponding concepts for bioenergy and other renewable energy technologies. The study expands existing models ("BENSIM" and "LandSHIFT"[3]) and addresses specific questions on the bio- and renewable energy heating market. The scientific literature often examines both the environmental impact of cultivating biomass for energy use and its competition with food production for land use (e. g. [9]). Land use models are suitable tools for analysing this complex problem (e. g. [10]). However, there is still no model for the high-resolution spatial analysis of the effects of biomass production on land use and the environment in Germany that takes into account both wood biomass and arable plants used to produce energy. This gap will be closed with the new version of the LandSHIFT model, which will be developed as part of this project.

3 A high-resolution version of the LandSHIFT land use model (250 m grid) for Germany (LandSHIFT-D) is created. The model is further developed in two areas: (1) The existing partial model for agriculture is supplemented by short-rotation plantations (SRP) as a potential option for offsetting the decreasing percentage of land used for biomass. (2) This is supplemented by a new partial model for the use of wood in forests. The enhanced model is the first German land use model to link the two sectors.

OUTLOOK

The result of the project is a previously non-existent, solid basis for the development of a reliable, economic and environmentally friendly provision of heat (bioenergy and other renewable energies). Through the project's scientific and political networks, the dialogue surrounding the sustainable use of biomass in the heating sector can be stabilised in terms of the energy strategy or the adjustment of expansion targets for renewable energy. Based on the project's findings, recommendations for action can be derived that can be used to design legal regulations and to define funding priorities and other political instruments. In addition, the analyses can take on an early warning function that discourages companies and politicians from developing and introducing products that meet with little acceptance, or to encourage them to think about utilisation modifications early on.

Project summary

Duration:	1/8/2016–31/3/2019
Project partners:	Center for Environmental Systems Research (CESR), University of Kassel, Helmholtz-Centre for Environmental Research GmbH – UFZ
Scientific contact:	Prof. Dr.-Ing. Daniela Thrän
Project number:	03KB113
Funding body:	Federal Ministry for Economic Affairs and Energy/ Project Management Jülich

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

CESR Center for Environmental Systems Research

Supported by: Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

ptj Projektträger Jülich Forschungszentrum Jülich

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THE RESEARCH FOCUS AREA “SYSTEM CONTRIBUTION OF BIOMASS”

The research focus area is intended to contribute to the development of sustainable bioenergy strategies at the national and international levels. This entails determining regionally and globally available biomass potentials and examinating and evaluating the various concepts for biomass utilisation. The overriding goal is to find methodological and system-engineering solutions to the problems of efficiency and sustainability of biomass use from an economic, ecological and technical perspective, taking into account the land resources and the processing and conversion technologies specific to energy sources. Combining these topics allows strategies and recommendations for action to be devised for decision-makers from politics and business.

Key reference projects and publications

Project: BEPASO – Bioökonomie 2050: Potenziale, Zielkonflikte, Lösungsstrategien, Bundesministerium für Bildung und Forschung/Projektträger Jülich, 01.12.2016–30.11.2019 (FKZ: 031B0232B)

Project: BioRestMon – AG Biomassereststoffmonitoring, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.07.2016–30.06.2018 (FKZ: 22019215)

Project: RecordBiomap – Research Coordination for a Low-Cost Biomethane Production at Small and Medium Scale Applications, EU-Projekt/Horizon2020, 01.04.2016–30.09.2018 (FKZ: GA 691911)

Project: Smarkt – Bewertung des Marktpotenzials und Systembeitrags von integrierten Bioenergiekonzepten, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.09.2017–31.12.2019 (FKZ: 03KB130)

Project: SYMOBIO – Systemisches Monitoring und Modellierung der Bioökonomie, Bundesministerium für Bildung und Forschung/Projektträger Jülich, 01.03.2017–29.02.2020 (FKZ: 031B0281C)

Publication: Billig, E.; Thrän, D. (2017). “Renewable methane: A technology evaluation by multi-criteria decision making from a European perspective”. *Energy*, Vol. 135 S. 468-484. DOI: 10.1016/j.energy.2017.07.164.

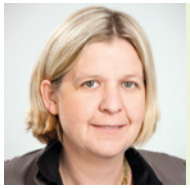
Publication: Millinger, M.; Ponitka, J.; Arendt, O.; Thrän, D. (2017). “Competitiveness of advanced and conventional biofuels: Results from least-cost modelling of biofuel competition in Germany”. *Energy Policy*, Vol. 107. S. 394–402. DOI: 10.1016/j.enpol.2017.05.013.

Publication: Oehmichen, K.; Thrän, D. (2017). “Fostering renewable energy provision from manure in Germany – Where to implement GHG emission reduction incentives”. *Energy Policy*, Vol. 110. S. 471–477. DOI: 10.1016/j.enpol.2017.08.014.

Publication: Szarka, N.; Eichhorn, M.; Kittler, R.; Bezama, A.; Thrän, D. (2017). “Interpreting long-term energy scenarios and the role of bioenergy in Germany”. *Renewable and Sustainable Energy Reviews* (ISSN: 1364-0321), H. 68, Part 2. S. 1222–1233. DOI: 10.1016/j.rser.2016.02.016.

Publication: Thrän, D.; Billig, E.; Brosowski, A.; Klemm, M.; Seitz, S. B.; Witt, J. (2018). “Bioenergy Carriers: From Smoothly Treated Biomass towards Solid and Gaseous Biofuels”. *Chemie Ingenieur Technik*. DOI: 10.1002/cite.201700083.

Publication: Thrän, D.; Pfeiffer, D. (Hrsg.) (2017). *Focus on Bioenergie im Strom- und Wärmemarkt: Projektergebnisse 2015–2016*. (Fokusheft Energetische Biomassenutzung). Leipzig: DBFZ. 86 S. ISBN: 978-3-946629-16-0



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4.2
ANAEROBIC PROCESSES

"Within the project 'MetHarmo', different approaches and methods for measuring total methane emissions from biogas plants are compared and harmonized based on common emission measurements. The resulting guideline aims to outline a standard procedure for applying the examined methods, thus comparable and reliable emission measurements are enabled in the future."

Dr. rer. nat. Tina Clauß, Project Manager

METHARMO – EUROPEAN HARMONISATION OF METHODS TO QUANTIFY METHANE EMISSIONS FROM BIOGAS PLANTS

Identifying and reducing methane emitted during the operation of biogas plants is important for the greenhouse gas (GHG) balance of this technology and thus for our ability to evaluate it in relation to the use of renewable energies. Methane is the relevant GHG for the biogas sector due to the quantities that are produced and stored and its high global warming potential (28 over 100 years [1]). Typical emission sources of biogas plants are leakages, the pressure relief valves (PRV), the gas utilisation units and the open handling of digestates (e. g. open storage, composting). The development and application of various measurement methods to determine total methane emissions from biogas plants has been the subject of research at the DBFZ for almost ten years now.

Fig. 9 Methane detection in a biogas plant

To date there is no common European directive or standard that enables total methane emissions from biogas plants to be uniformly determined and evaluated. Consequently, the comparison of emission measurement results from different research institutes using different methods for different biogas plant concepts is extremely difficult.The research project "MetHarmo" was initiated with the aim of combining and harmonising national approaches and methods, which are used to determine methane emissions from biogas plants in order to create a uniform European approach. The individual measurement approaches and methods should result in comparable and repeatable measurement results. Ideally, a subsequent standardisation process will be initiated. Afterwards, reliable measurement results can be used to compile an inventory of emissions. This includes, among other things, guidelines for determining and evaluating methane emission rates as well as an overview of the advantages and disadvantages of the methods. Furthermore, a description of their areas of application and limitations of the single methods will be given. The MetHarmo project follows directly on the project

"Comparison and evaluation of measurement methods to determine methane emissions from biogas plants" (Funding institution: Swedish Energy Agency, duration: 01/2014–07/2015). As part of this project, comparative emission measurements were carried out for the first time at a Swedish biowaste treatment plant using on-site and remote sensing methods (see section entitled Emission Measurement Methods) [2]. This first joint emission measurement produced important insights for the implementation of the "MetHarmo" project:

- A high variability of the measured methane emission rates was observed within a period of a few measuring days (e.g. due to different operating conditions and repairs that were carried out).
- The on-site approach requires the measurement of only a few large sources in order to determine the total emission rate (here: open digestate storage, open valve on the main biomethane compressor).
- The evaluation approaches must be harmonised (e.g. chamber measurement for open digestate storage with the on-site approach).
- The influence and the process of background methane measurement (variability during the day) for the use of the remote sensing approach must be clarified.
- A validation of the remote sensing approach through controlled and defined methane release (artificial source) should be carried out.
- The factors contributing to the differences between the individual methods must be clarified and/or narrowed down.

Based on these insights, "MetHarmo" aims to optimise the individual approaches and measuring methods and to harmonise them into a common guideline.

METHODS FOR MEASURING EMISSIONS

To achieve the mentioned project objectives, two joint measurement campaigns were carried out at German biogas plants with the participation of eight measurement institutions (3 times on-site methods, 5 times remote sensing methods). The on-site approach directly identifies and quantifies the individual emission sources

and thus shows their contribution to the overall emission rate of the plants under investigation. This is essential for the implementation of emission mitigation measures. The on-site teams used infrared gas cameras and methane detectors to detect leaks, as well as various individual methods for quantifying the respective emission sources. These included wind tunnels for leaks from biogas-bearing plant components, dynamic and static chambers to determine emission rates from the open digestate storage tank, and standardised methods to investigate channelled emission sources such as the CHP exhaust gas [2,3].
The remote sensing approach allows the measurement of the emissions from the entire biogas plant including all existing individual sources. The approach is very well suited for the continuous measurement of time-dependent and/or operational methane emissions. However, the system is a black box as it is not possible to break down and/or identify the individual sources. The measuring instruments are located at a certain distance from the source and therefore have no influence on the emissions during the measurement. All remote sensing methods determine the methane concentration on upwind and downwind of the biogas plant. The methane emission rate of the source is then calculated from the data using micro-meteorological models or by releasing a tracer gas (e.g. acetylene) in the area of the source during the measurement. Three remote sensing teams used the inverse dispersion modelling method (IDMM) with tunable diode laser absorption spectroscopy (TDLAS) in combination with a backward Lagrangian Stochastic model. Another team used cavity ring-down spectroscopy in combination with the tracer dispersion method (TDM, tracer gas = acetylene). The fifth team used differential absorption LIDAR (light detection and ranging, DIAL). The DIAL system was used as a reference method as it is not normally used in biogas plants for cost reasons.

COMPARATIVE EMISSION MEASUREMENTS

The measurement campaigns are the basis for the development of a standardised procedure for performing emission measurements on biogas plants. The two measurement phases occurred in October 2016 and May 2017. Comparative measurements between the individual approaches and measuring methods

Fig. 10 Group picture of the measuring teams of the research institutions ISWA, BOKU, DTU, RISE, IRSTEA, and DBFZ

were carried out simultaneously at two different German biogas plants. Figure 10 shows a group picture of the participating measuring teams (2nd measuring campaign) of the project consortium.
The measured emission factors of the first measurement campaign ranged from 0.2–1.2 % CH_4, while emissions in the second measurement phase ranged from 1.2–4.7 % CH_4. In addition to the above findings, the following conclusions can be drawn from the results:

On-site approach:

- The investigation of major emission sources is crucial for the accuracy of on-site measurements. The mode of plant operation and the operating data should be used to identify which sources must be examined and to what extent. The main emission sources on biogas plants can be:
  - Methane slip from the gas utilisation unit (CHP) (depending on full load/partial load operation, lambda value, operating hours after commissioning or general overhaul)
  - Methane slip from the biogas upgrading unit (depending on the type of upgrading unit and/or exhaust gas aftertreatment)
  - Open handling of digestate, especially open digestate storage (depending on the degree of degradation achieved in the process, filling level, temperature)
  - PRV (depending on average fillinglevel of the gasholder, biogas storage management incl. flare operation, determination only possible with continuous measurements)
  - Large leakages
- There must be a uniform procedure for leakage detection; otherwise, (particularly) small leaks will not be detected.

Remote sensing approach, using the IDMM method as an example:

- The positioning of the weather station is vital when modelling emission rates. The ambient atmospheric conditions should therefore be measured downwind.
- The measurement of the natural background methane concentration should ideally be continuous and be done parallel to the emission measurements.
- The temperature dependence of the laser spectrometer has to be taken into consideration and validated by one's own calibration measurements.

OUTLOOK

The project produced a guideline, which harmonises the individual approaches and measurement methods. The project results and the guideline were presented at a European workshop in Lund, Sweden on 1 February 2018. The now harmonised standard methods will be used in another proposed ERA-NET project "EvEmBi – Evaluation and reduction of methane emissions from different European biogas plant concepts" (funded by the 11th joint call of ERA-NET Bioenergy, planned project duration: 1/3/2018–28/2/2021). This project should develop a procedure to define representative and transferable methane emission factors for

the various European biogas plant concepts for the first time. The aim is to group the emission sources of biogas plants according to their importance and to include other sources of information (e. g. emission data from measuring points) by means of the now comparable practical measurements. Another aim is to ensure a substantial basis of data from which the emission factors can be developed. Furthermore, position papers and operator training programmes focusing on reducing methane emissions from biogas plants are to be developed by involving the biogas associations.

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Additional information:

www.dbfz.de/metharmo

www.sp.se/en/training/Sidor/MetHarmoWorkshop.aspx

THE RESEARCH FOCUS AREA "ANAEROBIC PROCESSES"

Processes that use microorganisms to convert biomass under anaerobic conditions are the basis of a large number of biotechnological processes that provide energy sources and materials for material use. In the research area "Anaerobic Processes", flexible and efficient processes are developed primarily for biogas production in order to meet the requirements of the future energy system. A higher added value is achieved by linking them to processes for material recycling. The research area focuses on the development of tools for process monitoring and control, concepts for flexible, low-emission plants and operating regimes, methods for evaluating and optimising efficiency, and methods for maximising material turnover, especially for difficult substrates.

Key reference projects and publications

Project: BMPIII – Biogas-Messprogramm III: Faktoren für einen effizienten Betrieb von Biogasanlagen – Teilvorhaben 1: Energiebilanzierung, Flexibilisierung, Ökonomie, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.12.2015–30.11.2018 (FKZ: 22403515)

Project: ChinaRes – Energetische Nutzung landwirtschaftlicher Reststoffe in Deutschland und China; Teilvorhaben 1: Erarbeitung von Konzepten für zukünftige Biogasanlagenbetreiber, Bundesministerium für Ernährung und Landwirtschaft/ Fachagentur Nachwachsende Rohstoffe e. V., 15.08.2017–31.10.2020 (FKZ: 22025816)

Project: DEMETER – Demonstrating more efficient enzyme production to increase biogas yields, EU/Horizon2020, 01.08.2016–31.07.2019 (GA 720714)

Project: eMikroBGAA – Effiziente Mikro-Biogasaufbereitung; Teilvorhaben 2: Potenzialabschätzung und betriebswirtschaftliche Bewertung für MikroBGAA, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.11.2015–31.10.2017 (FKZ: 22401615)

Project: GAZELLE – Ganzheitliche Regelung von Biogasanlagen zur Flexibilisierung und energetischen Optimierung, Sächsische Aufbaubank, 01.02.2017–31.01.2020 (FKZ: 100267056)

Publication: Kretzschmar, J.; Koch, C.; Liebetrau, J.; Mertig, M.; Harnisch, F. (2017). "Electroactive biofilms as sensor for volatile fatty acids: Cross sensitivity, response dynamics, latency and stability". *Sensors and Actuators B: Chemical* (ISSN: 0925-4005), H. 241. S. 466–472. DOI: 10.1016/j.snb.2016.10.097.

Publication: Mauky, E.; Weinrich, S.; Jacobi, H.-F.; Nägele, H.-J.; Liebetrau, J.; Nelles, M. (2017). "Demand-driven biogas production by flexible feeding in full-scale: Process stability and flexibility potentials". *Anaerobe*. H. 46, S. 86-95, DOI: 10.1016/j.anaerobe.2017.03.010.

Publication: Reinelt, T.; Delre, A.; Westerkamp, T.; Holmgren, M. A.; Liebetrau, J.; Scheutz, C. (2017). "Comparative use of different emission measurement approaches to determine methane emissions from a biogas plant". *Waste Management* (ISSN: 0956-053X), H. 68. S. 173–185. DOI: 10.1016/j.wasman.2017.05.053.

Publication: Trommler, M.; Barchmann, T.; Dotzauer, M.; Cieleit, A. (2017). "Can Biogas Plants Contribute to Lower the Demand for Power Grid Expansion?". *Chemical Engineering & Technology*, Vol. 40, H. 2. S. 359–366. DOI: 10.1002/ceat.201600230.

Publication: Urban, C.; Xu, J.; Sträuber, H.; dos Santos Dantas, T. R.; Mühlenberg, J.; Härtig, C.; Angenent, L. T.; Harnisch, F. (2017). "Production of drop-in fuels from biomass at high selectivity by combined microbial and electrochemical conversion". *Energy & Environmental Science* (ISSN: 1754-5706), H. 10. S. 2231–2244. DOI: 10.1039/C7EE01303E.

Project summary

Duration:	1/3/2016–28/2/2018
Project partners:	DBFZ (Germany, coordinator); Institute for Sanitary Engineering, Water Quality and Solid Waste Management, University of Stuttgart (Germany, ISWA); National Physical Laboratory (Great Britain, NPL, subcontractor of the DBFZ); Institute for Waste Management, University of Natural Resources and Life Sciences, Vienna (Austria, BOKU); Zentralanstalt für Meteorologie und Geodynamik (Austria, ZAMG); Bioenergy 2020+ GmbH (Austria); Energiforsk AB (Sweden); RISE Research Institutes of Sweden AB (Sweden, RISE); Avfall Sverige (Sweden); Department of Environmental Engineering, Technical University of Denmark (Denmark, DTU, associated partner); Boreal Laser Inc. (Canada, associated partner); Institut national de recherche en sciences et technologies pour l'environnement et l'agriculture (France, IRSTEA, associated partner, acquired during the project)
Scientific contact:	Dr. rer. nat. Tina Clauß
Project number:	22403115
Funding body:	ERA-NET Bioenergy; Federal Ministry of Food and Agriculture, Fachagentur Nachwachsende Rohstoffe e. V.

With support from

ERA-NET Bioenergy

Federal Ministry of Food and Agriculture

FNR Fachagentur Nachwachsende Rohstoffe e.V.

by decision of the German Bundestag

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4.3 PROCESSES FOR CHEMICAL BIOENERGY SOURCES AND FUELS

"Glycerine is a by-product of biodiesel production. In the EU project 'GRAIL', we have come together with our project partners to develop, evaluate and optimise concepts for converting this residual material into valuable products."

Stephanie Hauschild, Project Manager

GRAIL | GLYCEROL BIOREFINERY APPROACH FOR THE PRODUCTION OF HIGH QUALITY PRODUCTS OF INDUSTRIAL VALUE

In Europe, biodiesel (fatty acid methyl esters, FAME) is quantitatively the most important biofuel and contributes significantly to reducing greenhouse gas emissions in the transport sector. Biodiesel is produced through the transesterification of vegetable and animal fats and oils [1]. Using acidic or alkaline catalysts to break down the ester bonds in the acyl glycerides produces fatty acid residues which form a new ester bond with an added alcohol (e. g. methanol) [1]. Depending on the amount of FAME produced, glycerine is created as a by-product at a ratio of approx. 10 % (w/w) [2, 3, 4]. Due to its non-toxic and hygroscopic properties, it is traditionally used in the pharmaceutical, chemical and cosmetic industries or to produce animal feed [1].

Between November 2013 and October 2017, 14 partners from nine different countries developed and optimised innovative process concepts for utilising glycerine from biodiesel production. The aim of the consortium was to add more value

to glycerine of different qualities. A special focus was placed on fermentative and chemical conversion to biofuels, platform chemicals and dietary supplements. A key driver was to strengthen and expand the cost-effectiveness and competitiveness of European biodiesel manufacturers through the diverse product ranges of the various biorefinery concepts.
Under the direction of the Biorefineries department, the DBFZ contributed a wide variety of core competencies to the "GRAIL" project. The following objectives were defined for the DBFZ:

- Identification and evaluation of European glycerol potentials and geographical evaluation as a basis for a location analysis – Bioenergy Systems department
- Analytical analysis of glycerine qualities available on the market – Analytical Lab
- Development of biorefinery concepts and preparation of mass and energy balances through detailed process simulations – Biorefineries department
- Comparison of concepts to reference systems and products taking into account economic and ecological criteria and feedback on the results for process optimisation – Biorefineries and Bioenergy Systems department

METHODS/MEASURES

The project's strategy was based on the pillars "raw materials", "product development" and "industrial implementation" (see Figure 11). The DBFZ has been intensively involved in all three project pillars.
In the first years of the project, the Biorefineries department carried out a sampling of European biodiesel producers. This enabled the glycerine qualities available on the European market to be analysed. Potential fluctuations in quality, resulting from the raw materials, catalysts or production processes used, were estimated.
Another important aspect of this pillar was comprehensive market research on biodiesel plants, their production capacities (theoretical potential) and utilisation (technical potential) as well as national glycerine potentials and their spatial distribution. The data collected by the Bioenergy Systems department revealed in 2013 that 828,000 tonnes of glycerine of various qualities can be technically pro-

Fig. 11 Structure of the "GRAIL" project

duced in Europe annually. There were 203 plants in operation with a theoretical potential of 2,024,000 t a^{-1}. Based on this, a plant site selection was conducted as a basis for the investigations of the economic and ecological implementation. As the supply distance increased, the preferential regions spread from northern Belgium and the southern regions of the Netherlands to eastern Germany. More detailed information and method descriptions can be found in the paper published by Brosowski et al. 2017 [5].
As part of the second project pillar "product development", processes were developed for the production of biofuels, platform chemicals and dietary supplements. Corresponding experimental investigations were carried out by the project partners on a laboratory scale. The Biorefineries department transferred the experimental results to different process concepts on an industrial scale and used the ASPEN Plus® software to create detailed mass and energy balances through process simulations. Biofuels, such as ethanol or butanol in combination with hydrogen, were produced through fermentation or were chemically converted into a novel fuel with very good combustion properties in biodiesel mixtures (fatty acid glycerol formal ester, FAGE). The production of 1,3-propanediol and polyhydroxybutyric acid as platform chemicals was investigated especially for the polymer industry, with β-carotene, docosahexaenoic acid, vitamin B 12 and eicosapentaenoic acid used in the food industry.
Under the third pillar, the concepts were compared with specific reference systems taking into account economic and ecological criteria. A life cycle assessment (LCA) and the calculation of life cycle costing (LCC) enabled commercial implementation to be evaluated and any potential for optimisation to be determined. The methodological approach is shown in Figure 12. Based on the generated

mass and energy balances and taking into account site-specific conditions, the results were evaluated by the Bioenergy Systems and Biorefineries departments and recommendations for process optimisation were formulated.

