Karlsruhe Institute of Technology

Institute for Industrial Production

Annual Report 2021

Chair of Business Administration, Production and Operations Management




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Preface

This annual report from the Chair of Business Administration, Production and Operations Management at the Institute for Industrial Production (IIP), Karlsruhe Institute of Technology (KIT) highlights our main activities during the year 2021. Our three research groups "Sustainable Value Chains", "Risk Management", and "Project and Resource Management in the Built Environment" have conducted numerous projects on a regional, national and international level covering a broad range of topics. The team of the Chair consists of about 24 researchers, 4 administrative staff and a several student assistants.

[1]

During 2021, we worked on 20 third party funded research projects. We published 22 peer-reviewed journal papers, numerous articles in conference proceedings and book chapters. 4 PhDs and 1 Habilitation were completed. Teaching activities resulted in around 700 exams and about 80 bachelor and master theses were supervised. Though, due to the Corona pandemic our international collaborations were limited in 2021, we managed to deepen our national and international networks.

We hope that this report inspires your interest in our activities. Any comments are welcomed. We look forward to future collaborations around our research and teaching activities.

Prof. Dr. Frank Schultmann,

[1] Disclaimer: this picture has been taken in 2019. All following pictures have been taken considering the infection protection laws at the time.

Sustainable Value Chains

Head of research group: Dr. Simon Glöser-Chahoud

The research group *Sustainable Value Chains* develops strategies for a more sustainable design of value chains and production systems as well as the affiliated logistical, organisational and information related functions. In this context, sustainability is defined as the joint consideration of economic, ecological and social aspects. Major areas of research are related to circular economy concepts regarding both material or product cycles (closed-loop supply chains, reverse logistics) and the use of renewable, bio-based resources in industrial value chains (bioeconomy).

To cope with the related manifold problems, different approaches from economics, engineering as well as environmental and social sciences are implemented, adapted and enhanced. Methods and models are developed based on the regarded problems and transferred to specific applications.

A focus task is the development of computational planning models that enable an integrated analysis, assessment and optimization of material streams, complex interconnected plants or complete production networks. Other considered aspects are empirical stakeholder and acceptance analyses and policy advisory.

A further aim of our work is the development of sustainable concepts for material flow management and for decision support at regional, national and global scale. The research focus is currently on industrial plants, products and networks of the metal, energy, chemical and automotive industry as well as on the utilization of biomass.

Typical methods in use are:

- investment and production cost estimation, investment decision making
- operations research based modelling (optimization and simulation)
- empirical social studies (especially questionnaire-based surveys and statistics)
- Life Cycle Assessment (LCA), Life Cycle Costing (LCC), environmental impact assessment

Members of the research group (from l. to r.): Paul Heinzmann, Raphael Heck, Tobias Zimmer, Simon Glöser-Chahoud, (Marina Maier), Andreas Rudi, Sonja Rosenberg, Sandra Huster, Nina Treml (missing).

Risk Management

Head of research group: Dr. Marcus Wiens

The Risk Management Research Group works on scientific research questions and practice-relevant problems in the area of Risk Management with a special focus on systemic risks, behavioral risks, critical infrastructure and supply chains. The applied methods comprise economic modelling (in particular, OR and game theory), empirical approaches (e.g. surveys) and simulation studies (e.g. agent-based simulations).

Also, in the Risk Management Group, the year 2021 was still characterized by the Corona pandemic, so that again most meetings took place virtually. However, a final workshop of the PREVIEW project took place in September 2021, at which the previous research results of the project were presented in order to ensure the transfer of knowledge from previous work. It was organized as an interactive, hybrid format with interested parties from research, business and authorities. In addition, the project is extended by six months so that the work can be continued until February 2022. The continuous validation of the research results was pursued through publications and the participation of international conferences.

Despite the constraints, the Corona crisis proved to be an unexpected boost for the NOLAN project. The consortium was given the opportunity to extend the project for one year with full funding. Public-Private Emergency Collaboration (PPEC) remains the main topic in the extension phase with increased consideration of the experience gained in the Corona context. In addition, various final components of the project were initiated with a view to the foreseeable end of the project in 2022. At the end of November, a digital transfer workshop was held with experts, at which project results were presented. Moreover, a website, a brochure and a short video were developed to present the project results in different ways.

The DFG-ANR funded project INCA studying cross-border resilience was successfully completed already in August 2020. However, a track on transboundary resilience which was planned for the ISCRAM-conference in 2020 shifted to this year's conference due to Corona. Thus, in May 2021 the INCA consortium organized jointly with two Swedish researchers a successful track with interesting presentations and fruitful discussions. The project partners will continue their cooperation on the topic of transboundary resilience.

Moreover, the risk management research group is closely connected to the KASTEL Helmholtz Institute, which was found in 2021. The work with the other KASTEL partners continued and was extended by experimental research in the KASTEL-research group Human & Societal Factors.