MILESTONES/CHALLENGES

The DBFZ's study of the potentials of glycerine on the European market pointed to significant, currently unused, biodiesel and, hence, glycerine capacities. If these theoretical glycerine potentials are exploited in Europe, the conceptual design of add-on plants at existing biodiesel sites (biorefinery concept) is also feasible in addition to the creation of stand-alone recycling plants.
At the DBFZ, a total of 13 process concepts were developed and coordinated with the project partners, in which the processes, input concentrations and separation techniques varied. Detailed process simulations were created for the process routes under consideration and evaluated as mass and energy balances. This created a sound basis for assessing the product paths. Based on our activities involving concept development and evaluation, producing biofuels and platform chemicals from glycerine seems to make particular sense. From an economic and ecological point of view, both are significantly more attractive than the production of food additives which was considered in the project. However, for the latter option, the level of development is estimated to be significantly lower.
Important drivers of life cycle analysis and cost calculation were identified and addressed via feedback to the testing partners and using initial technology optimisation approaches. The quantities of raw materials and auxiliary materials used (e. g. yeast extract) were found to be the central factors influencing the greenhouse gas balance of fermentative processes. In terms of production costs, the processing of large quantities of process water has a considerable influence on energy costs. The latter has been discussed in numerous workshops with the partners. Different strategies were developed to reduce the high amount of water required by the fermentation processes or to optimise the energy efficiency of the respective processes. A special focus was placed on the investigation of different circuits of conventional and innovative separation processes (e. g. evaporation and reverse osmosis) and the evaluation of integrated systems to reduce product inhibition

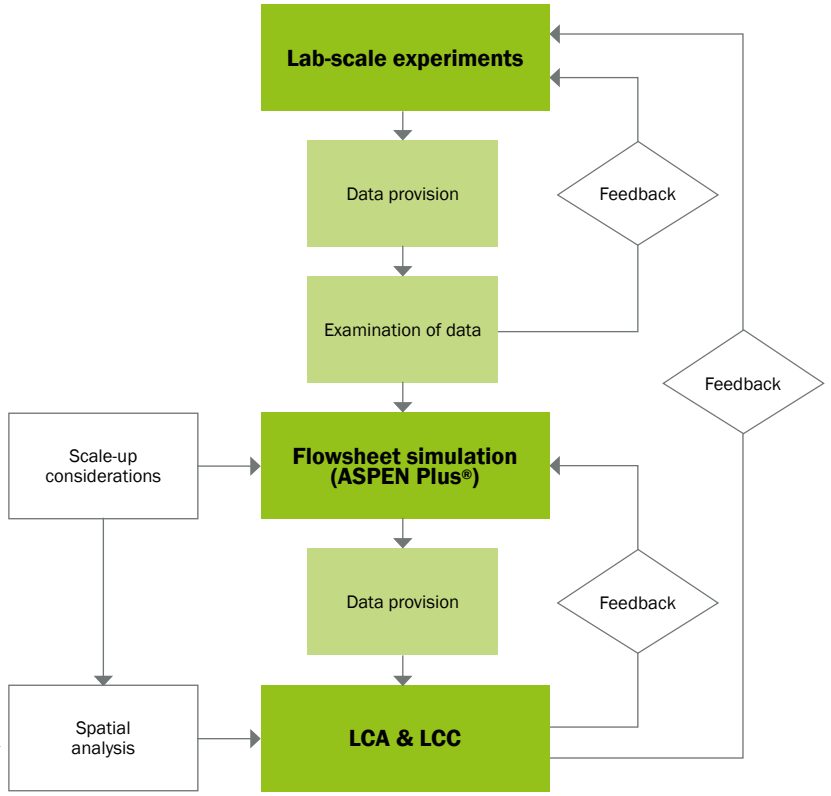

Fig. 12 **Methodical approach for balancing, evaluating and optimising project-relevant processes**

(e. g. using gases for in-situ stripping of the fermentation broth). Literature-based process simulations have already shown that the implementation of a simple reverse osmosis unit can separate over 51 % of the process water that is introduced. This means that the energy required for subsequent product production can be reduced by 46 %.

OUTLOOK

The many promising studies within the “GRAIL” project form a sound basis for the development of market-relevant processes for converting glycerine into valuable products. The processes for producing 1,3-propanediol as a platform chemical and ethanol as a biofuel are favoured because they are economically and ecologically competitive with the selected reference products. A special focus of further developments will be a detailed look at the upscaling of fermentation process routes, gradually transferring laboratory experiments to a demonstration scale. There are also optimisation potentials and development possibilities through the integration of separation techniques that are specially adapted to processing aqueous suspensions for selective product recovery and early water separation.

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The project “Glycerol Biorefinery Approach for the Production of High Quality Products of Industrial Value” (GRAIL) was funded by the Seventh Framework Programme of the European Union (FP 7) under grant agreement number 613667.

Additional information:
www.grail-project.eu

Project summary

Duration:	1/11/2013–31/10/2017
Project partner:	InKemia IUCT Group, S.A.; Consorzio In.Bio; Slovak University of Technology in Bratislava; Vertech Group SAS; MEGARA RESINS Anastasios Fanis S.A.; biozoon GmbH; ENEA; CENTIV GmbH; Pontificia Universidad Católica de Valparaíso; Processi Innovativi SRL; STIFTELSEN SINTEF; The Queen’s University of Belfast; The Technical University of Denmark
Scientific contact:	Stephanie Hauschild
Project number:	GA 613667
Funding body:	European Commission, 7th Framework Programme (FP 7)

THE RESEARCH FOCUS AREA “PROCESSES FOR CHEMICAL BIOENERGY SOURCES AND FUELS”

The research focus area is an integral part of the overall process chains, from the raw biomass material to biofuels and chemical bioenergy sources as products of biorefineries. In addition to process and concept development, it also implements processes on a laboratory and pilot plant scale and assesses technical systems. The overriding goal is to contribute to flexible, highly efficient and sustainable biorefinery concepts through innovative technology approaches and thus also to meet requirements in the context of the bioeconomy. Chemical refinement processes that focus on hydrothermal processes (HTP) are being further developed for this purpose. The development of fractionation processes for solid-liquid and

liquid-liquid separation plays a key role linking the individual research focus areas (especially in connection with anaerobic processes and HTP intermediates). Another element of research is the development of synthesis gas processes to create high-grade products with a focus on biomethane in the form of bio-synthetic natural gas (Bio-SNG). In the short term, a sample HTP-based biorefinery concept is being developed. To this end, work within the research focus areas will concentrate on (i) the analysis of relevant individual processes and required system components, (ii) preliminary tests for selected individual processes (e. g. HTP, gasification, methanisation to SNG) and (iii) the preparation of an accompanying technology assessment (focus: material and energy balancing, costs and cost-effectiveness, environmental effects).

Key reference projects and publications

Project: BBCHEM – Aufwertung von kohlenhydrathaltigen Stoffströmen zu bio-basierten Chemikalien. Teilvorhaben 2: Hydrothermale Umsetzung, Bundesministerium für Bildung und Forschung/Projektträger Jülich, 01.03.2016–31.08.2018 (FKZ: 033RK031B)

Project: CAROFIL – Entwicklung magnetisierbarer Filterkohlen zur hochselektiven Abscheidung von Partikeln, Bundesministerium für Bildung und Forschung/VDI-VDE-IT, 15.07.2017–14.07.2019 (FKZ: 03VNE1031C)

Project: DKA2 – Verbundvorhaben: Schnelltest zur Alterungsnachstellung von Dieselabgaskatalysatoren im Betrieb mit Biokraftstoffen; Teilvorhaben 1, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V./Forschungsvereinigung Verbrennungskraftmaschinen (FVV) e. V., 01.10.2014–31.12.2017 (FKZ FNR: 22014514; FKZ FVV: 6011792)

Project: Fermenthen – Alkenproduktion aus Biogas zur Nutzung von Überschussstrom, Sächsische Aufbaubank, 01.10.2016–30.09.2019 (FKZ:100244827)

Project: KomBiChemPRO – Demonstrationsvorhaben: Fein- und Plattformchemikalien aus Holz durch kombinierte chemisch-biologische Prozesse; Teilvorhaben B, Bundesministerium für Bildung und Forschung/Projektträger Jülich, 15.11.2015–14.05.2018 (FKZ: 031B0083B)

Publication: Klemm, M. (2017). Biomass Gasification for Rural Electrification, Small Scale. In: Meyers, R. A. (Hrsg.) *Encyclopedia of Sustainability Science and Technology.* New York, NY (USA): Springer. ISBN: 978-1-4939-2493-6. DOI: 10.1007/978-1-4939-2493-6_252-3.

Publication: Klemm, M.; Schmersahl, R.; Kirsten, C.; Weller, N.; Pollex, A.; Khalsa, J. H. A.; Zeng, T. (2017). Biofuels: Upgraded New Solids. In: Meyers, R. A. (Hrsg.) *Encyclopedia of Sustainability Science and Technology.* New York, NY (USA): Springer. ISBN: 978-1-4939-2493-6. DOI: 10.1007/978-1-4939-2493-6_247-3.

Publication: Matthischke, S.; Krüger, R.; Rönsch, S.; Güttel, R. (2016). "Unsteady-state methanation of carbon dioxide in a fixed-bed recycle reactor: Experimental results for transient flow rate ramps". *Fuel Processing Technology* (ISSN: 0378-3820), H. 153. S. 87–93. DOI: 10.1016/j.fuproc.2016.07.021

Publication: Pujan, R.; Hauschild, S.; Gröngröft, A. (2017). "Process simulation of a fluidized-bed catalytic cracking process for the conversion of algae oil to biokerosene". *Fuel Processing Technology* (ISSN: 0378-3820), H. 167. S. 582-607. DOI: 10.1016/j.fuproc.2017.07.029.

Publication: Rönsch, S.; Ortwein, A.; Dietrich, S. (2017). "Start-and-Stop Operation of Fixed-Bed Methanation Reactors: Results from Modeling and Simulation". *Chemical Engineering & Technology* (ISSN: 0930-7516), Vol. 40, H. 12. S. 2314–2321. DOI: 10.1002/ceat.201700229.

Veröffentlichung: Schröder, J.; Hartmann, F.; Publication, R.; Worch, D.; Böhm, J.; Gläser, R.; Müller-Langer, F. (2017). "Accelerated performance and durability test of the exhaust aftertreatment system by contaminated biodiesel". International Journal of Engine Research (ISSN: 1468-0874), Vol. 18, H. 10. S. 1067–1076. DOI: 10.1177/1468087417700762.

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4.4 SMARTBIOMASSHEAT

"Standardised and automated communication options for the individual components are indispensable if there is to be an effective interaction between all renewable energies in the heat supply of tomorrow."

Dr.-Ing. Volker Lenz,
Head of the Research Focus Area "SmartBiomassHeat"

AUTOBUS PLUG-AND-RUN PRINCIPLE – AUTOMATICALLY INTEGRATING GENERATORS AND CONSUMERS OF HEAT AND POWER INTO A BUILDING'S SUPPLY SYSTEM USING THE PLUG-AND-RUN PRINCIPLE

The DBFZ has been investigating the system behaviour, efficiency and exhaust emissions of biomass conversion plants for heat and power generation for many years. In addition to the scientific work on pure combustion plants, such as pellet or log wood furnaces, the core competencies of the DBFZ also include research on CHP plants, such as biomethane-based fuel cells or charcoal gasifiers with motor CHP.
However, in order to provide energy within a sustainable and stable energy system in the future, concentrating on the individual generation plants is not enough. In light of the need to reduce CO_2 emissions, it is important today to start linking several production plants for the supply of one building in order to form an overall concept. In addition to combining various heat generators, such as pellet boilers with solar thermal systems or heat pumps with log boilers, the coupling of the heat and electricity sectors is becoming an increasingly important component of modern energy supply to buildings.
At present, linking the energy supply systems in the low power range (< 50 kW_{th}, < 15 kW_{el}) has only been achieved in individual cases (mostly at research facilities) and using individual or manufacturer-dependent solutions. In larger buildings, individual solutions are usually used to construct control and regulation technology. In the lower power range, the various individual component controls presently work together very inefficiently in many cases. A supply network currently does not exist, in particular for single-family homes, apartment buildings and smaller commercial properties, whereby the parties involved in the supply system, including bioenergy plants, multiple consumers, other conversion plants, sensors and actuators can be integrated easily, automatically and regardless of the manufacturer. For this reason, the DBFZ has set itself the task of developing a procedure with which system participants can be automatically integrated into an energy management system or a building supply system through a specified bus system according to the plug-and-run principle.

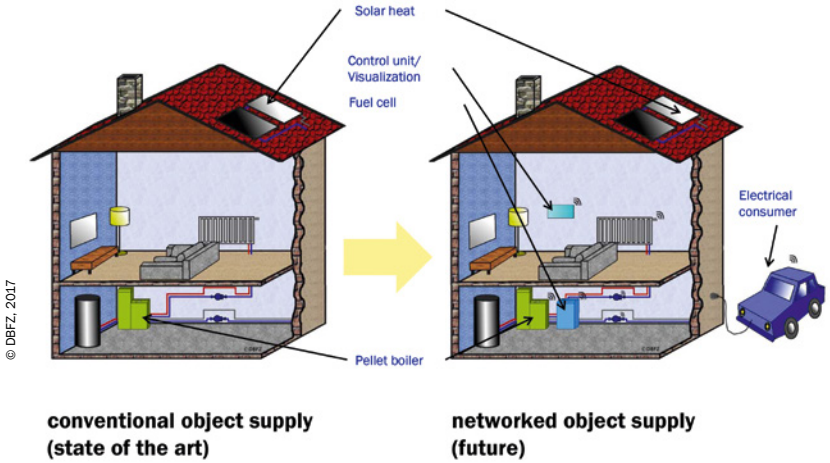


Fig. 13 AUTOBUS project approach (radio signals in the right half of the image signal the innovative plug-and-run integration of the components)

The plug-and-run principle describes the automatic integration of system users after they have been connected to the building supply network and can be compared with the connection of PC hardware via the USB interface of a Windows PC. The connected system participants are recognised by a central controller and are ready for operation after a short period of time without separate, manual intervention. The system should also be highly compatible and vendor-independent.
In the project, basic research is conducted on the design of a suitable bus system and a concept is created and evaluated using a demonstration model.

METHODS/MEASURES

There is a whole range of possible data transmission options for buildings. First, a decision was made on whether to use cabling or wireless communication. In order to be able to retrofit components that change regularly over the service life of a building (e. g. supplementing a solar thermal system, replacing an oil boiler with a heat pump), wireless communication was recommended. When selecting the right networking technology for the project, an evaluation methodology was developed to analyse and evaluate the respective properties of the options available on the market. Evaluation criteria were defined, which were divided into three categories (hardware, data transmission, software/protocols) and summarised in an evaluation matrix. Each evaluation criterion was rated 1 to 100 depending on priority, with 100 having the highest priority. This specification was based on previously defined requirements for the integration of (bioenergy) supply systems, energy consumers, sensors and actuators. The evaluation of the individual technologies was carried out using a point system from 1 to 10, with 1 defined as the least and 10 the most suitable.
Table 1 is an example of the evaluation of the transmission speed of the available wireless transmission technologies. Using the transmission speed and the information about the protocol structure of the individual transmission technologies enables the number of user data bytes that can be transmitted per time unit to be calculated. This; in turn; provides information about the necessary standby times and consequently also information about the energy consumption of the interface technology. The suitability of the technology for this criterion can be quickly con-

Tab. 1 Sample evaluation of the transmission speed

Technology	Transmission speed [kBit/s]	Evaluation
ZigBee	250	1
Z-Wave	40	1
WLAN	300,000	10
Bluetooth 4.0–4.2 (BLE)	1,000	4
Bluetooth 5.0 (BLE)	2,000	7
Enocean	125	1
DECT ULE	1,152	4
KNX-RF	16	1
wMBUS	67	1

firmed or rejected using extensive literature research to determine the number of user data bytes transmitted by selected system participants (e. g. pellet boilers). At the end of the evaluation, the evaluation matrix identifies the preferred technology for future use. Based on defined requirements for system participants, different technologies can be preferred for (bioenergy) supply systems, energy consumers, sensors and actuators. In a further step the properties of the preferred types will be combined into a suitable system or an existing system will be modified.
The plug-and-run function is integrated into the software via an automated data query between the controller and the system participant. The data exchange essentially consists of a handshake, the parameterisation phase and the control process phase. The criterion on which the success of the project was based was a working demonstration model in a laboratory environment in which the procedure for integrating system participants is proven and validated according to the plug-and-run principle. One of the central units of the demonstration model is the interface module. Various system devices are connected to the controller via the specified transmission technology (bus system) (see Figure 14).

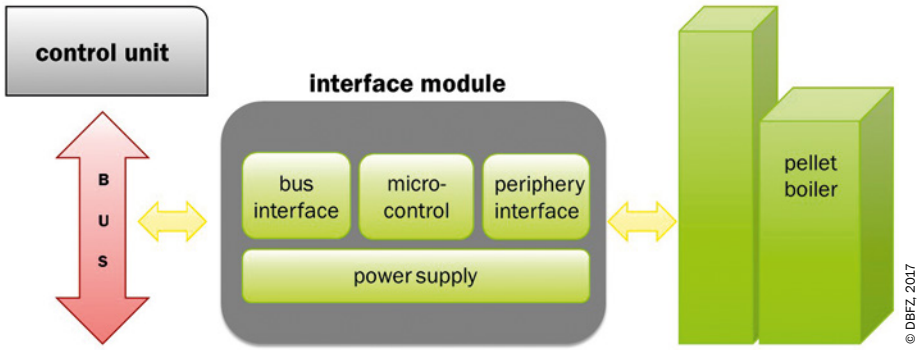


Fig. 14 Interface module

The interface module essentially consists of a bus interface, microcontroller, peripheral interface, level converter and power supply. The bus interface ensures communication according to the requirements specified in the project. The microcontroller interrogates the system data, converts the protocols and controls the plug-and-run functions in combination with the controller. The peripheral interface establishes a connection with the system participant via the specified manufacturer-specific bus (e. g. Modbus, LON bus). The level converter transforms the voltage levels of the two bus systems into a corresponding TTL level for further processing in the microcontroller. The power supply supplies the interface module with the necessary current.

MILESTONES/CHALLENGES

The very broadly positioned end-customer market is the biggest challenge facing successful implementation of the technology on the market in the future. There is a range of components made by many different producers that have very different internal data communication channels and interfaces. In addition, energy supply systems in buildings grow and change “organically”. Rooms undergo changes in use, individual components are replaced or supplemented and, over time, a wide variety of systems, components and controllers are created. In addition, companies have already started to offer SmartHome solutions without agreeing on a generally accepted standard. In this respect, the solution must be universally applicable as well as being inexpensive to implement without requiring a tradesman with any special IT knowledge. With this in mind, the following results have been achieved so far and the following activities have yet to be implemented:

The evaluation of the available in-house communication systems was largely completed by the end of 2017. The decision was made in favour of Bluetooth 4.x, as it offers low power consumption, the appropriate data transfer rate and, thanks to the newly introduced chain technology option, connection to larger buildings. In addition, Bluetooth 4.x allows specific scripts to be set up in the existing communication technology, so that all the necessary communication levels for linking and data security are already available. To connect sensors and actuators to the Bluetooth communication level, a sensor tag has been identified that can transfer the data streams in the Bluetooth environment and forward them bidirectionally. Work is currently underway on the EthernetShields, which transfer the data streams of the individual components into data formats that can be read by the sensor tags. This is a particular challenge for subsequent implementation as these EthernetShields should, in future, be provided directly by the component manufacturers in the appropriate data format for the SensorTag. Automatic data retrieval and forwarding within the BUS system has also been largely implemented.

One critical point that remains open is the development of a database and/or provision of Internet-enabled data on the behaviour of the manufacturer’s components so that the controller that is integrated later on will receive the necessary parameters to describe the respective components. These parameters include possible setting intervals and the speed at which the component reacts to control signals.

OUTLOOK

A technical solution should be available upon successful completion of the project “Automatic integration of heat and power generators and consumers in a building’s supply according to the plug-and-run principle” which is funded by the Sächsische Aufbaubank (SAB) with ERDF funding from the EU. This solution en-

ables components from different manufacturers for the heat (and power) supply of buildings to be integrated into a common communication network in a few simple steps and without much background knowledge. This provides the vital foundations for the intelligent interconnection and control of various renewable energy sources that are effective and efficient and which do not require expensive specialists. The communication technology connecting the individual components allows data to be exchanged on a common level and central control devices to be connected. Control algorithms for optimised heat (and power) supply have already been developed at the DBFZ for various system combinations and tested in a practical setting (solar thermal system – thermal buffer storage – pellet boiler or solar thermal system – thermal buffer storage – pellet stirling). In the past, data was exchanged using individual solutions. These control algorithms and the associated controllers can be connected to the individual measurement and control components much more easily thanks to the AUTOBUS undergoing development as part of this project. Further controller development and validation can thus take place much faster in the future.
In the next step, the AUTOBUS and its hardware components will be installed in several buildings in order to validate them in a real-world setting. Based on these results, an installation manual for tradesmen will be prepared listing the technical components that can be used and describing the necessary installation process in detail. At the same time, companies interested in control concepts will be informed in workshops on how they can connect their control system to the communication platform and which options they have for joint optimisation of the systems via remote access. At the same time, manufacturers of energy technology components (e.g. heat generators, power generators, pumps, valves, measuring sensors) will be informed about how they can provide datasets on the behaviour of their components on the Internet so that the individual components can be automatically integrated into the control concepts.

Additional information:
www.smartbiomassheat.com

Project summary

Duration:	1/8/2016–31/7/2019
Project partner:	–
Scientific contact:	Daniel Büchner
Project number:	100250636
Funding body:	Sächsische Aufbaubank (SAB) for the state of Saxony

SAB
Sächsische AufbauBank

THE RESEARCH FOCUS AREA "SMARTBIOMASSHEAT"

The focus is on small-scale, renewable heat supply to individual buildings and small groups of buildings up to village communities using other renewable energy sources and cross-linking intelligent heating technologies based on biomass originating primarily from residual materials, by-products and waste. The aim is to make optimal use of all renewable heat sources, both technologically and economically, through the flexible and demand-based use of biomass-based heating technologies. For this purpose, the entire chain must be mapped, examined, simulated and optimised individually and collectively, from the refining of biomass fuels, to new conversion plants and integration into the heat and electricity network of the biomass heating systems that will also be designed as heat, power and cooling plants in the future. It will require the development of technical components and related control research and development in order to achieve efficient, environmentally friendly, economical, safe, demand-based, flexible and sustainable (smart) operation via flexible operation (including micro- and small-scale CHP).

Key reference projects and publications

Project: CLEANPELLET – Entwicklung eines Verfahrens für die Erzeugung emissionsarm verbrennbarer Gärrestpellets zur Nutzung als Brennstoff für Haus- und Kleinfeuerungsanlagen, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.09.2014–31.08.2017 (FKZ: 03KB099D)

Project: Dampf-KWK – Entwicklung eines Klein-KWK-Dampfmotors zur Nachrüstung von Feuerungsanlagen im mittleren Leistungsbereich, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.07.2016–30.06.2019 (FKZ: 03KB118A)

Project: KvaliN – Implementation of capacity building measures for introduction of EU aligned testing services in Serbia, GIZ GmbH (inhouse), 07.07.2017–31.10.2017

Project: REFAWOOD – ERA-NET Bioenergy: Ressourceneffiziente Brennstoffadditive zur Verringerung der verbrennungstechnischen Probleme bei der Rest- und Gebrauchtholzverbrennung, ERANET/Fachagentur Nachwachsende Rohstoffe e.V., 01.04.2016–31.03.2019 (FKZ: 22404215)

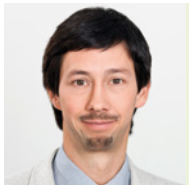
Project: STEP – Verwertung strohbasierter Energiepellets und Geflügelmist in Biogasanlagen mit wärmeautarker Gärrestveredlung; Teilvorhaben: Verbesserung der Verbrennungseigenschaften projektspezifischer Gärreste, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.08.2016–31.01.2019 (FKZ: 03KB116B)

Publication: Lenz, V.; Ortwein, A. (2017). "Smart-BiomassHeat: Heat from Solid Biofuels as an Integral Part of a Future Energy System Based on Renewables". *Chemical Engineering & Technology*, Vol. 40, H. 2. S. 313–322. DOI: 10.1002/ceat.201600188.

Publication: Matthes, M.; Hartmann, I. (2017). "Improvement of Efficiency and Emissions from Wood Log Stoves by Retrofit Solutions". *Chemical Engineering & Technology*, Vol. 40, H. 2. S. 340–350. DOI: 10.1002/ceat.201600172.

Publication: Zeng, T.; Sonntag, J. von; Weller, N.; Pilz, A.; Lenz, V.; Nelles, M. (2017). "CO, NO_x, PCDD/F, and Total Particulate Matter Emissions from Two Small Scale Combustion Appliances Using Agricultural Biomass Type Test Fuels". *Energy and Fuels* (ISSN: 0887-0624). DOI: 10.1021/acs.energyfuels.7b00513.

Publication: Zeng, T.; Pollex, A.; Weller, N.; Lenz, V.; Nelles, M. (2018). "Blended biomass pellets as fuel for small scale combustion appliances: Effect of blending on slag formation in the bottom ash and pre-evaluation options". Fuel (ISSN: 0016-2361), H. 212. S. 108–116. DOI: 10.1016/j.fuel.2017.10.036.



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4.5
CATALYTIC EMISSION CONTROL

"Process development is aimed at increasing the use of the previously unused and significantly available potentials of biogenic residues and waste materials in Germany. To date, there has been a lack of suitable exhaust gas purification processes that can be used cost-effectively in decentralised systems."

Mario König, Project Manager

SCRCOAT – OPTIMISATION AND VALIDATION OF PROCESSES FOR THE COMBINED REDUCTION OF FINE PARTICULATES AND ACID POLLUTANTS IN BIOMASS FURNACES; SUB-PROJECT: EXPERIMENTAL INVESTIGATIONS IN COMBINING SCR AND PRECOAT PROCESSES ON A FABRIC FILTER.

The energetic use of biomass contributes greatly to the success of the energy transition in Germany. Due to the growing competition over the use of high-quality wood, more and more biogenic residual and waste materials will have to be used in the future to produce energy from biomass. Biogenic waste, such as cereal debris, manure from raising chickens and horses, and all categories of waste wood, is particularly suitable at the end of the cascade.
When these residues and waste materials are incinerated, increased concentrations of dust and nitrogen oxides, as well as emissions containing sulphur and chlorine, are emitted. This causes considerable damage to human health

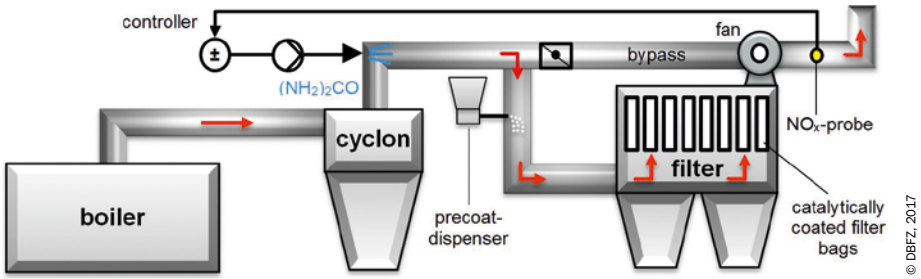

Fig. 15 Process diagram of the combined reduction of gaseous and particulate pollutants

and the environment. These emissions must be kept to a minimum in order to ensure compliance with constantly increasing limit value requirements and if the plants are to be accepted by the public. Due to the current amendment to TA Luft, the emission limits are also expected to be significantly tightened. Compliance with existing and future emission limits for biogenic residual and waste streams can only be guaranteed through the use of secondary reduction measures. The processes available on the market for exhaust gas purification of all the relevant components are currently not economically viable in small and medium capacity plants. The project therefore aims to develop and test a cost-effective process for the combined reduction of fine particles, nitrogen oxides, HCl and SO_2 as well as dioxins and furans in biomass furnaces operated with residual and waste materials in the power range 0.1–5 MW_{th}. The approach pursued in the project consists of combining different processes in a compact module and thus saving investment and operating costs in order to enable economical use in small and medium-sized plants. To achieve a combined reduction of the different pollutant groups, a fabric filter has been selected that is equipped with catalytically coated filter bags and is coated with a precoat material. Adding reducing agents (NH_3-based) achieves a selective catalytic reduction in the nitrogen oxides (NO_X) present in the exhaust gas at the catalytically active fabric filter. The NO_X concentration in the clean gas is constantly measured to ensure that the NO_X concentration is sufficiently lowered and to avoid high NH_3 slip due to excessive dosing of the reducing agent. Based on the current values,

the quantity of reducing agent introduced is permanently adjusted. Adding the precoat material reduces harmful acidic gases such as HCl and SO_2 and the additional support of the precoat layer achieves a very high degree of separation of dust particles from the exhaust gas at the fabric filter. The corresponding process diagram is shown in Figure 15.

PROJECT CONSORTIUM AND DIVISION OF TASKS

Four practice partners and three research institutions are involved in the project, each tasked with a specific sub-task:

DBFZ
The DBFZ is the project coordinator. It is also responsible for carrying out experimental investigations on a pilot plant scale. The tests take place in a 120 kW pilot plant and process efficiency is investigated with respect to different fuels and operating conditions. The findings from the tests are used to optimally operate the field system.

Hellmich GmbH & Co. KG
Hellmich has many years of experience in filter construction. In the project, it is responsible for the design and construction of a fabric filter for the field system. Hellmich also has practical experience in the area of precoating, which is used for setting up and operating the field system.

Dr. Weigel Plant Engineering GmbH
The company Dr. Weigel Anlagenbau GmbH is responsible for the optimisation and retrofitting of the fabric filter at the DBFZ. Here the primary focus is on increasing separation efficiency and conversion to precoat operation.

Industrial Engineering Barleben GmbH
ITB uses its experience in specialised plant construction to develop suitable dosing systems for the reducing agent and the precoat material.

Fraunhofer Institute for Factory Operation and Automation IFF
The Fraunhofer IFF specialises in the design and implementation of process control technology for process plants. Within the scope of the project, the IFF adapts and expands the process control technology of the existing pilot plant, and designs and implements the overall control systems of the exhaust gas purification process in the field plant. The user interface created by the Fraunhofer IFF for the test system is used to visualise and control all system components (see Figure 16).

University of Paderborn, Chair of Particle Process Engineering
Several research projects on the precoating of fabric filters have already been carried out at the Chair of Particle Process Engineering at the University of Paderborn. For the SCRCOAT project, the partner carries out laboratory tests on precoat materials.

A. P. Bioenergietechnik GmbH
A.P. Bioenergietechnik is a plant manufacturer in the project consortium. It operates a 450 kW plant at its own site, which is equipped with an SCR filter and the corresponding dosing technology for reducing agents and precoat materials. The company will conduct field measurements at the plant for two heating periods in order to validate the process.

OUTLOOK

The project partners intend to scientifically investigate the process approaches for simultaneous particle separation and for reducing all relevant gaseous pollutant components on a fabric filter. They also want to develop the necessary components (taking into account possible synergies) and to optimise the overall plant. The aim is to develop a marketable process for 0.1 to 5 MW_{th} biomass furnaces to ensure that the system remains below all current and, in the future, more stringent limit values of TA Luft for the combustion of alternative biogenic solid fuels. For example, the adsorption of harmful acidic gas components provides an integrated option that protects the SCR catalyst against rapid chemical

deactivation. An investigation of different process variants is planned in order to meet project goals. First, the combination of precoating and SCR on the fabric filter is investigated, whereby the precoat agent is introduced into the exhaust gas by means of a solid doser and the liquid reducing agent by means of a spray nozzle in front of the filter. In another process variant under investigation, the precoat material and reducing agent are combined and introduced through only one dosing system.

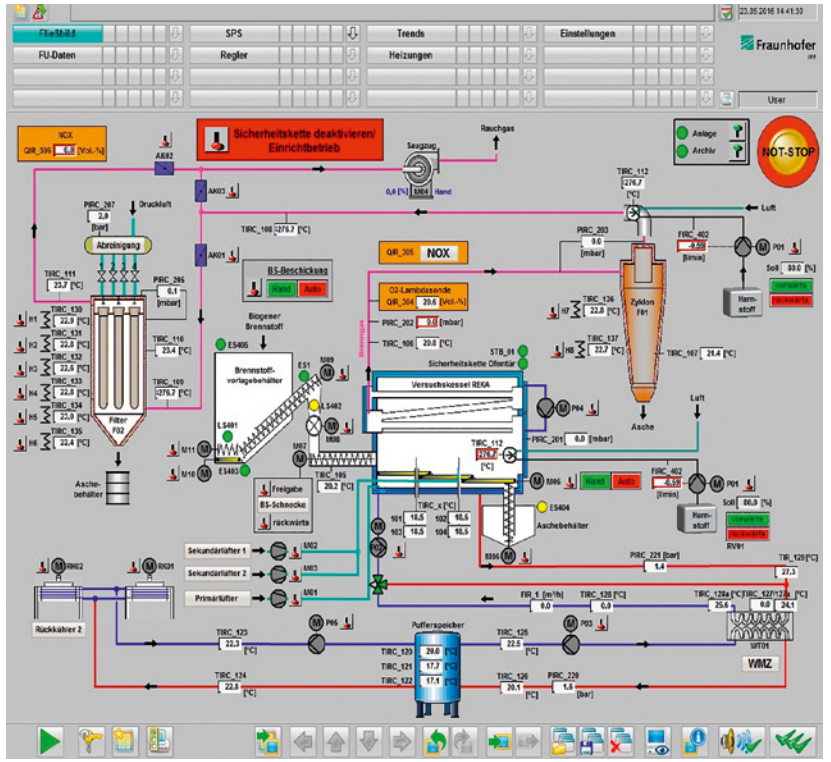

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Fig. 16 Process monitoring and control of the pilot plant

The project aims to achieve the following technical developments and goals:

- Investigations into combining precoating and SCR on a fabric filter
- Cleaning/Regeneration the filter also for tenacious/adhesive dust (by means of precoating)
- Optimisation of the dosage of reducing agent and precoat material to minimise NH_3 slip and operating costs
- Development of a cost-effective, industrially applicable measuring system to control the SCR system and to continuously measure NO_x
- Development of an overall control system with optimum dosage coordination of solids and reducing agent based on volume flow rate and pollutant load of the flue gas
- Investigations into the long-term stability of the SCR catalyst (deactivation)
- Demonstration of the effectiveness of the process at an operational plant for different biogenic solid fuels
- Target values (reference: 6 vol.% O_2):

dust particles, SO_2, HCl, NH_3	< 5	mg/Nm³
NO_x	< 75	mg/Nm³
PCDD/PCDF	< 0.05	ng/Nm³

The developments and design investigations are carried out on a biomass boiler with 120 kW nominal output in the DBFZ pilot plant, which is suitable for the combustion of wood chips, pellets and alternative biogenic fuels such as straw. Furthermore, the practical suitability of the process is demonstrated by field measurements on a 450 kW multi-fuel Ökotherm boiler.
The research project should make a significant contribution to the decentralised energetic use of biogenic residues. The availability of an economically viable waste gas purification process is an essential prerequisite for the increased use of the large quantities of residual material potentially available in Germany.

Project summary

Duration: 1/9/2017–31/8/2020
Project partner: DBFZ, WAB, ITB, IFF, University of Paderborn, Hellmich, A.P. Bioenergietechnik
Scientific contact: Mario König
Project number: 03KB135A
Funding body: Federal Ministry for Economic Affairs and Energy/ Project Management Jülich

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag
PtJ Projektträger Jülich Forschungszentrum Jülich

THE RESEARCH FOCUS AREA “CATALYTIC EMISSION CONTROL”

The objective of this area of research is to investigate catalytic emission reduction in combustion plants for gaseous, liquid and solid bioenergy carriers. The focus is on the catalytic reduction of combustion emissions of methane (CH_4), volatile organic compounds (NMVOC), semi- and low-volatile hydrocarbons, such as polycyclic aromatics (PAK), polychlorinated dioxins and furans (PCDD/PCDF), soot particles (black carbon) and nitrogen oxides (NO_x). These pollutants are significantly reduced by using integrated catalytic processes on the exhaust gas end. The aim is to develop catalysts and processes that enable the combustion of bioenergy sources that is practically emission free and thus environmentally friendly.

Key reference projects and publications

Project: Bio-Mini – Verbundvorhaben: Entwicklung einer marktnahen emissionsarmen Biomasse-Kleinstfeuerung für Niedrigenergie- und Passivhäuser; Teilvorhaben 1: Feuerungstechnische Entwicklung (Gesamtkonzept) und Charakterisierung einer Biomasse-Kleinstfeuerung für Niedrigenergie- und Passivhäuser, Bundesministerium für Ernährung und Landwirtschaft/ Fachagentur Nachwachsende Rohstoffe e.V., 01.10.2017–30.09.2019 (FKZ: 22025816)

Project: HF-Technologie Abgas – Entwicklung einer innovativen Abgasnachbehandlungsanlage für Biomasse-Kleinfeuerungsanlagen unter Nutzung neuartiger Katalysatoren und dielektrischer Erwärmung, Bundesministerium für Wirtschaft und Energie/VDI/VDE IT, 01.07.2015–31.12.2017 (FKZ: 16KN041428)

Project: SCRCOAT – Optimierung und Validierung von Verfahren zur kombinierten Reduktion von Feinstaub und sauren Schadgasen an Biomassefeuerungen; Teilvorhaben: Experimentelle Untersuchungen zur Kombination von SCR- und Precoatverfahren an einem Gewebefilter, Bundesministerium für Wirtschaft und Energie/ Projektträger Jülich, 01.09.2017–31.08.2020 (FKZ: 03KB135A)

Publication: Hartmann, I.; Bindig, R. (2017). *Möglichkeiten, Limitierungen und Entwicklungsbedarf zur katalytischen Emissionsminderung. Vortrag gehalten:* VDI-Forum: Emissionen aus Biogasanlagen, Stuttgart, 03.–04.07.2017.

Publication: König, M.; Hartmann, I.; Matthes, M. (2017). Emission reduction in the energetic utilization of agricultural residues: combined reduction of PM and NO_x. In: Kühle-Weidemeier, M.; Büscher, Katrin (Hrsg.) *Waste-to-resources 2017: 7. Internationale Tagung MBA, Sortierung und Recycling: Rohstoffe und Energie aus Abfällen. Tagungsband, 16.–18. Mai 2017.* Göttingen: Cuvillier. ISBN: 978-3-7369-9533-8. S. 612–625

Publication: Matthes, M.; Hartmann, I. (2017). "Improvement of Efficiency and Emissions from Wood Log Stoves by Retrofit Solutions". *Chemical Engineering & Technology*, Vol. 40, H. 2. S. 340–350. DOI: 10.1002/ceat.201600172.

Publication: Matthes, M.; Hartmann, I.; Schenk, J.; Enke, D. (2017). "Characterization and integration of oxidation catalysts at small-scale biomass combustion furnaces". In: Wzorek, M.; Królczyk, G.; Król, A. (Hrsg.) *International Conference Energy, Environment and Material Systems (EEMS 2017): Polanica Zdrój, Poland, September 13–15, 2017. E3S Web of Conferences.* H. 19. DOI: 10.1051/e3sconf/20171901006.

Publication: Schliermann, T.; Hartmann, I.; Schneider, D.; Wassersleben, S.; Enke, D.; Jobst, T.; Lange, A.; Roelofs, F.; Fellner, A.; Schneider, P. (2017). High-quality biogenic silica from agricultural residues. In: Kühle-Weidemeier, M.; Büscher, Katrin (Hrsg.) *Waste-to-resources 2017: 7. Internationale Tagung MBA, Sortierung und Recycling: Rohstoffe und Energie aus Abfällen. Tagungsband, 16.–18. Mai 2017.* Göttingen: Cuvillier. ISBN: 978-3-7369-9533-8. S. 676–687

Head of the Research Focus Area

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5 COOPERATION AND NETWORKING

R&D COOPERATION WITH THE LOCAL ECONOMY

The applied research and development work (R&D) of the DBFZ is carried out in close cooperation with partners from industry and other research institutions. This leads to well-needed practical approaches, important market information and an orientation towards innovative and feasible solutions. In cooperation projects with industry, the DBFZ guarantees a neutral and holistic view and approach and can thus contribute its comprehensive expertise to market-oriented R&D projects. Strong company participation is imperative, especially in externally funded projects. Thus, the research departments at the DBFZ are connected to national and international networks with R&D companies as well as industry-relevant networks in the bioenergy industry. The DBFZ is integrated in the BMBF-funded BioEconomy Leading-Edge Cluster, which acts as an important beacon for the coupled material-energetic use of biomass with a focus on beech wood. Further collaborations are being developed in the areas of nutrient recycling, hydrothermal processes, biogas and waste management. It is also a part of the regional network Leipzig Energy and Environment Cluster (NEU e. V.) and is a member of the Energy Saxony e. V. network.

BioEconomy Cluster · NEU Netzwerk Energie & Umwelt e.V. · energy saxony · HTP Hydrothermale Prozesse

SCIENTIFIC COOPERATION WITH UNIVERSITIES

Scientific cooperation with universities and other research institutions in the field of energetic and integrated material use of biomass is an essential part of the research activities of the DBFZ. The activities focus on the implementation of the defined research goals within the framework of applied research and development (R&D). In order to achieve the strongest possible linking of knowledge,

subquestions are answered in collaboration with project partners. The aim is to create stable research networks by actively linking nationally and internationally renowned R&D partners in the area of bioenergy and bioeconomics. There is continuous cooperation with long-term scientific partners, especially in matters pertaining to basic research. There has been a long-standing strategic partnership with the Helmholtz Centre for Environmental Research – UFZ when it comes to answering questions pertaining to the system evaluation of bioenergy and the microbiological foundations of biochemical processes. For example, the DBFZ Bioenergy Systems department works closely with the UFZ Department of Bioenergy. The Biochemical Conversion department also cooperates closely with the UFZ Department of Microbiology. In the field of the energetic utilisation of organic waste and residual materials, there is also an intensive and strategically oriented cooperation between the DBFZ research focus areas and the Rostock Chair of Waste and Material Flow Management (ASW), represented by the scientific managing director of the DBFZ, Prof. Michael Nelles. The cooperation with the University of Rostock, newly announced in January 2018, focuses on mutual scientific support, joint implementation of research projects and intensification of networking by doctoral students and visiting professors. In addition, the University of Rostock, in cooperation with the DBFZ, organises joint events such as the annual Rostock Bioenergy Forum.

UNIVERSITÄT LEIPZIG

Universität Rostock Traditio et Innovatio

The appointment of Prof. Daniela Thrän to the Chair of Bioenergy Systems at the Faculty of Economic Sciences (IIRM – Institute for Infrastructure and Resource Management) has provided a link between the University of Leipzig and the intensive research activities of the DBFZ since the end of 2011. In addition, the DBFZ Biorefineries department is linked to the Institute of Technical Chemistry (Chair of Heterogeneous Catalysis). Two joint research projects are currently being conducted in the research area “Catalytic Emission Control”. As of February 2018,

Fig. 17 Renewed cooperation agreement between the University of Rostock and the DBFZ in January 2018/Rostock Bioenergy Forum on 22 June 2017

eight scientists from the DBFZ are also working on their doctoral dissertations in cooperation with the University of Leipzig. In addition to the University of Leipzig, other national universities such as Merseburg University of Applied Sciences, the Ernst Abbe University in Jena and the University of Applied Sciences Erfurt has links to the DBFZ through the teaching activities of the DBFZ staff.

SMILE – SCIENTIFIC BUSINESS START-UPS

The DBFZ organises regular workshops and matchmaking events to stimulate the entrepreneurial culture at the DBFZ. Start-up projects of researchers and students are also supported through mentoring and by helping to apply for funding and draw up business plans. Since 2015, the DBFZ has been a member of the Leipzig start-up network "SMILE – SelbstManagement-Initiative LEipzig". Business consultant Ronny Kittler supports the transfer of research results which can be further expanded on and developed by founding start-ups or spin-offs, for example in the Leipzig incubator "Bioenergy Innovation Centre" or through start-up support in the BioEconomy Leading-Edge Cluster.

Fig. 18 Conference reader "The Power of Standardisation" as part of the DBFZ publication series

THE POWER OF STANDARDISATION: SECURING INNOVATIONS THROUGH STANDARDS & NORMS AND SUCCESSFULLY ESTABLISHING THEM ON THE MARKET

Standardising products and services increasingly ensures the security and marketability of innovations. Standardisation and norms thus represent an important instrument in the transfer of knowledge and technology and in securing market access and market potential for spin-offs from science. The aim of the event "The Power of Standardisation – Securing and successfully establishing innovations through standards" (9 May 2017) was to provide introductory lectures as well as information on funding opportunities within the framework of the "WIPANO" and "VIP+" programmes. Afterwards, the 40 participants had the opportunity to attend two parallel workshops on specific topics and to discuss questions and challenges using best-practice examples. The conference reader for the event is available in german language as a free PDF download at **www.dbfz.de/smile**.

DEVELOP YOUR BUSINESS IDEAS: DBFZ-HHL INNOVATION BOOTCAMP

The DBFZ-HHL Innovation Bootcamp brought together interdisciplinary teams of scientists and students from the University of Leipzig, the UFZ and the DBFZ as well as the HHL Leipzig Graduate School of Management. The aim of the event was to explore, over a period of three months, the exploitation potential of various technologies and services and to develop business models from this. At the closing event on 14 December 2017, the three teams pitched their results to a jury. The Mycos team convinced the judges with its business idea to produce ecologically sustainable children's toys, made from fungal mycelium and free of harmful substances. The winner received 1,500 euros from the KARL-KOLLE Foundation.

© HHL – Leipzig Graduate School of Management

Fig. 19 Winners of the DBFZ-HHL Innovation Bootcamp (14 December 2017)

Tab. 2 SMILE events in 2017

Date	Event title
16 March 2017	PITCH!!! Your IDEA for the BioEconomy Region 2017
30 March 2017	Career Day at Leipzig University: Smart Bioenergy & Bioeconomy – Research for the sustainable economy of the future
9 May 2017	The Power of Standardisation: Securing innovations through standards and establishing them successfully on the market
12 May 2017	Startup Safary: Future Bioeconomy Markets – Opportunities for Entrepreneurs
23 May 2017	Vitamins for Science & Start-ups – Idea Workshop
8 June 2017	It is More Quality than Quantity that Counts – Quality Management ISO 9001 & ISO 17025
19 September 2017	Research to Market: Raising Data Treasures
26 September 2017	Bioenergy & Bioeconomics: Furniture & detergents from the biogas plant?
27 September 2017	Sovereign in the Spotlight: Scientific Presentation with Powerpoint
13/14 October 2017	Develop your Business Ideas: DBFZ-HHL Innovation Bootcamp

Europa fördert Sachsen ESF

Additional information: www.dbfz.de/smile

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6
EXECUTIVE SUPPORT TEAM

"The world of science is becoming ever more complex and dynamic. Good management is therefore a key factor in the success of scientific establishments looking to survive and prosper in the internationally competitive environment."

Dr. Nikolaus Blum, Commercial Director of the Helmholtz Centre in Munich

Fig. 20 Staff of the administrative departments and the press and public relations department at the DBFZ in January 2018

The DBFZ's administrative departments (executive support team) are under the scientific management of Prof. Michael Nelles. In addition to the Press and Public Relations department, the coordinators of Research, Innovation and International Knowledge and Technology Transfer work closely with the four research departments of the DBFZ and the heads of the five research focus areas. The aim of the administrative departments is to develop the synergies in the strategic orientation of research and projects, form consortia and internationalise the entire research centre.

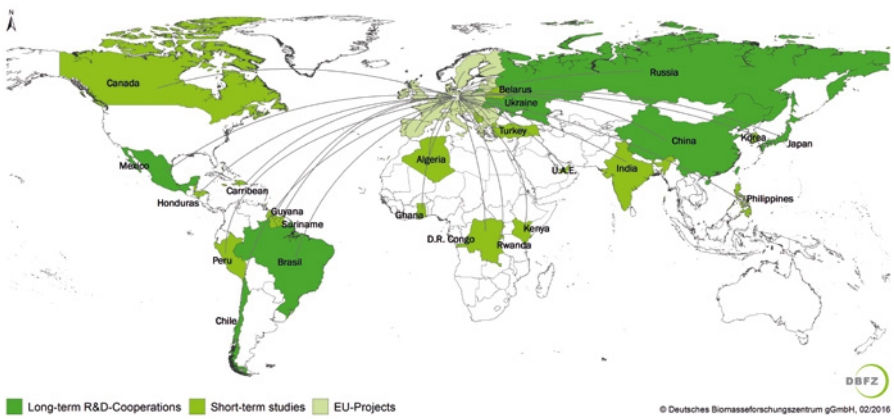

Fig. 21 International partnerships with the DBFZ

COORDINATOR OF INTERNATIONAL KNOWLEDGE AND TECHNOLOGY TRANSFER

The International Knowledge and Technology Transfer department, headed by Dr. Sven Schaller, aims to make the scientific expertise of the DBFZ available to international partners through joint research projects, the exchange of doctoral candidates and reciprocal research visits. In addition, international networks are consolidated and selectively expanded. This also includes the initiation and arrangement of mutual visits as well as the organisation of workshops and conferences. It is also the declared aim of the administrative department to further intensify cooperation with top international universities and non-university research institutes.

ROYALS VISIT FROM THE NETHERLANDS

On their trip through Germany, the Dutch royal couple Willem Alexander and his wife Máxima travelled through Saxony, Saxony-Anhalt and Thuringia, stopping in Leipzig on 9 February 2017. Together with the Helmholtz Centre for Environmental Research, two MoUs (memoranda of understanding) were concluded between German and Dutch companies and research institutes in the presence of the royal couple. Following the very successful cooperation in the EU project SECTOR, the MoU, signed by the DBFZ and the Dutch institute ECN, aims to pave the way for further joint research projects and to intensify the exchange of scientists between

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Fig. 22 Prof. Daniela Thrän (UFZ/DBFZ) outlines the results of the German-Dutch matchmaking event (9 February 2017)

Germany and the Netherlands. The second memorandum of understanding was signed between the Leading-Edge Cluster BioEconomy and the Dutch company Biobased Delta.

Scientific cooperation with China intensified in 2017. On 26 July 2017, the Agency for Renewable Resources (FNR) issued its funding decision for the joint project “Energy use of agricultural residues in Germany and China” (ChinaRes). From November 2017 to October 2020, the partners involved, including the Leibniz Institute for Agricultural Engineering Potsdam-Bornim e. V. (ATB) and the Chinese partners, China Agricultural University (CAU), China University of Petroleum (CUPB), Hefei University and the Chinese Academy of Agricultural Engineering (CAAE), will be looking for ways to improve the energetic use of agricultural residues, such as manure or slurry, and to reduce emissions from the storage of the excrement of these animals. German-Chinese workshops to exchange knowledge about the state of technology and research are planned, as well as visits to best-case facilities in both countries in order to improve networking between the participants. The research project has a funding volume of 550,000 euros and is coordinated by the DBFZ.

OPENING OF GERMAN-CHINESE COOPERATION CENTRES

On 11 August 2017, the scientific managing director of the DBFZ, Prof. Michael Nelles, together with Prof. Jingmin Cai (senate president of Hefei University), Minsheng Wang (vice mayor of Hefei), Daming Zhang (deputy director of the Office of Foreign Experts of Anhui Province) and Zhongyong Yu (director of the Chao See Administration Office, Anhui) opened the "German-Chinese Regional Centre for Biomass Research". The new centre will focus on the current challenges facing the material and energy recovery of agricultural residues, but its activities will be limited to Anhui province (approx. 65 million inhabitants). With the inauguration of the centre, the DBFZ continues the diverse partnerships that Hefei University has maintained in Germany for around 30 years.
Just one week later, on 18 August 2017, the Chinese-German Centre for Biomass Research (C-DBFZ) was inaugurated at the CAAE in Beijing. The centre's main objectives are to tackle the many challenges facing Chinese agriculture and to

Fig. 23 **Official opening of a German-Chinese Cooperation Centre in the field of bioenergy (13 September 2017)**

conduct research on climate protection and the environment. Both the head of the CAAE, Prof Bin Sui, and Prof Michael Nelles expressed their wish to initiate joint research projects through the new centre and to develop practical solutions for the many challenges facing the use of agricultural waste streams. The CAAE has about 600 employees and reports to the Chinese Ministry of Agriculture.
At the third inauguration of 2017, representatives of the DBFZ, the Federal Ministry for Nature, Environment, Building and Nuclear Safety and the CAAE were on hand to mark the establishment of a German-Chinese Bioenergy Cooperation Centre in Leipzig on 13 September 2017. Existing research contacts will be strengthened and new joint projects in the field of bioenergy and waste management will be initiated via the centre.

Further information:
www.dbfz.de/en/research-departments/international
www.dbfz.de/en/news/newsletter

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INNOVATION COORDINATOR

Bioenergy is an integral part of the renewable energy system and the bioeconomy. Bioenergy technologies open up a wide range of new innovation fields and innovation potential. The Innovation Coordination department, under the direction of Romann Glowacki, searches for, develops and links the application-oriented research of the DBFZ with new partners and R&D&I structures. The DBFZ's research partners from small and medium-sized enterprises (SMEs) are also included in these structures. One example of this is the participation in the BMBF's Leading-Edge Cluster BioEconomy, which is based in Halle/Saale. Further tasks of the innovation coordinator include the design and implementation of in-house innovation, the exploitation of intellectual property rights, the transfer of technology and knowledge as well as the development of innovation structures in the area of spin-off promotion.

CONTACT PERSON FOR SMALL AND MEDIUM-SIZED COMPANIES

In order to facilitate access to the research infrastructure at the DBFZ, especially for SMEs, and to develop joint R&D projects, the innovation coordinator acts as a direct contact for newcomers to research and for companies with little R&D experience. To achieve this objective, the Innovation Centre for Bioenergy was established in Leipzig in 2014 in cooperation with the Network for Energy & Environmental Technology (Netzwerk Energie & Umwelt e. V.). The incubator provides companies and spin-offs with complementary competencies in the areas of patent and trademark protection, the financing and marketing of innovation, and in the application process. It also serves as a platform for settlements in the direct vicinity of the DBFZ. In 2017, more than 30 business inquiries were successfully handled in-house by the innovation coordinator.

EXPANSION OF EUROPEAN INNOVATION NETWORKS

In 2017, the "TREC – Transnational Renewable Energy Cluster" project continued to successfully establish and expand European innovation networks. This strengthened the web of networks and clusters between 15 partners from ten countries in Southeastern and Central Eastern Europe. Several conferences and workshops focused on applying for projects under the EU funding programme Horizon2020. New partners from Croatia also joined. The TREC's focus has shifted to bioeconomics and the valorisation of biogenic waste and residual material flows.

TREC

Fig. 24 TREC Workshop in Leipzig (28–30 November 2017)

THE BIOECONOMY – A SPACE FOR INNOVATION

The DBFZ is currently coordinating the conceptual design of a space for bioeconomic innovation on behalf of a team of initiators from the Leading-Edge Cluster BioEconomy. The aim is to create an environment in which industry stakeholders and research partners can come together more quickly and conduct excellent research with a strong market orientation.

PROJECT INITIATION EVENTS

The DBFZ regularly offers workshops, technical discussions and moderated events as part of project initiations with companies. The aim is to provide the research and development infrastructure of the DBFZ to business partners who are developing new processes, procedures or products. Formats include the innovation workshop for intelligent material and energy recovery of by-products in food production, which was held on 26 April 2017 under the patronage of the Saxon State Ministry for the Environment and Agriculture.

Further information (german language):
www.dbfz.de/forschung/kooperationen
www.innovationszentrum-bioenergie.de
www.energiemetropole-leipzig.de/de/schwerpunkte/bioenergie
www.trec-network.eu

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RESEARCH COORDINATOR

The Research Coordination department, led by Dr. Elena H. Angelova, supports and coordinates the networking of scientists between the five research focus areas of the DBFZ and other research institutions and partner organisations. The aim is to use synergies and expertise within the company to initiate concrete research partnerships and to find suitable funding for the implementation of the research idea. The main areas of responsibility of the Research Coordination department include:

- Consultation and provision of information on current calls as well as on proposal submission and project management
- Support and evaluation in the cross-sector development of national and international project applications
- Optimisation of scientific management and quality assurance at DBFZ through good scientific practice
- Collection and evaluation of key scientific data to ensure scientific quality
- Preparation, organisation and support of internal and external evaluations as well as supervision of the Research Advisory Council
- Monitoring of medium and long-term research planning
- Coordination of information exchange and reporting on the research activities undertaken at the DBFZ to the institutional sponsor BMEL and the Research Advisory Council
- Implementation of the doctoral programme and support of the PhD students at the DBFZ

SUCCESSFUL EVALUATION OF THE DBFZ BY THE GERMAN COUNCIL OF SCIENCE AND HUMANITIES (WR)

After the DBFZ underwent extensive evaluation by the German Council of Science and Humanities in 2013 and 2014, it successfully implemented a range of suggestions in the following years. The final report presented by the German Council of Science and Humanities on 20 October 2017 attests to the exemplary development of the DBFZ and the results of the evaluation were rated very good. Among other things, it was acknowledged that the DBFZ had “used the recommendations made in the statement of the German Council of Science and Humanities from 2014 to review and further develop its strategy. This initiated important processes that will help the DBFZ perform its role as a national hub and strengthen its international visibility in the future.” The next evaluation is expected to take place in 2020. Further information on the assessment of the DBFZ by the German Council of Science and Humanities can be found at: **www.wissenschaftsrat.de/download/archiv/6664-17.pdf** (german language)

WR | WISSENSCHAFTSRAT

PROJECT FUNDING

A total of 50 proposals were submitted by 149 institutions in the penultimate round of funding under the Federal Ministry for Economic Affairs and Energy’s funding programme “Biomass Energy Use”, whose submission deadline ended on 30 September 2016. The main focus is on the efficient generation of heat from biomass and combined heat and power generation. Fifteen projects were funded, five of them with DBFZ participation (as the coordinator of four and the project partner of one). In the last funding round, whose submission deadline ended on 27 September 2017, a total of 37 outlines were submitted, eleven with DBFZ participation (as the coordinator of nine and the project partner of two).

Biomass energy use

Fig. 25 Participants of the 5th Doctoral Seminar at the DBFZ (27/28 February 2017)

SCIENTIFIC PUBLICATIONS (PEER-REVIEWED/OPEN ACCESS)

Last year, DBFZ staff wrote and published 51 scientific papers (peer reviewed). In addition, 14 journal articles (reviewed) were published online, which will not appear in print until 2018. The number of open access publications of DBFZ researchers remained at the same level as the previous year (17 OA publications). An overview of all publications can be found in the notes to this annual report starting on page 168.

FIFTH DOCTORAL SEMINAR AT THE DBFZ

On 27 and 28 February 2017, around 30 participants convened at the fifth doctoral seminar held at the DBFZ. Thirteen doctoral students presented the status of their work, discussed the results of their doctoral projects and exchanged views with the other doctoral students and their internal and external supervisors. In addition to a technical discussion, the audience was once again called upon to select the best presentation. Andrea Dernbecher (research focus area “SmartBiomass-Heat”) won a book voucher worth 44 euros for her topic “Numerical investigation of emissions from small-scale biomass heating systems”. The PhD students were joined by three guest speakers from the BMEL, the University of Leipzig/UFZ and the company deepmello to discuss, among other things, the topic “Doctorate and then what? Career planning with a strategy”. Other topics of conversation were the pathways to a professorship, a government ministry career, and the founding of a scientific spin-off.

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7
DOCTORAL PROGRAMME

In 2017, a total of 70 doctoral projects were running at or in cooperation with the DBFZ. For this purpose, the DBFZ cooperates with eight German universities and one German university of applied sciences as well as three foreign universities. A total of 17 doctoral projects are being carried out in cooperation with the Helmholtz Centre for Environmental Research – UFZ in Leipzig and 15 with the Chair of Waste and Material Flow Management (ASW) at the University of Rostock. The DBFZ particularly supports in-service training with 20 employees obtaining their doctorates while working. A concept for structuring the DBFZ doctoral programme was developed, then discussed and agreed with the management of the DBFZ and the doctoral students at the DBFZ. The aim is to more strongly develop future topics relevant to research and industry through dissertations. This provides outstanding scientists the opportunity to do their doctorate under excellent conditions. The structured concept is to be finalised and implemented in 2018.
Three joint doctoral projects were successfully completed in 2017 as part of the DBFZ doctoral programme and the doctoral programme “Material and Energy

Fig. 26 **Successful doctorate at the University of Rostock: DBFZ employee Sören Weinrich (centre) completed his doctorate with top marks (summa cum laude)**

Utilisation of Waste and Biomass" of the Chair of Waste and Material Flow Management. On 27 October 2017, DBFZ employee Sören Weinrich successfully defended his dissertation "Practical Modelling of Biogas Plants" at the Faculty of Agricultural and Environmental Sciences (AUF) at the University of Rostock, setting new standards for quality. Four written assessments each gave the dissertation an outstanding grade of 1.0, and recommended that the Faculty Council award him a PhD in engineering with summa cum laude (with highest honour).

SAMPLE DISSERTATION BY JÖRG KRETZSCHMAR

Characterisation of a microbial electrochemical sensor platform for anaerobic digestion process control

Energy generation from biogas accounts for approx. 8 % of gross energy production in Germany. While electricity generation from solar and wind power plants depends on fluctuating weather conditions and the time of day, electricity generation from biogas is able to provide electricity and heat on demand. Flexible energy generation from biogas can be made possible, for example, by installing additional gas storage facilities. Another approach is to produce biogas according to the demand by supplying substrates such as maize silage, cattle manure and straw in variable amounts at variable times. However, since high substrate input rates can interfere with the process, there are special process monitoring requirements. In order to establish successful process control in the future, real-time monitoring of central process indicators, such as acetate concentration, is

Fig. 27 Former PhD student Jörg Kretzschmar

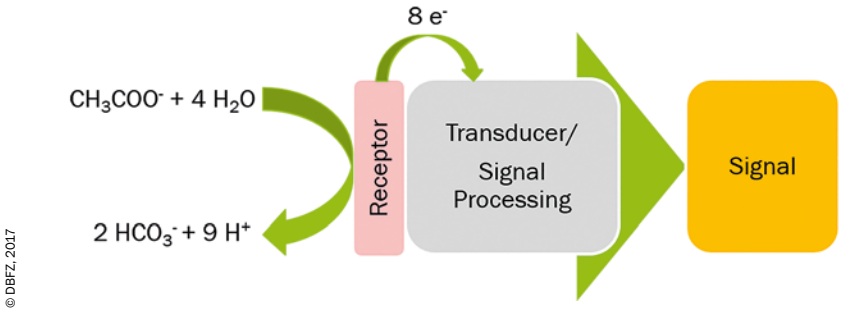

Fig. 28 Functional diagram of a microbial electrochemical sensor. The receptor consists of a Geobacter sp.-dominated biofilm on a graphite electrode

necessary. Currently, the acetate concentration and the concentration of other important volatile fatty acids or their salts (e. g. propionate and butyrate) are determined using time-consuming and costly methods such as gas or liquid chromatography or automated titration. The aim of this work was therefore to develop and characterise a microbial electrochemical sensor for real-time measurement of acetate in the biogas process. The most important part of the biosensor, the receptor, consists of a Geobacter sp.-dominated biofilm on a graphite electrode. The bacteria oxidise acetate, among other things, as part of their energy metabolism. The amount of oxidised acetate correlates with the number of electrons transferred and thus with the sensor current. Within the scope of the work, basic sensor parameters, such as measuring range, measurement resolution, cross-sensitivity and functional stability of the biosensor were examined. In addition to determining these parameters in artificial wastewater, experiments were carried out to verify the sensor's function in its future process environment, the biogas process. Furthermore, possible impurities from the biogas process were investigated for the microbial receptor. The focus here was on a high salt and ammonium concentration and the effect of fumarate as an alternative electron acceptor. Finally, the suitability of electrochemical impedance spectroscopy as a tool for the in situ monitoring of biosensor functionality was investigated. For this purpose, electrochemical impedance measurements were carried out on metabolically active receptors.

The characterisation of the biosensor showed a measuring range of 0.5–5 mmol L^{-1} acetate and a measuring resolution of 0.25–1 mmol L^{-1}. When the biosensor is used in the biogas process, the upper measuring limit of 5 mmol L^{-1} acetate must be raised to at least 20 mmol L^{-1}. This can be achieved by using a membrane as an additional diffusion barrier. The proof of function in the biogas process proved there is a clear correlation between sensor current and acetate concentration. However, the investigations identified an inhibition of the sensor and the microbial receptor over a period of 1–8 days. The investigation for possible impurities revealed the biofilms have a tolerance to a high salt concentration of (13.5 g L^{-1}) and an ammonium concentration of up to 3 g L^{-1} NH_4+, a typical value for biogas reactors. Based on the current state of knowledge, using the biosensor to monitor the biogas process or other processes in which acetate plays a role seems possible in principle. In order to further develop the sensor concept into a market-ready product, further measures must be tested and implemented in order to increase the measuring range and to stabilise and monitor the biological receptor.

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Tab. 3 List of doctoral theses at the DBFZ, excluding cooperation partners UFZ/University of Rostock (as per: February 2018)

Name	Dissertation subject	Institution	Type of doctorate
Bdour, Mathhar Abdelmahni	Development of combined heat, power and cooling system based on agricultural residues and biogenic waste	University of Rostock	Finished in 2017
Beidaghy, Hossein	Ash-related aspects during the thermo-chemical conversion of leached silicon rich biomass assortments for the production of heat and power and the combined transformation into valuable inorganic multipurpose chemical compounds	University of Leipzig	Doctorate (BLE/BMEL PhD project Iran)
Bindig, René	Cleaning of waste gases from small-scale biomass furnaces on innovative monolithic catalysts	University of Leipzig	Doctorate (part-time)
Brosowski, André	National Resource Monitoring for Biogenic Residues, Wastes and By-products – Development of a Systematic Data Collection, Management and Assessment for Germany	University of Leipzig	Doctorate (part-time)
Butt, Saad	High-temperature oxidation of pollutants on solid state catalysts	University of Leipzig	Doctorate (part-time)
Büchner, Daniel	Optimised control strategies for combination pellet/solar plants to improve system efficiency while minimising environmental impact	Technical University Dresden	Doctorate (part-time)
Dernbecher, Andrea	Method for modelling thermochemical biomass conversion in a CFD-based simulation	Technical University Berlin	Doctorate (work programme)
Dietrich, Sebastian	Trialling and intensification of a process for alkene synthesis from biogas and wind-H_2	Technical University Berlin	PhD position in externally funded research project
Dotzauer, Martin	Numeric input/output model of plants for electricity generation from biomass in Germany and derivation of medium-term trend scenarios	(To be confirmed)	Doctorate (part-time)
Gallegos, Daniela	Potential of water plants for water cleaning and sustainable energy production for Mexico	University of Rostock	Doctorate (grant)
Gökgöz, Fatih	Development and optimisation of self-sufficient biogas treatment plants with integrated filling station technology for a local biomethane fuel supply	University of Rostock	Doctorate (grant)

Name	Dissertation subject	Institution	Type of doctorate
Gröngröft, Arne	Optimising the conversion efficiency of bioethanol refineries	Technical University Hamburg	Doctorate (part-time)
Hahn, Alena	The role of smart bioenergy in combination with CO_2 removal in decarbonisation scenarios	(To be confirmed)	Doctorate
Herrmann, André	Combined high-temperature combustion gas cleaning via moving bed reactor (topic currently being adapted)	Technical University Hamburg	Doctorate (part-time)
Horschig, Thomas	Using system dynamics to model the German and European biomethane markets	University of Leipzig	Doctorate (work programme)
Janke, Leandro	Biogas from residual materials from the sugar and ethanol industry in Brazil	University of Rostock	Finished in 2017
Kar, Indrani	Maintaining regional soil quality for a biobased economy	(To be confirmed)	Doctorate
Kirsten, Claudia	Contribution to optimising the pelleting behaviour of fermentation residues and landscape conservation hay and mixtures	Technical University/ Mining Academy Freiberg	Doctorate (part-time)
Kirstein, Niels	Development of methods to analyse and forecast the market penetration of smart bioenergy applications	University of Leipzig	Doctorate
Köchermann, Jakob	Hydrothermal conversion of wood pulp solutions for the production of furan derivatives	Technical University Berlin	PhD position in externally funded research project
König, Mario	Catalytically aided reduction of gaseous and particulate emissions from wood burning in Chilean households	University of Leipzig/ University of Talca	Doctorate (part-time)
Kretzschmar, Jörg	Development of an electrochemical sensor platform for biogas reactors	Technical University Dresden	Doctorate (work programme)
Kröger, Michael	Thermo-chemical utilisation of algae with a focus on hydrothermal processes	University of Rostock	Doctorate (part-time)
Krüger, Dennis	Development and system integration of a micro-scale combined heat and power plant for solid biomass	Technical University Chemnitz	Doctorate (part-time)

Name	Dissertation subject	Institution	Type of doctorate
Lauer, Markus	Macro-economic assessment of biogas plants as an option to enhance flexibility in the electricity system of the future	University of Leipzig	Doctorate (work programme)
Matthischke, Steffi	Load flexibility of catalytic reactors based on the example of the methanation of carbon oxides	Technical University Clausthal	Promotion (grant)
Mauky, Eric	On-demand biogas supply based on process control	University of Rostock	Doctorate (part-time)
Müller, Liane	Improving the efficiency of the anaerobic degradation of nitrogen-rich compounds through the use of enzymes	University of Rostock	Doctorate (part-time)
Müller, Mirjam	Emissions reduction in small-scale biomass furnaces based on integrated catalysis	Leipzig University of Applied Sciences (HTWK)	Doctorate (part-time)
Nitzsche, Roy	Adsorption and membrane filtration for the treatment of aqueous product solutions in lignocellulose biorefineries	Technical University Berlin	PhD position in externally funded research project
Rönsch, Cornelia	Development of a method for the utilisation of chimney-sweeping data in energy reporting	University of Leipzig	Doctorate (work programme)
Schlüter, Michael	Optimising methane yield in heterogeneously catalysed methanation at reduced temperatures and pressures through targeted balance shifting	University of Rostock	Doctorate (work programme)
Seidler, Andreas	Trace substance analysis by time and location in biomass solid fuel furnaces using laser mass spectrometry	University of Rostock	Doctorate (externally while working)
Zech, Konstantin	Theoretical, economic and political potential for GHG reduction in relation to food and biofuel production	HHL Leipzig Graduate School of Management	Doctorate (externally while working)
Zeng, Thomas	Targeted treatment of wood-type biomass residues for use as fuel in small-scale furnaces for heat supply	University of Rostock	Doctorate (part-time)

8
THE DBFZ IN PUBLIC

In 2017, press and public relations work focused on a range of activities with which the DBFZ was able to share its topics of research both with scientific experts and with the interested public. In addition to participating in various conferences and trade fairs, at which the DBFZ appeared with its own trade fair booth, new scientific publications were also compiled within the framework of the DBFZ's publication series. The DBFZ's research topics also attracted the media's attention throughout the year (print/online/TV/ radio).

NEW VISITOR RECORD AT THE DBFZ

Presenting itself extensively to the public, the DBFZ set a new visitor record last year with a total of 700 guests. Project partners, study groups, politicians and a range of other guests from all over Germany, Europe and the world (including

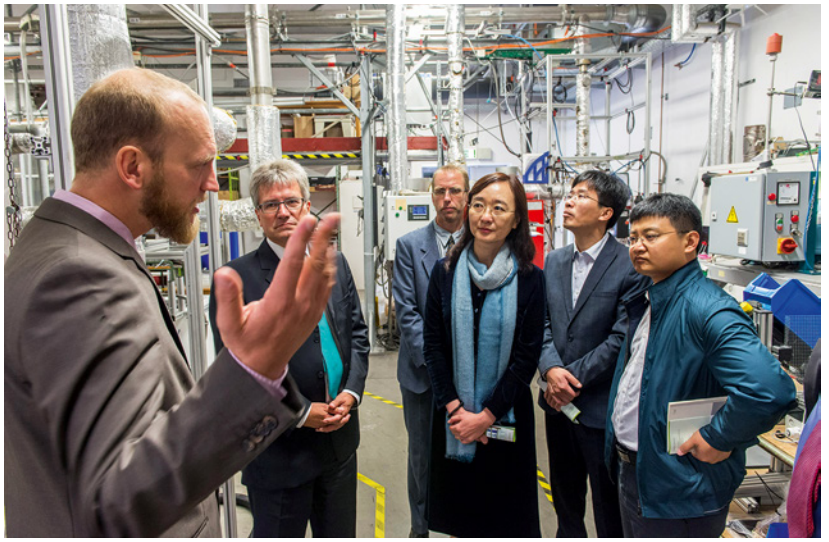

Fig. 29 Chinese guests from the CAAE at the DBFZ's combustion lab (13 September 2017)

Brazil, Australia, China, Japan, France, USA, Chile, Morocco, Shanghai, Argentina, Vietnam, Belarus) visited the DBFZ in 2017. They were informed about the latest research methods in the field of energetic and integrated use of biomass and witnessed their technical implementation in the test beds and laboratories of the DBFZ.

NEW PUBLICATIONS

As part of the DBFZ publication series DBFZ Report, three new issues were published in 2017 dealing with the topics biogas (repowering and biogas/biomethane plant stock) and the funding measure “Bioenergy Regions 2012–2015”. Accompanying conference readers with up to 330 pages were also published for the various DBFZ event series (specialist forum “Hydrothermal Processes”, expert talks “Particle Separators in Domestic Firing Systems” and the workshop “The Power of Standardisation”). All publications are available free of charge as PDF downloads and (partly) as print versions. The DBFZ’s funding programme “Biomass Energy Use” has also published new publications as part of its series of publications in 2017. In addition to a collection of measuring methods for wood gasification, these include a focus booklet “Bioenergy in the electricity and heating market – project results 2015–2016”, a biogas flyer booklet and the conference readers for the 7th status conference “Bioenergy. Flexible and integrated into the next era” and the “3rd conference on the monitoring & process control of anaerobic digestion plants” (Process Measurement Conference). All publications are available free of charge as PDF downloads on the funding programme’s website.

Free downloads:
www.dbfz.de/en/publications
www.energetische-biomassenutzung.de/en/publications/

Fig. 30 New issues of the DBFZ publication series and the “Biomass Energy Use” funding programme

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Fig. 31 Topping-out ceremony of the new DBFZ building (18 September 2017)

EVENT HIGHLIGHTS

The topping-out ceremony for the new DBFZ building on 18 September 2017, organised by the Staatsbetrieb Sächsisches Immobilien- und Baumanagement (SIB), was an internal event highlight. In the presence of a large number of participants from the construction industry and representatives from the Ministry of Food and Agriculture, the topping-out wreath was raised in celebration of the completion of the shell construction phase. In his welcome address, Dr. Hermann Onko Aeikens, state secretary of the BMEL, thanked the German Bundestag for its support and for providing around 52 million euros for the construction project. "The scientific background of the DBFZ and its effective national and international networking make it a competent policy advisor and provider of support for scientifically sound decision-making. Today's topping-out ceremony marks another milestone on the road to excellent research at the DBFZ, which is equipped with state-of-the-art infrastructure," said the state secretary. The completion of the shell of the new office building and event venue, as well as the large technical centre on Torgauer Strasse, marks the beginning of the interior construction work. The new building is scheduled to be finished in spring 2019.

Further highlights in the field of event management included participation in bioenergy congresses such as the East German Energy Forum, the Berlin Energy Days, the Rostock Bioenergy Forum and the annual conference of the German Renewable Energy Research Association (FVEE) in Berlin. The DBFZ again organised various events of its own in 2017. In addition to the established series "Leipzig Expert Talks", numerous visitors came to Leipzig on 12–13 September 2017 attracted by the HTP Expert Forum "Bio-based Hydrothermal Processes – Technologies for Material and Energy Use". Held for the third time, the forum has established itself as an important national event in the field of hydrothermal processes. The next event will take place on 19–20 September 2018 as part of the DBFZ annual conference.

Further information is available at:
www.dbfz.de/htp

Fig. 32 Session at the 3rd HTP Expert Forum in Leipzig (12–13 September 2017)

UPCOMING EVENTS

In the current year of 2018 we are looking forward to the following events, which we cordially invite you to now: on 23/24 April 2018, the "Science Management Forum" (FoWi), a conference dealing with the administrative topics of human resources, finance, purchasing and research infrastructure, will take place for the first time in Leipzig. The conference is organised by the DBFZ in cooperation with the Helmholtz Centre for Environmental Research – UFZ, the Leibniz Institute for Tropospheric Research e.V. (TROPOS) and the Leibniz Institute of Surface Engineering (IOM). Further information at **www.fowi-leipzig.de** (german language).

The aim of the "Long Night of Science" is to make science accessible to everyone. It will take place on 22 June 2018 from 6 p.m. to midnight at a number of research institutions throughout Leipzig. The motto of this year's event is "Working Worlds". The DBFZ will again offer interesting exhibits, participatory experiments and insights into bioenergy research at Leipzig's KUBUS. We look forward to your visit to our booth. Further information at: **www.wissenschaftsnacht-leipzig.de** (german language).

Finally, we would like to draw your attention to the DBFZ's annual conference. On 19–20 September 2018, important and future-oriented research topics in the field of bioenergy will again be discussed an attempt will be made to peer into the crystal ball. What is the current state of research and how will renewable raw materials contribute to a sustainable energy supply and a bioeconomy of the future? Within the scope of this year's conference, the 4th expert forum "Hydrothermal Processes" and a doctoral seminar will also take place. Further information at **www.bioenergiekonferenz.de**.

fowi FORUM WISSENSCHAFTS-MANAGEMENT LEIPZIG

Lange Nacht der Wissen—schaften Leipzig 22/6/18

DBFZ Annual Conference 2018

Additional information:
www.dbfz.de/veranstaltungen (german language)
www.flickr.com/photos/139453872@N08/albums
www.dbfz.de/index.php?id=1130&L=1

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9 CONTRACT RESEARCH AND SCIENCE-BASED SERVICES

As a research institute conducting predominantly applied research, the DBFZ strives to closely co-operate with project partners from industry. It offers extensive contract research and a wide range of science-based services. These go beyond the research focus areas and are directed equally at politicians, industry, associations, experts and committees. Work is implemented across departments and disciplines, so that the entire expertise of the DBFZ can be used comprehensively and efficiently for the following consulting and technical services.

Fig. 33 Working at the engine test bed of the DBFZ

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9.1
POLICY ADVICE

The DBFZ offers a variety of consulting services for policy-makers, including the long-term observation of the development of bioenergy markets as part of various monitoring projects (in the area of electricity generation from biomass and the use of biofuels). This information supports the design of political instruments (e. g. EEG, EEWärmeG, Biokraft-NachV, etc.). In addition, the DBFZ offers targeted support to political decision-makers in the form of statements (e. g. within the framework of legislative procedures) and factual papers (above all on the current potentials of biogenic waste and residual materials for energetic use, on existing waste-wood plants, on heat utilisation, and on the consequences of the adjustment of the biofuel quota).

Since January 2017, part of the policy advice has taken the form of a direct delegation of DBFZ employees to Berlin. The aim is to provide content support to the BMEL's Unit 524 "Bioenergy and Energy Matters" for the negotiations on the next Renewable Energy Directive (RED II). RED II sets the targets for the further development of renewable energies in the EU for the 2020 to 2030 period. In the course of the departmental negotiations on RED II, many ad hoc inquiries were also made directly to the DBFZ, which could be answered competently and quickly. Since 2017, a strategy for the future of heat generation from biomass has also been developed for the BMEL. The project "Investigations on the design of biofuel legislation" (acronym BKSQuote) will provide a basis for discussions and decision-making with regard to further and higher-level strategy development for the use of renewable energy in the transport sector, focusing on biofuels.

In addition to collecting, evaluating and presenting data and information on market developments, available biomass potential, and typical parameters of current and future bioenergy technologies (costs, technical parameters or potential en-

vironmental effects), the DBFZ has also developed suitable tools in recent years for the development of medium and long-term bioenergy scenarios for strategy development (as part of the research project “Milestones 2030”). It also supports the scientific and technological development of bioenergy.

Tab. 4 Key policy advice projects in 2017 (selection)

Project	Client
BioRestMon – WG Biomass Residue Monitoring	Federal Ministry of Food and Agriculture
Feasibility study for a PTG-HEFA hybrid refinery in Germany	Federal Ministry of Transport and Digital Infrastructure
SYMOBIO – Systemic Monitoring and Modelling of Bioeconomics	Federal Ministry of Education and Research
TATBIO – Techno-economic Analysis of the National Biomass Potential	Federal Ministry for Economic Affairs and Energy

AN OVERVIEW OF SERVICE

- Scientific support of strategic policy development and derivation of recommendations for action
- Opinions on legislative procedures and support for their further development
- Development and implementation of suitable monitoring systems under changing (research policy) conditions

Additional information (partly in german language):
www.dbfz.de/referenzen-publikationen/statements
www.dbfz.de/referenzen-publikationen/studien
www.energetische-biomassenutzung.de/publikationen/stellungnahmen/

© BINE Informationsdienst/Jutta Perl-Mai

Fig. 34 Representatives of the research networks present Torsten Herdan, Head of the Energy Policy – Heat and Efficiency Department at the BMWi, their recommendation for a future energy research policy. From left to right: Dr. P. Fath (RTC Solutiones), Prof. A. Reuter (FhG-IWES), Dr. C. Sourkounis (University of Bochum), Prof. D. Thrän (DBFZ/UFZ), Prof. A. Praktiknjo (RWTH Aachen), T. Herdan (BMWi), Prof. E. Abele (TU Darmstadt), Dr. E. Klapdor (Siemens), C. Beier (Fraunhofer Umsicht).

9.2 MARKET ANALYSES AND DATA PROVISION

Bioenergy continues to play a key role in the replacement of fossil fuels (FNR, 2016). Accordingly, the trend in recent years is being sustained, and both regional and international usage channels are being expanded further. With the parallel development of the bioeconomy sector, the number of players on the market potentially competing for the limitedly available biomass is rising. Due to steadily rising demands in terms of efficient utilisation technologies for sustainable bioenergy production and use, a comprehensive, up-to-date dataset is the key strategy for customised planning and the ongoing development of policy framework conditions. This includes the depiction of market trends, as well as trading and raw material flows. The DBFZ is also pursuing the objective of providing technological, economic and ecological data to analyse and assess biomass production, supply concepts and technology options. A further opportunity is to provide established and potential market players or other interested parties with transparent information on the continually rising quality and sustainability demands. Since February 2016, data management and provision at the DBFZ has been boosted by the establishment of a structured research data management system.

AN OVERVIEW OF SERVICES

- Determination of biomass potential and development of usage scenarios and recycling strategies for different players on biomass markets (material and energy use)
- Monitoring of market and technology trends, including systematic recording in databases, and drafting of market and technology overview reports

Fig. 35 A large amount of data on bioenergy use is collected at the DBFZ

- Forecasting future development trends in bioenergy and bioeconomics
- Data provision on biomass/bioenergy trading (costs, prices and quantities), and cost analysis of biomass production and supply (cost-supply curves)
- Provision of structural data on the power, heat and fuel market as well as analysis of the marketing strategies of plant and grid operators (e. g. for on-demand energy supply)
- Data provision on ecological and social aspects (e. g. emissions, environmental impact, sustainability indicators) and the policy-making framework
- Depending on the question at hand, efficiency and sustainability analyses can be conducted in the course of economic, ecological and technical assessment and underpinned by sensitivity calculations and scenario analyses. This also applies to the evaluation of market and system integration concepts for flexible bioenergy supply

9.3 TECHNICAL, ECONOMIC AND ECOLOGICAL ASSESSMENT

The increasing competition for limited biomass resources in conjunction with the continually rising and changing demands for economical and ecological performance capability, is placing increased pressure on bioenergy plant operators to innovate and optimise. The DBFZ offers market players a range of services for analysing and optimising existing and future bioenergy technologies and concepts. Alongside appraisals of the technical, economic and ecological characteristics of bioenergy plants, the analyses provide a suitable basis for process and concept optimisation.

AN OVERVIEW OF SERVICES

Technical evaluation

- Material and energy life cycle assessment
- Technical feasibility
- Technology screening and learning curves
- Characteristic data-based evaluation
  (e. g. specific efficiencies, availabilities, quality level, classification by technical development status)

Economic evaluation

- Feasibility studies and assessment of usage/operating concepts including costs of new plants, plant upgrades or repurposing projects

- Cost and economic viability analyses for biogenic supply concepts (power, heat, fuels, chemical bioenergy sources)
- Analysis of value chains based on life cycle cost analyses (LCC, social life cycle assessment) and assessments of the regional added value of the biomass usage concepts

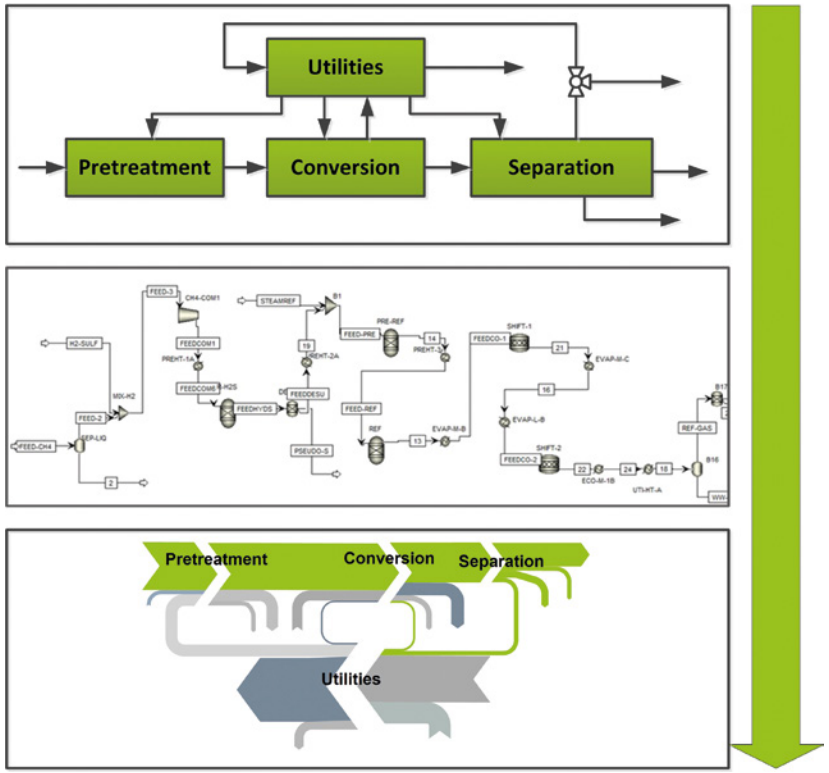

Fig. 36 From plant design and process simulation to technical evaluation

Ecological assessment

- Life cycle assessment (LCA) related to greenhouse gas emissions and other environmental impacts (including biological water balance, humus, eutrophication, acidification) as well as primary energy consumption
- Competing land use

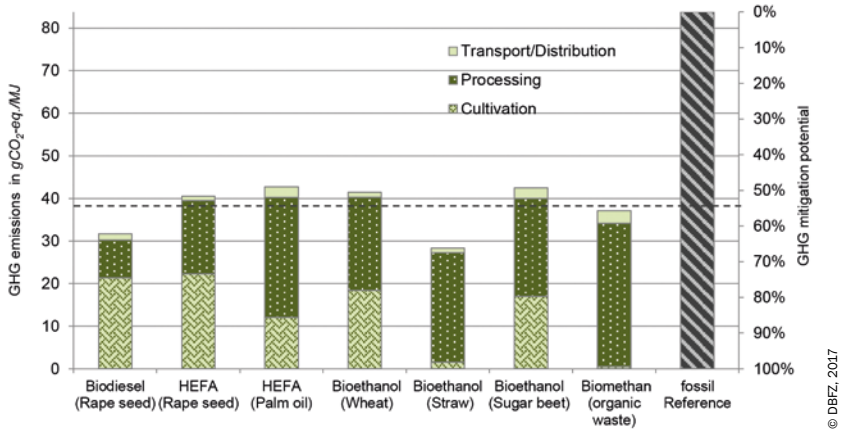

Fig. 37 GHG reduction potentials through various options of biomethane utilisation

9.4 CONCEPT AND PROCESS DEVELOPMENT AND OPTIMISATION

Concept and process development play a key role in bioenergy research and as a means of meeting the challenges of evolving political and social conditions. Practical in-house bioenergy developments form the basis of the services on offer. Know-how on the technical state of the art is continually deployed in the ongoing advancement of processes. Key tools alongside in-house pilot plants are self-developed computer models for the calculation of material and energy flows. These relate to entire biorefineries, or to individual components such as incinerators, gasifiers and synthesisers. In this way, the experiments are supported and enriched by numeric calculations. Depending on the subject under investigation, process flow simulations, using Matlab and Aspen Plus, or CFD models using Open FOAM and Ansys CFD, are employed to provide a detailed understanding of processes and techniques and to enhance the predictive accuracy of the models.

Process flow simulations can be used to analyse the interactions of the various process steps. In particular, the analysis of mass and energy balances of complete or partial biorefineries provides ways to enhance efficiency at an early stage. The results also provide a key basis for economic and ecological analyses. The effects of modifications to existing plants can also be effectively depicted by process flow simulations. CFD simulations depict plants of any scale three-dimensionally, enabling their physical-chemical processes to be analysed. This particularly focuses on investigating flow processes, taking into account the chemical reactions that occur. By varying parameters, the processes can be controlled and optimisation potentials can be identified, for example to reduce emissions from furnaces or enhance the efficiency of synthesiser plants.

AN OVERVIEW OF SERVICES

- Development of new process concepts
- Calculation of material and energy flows (process balancing)
- Upscaling of processes
- Testing and development of new technologies and process steps
- Optimisation of existing technologies, process steps and material flow management concepts
- CFD and process flow simulations (stationary and dynamic)
- Kinetic measurements for catalysts
- Development of control concepts

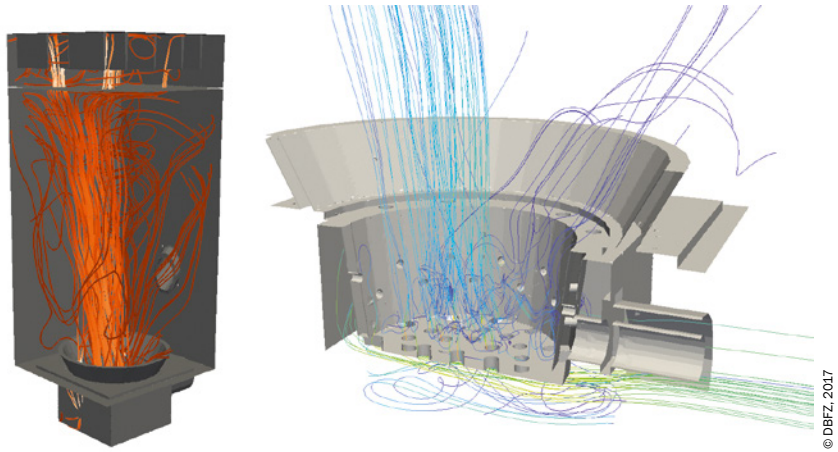

Fig. 38 Flow lines in a pellet burner (left) and a pellet burner (right) from a CFD simulation

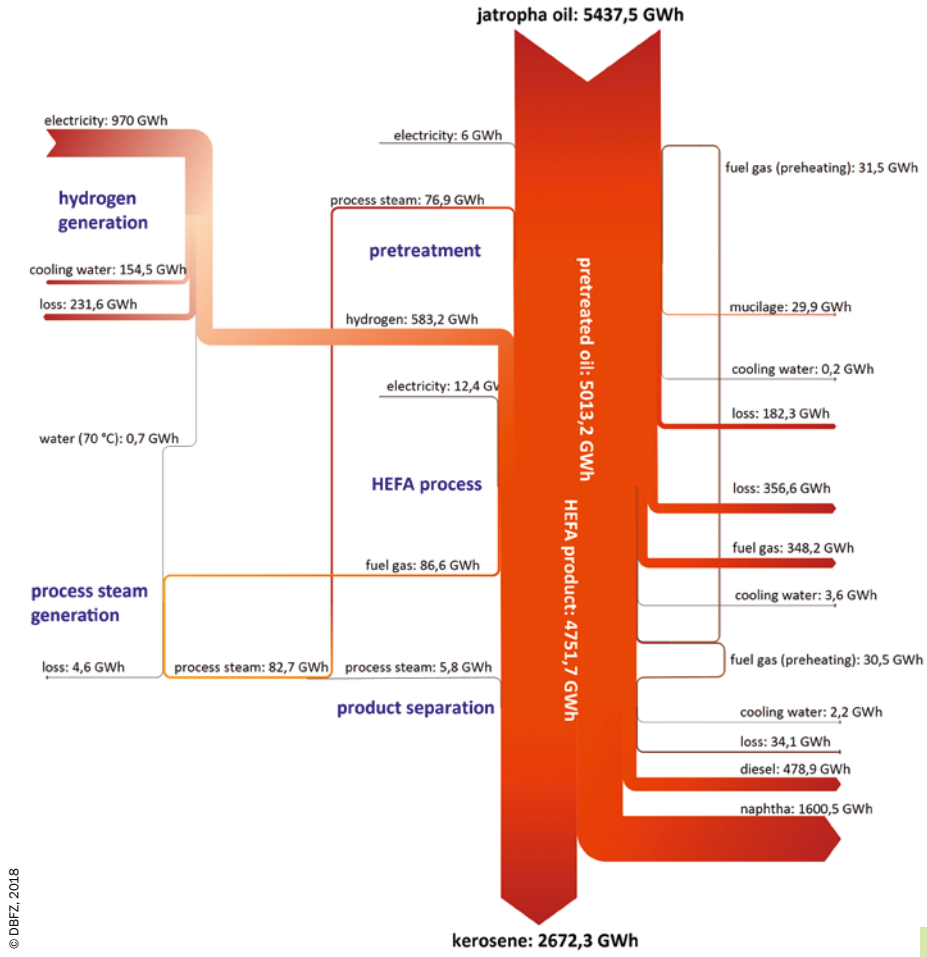

Fig. 39 Energy balance of the PTG-HEFA concept for the supply of kerosene from vegetable oils and electricity

9.5 SCIENTIFIC SUPPORT FOR R&D PROJECTS

One example of successful scientific support for R&D projects is the “Biomass Energy Use” programme funded by the Federal Ministry for Economic Affairs and Energy (BMWi), which has been running at the DBFZ for the last nine years. In the course of events, such as scientific conferences and workshops, the programme has successfully created to date a network of 133 projects and 330 project partners in the SME sector. Other key aspects are the collation of the scientific output of the programme’s participants and the transfer of these results to various interested parties (in the fields of policy-making, research and practical application). A series of scientific publications has been published, currently comprising 20 volumes, and five specialised “Focus on” issues have been published on various keynote topics (biogas, solid fuels, hydrothermal processes, bioenergy technologies, etc.). The programme’s support activities also include organising the cross-project working groups as part of the process to harmonise scientific methods. Based on intensive discussions with programme participants, the measurement methodologies relating to biogas, fine dust and gasification, and a method handbook (in German and English) have been developed and joint statements on political processes have been prepared. Since 2016 the programme has been a member of the Energy Research Network, which was initiated by the BMWi. In this context the programme supported the coordinated development of future R&D recommendations as part of the consultation process for the 7th Energy Research Programme.

Fig. 40 Seventh status conference of the Federal Ministry for Economic Affairs and Energy’s funding programme “Biomass Energy Use” in Leipzig (20/21 November 2017)

AN OVERVIEW OF SERVICES

- Initiation of and scientific support for demo and pilot plants
- Accompanying scientific research on complex R&D projects
- Scientific advice and support for bioenergy initiatives of local authorities/ regions
- Scientific support for research programmes by:
    - Interlinking projects
    - Converging scientific output (press and public relations)
    - Enhancing visibility and presentation of programmes
    - Coordination of cross-project working groups
- Coordination of events and compilation of publications
- Support for ongoing scientific and technical dialogue
- Coordination of harmonisation procedure

Fig. 41 Participants of the 3rd Forum on Hydrothermal Processes (12–13 September 2017)

9.6 KNOWLEDGE AND TECHNOLOGY TRANSFER

In addition to a series of expert talks in Leipzig (biogas, biofuels, solid biomass), the DBFZ also organises conferences on specific topics (e.g. hydrothermal processes, process measurement technology of biogas plants, computational fluid dynamics – CFD, dust separators in domestic furnaces). In addition, numerous publications (final reports, dissertations, guidelines, manuals, conference proceedings and reports) provide a comprehensive portfolio of scientific reports which can be downloaded free of charge from the Internet. The Bioenergy Innovation Centre also guides and coordinates innovation processes and establishes and expands national and international networks. Through a wide variety of cooperation projects in Germany and abroad, there is a continuous transfer of knowledge and technology through workshops, guidelines and employee training courses.

AN OVERVIEW OF SERVICES

- Organisation and implementation of specialist events (technical discussions, conferences, workshops)
- Coordination of innovation processes
- Preparation of guidelines and manuals
- Development and creation of web-based information platforms and open-source portals
- Further education (summer school)

9.7
TECHNICAL AND SCIENTIFIC SERVICES

In addition to the services mentioned so far, the DBFZ offers a special R&D infrastructure in the three technical research departments of biochemical conversion, thermo-chemical conversion and biorefineries. The technical and scientific services are provided to plant and mechanical engineering companies, process developers, plant operators and other companies and institutions conducting R&D. A detailed overview of the individual technical facilities, test beds and laboratories located at the DBFZ can be found at the end of this annual report starting on page 145.

THE THERMO-CHEMICAL CONVERSION DEPARTMENT

The Thermo-Chemical Conversion department deals with selected questions surrounding the thermo-chemical conversion of biogenic solid fuels for the efficient and demand-oriented provision of heat, electricity and cooling. Research services are on offer along the entire chain, from fuel (processing, conditioning, pelleting) to the development and optimisation of combustion plants and small and micro-scale combined heat and power plants (including CFD support), also in connection with emission-reducing measures (catalysis and separators), on up to the control and regulation of individual plants and system networks (also with other heat sources and electricity network integration). Services also include laboratory and field measurements to determine emissions (dust, CO and VOC also accredited in accordance with DIN EN ISO/IEC 17025:2005), separator tests, catalyst tests and the discussion and classification of the respective results in the market environment of bioenergy use.

THE BIOCHEMICAL CONVERSION DEPARTMENT

The research in the Biochemical Conversion department concentrates on the use of microorganisms to produce biomass energy sources. The focus here is on technology for biogas production and use. The department also studies the efficient use of material flows and the closure of nutrient cycles. In addition, it provides support in demonstrating new and improved plants and components. All activities are done in conjunction with a comprehensive evaluation of the market and the state of the art, which is ensured through its participation in various monitoring projects. As part of its intensive cooperation with the Helmholtz Centre for Environmental Research, solutions are sought to a variety of questions surrounding the properties of the microorganisms involved and their population dynamics.

Fig. 42 Working in the Fuel Technical Centre of the DBFZ

THE BIOREFINERIES DEPARTMENT

The Biorefineries department focuses on processes for chemical bioenergy carriers and fuels. The emphasis here is on efficient chains and innovative biorefinery concepts for synthesis gas processes and hydrothermal processes. This also includes the implementation of conversion and separation processes in the pilot plant, including laboratory analyses for the comprehensive chemical-physical characterisation of biomass and production processes as well as test bench investigations of the motor behaviour of liquid and gaseous biofuels. This is rounded off by the evaluation of technology, cost accounting, and the ecological assessment of diverse concepts for biorefineries and various biofuels. In addition, questions of balancing and optimising processes and concepts on the basis of stationary and dynamic flowchart simulations are also the subject of investigation. Another goal is the initiation of pilot/demonstration projects and their scientific support.

THE ANALYTICAL LAB

In order to assess the potential applications of various biomasses, the DBFZ's analytical lab analyses the chemical composition and combustion properties of liquid fuels, solid biofuels, biogas substrates, by-products and residual materials, as well as their conversion products, such as ash, filtration dust and waste water. Analyses are carried out in accordance with commonly applied standards and also depending on a problem-oriented methodology. Based on the available equipment the following parameters can be determined: gross density, bulk density, particle size distribution, amount of fines, durability, gross/net calorific value, water content, volatiles, fixed, elementary and organic carbon, CHNS-composition, ash content, elemental composition including major and minor elements, total content of sulfur and chlorine as well as elutable elements, density, viscosity, acid and saponification value, refraction index, flashpoint and pH value. Polycyclic aromatic hydrocarbons (PAHs), fatty acid methyl esters (FAMEs) and phenols can be identified and quantified with chromatographic equipment; carbohydrates and furan derivatives can be quantified with HPLC. Prospectively, the capability will be also available for volatile aromatic hydrocarbons (BTEX).

Fig. 43 Work in the analytical lab of the DBFZ

Romann Glowacki is the DBFZ's innovation coordinator and is the point of contact for "Contract Research and Science-based Services".

Contact

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10 ORGANISATION AND STRUCTURE

Fig. 44 The DBFZ's current main building (building 6) with adjoining day-care centre in summer 2016

The DBFZ was founded as a non-profit limited company in Berlin on 28 February 2008 against the backdrop of complex questions surrounding the provision and use of bioenergy. The research institute is owned by the Federal Republic of Germany and is represented by the Federal Ministry of Food and Agriculture.

10.1 SCIENTIFIC MISSION

"The objective of the institute is to conduct application-oriented research and development in the field of energetic and integrated use of renewable raw materials in the bioeconomy, with special consideration of innovative technologies, economic impact and environmental concerns".
(Scientific mission of the DBFZ)

The DBFZ was founded in 2008 by the former Federal Ministry of Food, Agriculture and Consumer Protection (BMELV). The aim was to establish a central research institution for all relevant fields of bioenergy research and to link the results of the very complex German research landscape in this sector. The scientific mission of the DBFZ covers technical, ecological, economic, social and energy aspects along the entire process chain, i. e. from production to provision and use of bioenergy. The development of new processes, procedures and concepts is accompanied and supported by the DBFZ in close cooperation with partners from science and industry. At the same time, it networks closely with German public research in the agricultural, forestry and environmental sectors as well as with European and international institutions. Using this broad research background, the DBFZ also develops scientifically sound decision-making tools for policymakers.

10.2
RESEARCH DEPARTMENTS

Four research departments cooperate closely with each other to create an organisational framework for the numerous scientific research tasks at the DBFZ. While the areas of biochemical conversion, thermo-chemical conversion and biorefineries mainly carry out applied research tasks, the DBFZ provides policy advice and develops potential analyses, acceptance studies and a wide variety of scenarios for biomass use in the field of bioenergy systems.

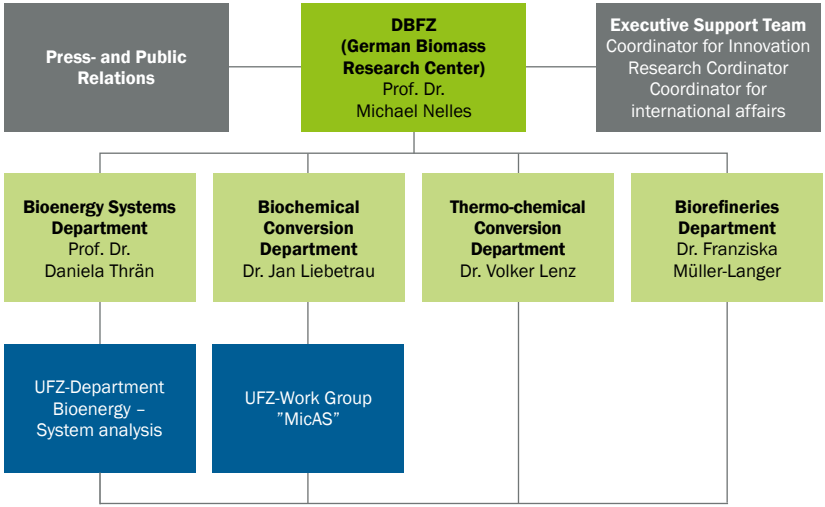

Fig. 45 The research departments of the DBFZ including the cooperation department with the UFZ

10.3
SUPERVISORY BOARD AND RESEARCH ADVISORY COUNCIL

The Research Advisory Council (RAC) is made up of international members and advises the DBFZ on the content of its scientific work. Ten national and eight internationally renowned scientists from bioenergy research belong to this group. The members of the Research Advisory Council are appointed by the Supervisory Board, which is composed of representatives from the five most important federal ministries related to the work of the DBFZ.

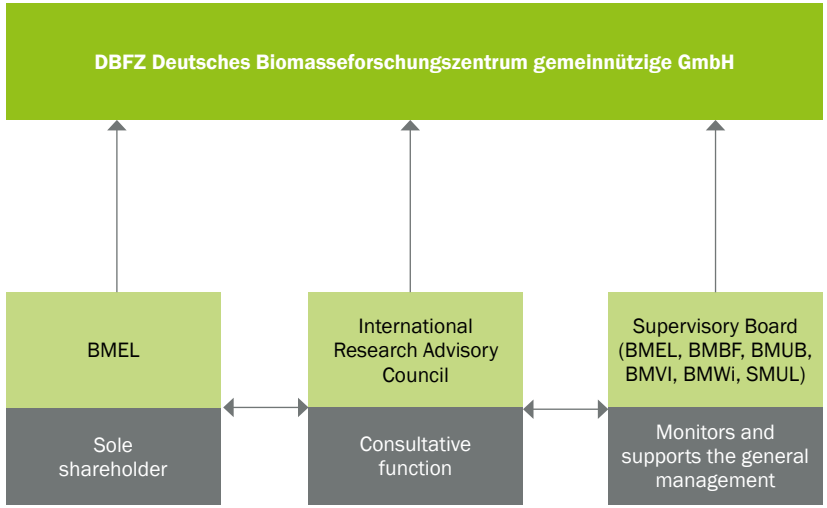

Fig. 46 The regulatory bodies of the DBFZ

THE SUPERVISORY BOARD OF THE DBFZ

The Supervisory Board, chaired by the Federal Ministry of Food and Agriculture (BMEL), takes the groundbreaking, content- and organisation-related decisions regarding the development of the DBFZ. Other members are the Federal Ministry of Education and Research (BMBF), the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), the Federal Ministry of Transport and Digital Infrastructure (BMVI), the Federal Ministry for Economic Affairs and Energy (BMWi) and the Saxon State Ministry of the Environment and Agriculture (SMUL). The Supervisory Board meets twice a year at the DBFZ.

The Supervisory Board is made up of the following members

(as of 15 January 2018):

Bernt Farcke (Chairman)
Head of Department 52 “Sustainability, regrowable resources”,
Federal Ministry of Food and Agriculture (BMEL)

Deputy Director Berthold Goeke (Deputy Chairman)
Head of Department “KI I Climate Protection Policy”, Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)

Daniel Gellner
Head of Department “Agriculture and Forestry”,
Saxon State Ministry of the Environment and Agriculture (SMUL)

Dr. Karin Freier
Head of Department III B Renewable Energies in the Electricity Sector,
Federal Ministry for Economic Affairs and Energy (BMWi)

Dr. Christoph Rövekamp
Head of Division – Division 722 – Basic Energy Research,
Federal Ministry of Education and Research (BMBF)

Birgitta Worringen
Head of Department G2 – Sustainable Mobility, Energy, Logistics,
Federal Ministry of Transport and Digital Infrastructure (BMVI)

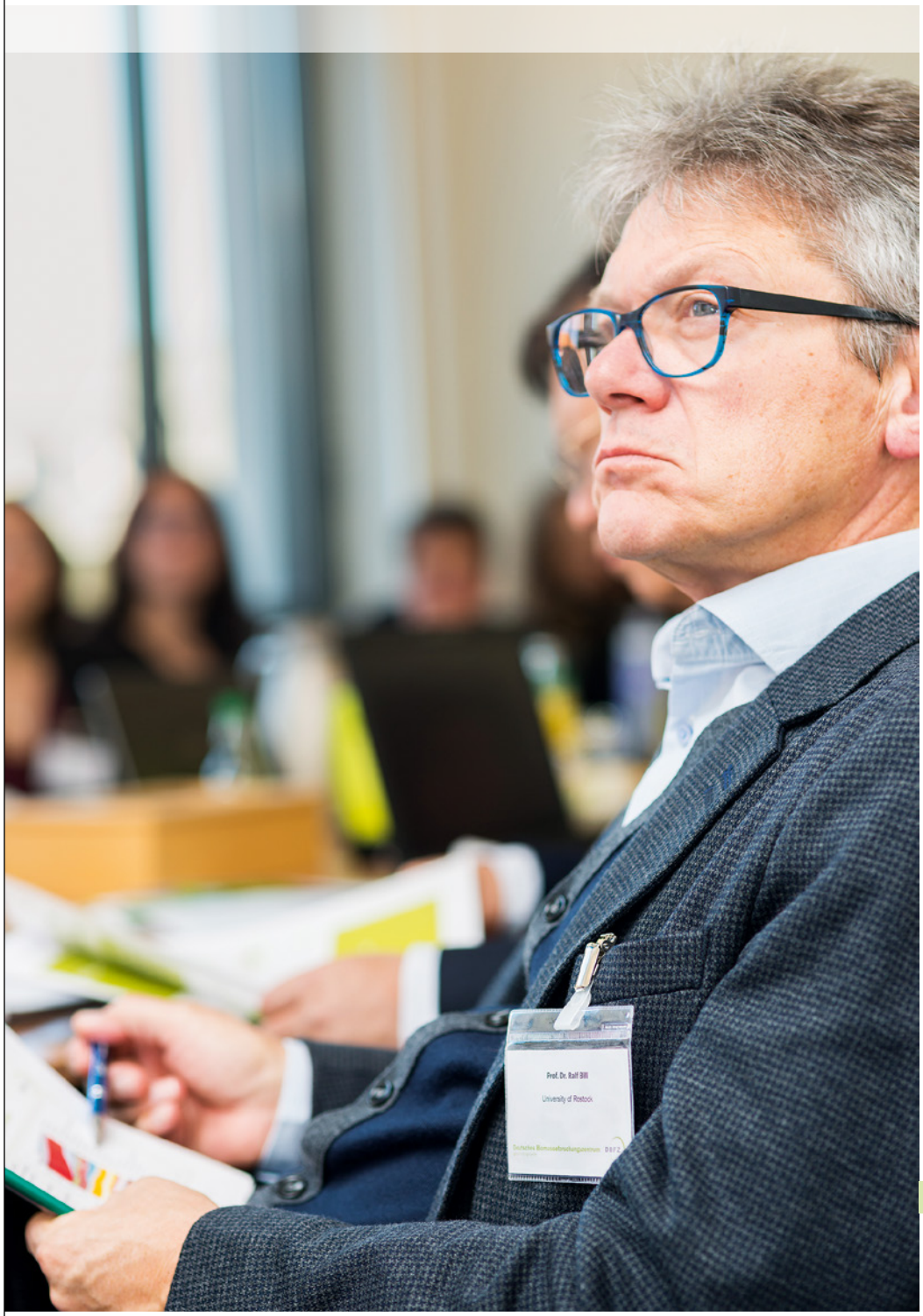

Fig. 47 The Research Advisory Council of the DBFZ (7 November 2017)

THE RESEARCH ADVISORY COUNCIL

The Research Advisory Council is composed of nationally and internationally renowned bioenergy experts and advises the DBFZ on the orientation of its scientific activities. This ensures that the research carried out with institutional funding is scientifically sound and highly relevant for the current and future use of bioenergy in the energy system. The Research Advisory Council meets once a year at the DBFZ.

Tab. 5 The Research Advisory Council includes the following members (as of 15 January 2018)

Member	Organisation	City and Country
Barbosa, PhD Maria	Microalgal Biotechnology Algae PARC, Wageningen University	Wageningen, Netherlands
Bauen, Dr. Ausilio	Imperial College London	London, England
Bill, Prof. Dr. Ralf	University of Rostock – Faculty of Agricultural and Environmental Sciences	Rostock, Germany
Chiaramonti, Prof. Dr. David (Chair)	Renewable Energy Consortium R&D, University of Florence	Florence, Italy
Christen, Prof. Dr. Olaf	Martin Luther University, Halle-Wittenberg	Halle/Saale, Germany
Dach, Prof. Dr. Jacek	Poznan University of Life Sciences	Posen, Poland
Dong, Prof. Dr. Renjie	China Agricultural University (CAU)	Beijing, China
Dornack, Prof. Dr. Christina	TU Dresden – Institute of Waste Management and Circular Economy	Dresden, Germany
Hartmann, Dr. Hans	Technology and Promotion Centre at the Regrowable Ressource Competence Centre (TFZ)	Straubing, Germany
Hirth, Prof. Dr. Thomas	Karlsruhe Institute of Technology (KIT); University of Stuttgart – Faculty of Energy-, Process- and Bio-Engineering	Stuttgart, Germany
Kemfert, Prof. Dr. Claudia	German Institute for Economic Research (DIW Berlin)	Berlin, Germany
Kruse, Prof. Dr. Andrea	University of Hohenheim	Stuttgart, Germany
Meyer, Prof. Dr. Bernd	Institute of Energy Process Engineering and Chemical Engineering TU Bergakademie Freiberg	Freiberg, Germany
Moreira, Dr. José Roberto	Universidade de São Paulo, Instituto de Eletrotécnica e Energia	São Paulo, Brazil
Serrano, Prof. Dr. David	IMDEA Energy Institute	Madrid, Spain
Teutsch, Prof. Dr. Georg	Helmholtz Centre for Environmental Research – UFZ	Leipzig, Germany
Thiffault, PhD Evelyne	University Laval Canada Québec	Québec, Canada
Walther, Prof. Dr. Grit	RWTH Aachen – Faculty of Economic Sciences	Aachen, Germany

10.4
FINANCE AND PERSONNEL

The DBFZ was founded as a non-profit limited liability company (gGmbH) in order to be able to make flexible and transparent use of public research funding and to work in a research and advisory capacity on behalf of external parties. The DBFZ is financed by an institutional grant from the Federal Ministry of Food and Agriculture (BMEL) as well as by project grants and research contracts acquired through competitions. In 2017, the DBFZ received 18.9 million euros of funding from the BMEL. In addition, around seven million euros of external funding were raised (see Figure 48). In terms of expenditures, approx. 62 % of expenditures were related to investments in a new construction project. Further expenses were distributed between personnel costs at approx. 27 % and material costs at 11 %.

PERSONNEL

In 2017, the DBFZ employed an average of 177 employees under collective bargaining agreements. Including the scientific support team and the press and public relations department, 139 employees worked in the scientific/technical departments and 38 in the administrative department (including property management and IT). Numerous papers were overseen at the DBFZ in 2017. A total of 35 internships and student research projects as well as 57 bachelor, master and diploma dissertations were supervised. In addition, 33 guest researchers, foreign interns and grant holders worked at the DBFZ last year.

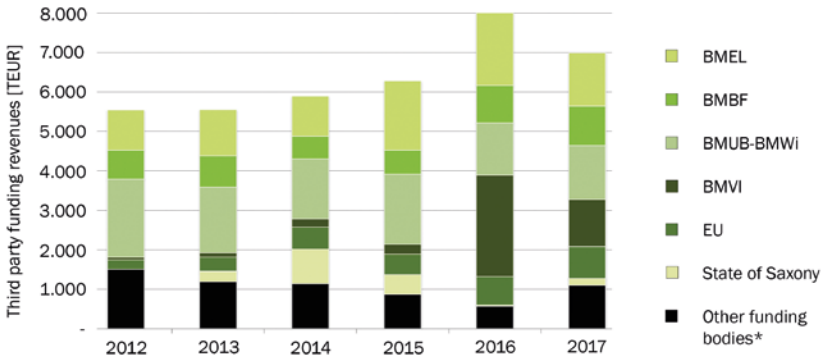

Fig. 48 Overview of external funding income for 2012–2017 (preliminary figures) (* Contract research and services for private and public clients)

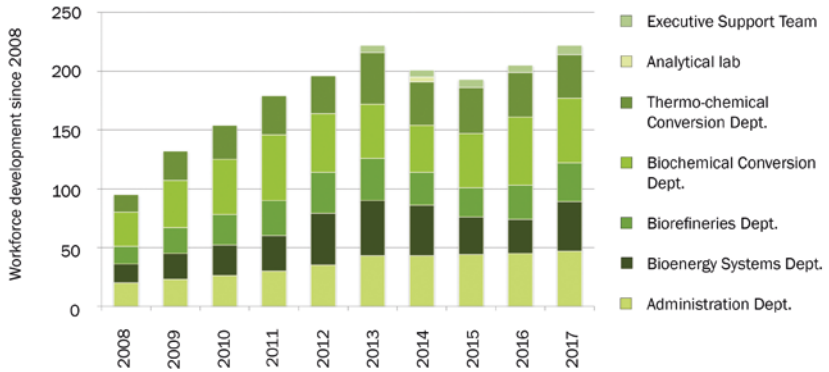

Fig. 49 Workforce development at the DBFZ (2008–2017)

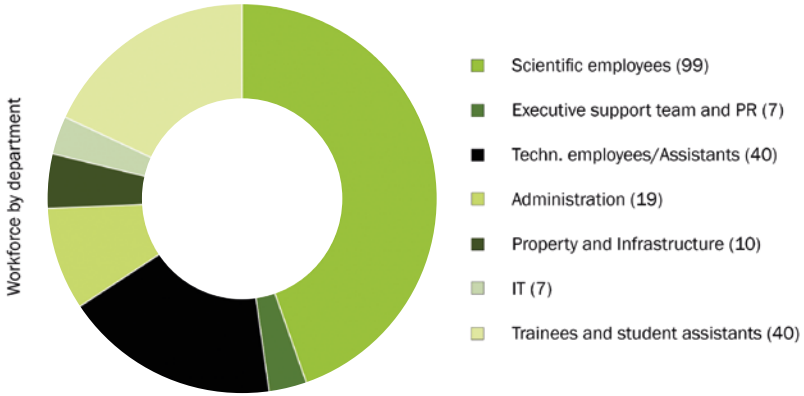

Fig. 50 Breakdown of the DBFZ workforce by department (as of 31/12/2017)

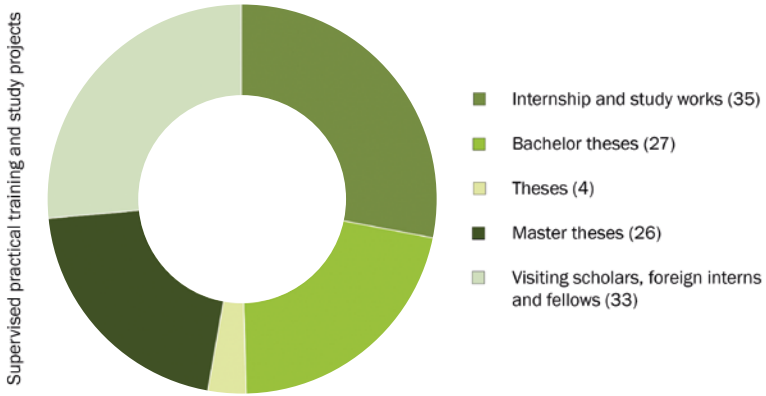

Fig. 51 Overview of study projects supervised at the DBFZ in 2017 (as of 31/12/2017)

TRAINEES AT THE DBFZ

The DBFZ has been a training company since its foundation in 2008. During this time, a total of 16 trainees have successfully completed training or retraining. In 2017, five trainees had apprenticeships in the fields of event management, office management clerk, electronics technician and personnel services clerk (new since 2017), and five BA students had traineeships in the fields of environmental technology, information technology, controlling and biotechnology (new since 2017). Two training courses were successfully completed in 2017.

10.5 SCIENTIFIC BODIES, ADVISORY BOARDS AND COMMITTEES

The DBFZ strives to achieve an intensive knowledge transfer with other institutions and the wider scientific community. These are part of the objectives of applied research and the exploitation of research results. The scientists at the DBFZ are represented on various scientific committees, advisory boards, working groups, networks and committees, as well as (visiting) professors in Germany and abroad.

SCIENTIFIC COMMITTEES/EXECUTIVE BOARDS/DIRECTORATES (A SELECTION)

Committee/Event	Role	Country	Since
6th International Conference on Solid Waste Management	Member of the Scientific Committee	India	2014
aireg – Aviation Initiative for Renewable Energy in Germany e.V.	Member of the Advisory Board	Germany	2011
Bioeconomy Council – Independent Advisory Committee for the German Government	Member	Germany	2014
Biomass to Power and Heat	Member of the Programme Committee	Germany	2012
BMBF Leading-Edge Cluster BioEconomy	Member of the Executive Board	Germany	2012
Bundesverband Bioenergie e.V. (BBE)	Member of the Advisory Board	Germany	2012
Chinese-German Centre for Environmental Technology and Knowledge Transfer (CETK) of Anhui Provence	Director	China	2005

Committee/Event	Role	Country	Since
Competence Centre for Biomass Use Schleswig-Holstein	Member of the Scientific Advisory Board	Germany	2013
DGAW – Deutsche Gesellschaft für Abfallwirtschaft e. V.	Member of the Executive Board	Germany	2014
Economic and Scientific Strategy Council Mecklenburg Western-Pomerania	Speaker for the Future Field of Energy	Germany	2014
Energie und Umweltstiftung Leipzig	Member of the Board of Trustees	Germany	2013
Energy Council Saxony, state-level	Member of the Committee of Experts	Germany	2012
European Biogas Association (EBA)	Member of the Scientific Advisory Board	Belgium	2014
Export Initiative RETech “Recycling & Waste Management in Germany” of the German Federal Government (BMUB, BMWi, BMZ)	Member of the Executive Board and Head of the China Working Group	Germany	2014
German-Chinese Centre in Anhui Province	Member of the Executive Board	China	2009
Helmholtz Centre for Enviornmental Research – UFZ	Member of the Scientific Advisory Board	Germany	2013
Institute for Non-Classic Chemistry at the University of Leipzig (INC)	Member of the Advisory Board	Germany	2013
Ministry of Agriculture, Environment and Consumer Protection, Mecklenburg Western-Pomerania	Member of the Scientific Advisory Board	Germany	2017
Research Steering Group for the Federal Ministry of Food and Agriculture (BMEL)	Member	Germany	2012
Scientific Journal “Müll & Abfall”	Member of the Advisory Board	Germany	2007
Scientific Journal “Waste Management”	Co-publisher	International	2008
State Energy Council Mecklenburg Western-Pomerania	Member and Head of the F&L Working Group	Germany	2012
Steering Committee for the 2nd Phase of the 1st Federal Immission Control Act	Member and Head of the Technology Working Group	Germany	2014
The Association of German Engineers (VDI), District Association for Mecklenburg Western-Pomerania	Member of the Directives Committee	Germany	2013
The Research Association for Diesel Emission Control Technologies (FAD) e. V.	Member of the Advisory Board	Germany	2013
ZIM-Network – Application and Research Network “Radiowave Technology” (RWTec)	Member of the Advisory Board	Germany	2014

WORKING GROUPS/COMMITTEES

Committee	Role	Country	Since
Ad Hoc Working Group of the 1st Federal Immission Control Act, Federal Environmental Agency (UBA)	Member	Germany	2012
European Biofuels Technology Platform (EBTP)	Member, WG1 European Technology and WG4 Policy and Sustainability	EU	2008
German RETech Partnership “Recycling & Waste Management in Germany”	Member of the International (Emerging and Developing Countries) Working Group	Germany	2017
IEA Bioenergy, Task 37 “Energy from Biogas”	Member	France	2016
IEA Bioenergy, Task 39 “Commercializing Conventional & Advanced Liquid Biofuels from Biomass”	German Representative	France	2014
IEA Bioenergy, Task 40 “Sustainable International Bionenergy Trade – Securing Supply and Demand”	German Representative	France	2010
Platform for Renewable Heating and Cooling (ETP-RHC)	RHC-ETIP Steering Committee Member	Belgium	2015
ProcessNet – Sustainable Production, Energy and Resources (SuPER), “Energieverfahrenstechnik”	Member	Germany	2014
ProcessNet – Sustainable Production, Energy and Resources (SuPER), “Hochtemperaturtechnik”	Member of the Advisory Board	Germany	2015
ProcessNet- Sustainable Production, Energy and Resources (SuPER), “Integrierte stoffliche und energetische Nutzung von Biomasse”	Member	Germany	2013
ProcessNet- Sustainable Production, Energy and Resources (SuPER), “Alternative Brenn- und Kraftstoffe”	Member	Germany	2015
Research Association Think Tank, Helmholtz-Association UFZ	Member	Germany	2014
Working Group “Bioökonomie der strukturbezogenen Kommission Technikbewertung und -gestaltung” of the Saxon Academy of Sciences at state level	Member	Germany	2014
Working Group “Blauer Engel”, Environmental Action Germany (DUH)	Advisory Role	Germany	2014
Working Group “Bibliothekskonzepte” of the BMEL Departmental Research Institutes	Member	Germany	2016

Committee	Role	Country	Since
Working Group “OpenAgrar” of the BMEL Departmental Research Institutes	Member	Germany	2016
Working Committee ”Stoffspezifische Abfallbehandlung”, ASA e. V.	Member of the Advisory Board	Germany	2009
Working Group “Wärme” of the Funding Programme “Biomass Energy Use”	Member	Germany	2017

NETWORKS/ASSOCIATIONS/PLATFORMS (A SELECTION)

Committee	Role	Country	Since
BioRaf Network	Member	Germany	2016
Combustion Institute (German department)	Member	Germany	2019
DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e. V.	Member of the Advisory Board	Germany	2015
Dena Biogaspartner (German Energy Agency)	Member	Germany	2017
Energy Committe of Leipzig Chamber of Industry and Commerce (IHK)	Member	Germany	2016
Energy Raw Materials Network (ERN)	Founding Member	Germany	2012
Energy Saxony – the Energy Cluster for Saxony (joint initiative)	Member	Germany	2010
European Bioeconomy Stakeholders’ Panel	Member	Belgium	2016
Forschungsnetzwerk Biokraftstoffe (ForNeBIK)	Member	Germany	2011
International Energy Agency (IEA)	Member	France	2010
KUP-Network	Member	Germany	2012
Netzwerk Energie und Umwelt e. V. (NEU e. V.) – Bioenergy Cluster	Member of the Advisory Board	Germany	2014
RAL – Bundesgütegemeinschaft Brennholz	Member	Germany	2016
Renewable Energy Research Association FVEE (Forschungsverbund Erneuerbare Energien)	Member of the FVEE Directorate, Speaker (2018)	Germany	2015
Sustainable Development Solutions Network (SDSN)	Member of the Extended Steering Committee	Germany	2016
The Association of German Engineers (VDI)	Member of the Executive Board	Germany	2008
VGB PowerTech e. V.	Member	Germany	2014

DIN/ISO – STANDARDS COMMITTEES (A SELECTION)

Committee	Role	Country	Since
DIN: NA 062-05-82 Working Committee “Feste Biobrennstoffe”	Expert	Germany	2016
DIN: 33999 Working Committee “Staubabscheiderprüfung”	Member	Germany	2013
ISO TC 255 “Biogas”	Member	Germany	2015
ISO TC 238 WG7 + WG4 + WG1 + WG2 + WG4 + WG5	Representative WG	Switzerland	2014
VDI 3461 “Emissionsminderung thermochemischer Vergasung von Biomasse in Kraft-Wärme-Kopplung”	Member	Germany	2012
VDI 3670 “Abgasreinigung – Nachgeschaltete Staubminderungseinrichtungen für kleinere und mittlere Kleinfeuerungsanlagen für feste Brennstoffe”	Member	Germany	2014
VDI 4630 “Vergärung organischer Stoffe Substratcharakterisierung, Probenahme, Stoffdatenerhebung, Gärversuche”	Member of Directives Committee	Germany	2013
VDI/DIN: AG “Herstellung von Biokarbonisaten”, Air Pollution Control Commission	Member	Germany	2013

PROFESSORSHIPS

Committee	Role	Country	Since
College of Energy and Environment, Shenyang Aerospace University	Professorship	China	2011
Environmental Economics at the Department of Industrial Engineering and Management, Ernst Abbe University of Applied Sciences (EAH), Jena	Professorship	Germany	2016
Faculty of Agricultural and Environmental Sciences, University of Rostock	Professorship	Germany	2006
Faculty of Environmental and Biotechnology Hefei University of Technology	Professorship	China	2002
Institute for Infrastructure and Resource Management, Chair of Bioenergy Systems, University of Leipzig	Professorship	Germany	2011
Institute of Renewable Energies, China Petroleum University Beijing	Professorship	China	2014

11 TECHNICAL EQUIPMENT

THE RESEARCH BIOGAS PLANT

The research biogas plant extends the range of application-oriented research being carried out at the DBFZ. Its aim is to better understand processes and improve the efficiency of biogas production. The dimensions of the fermenters allow experiments to be conducted on a technical scale, thus ensuring good transferability of results into practice. The facility features two independent lines with identical capacity which can be operated as a multi-stage system. The first line is a wet fermentation with a main fermenter in the form of a continuous stirred tank with a central agitator. The second line can optionally be run with a main fermenter of identical design or with a plug-flow fermenter. A post-digester with a gas reservoir

Fig. 52 The DBFZ's biogas pilot plant

cover collects the fermentation residues from both lines and routes them to the final post digester. The biogas is used in a CHP (combined heat and power) plant with an electric power output of 75 kW to cover the facility's own energy demands. Surplus power can be fed into the DBFZ grid. The generated heat is used solely to meet in-house demands. For substrate supply, small amounts of silage can be stored on-site. To measure the gas production volumes precisely, individual fermenters are fitted with permanent covers. Terminal units in the pipeline system and at the gas capture point permit sampling and the installation of measuring instruments.

THE BIOGAS LAB

The biogas lab is designed and equipped to simulate large-scale technical processes on a laboratory and semi-technical scale, complete with the corresponding analytics. Its aims are to optimise processes and to improve the basic understanding of the individual processes involved in methane formation. It operates extensive (continuous and discontinuous) pilot plants with reaction volumes between 0.25 and 500 litres, as well as the biogas pilot plant. It investigates a variety of substrate mixes from agriculture, the waste management sector and industry on behalf of research and industrial partners. Alongside in-process analytics, the analytics of instrument function is one of its key areas of activity. Resources available to the scientists include high-performance liquid chromatography (HPLC) as well as gas chromatographs (GCs) for the analysis of interim products. The cooperation agreement with the Helmholtz Centre for Environmental Research – UFZ means microbiological analyses are also possible. In addition to laboratory simulation and the associated stationary systems, resources also include various instruments for conducting field measurements. When combined, these resources enable the efficiency and emissions of large-scale plants to be assessed.

Fig. 53 Emission measurements in the field

EMISSION MEASUREMENTS

The Biochemical Conversion research department has an extensive range of measuring instruments for identifying diffuse methane leakages. The portfolio includes an infrared camera capable of visualising methane losses in real time, a methane laser, as well as various hand-held instruments which are able to detect sources of methane emissions. There is also an extensive range of equipment for quantifying climate-related emissions from both conducted and diffuse sources. Methodological resources include open/dynamic and closed/static chambers. Optical remote sensing methods can also be employed to determine emissions based on tunable diode laser absorption spectrometry and dispersion models. The department also has at its disposal explosion-proof sensors and methods for the continuous monitoring of operational methane emissions from pressure relief valves.

THE ANALYTICAL LAB

The analytical lab is equipped with the following devices for the characterization of liquid fuels, solid biofuels, biogas substrates, by-products and residual materials, as well as their conversion products, such as ash, filtration dust and waste water: Karl Fischer headspace titrator; bomb calorimeter; Stabinger viscometer; ion chromatography; elementary analysis; EC/OC; ICP-OES; flashpoint analyser; titration workplace; copper corrosion test; microwave digestion systems and freeze dryer. The lab additionally features a UV-VIS spectrometer, a refractometer, and two GC-MS units to identify and quantify organic components (e.g. phenols) as well as a HPLC, which will prospectively be used to analyse sugars and furan derivatives.

THE FUEL TECHNICAL CENTRE

In the DBFZ's Fuel Technical Centre, essential process steps for the conversion of (aqueous) biomass flows into solid, liquid and gaseous bioenergy carriers as well as basic chemicals are investigated and further developed. A wide range of test benches are available for research tasks and service contracts requiring the investigation of hydrothermal processes (HTC/HTV), biomass gasification, gas purification and catalytic synthesis as well as various processing technologies.
For the hydrothermal laboratory tests, three batch reactors (2x 500 ml, 1x 10 L), a continuous tube reactor and a two-stage, continuous plant are used. In addition to the screening of a wide variety of biomasses, extensive tests are carried out to determine the dependence of the yield and composition of the products on the reaction parameters. The liquid and solid (intermediate) products are examined with regard to their chemical composition and their fuel properties in the analytical laboratory of the DBFZ.
An entrained-flow and a fixed-bed gasifier are available for the investigation of biomass gasification. In the entrained-flow gasifier, biomass with particle diameters below 1 mm is converted into a synthesis gas with low tar content at temperatures of up to 1,200 °C and at atmospheric pressure, using air, steam and oxygen as gasifiers. The fixed-bed gasifier is designed for temperatures up to 1,050 °C, pressures up to 20 bars and variably adjustable mixtures of oxygen, nitrogen, air, water vapour and CO_2 as gasification agents. In addition to gravimetric monitoring of the fixed bed over time, temperatures and gas compositions can be measured in situ along the length of the bed. Two different gas purification systems complete the gasification test rigs. In addition to a heatable three-chamber system for different sorbents, a small-scale mobile pilot plant is available for the two-stage hot deaeration of product gases.
Four different fixed-bed reactors are currently being used to investigate the catalytic conversion of the synthesis gas into fuels and basic chemicals such as methane (SNG) and short-chain alkenes. The aim is to investigate the dynamic reactor behaviour and the product gas composition with fluctuating synthesis gas qualities and volume flows (see power-to-gas) as well as catalyst deactivation. Due to the wide temperature and pressure window of the plants (p≤ °C, T≤bar), different reactor concepts and operating conditions as well as classic and innovative catalysts can be compared directly with one another. In addition to the reactant gases H_2, CO and CO_2, water vapour and chemical pollution (e.g. H_2S) can be directed into the reactor system to investigate their influence on the reaction.
With the aid of a decanter test stand, continuous two-phase separation of product flows is also possible below 100 L h^{-1}. The solid-liquid separation is supplemented by a hydraulic hot drainage system for suspensions rich in solids. It is suitable for highly water-binding substances and offers the advantage of being able to drain hot intermediate streams directly without upstream cooling. The membrane filtration plant can be used for investigations in the fields of micro-, ultra- and nanofiltration as well as in the field of reverse osmosis. It enables membrane screening in wide pressure, temperature and pH ranges. Preparative HPLC enables a highly selective separation of various valuable products, such as sugar, furans, phenols or carboxylic acids, from the aqueous phase. This is done as part of a broad range of applications at high flow rates and pressures.

Fig. 54 Engine test bed at the DBFZ

ENGINE TEST BED

In response to the complex demands on motor fuels in the transport sector, the DBFZ operates an engine test bed for research activities. The primary aim is to test novel renewables-based fuels in combustion engines. Specifically, the single-cylinder research engine is used to test thermodynamic implementation (such as power output and consumption), legally limited and unlimited pollutants, engine oil dilution and the application of exhaust gas cleaning systems with respect to the fuel. A variety of different measurement and analytical techniques are used. Exhaust emissions can be measured by FTIR spectrometer, smoke meter, PMD, FID, lambda meter and NDIR, among other methods. Further analytical facilities are available in conjunction with the in-house analytical lab. The combustion process is analysed by a high-pressure indication system with online visualisation. Moreover, a freely programmable automation system enables typical engine properties, such as speed, load, rail pressure, charge air pressure, engine oil temperature and coolant temperature to be freely configured and continuously recorded. The modular design of the test bed also enables combustion engines to be modified quickly and autonomously.

In order to more effectively assess the high demands on exhaust gas cleaning systems when using renewable fuels, the DBFZ has developed a laboratory-scale catalyst-ageing test bed which is particularly capable of testing the durability of exhaust gas cleaning components (e. g. diesel oxidation catalysts or SCR catalysts). The exhaust gas is produced by a burner rather than by a combustion engine. The test bed thus permits the analysis of a catalyst's suitability in relation to various motor fuels during the development phase.

With a view to the steady progression of electromobility in Germany, technical potential can be analysed on a specially-built test bed for range-extender modules and an electric vehicle with integrated range-extender. Regeneratively-powered electric vehicles combined with regeneratively-powered range-extender modules can help to dispel prejudices against electromobility and at the same time open up opportunities for novel fuels which are only available in small quantities on a regional scale.

TECHNICAL CENTRE WITH 12 COMBUSTION TEST BEDS

In the combustion lab, the DBFZ conducts experiments on raw or pre-conditioned biomass by means of thermo-chemical conversion. It is also able to carry out detailed analyses of exhaust gas emissions and particulate formation processes. The combustion lab is equipped with a full-flow dilution tunnel test bed, a separator test bed with variable volumetric flow, a tiled stove test bed, a catalytic converter development stand, 15 exhaust analysers (including FTIR, SMPS, exposition chamber), seven dust measurement devices and six boiler vessels in various experimental setups.

FUEL CONDITIONING AND COMBUSTION LAB

Based on its extensive and widely respected experience and know-how, the DBFZ's fuel conditioning and combustion lab joins forces with its analytical lab to conduct a wide variety of tests and experiments in close cooperation with leading scientific and industrial partners. Fuel conditioning experiments can be performed on a wide variety of different fuels. A warehouse facility covering an area of over 800 m² currently contains more than 150 different fuel variants. The fuel conditioning and combustion lab has dedicated conditioning systems and a new 30 kW ring-matrix press with which it conducts experiments in the production of novel biogenic solid fuels, particularly fuel mixes. The pellets produced can be fully characterised in accordance with the European standards governing solid biofuels.

DATABASES

In the research focus area "System Contribution of Biomass", a wide range of data is collected in close partnership with the other research areas of the DBFZ. This data is used to monitor the development of the bioenergy market and includes technical, economic, licensing and actor-relevant information, e. g. for the German bioenergy plant park or the market development of biogenic raw materials and

Fig. 55 Working in the combustion lab of the DBFZ

fuels. Due to many years of monitoring the provision and use of bioenergy, corresponding time series are often available. Standardised data management tools, including various database systems, are used to systematically collect and evaluate data, sometimes in combination with geographical information systems (GIS). Using the data provided by the bioenergy plant park in Germany, as well as data on international raw material/fuel markets and trade flows, the DBFZ offers private and public decision-makers outstanding advisory services on strategic policy issues and market-relevant decisions. The extensive and systematically expanded data enables an evidence-based depiction of the market dynamics against the background of changing framework conditions and the estimation of future development trends.

ASSESMENT METHODS

For the sustainable design of the future energy system, the limited biomass potential must be used efficiently. Due to the versatile properties and utilisation options of biomass, methods and tools are needed to control the sectoral use of biomass in accordance with social requirements (e. g. for climate protection or for the provision of system services). To this end, methods for evaluating the technical, ecological, social and economic effects of the use of biomass as an energy source are being further developed in the research focus area “System Contribution of Biomass”. The development of dynamic scenario approaches offers a way to classify these results into different contexts. In conjunction with the existing database on current bioenergy technologies at the DBFZ, they can be used to support policy and business decision-makers.

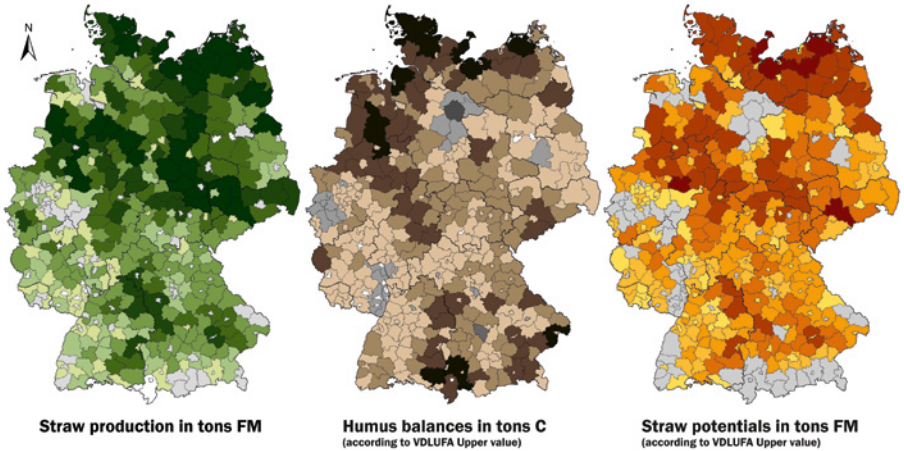

Fig. 56 Potential analyses for straw and humus in individual districts

POTENTIAL ANALYSES

In order to assess the availability of sustainable raw materials and residues, the DBFZ is developing a far-reaching model that can be used to calculate regional, national and international biomass potential for energy production. Tools employed include geographic information systems (GIS) to localise biomass potential. Scenarios are then developed in conjunction with the latest statistics, official geo-databases and freely available geo-data. Alongside freely accessible information, a joint project enables numerous individual topics to be covered in order to meet the specific needs of the client.

Additional information (german language):
www.dbfz.de/biomassepotenziale

12 CONTACTS

GENERAL MANAGEMENT

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Administrative Managing Director

Dipl.-Kfm. (FH), LL. M. Daniel Mayer
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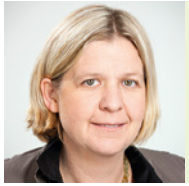
HEADS OF THE RESEARCH FOCUS AREAS



Systemic Contribution of Biomass

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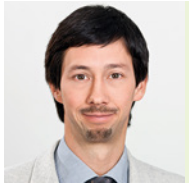

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13 PROJECTS AND PUBLICATIONS

The most important projects and publications from 2017 are listed to show the current working areas of the DBFZ. The language of the title reflects the language of the project/publication.

PROJECTS (SELECTION)

Federal Ministry of Food and Agriculture (BMEL)

AquaMak – Aquatische Makrophyten – ökologisch und ökonomisch optimierte Nutzung – Teilvorhaben 3: Konservierung aquatischer Makrophyten zur ganzjährigen Nutzung für die anaerobe Vergärung, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.10.2014–30.09.2017 (FKZ: 22401914)

BE20PLUS – BIO E Bioenergie – Potenziale, Langfristperspektiven und Strategien für Anlagen zur Stromerzeugung nach 2020, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.11.2017–31.10.2019 (FKZ: 22404016)

BetEmBGA – Betriebsbedingte Emissionen an Biogasanlagen, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.02.2015–31.07.2018 (FKZ: 22020313)

BiogasFingerprint – Verbundvorhaben: Flexible Steuerung der Biogasproduktion mittels bioinformatischer Populationsanalyse, Teilvorhaben 2: Flexible Steuerung eines Pfropfenstromfermenters mit nachgeschaltetem Rührkesselfermenter, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.02.2015–31.01.2018 (FKZ: 22009114)

Bio-Mini – Verbundvorhaben: Entwicklung einer marktnahen emissionsarmen Biomasse-Kleinstfeuerung für Niedrigenergie- und Passivhäuser; Teilvorhaben 1: Feuerungstechnische Entwicklung (Gesamtkonzept) und Charakterisierung einer Biomasse-Kleinstfeuerung für Niedrigenergie- und Passivhäuser, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.10.2017–30.09.2019 (FKZ: 22025816)

BioRestMon – AG Biomassereststoffmonitoring, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.07.2016–30.06.2018 (FKZ: 22019215)

BioRexWiVe – Verbundvorhaben: Entwicklung und Demonstration eines bio-kraftstoffbetriebenen Range-Extender-Systems zur Reichweitenverlängerung elektrisch betriebener Nutzfahrzeuge im Wirtschaftsverkehr; Teilvorhaben 1: Biokraftstoffe, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.12.2016–31.05.2018 (FKZ: 22401315)

BKSQuote – Untersuchungen zur Ausgestaltung der Biokraftstoffgesetzgebung, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.06.2016–31.01.2018 (FKZ: 22401416)

BMPIII – Biogas-Messprogramm III: Faktoren für einen effizienten Betrieb von Biogasanlagen; Teilvorhaben 1: Energiebilanzierung, Flexibilisierung, Ökonomie, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.12.2015–30.11.2018 (FKZ: 22403515)

CARBOWERT – Einsatz der Hydrothermalen Carbonisierung (HTC) für die nachhaltige Behandlung und Verwertung von Fraktionen des Sanitärsektors im Sinne eines Biochar/Swechar-Konzeptes, Bundesministerium für Ernährung und Landwirtschaft/Bundesanstalt für Landwirtschaft und Ernährung, 01.10.2013–30.04.2017 (FKZ: 2815600211)

ChinaRes – Energetische Nutzung landwirtschaftlicher Reststoffe in Deutschland und China; Teilvorhaben 1: Erarbeitung von Konzepten für zukünftige Biogasanlagenbetreiber, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 15.08.2017–31.10.2020 (FKZ: 22025816)

DKA2 – Diesel Kat Aging II – Verbundvorhaben: Schnelltest zur Alterungsnachstellung von Dieselabgaskatalysatoren im Betrieb mit Biokraftstoffen; Teilvorhaben 1, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V./Forschungsvereinigung Verbrennungskraftmaschinen (FVV) e. V., 01.10.2014–31.12.2017 (FKZ FNR: 22014514; FKZ FVV: 6011792)

eMikroBGAA – Effiziente Mikro-Biogasaufbereitung; Teilvorhaben 2: Potenzialabschätzung und betriebswirtschaftliche Bewertung für MikroBGAA, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.11.2015–31.10.2017 (FKZ: 22401615)

HYTORF – Herstellung von Torfersatzstoffen auf Basis der hydrothermalen Umwandlung aus

Landschaftspflegematerial, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.11.2017–31.10.2018 (FKZ: 22009916)

Isotop Biogas – Überwachung von Biogasanlagen mittels der Analyse von Verhältnissen stabiler Isotope; Teilvorhaben 3: Referenzversuche zur Verifizierung des Isotopenuntersuchungskonzeptes und Entwicklung einer Zustandsklassifizierung, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.09.2014–31.08.2017 (FKZ: 22013113)

KOMBIOPT – Energiemanagementsystem zur kombinierten Nutzung erneuerbarer Energien, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.02.2015–31.07.2017 (FKZ: 22403113)

Krobio – MakroBiogas Analyse der gesamtökonomischen Effekte von Biogasanlagen – Wirkungsabschätzung des EEG, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.10.2017–30.09.2018 (FKZ: 22406717)

LemnaGas – Energieerzeugung aus aquatischen Biomassen am Beispiel der Co-Kultivierung von Wasserlinsen und Cyanobakterien; Teilvorhaben 2: Konservierung und Konversion der aquatischen Biomassen zu Biogas, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.08.2014–31.07.2017 (FKZ: 22401514)

LF Flex – Leitfaden Flexibilisierung der Strombereitstellung von Biogasanlagen, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.11.2017–30.04.2019 (FKZ: 22402615)

MetHarmo – ERA-NET Bioenergy: Europäische Harmonisierung von Messmethoden zur Bestimmung von Methanemissionen aus Biogasanlagen; Teilvorhaben 1: Einsatz, Optimierung und Harmonisierung von Vor-Ort und Fernmessmethoden durch vergleichende Emissionsmessungen an einer Biogasanlage in Deutschland, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.03.2016–28.02.2018 (FKZ: 22403215)

MPell – Kleinpellets – Grundlegende Voruntersuchungen zum Einsatz kleiner Holzpellets in Pelletöfen zur Emissionsminderung, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.08.2016–31.07.2017 (FKZ: 22404615)

NiCo – Spurenelemente durch Energiepflanzen – Stoffströme und Handlungsempfehlungen für eine optimierte Prozessbiologie in Biogasanlagen, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.12.2014–30.06.2018 (FKZ: 22019114)

OptiFlex – Optimierung des Betriebs und Design von Biogasanlagen für eine bedarfsgerechte, flexibilisierte und effiziente Biogasproduktion unter Berücksichtigung der Prozessstabilität als Post-EEG Strategie, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.10.2017–30.09.2020 (FKZ: 22401717)

REFAWOOD – ERA-NET Bioenergy: Ressourceneffiziente Brennstoffadditive zur Verringerung der verbrennungstechnischen Probleme bei der Rest- und Gebrauchtholzverbrennung, ERA-NET/Fachagentur Nachwachsende Rohstoffe e. V., 01.04.2016–31.03.2019 (FKZ: 22404215)

SenSTEF – Sensorgestützte Verbrennungsluftregelung zur Minimierung der Emissionen von Biomasseheizkesseln, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.05.2015–31.05.2017 (FKZ: 22037314)

STM-DE – Auktionsmodell für eine nachhaltige Nutzung von Stroh in Deutschland, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.10.2017–31.05.2018 (FKZ: 22027216)

SubEval – Verbundvorhaben: Bewertung von Substraten hinsichtlich des Gasertrags – vom Labor zur großtechnischen Anlage; Teilvorhaben 1: Durchführung der Labor- und Praxisversuche, Bundesministerium für Ernährung und Landwirtschaft/Fachagentur Nachwachsende Rohstoffe e. V., 01.10.2015–30.09.2018 (FKZ: 22034614)

Federal Ministry for Education and Research (BMBF)

BBCHEM – Aufwertung von kohlenhydrathaltigen Stoffströmen zu bio-basierten Chemikalien. Teilvorhaben 2: Hydrothermale Umsetzung, Bundesministerium für Bildung und Forschung/Projektträger Jülich, 01.03.2016–31.08.2018 (FKZ: 033RK031B)

BEPASO – Bioökonomie 2050: Potenziale, Zielkonflikte, Lösungsstrategien, Bundesministerium für Bildung und Forschung/Projektträger Jülich, 01.12.2016–30.11.2019 (FKZ: 031B0232B)

BIONET – Int. Ausschreibung zur Ausarbeitung und Einreichung von drei EU-Anträgen zum thema BioE und BioÖk, Bundesministerium für Bildung und Forschung/Deutsches Zentrum für Luft- und Raumfahrt, 01.07.2016–30.06.2018 (FKZ: 01DS16030)

BIOSOL – Entwicklung und Demonstration eines hybriden CSP-Biomassevergaser Systems, ERA-NET MED/Bundesministerium für Bildung und Forschung/Deutsches Zentrum für Luft- und Raumfahrt, 01.10.2016–30.09.2019 (FKZ: 01DH16006A)

BiostRoh – Gewinnung strategischer Rohstoffe mittel Biomasse in Brasilien, Bundesministerium für Bildung und Forschung/Deutsches Zentrum für Luft- und Raumfahrt, 01.07.2017–31.03.2018 (FKZ: 01DN17027)

BioXfrac – Dezentrale Biomassekonversion durch Kombination innovativer thermomechanischer und biochemischer Technologien zur Gewinnung von fermentierbaren Zuckern und BioEnergie; Teilvorhaben C, Bundesministerium für Bildung und Forschung/Projektträger Jülich, 01.01.2015–31.08.2017 (FKZ: 031A438C)

CapAcidy – Bio-basierte Capron- und Caprylsäure – Herstellung, Aufreinigung, Vermarktungsstrategie, Bundesministerium für Bildung und Forschung/Projektträger Jülich, 01.07.2017–30.06.2019 (FKZ: 031B0389A)

CAROFIL – Entwicklung magnetisierbarer Filterkohlen zur hochselektiven Abscheidung von Partikeln, Bundesministerium für Bildung und Forschung/VDI-VDE-IT, 15.07.2017–14.07.2019 (FKZ: 03VNE1031C)

ESYS – Energiesysteme der Zukunft, Langfriststrategie Bioenergie, acatech – Deutsche Akademie der Technikwissenschaften, 01.09.2017–31.08.2018

HTCuPH – Spitzencluster BioEconomy: TG 4, Bioraffinerie zur integrierten hydrothermalen Produktion von Brennstoff sowie der Grundchemikalien Phenol und Furan aus Biomasse, Bundesministerium für Bildung und Forschung/Projektträger Jülich, 01.11.2014–30.09.2017 (FKZ: 031A445A)

HYBE – Entwicklung einer innovativen Hybridanlage für erneuerbare Energien basierend auf einer Kombination von Biomasse und Solarenergie und Entwicklung von fundierten Kenntnissen als Voraussetzung zur Anwendung in Ägypten und Marokko, ERA-NET MED/Bundesministerium für Bildung und Forschung/Deutsches Zentrum für Luft- und Raumfahrt, 01.10.2016–30.09.2018 (FKZ: 01DH16005C)

KomBiChem^{PRO} – Demonstrationsvorhaben: Fein- und Plattformchemikalien aus Holz durch kombinierte chemisch-biologische Prozesse; Teilvorhaben B, Bundesministerium für Bildung und Forschung/Projektträger Jülich, 15.11.2015–14.05.2018 (FKZ: 031B0083B)

MaiD – Entwicklung eines Verfahrens zur Maisspindelernte sowie Erzeugung eines auf Naturmaterial basierenden Einblasdämmstoffes, Bundesministerium für Bildung und Forschung/Projektträger Jülich, 01.09.2016–31.05.2017 (FKZ: 031B0258)

MKMeiler – Entwicklung eines ausgereiften Mehrkammerbiomeilers zur professionellen Wärmeerzeugung und Kompostgewinnung, Bundesministerium für Bildung und Forschung/Projektträger Jülich, 01.09.2016–31.05.2017 (FKZ: 031B0244)

NEUWERT – stadtPARTHEland, Bundesministerium für Bildung und Forschung/Projektträger Jülich, 01.09.2014–31.08.2019 (FKZ: 033L119E)

PhotoBioSense – Dual getriebener photonischer Sensor zur Überwachung von Biogasanlagen; Teilvorhaben: Validierung des Demonstrators, Bundesministerium für Bildung und Forschung/VDI Technologiezentrum GmbH, 01.01.2016–31.12.2018 (FKZ: 13N13827)

SchlauFe – kontinuierliche Schlauchfermentierung, Bundesministerium für Bildung und Forschung/Projektträger Jülich, 01.04.2017–31.12.2017 (FKZ: 031B0327)

Spitzencluster BioEconomy – TG 5, Begleitforschung: Nachhaltige wettbewerbsstrategische Handlungskonzepte und Steuerungsinstrumente des BioEconomy-Cluster in

Mitteldeutschland, TP 5.1.1, Bundesministerium für Bildung und Forschung/Projektträger Jülich, 01.07.2012–30.06.2017 (FKZ: 031A078B)

SYMOBIO – Systemisches Monitoring und Modellierung der Bioökonomie, Bundesministerium für Bildung und Forschung/Projektträger Jülich, 01.03.2017–29.02.2020 (FKZ: 031B0281C)

TREC-Donau II – Transnational Renewable Energy Cluster – Donau; Thematische Fokussierung Bioenergie, Koordination, Bundesministerium für Bildung und Forschung/Deutsches Zentrum für Luft- und Raumfahrt, 01.09.2016–31.08.2017

ZEBS – Verbundprojekt: Abgasreinigungsanlage für emissionsfreie Biomasseöfen; Teilvorhaben: DBFZ, Bundesministerium für Bildung und Forschung/Deutsches Zentrum für Luft- und Raumfahrt, 01.09.2017–28.02.2019 (FKZ: 01DN17040A)

Federal Ministry of Transport and Digital Infrastructure (BMVI)

DEMO-SPK – Forschungs- und Demonstrationsvorhaben: Einsatz von erneuerbarem Kerosin am Flughafen Leipzig/Halle, Bundesministerium für Verkehr und digitale Infrastruktur (Inhouse), 04.11.2016–30.04.2019

OpenGeoEdu – Offene Daten für Lehre und Forschung in raumbezogenen Studiengängen; Teilvorhaben e-Learning: Räumliche Verteilung von biogenen Ressourcen, Bundesministerium für Verkehr und digitale Infrastruktur/Vdl/VDE/IT + TÜV Rheinland, 01.05.2017–30.04.2020 (FKZ: 19S2007D)

Federal Ministry for Economic Affairs and Energy (BMWi)/Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)

AGRASIL – Herstellung hochwertiger poröser Silikate und Wassergläser durch kombinierte stoffliche und energetische Verwertung verschiedener SiO2-angereicherter Agrarreststoffe, Bundesministerium für Wirtschaft und Energie/Arbeitsgemeinschaft industrieller Forschungsvereinigungen “Otto von Guericke” e.V., 01.04.2015–31.03.2018 (FKZ: KF2028019ST4)

BioplanW – Systemlösungen Bioenergie im Wärmesektor im Kontext zukünftiger Entwicklungen, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.08.2016–31.03.2019 (FKZ: 03KB113A)

BioToM – Bioökonomie to Market– Konzeptphase, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 19.06.2017–11.07.2017 (FKZ: 031B0457)

CIP – Entwicklung einer kostengünstigen Wertschöpfungskette für biobasierte Olefine und Komplexnährmedien auf Basis von Insektenbiomasse für die industrielle Anwendung, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.10.2017–31.12.2019 (FKZ: 031B0338A)

CLEANPELLET – Entwicklung eines Verfahrens für die Erzeugung emissionsarm verbrennbarer Gärrestpellets zur Nutzung als Brennstoff für Haus- und Kleinfeuerungsanlagen, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.09.2014–31.08.2017 (FKZ: 03KB099D)

Dampf-KWK – Entwicklung eines Klein-KWK-Dampfmotors zur Nachrüstung von Feuerungsanlagen im mittleren Leistungsbereich, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.07.2016–30.06.2019 (FKZ: 03KB118A)

ELEoE – Elektrisch leitfähige Emaillierung ohne Edelmetall, Bundesministerium für Wirtschaft und Energie/Arbeitsgemeinschaft industrieller Forschungsvereinigungen “Otto von Guericke” e.V., 01.03.2015–28.02.2017 (FKZ: KF2028018AG4)

ELIRAS – Entwicklung eines Leitfadens zur Auswahl von standortspezifisch angepassten Rühr- und Substrataufschlussverfahren für Biogasanlagen, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.01.2015–31.12.2017 (FKZ: 03KB106A)

EVEREST – Entwicklung eines emissionsarmen Holzpellet Vergaserkessels mit einer kombinierten Scheitholznotfeuerung, Bundesministerium für Wirtschaft und Energie/Arbeitsgemeinschaft industrieller Forschungsvereinigungen “Otto von Guericke” e.V., 01.07.2014–31.07.2017 (FKZ: KF2028009CL3)

FermKomp – Abgestimmte Effizienzsteigerung und Emissionsminderung der Feststofffermentation mit nachfolgender Kompostierung, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.10.2014–31.03.2018 (FKZ: 03KB100A)

FlexiTorr – Flexibilisierung der Energiebereitstellung durch den Einsatz torrefizierter Brennstoffe, Bundesministerium für Wirtschaft und Energie, 09.09.2013–31.12.2017 (FKZ: 03KB091A)

HF-Technologie Abgas – Entwicklung einer innovativen Abgasnachbehandlungsanlage für Biomasse-Kleinfeuerungsanlagen unter Nutzung neuartiger Katalysatoren und dielektrischer Erwärmung, Bundesministerium für Wirtschaft und Energie/VDI/VDE IT, 01.07.2015–31.12.2017 (FKZ: 16KN041428)

HEPT – HEPT/Thermo-Chemische Vorbehandlung, Edukt- und Filtermaterial-Definition, VDI/VDE IT, 01.07.2016–31.12.2017 (FKZ: 16KN058423)

HTK-Vergärung – Gewinnung von Biogas aus Hühnertrockenkot durch psychrophile Mono-Vergärung, Bundesministerium für Wirtschaft und Energie/Arbeitsgemeinschaft industrieller Forschungsvereinigungen “Otto von Guericke” e.V., 01.07.2015–30.06.2017 (FKZ: KF2028021SB4)

ManBio – Entwicklung von technischen Maßnahmen zur Verbesserung des Gasmanagements von Biogasanlagen, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.09.2014–28.02.2017 (FKZ: 03KB094A)

MiniGas – Optimierung und Validierung von Verfahren zur kombinierten Reduktion von Feinstaub und sauren Schadgasen an Biomassefeuerungen; Teilvorhaben: Experimentelle Untersuchungen zur Kombination von SCR-u. Precoatverfahren an einem Gewebefilter, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.09.2017–31.08.2020 (FKZ: 03KB131B)

MiscPellTherm – Miscanthus-Mischpellet Brenner mit kleiner Wärmeleistung – Experimentelle Brennerentwicklung auf dem Prüfstand, Bundesministerium für Wirtschaft und Energie/Arbeitsgemeinschaft industrieller Forschungsvereinigungen “Otto von Guericke” e.V., 01.07.2014–30.06.2017 (FKZ: KF2028012ST4)

OptiMand – Optimierter Einsatz von Mühlennachprodukten zur bedarfsgerechten Bioenergieproduktion durch innovative Überwachungs-, Mess- und Regelungsmethoden, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 15.09.2016–14.03.2019 (FKZ: 03KB115A)

Pellwood – Entwicklung einer Hybrid-Kleinfeuerungsanlage unter 5 kW für Scheitholz und Holzpellets – Entwicklung des Pelletvergaserbrenners und der Verbrennungsregelung, Bundesministerium für Wirtschaft und Energie/Arbeitsgemeinschaft industrieller Forschungsvereinigungen “Otto von Guericke” e.V., 01.05.2017–31.10.2019 (FKZ: ZF4077203ST7)

ProgBeg – Programmbegleitung für das Förderprogramm zur Optimierung der energetischen Biomassenutzung, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.01.2014–31.03.2017 (FKZ: 03KB001A)

ProgBegII – Programmbegleitung des BMWi-Förderprogramms “Energetische Biomassenutzung” – Ausbau des Wissenstransfers, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.07.2016–31.12.2019 (FKZ: 03KB001B)

SCRCOAT – Optimierung und Validierung von Verfahren zur kombinierten Reduktion von Feinstaub und sauren Schadgasen an Biomassefeuerungen; Teilvorhaben: Experimentelle Untersuchungen zur Kombination von SCR- und Precoatverfahren an einem Gewebefilter, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.09.2017–31.08.2020 (FKZ: 03KB135A)

Smarkt – Bewertung des Marktpotenzials und Systembeitrags von integrierten Bioenergiekonzepten, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.09.2017–31.12.2019 (FKZ: 03KB130)

SNuKR – Steigerung des Nutzens von kleinen, biomassebefeuerten BHKWs durch bedarfsgerechte Regelung; Teilvorhaben: Entwicklung des Regelungsalgorithmus, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.07.2017–30.06.2020 (FKZ: 03KB121A)

Spitzencluster BioEconomy – TG4: Entwicklung eines Demonstrators zur emissionsarmen Bereitstellung von Prozessenergie und Elektrizität aus Reststoffen der Bioökonomie, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.03.2015–30.09.2017 (FKZ: 031A598A)

STEP – Verwertung strohbasierter Energiepellets und Geflügelmist in Biogasanlagen mit wärmeautarker Gärrestveredlung; Teilvorhaben: Verbesserung der Verbrennungseigenschaften projektspezifischer Gärreste, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.08.2016–31.01.2019 (FKZ: 03KB116B)

stROhgas – Entwicklung eines Verfahrens zur Vergasung von asche- und chlorhaltiger Biomasse am Beispiel Stroh, Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit/Projektträger Jülich, 01.08.2013–30.04.2018 (FKZ: 03KB085B)

TATBIO – Technoökonomische Analyse und Transformationspfade des energetischen Biomassepotenzials, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 10.10.2017–31.01.2019 (FKZ: 03MAP362)

ToxOAb – Optimierung der Feinstaubminderung von Abscheidern für Biomassefeuerungen unter Berücksichtigung der toxikologischen Relevanz mittels mikrobieller Testsysteme, Bundesministerium für Wirtschaft und Energie/Projektträger Jülich, 01.09.2013–31.01.2017 (FKZ: 03KB090A)

XEFOK – Entwicklung eines neuartigen Adsorbers auf der Basis von Xerogelformkörpern und Einsatz zur Reinigung von biogenen Gasen, Bundesministerium für Wirtschaft und Energie/AiF-ZIM, 01.05.2014–31.07.2017 (FKZ: KF2028020ST4)

EU projects

BECOOL – Brazil-EU Cooperation for Development of Advanced Lignocellulosic Biofuels, EU-Projekt /Horizon2020, 01.06.2017–31.05.2021 (GA 744821)

Bioenergy4Business – Uptake of solid bioenergy in European commercial sectors (industry, trade, agricultural and service sectors), EU-Projekt/Horizon2020, 01.01.2015–31.08.2017 (GA 646495)

BIOORC – Construction of cogeneration system with small to medium size biomass boilers, KIC InnoEnergy, EU-Projekt, 01.01.2015–31.03.2017 (FKZ: 13_2014_IP92_BioOrc)

BIOSURF – Unterstützung der Marktimplementierung von Biomethan, EU-Projekt/Horizon2020, 01.01.2015–31.12.2017 (GA 646533)

DEMETER – Demonstrating more efficient enzyme production to increase biogas yields, EU-Projekt/Horizon2020, 01.08.2016–31.07.2019 (GA 720714)

HTCHANF – Torf aus Hanf, VOFA Vogtlandfaser GmbH & Co. (FKZ: 2016LFE0014)

HyFlexFuel – Hydrothermal liquefaction: Enhanced performance and feedstock flexibility for efficient biofuel production, EU-Projekt/Horizon2020, 01.10.2017–30.09.2020 (GA 764734)

GRAIL – Glycerol Biorefinery Approach for the Production of High Quality Products of Industrial Value, EU-Projekt, 01.11.2013–31.10.2017 (GA 613667)

RecordBiomap – Research Coordination for a Low-Cost Biomethane Production at Small and Medium Scale Applications, EU-Projekt/Horizon2020, 01.04.2016–30.09.2018 (FKZ: GA 691911)

STAR-ProBio – Sustainability Transition Assessment and Research of Bio-based Products, EU-Projekt/Horizon2020, 01.05.2017–30.04.2020 (GA 727740)

Service/Contract research

Advanced adfuels – Abschätzung der Potenziale fortschrittlicher Biokraftstoffe, VDB Verband der Deutschen Biokraftstoffindustrie e.V., 11.09.2017–30.11.2017

ADIndia – Assessment of the status quo of the implementation and potentials of Anaerobic Digestion in India, Marktprojekt, 01.01.2017–31.12.2017

AuV Holz – Analyse und Verbrennung von Holzpelletchargen, Georg-August-Universität Göttingen, 04.12.2017–26.01.2018

BGA-H_2S – Ermittlung des H_2S-Gehaltes in Behältern von Biogasanlagen an Praxisanlagen, Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie, 01.11.2015–31.05.2017

BiokolAB – P-Verhalten während Klärschlamm-HTC, Biokol Sverige AB, 14.02.2017–31.05.2017

BIOWEISS – Bewertung zukünftiger Anlagenkonzepte für das Kompostwerk Weißenfels, AW SAS-AöR, 17.06.2017–31.12.2017

CoFire2 – Begutachtung von Biowärme aus Mitverbrennung von Biomasse in konventionellen Heizkraftwerken, Vattenfall Europe Wärme AG, 01.01.2014–31.08.2019

FLEXFEED – FlexFW Bewertung des Potenzials bedarfsgerechter Fütterung an der BGA Kompostwerk Weißenfels, Bio Komp-SAS GmbH, 11.08.2017–28.02.2018

GREENGAS – GGCert GreenGasCertification, University College Cork, 19.04.2017–18.04.2018 (IERC_2017_002)

HemBio – Aktuelle Entwicklung und Perspektiven der Biogasproduktion aus Bioabfall und Gülle, Umweltbundesamt, 01.10.2017–30.04.2018

IEA Task 37 – Energy from Biogas: Report on Methane Emissions from Biogas plants, University College Cork, 20.09.2016–31.12.2018

IEA Task 39 – Study on Survey on Advanced Fuels for Advanced Engines, Hochschule Coburg, 01.05.2017–01.01.2018

IEAtrade – Sustainable Biomass Markets and International Trade to support the biobased economy, IEA Bioenergy Task 40, 01.05.2013–31.12.2017

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KvaliN – Implementation of capacity building measures for introduction of EU aligned testing services in Serbia, GIZ GmbH (Inhouse), 07.07.2017–31.10.2017

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MethBos2 – Bioenergy Component – Advisory for biomass potential map development in Bosnia and Herzegovina, GIZ GmbH, 05.09.2017–30.08.2018

MOVE – Megatrends für Mobilität und Verkehr, IAV GmbH, 07.08.2017–15.10.2017

PELI18 – Analyse und Bewertung von 18 Holzpelletchargen, Georg-August-Universität Göttingen, 27.02.2017–20.05.2017

Plausi – Plausibilitätsprüfung einer Studie für die Beschaffung von Biomasse, Uniper Technologies GmbH, 15.09.2017–15.10. 2017

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TF_EW – Technologiebewertung für Biomasse und Power-to-gas (biologische Methanisierung), Wuppertal Institut für Klima, Umwelt, Energie gGmbH, 01.08.2016–31.01.2018

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