The year 2021 was also driven by change. In June, Dr. Marcus Wiens successfully completed his habilitation process and obtained the Venia Legendi in business administration. The title of the habilitation thesis is "Resilient Systems – an Economic, Operational, and Behavioral Perspective". He left the IIP in October to start as a professor in Innovation and Risk Management at the Technical University of Freiberg. The Risk Management Research Group deeply thanks him for his commitment as the head of the group over the past years, sincerely congratulates him on the professorship and wishes him all the best for the future. Furthermore, in March Florian Diehlmann successfully completed his PhD with a thesis on "Facility Location Planning in Relief Logistics: Decision Support for German Authorities" and in October, Miriam Klein also successfully completed her PhD with a thesis on "Cross-Border Collaboration in Disaster Management". The Risk Management Research Group warmly congratulates Florian and Miriam for the great achievements.

Members of the research group (from l. to r.): Rebecca Wehrle, Francois Nyobeu, Markus Lüttenberg, Marcus Wiens, Florian-Klaus Kaiser, Miriam Klein, Florian Diehlmann, (Farnaz Mahdavian).

Project and Resource Management in the Built Environment

Head of research group: Dr. Rebekka Volk

The Project and Resource Management in the Built Environment (PRM) group carries out technical, economic and environmental model-based analysis of energy-efficient, resource-efficient technologies and renewable/sustainable policies , as well as their potentials regarding the built environment. Especially in the fields of deconstruction and circular economy, decommissioning and dismantling of nuclear facilities, sustainable urban development, energy and resource efficiency in industrial processes, buildings and urban districts and the use of renewable energies in buildings, research projects are currently being worked on.

To offer decision support for different planning activities on consumer/user perspective, building level, district, regional or national level, several optimization models have been developed and employed, among others the AWOHM model, the ECCO models for greenhouse gas quantification in value chains and the ResourceApp and MogaMaR/NukPlaRStoR models for optimized (nuclear) decommissioning project planning. AWOHM is an agent-based simulation model for the German residential building stock, the building stock's energetic quality and technical equipment as well as its owners and residents to identify economically feasible retrofit options and the resulting national greenhouse gas emissions. The ResourceApp, MogaMaR and NukPlaRStoR models are linear optimization models for robust project planning under resource constraints and uncertainty particularly for deconstruction and decommissioning of buildings and structures. While the ResourceApp model is focusing on residential and non-residential buildings, MogaMaR and NukPlaStoR are addressing nuclear power plants and facilities and include large-scale projects and optimize material flows. This year, the MogaMaR/NukPlaRStoR model was transferred to a new software product called OPTIRA and won the 3. KIT transfer price of the innovation office. Furthermore, we work on the planning and decision support model namares for a sustainable urban development on district level together with the city administration Karlsruhe and other key stakeholders. Key aspects are the sustainable and efficient resource usage and management with a focus on land use, water, ecosystems and materials. Other models that are currently developed include the detection and analysis of thermal bridges in buildings and leaks in district heating networks. As well, we analyse current and emerging recycling technologies and supply chains with respect to more resource efficient (recyclable and/or CO_2-reduced) building materials and products, ranging from steel, aluminium, autoclaved aerated concrete (research project REPOST) to different types of plastics (research projects Kreislaufwirtschaft für Kunststoffe, Rückbau und Recyclingstandards für Rotorblätter). In these projects, we analyse processes and production methods, new production technologies and assess the whole supply chains and material flow systems for decision support. Furthermore, we perform location, capacity and logistics planning based on economic and ecological factors.

Typical methods used in the PRM group are:

- agent-based modelling to identify cost-efficient renewable energies' potentials in residential building stocks and municipalities,
- model-based material stock/flow and life cycle analyses and
- automated image processing to identify potential cost savings of heat and cooling losses,
- techno-economic assessments and scenario analyses,
- project management optimization methods.

Members of the research group (from l. to r.): Mihir Rambhia, Christoph Stallkamp, Marco Gehring, Rebekka Volk, Zoe Mayer, Elias Naber, Justus Steins (missing in the picture: Elena Vollmer, Niklas Braun, Simon Steffl).

Research Projects

CEDIM – Center for Disaster Management and Risk Reduction Technology

Marcus Wiens & group members

Partner: Geodetic Institute (GIK), Geophysical Institute (GPI), Institute of Applied Geosciences, Institut für Finanzwirtschaft, Banken und Versicherungen (FBV), Institute for Hydromechanics (IfH), Institute for Industrial Production (IIP), Institute for Nuclear and Energy Technologies (IKET), Institute of Concrete Structures and Building Materials - Materials Testing and Research Institute (MPA Karlsruhe), Institute of Meteorology and Climate Research, Institute of Photogrammetry and Remote Sensing (IPF), Institute of Regional Science (IfR), Institute for Technology Assessment and Systems Analysis (ITAS), Institute of Technology and Management in Construction, Institute of Economics (ECON), Institut für Wasser und Gewässerentwicklung

Funding: Karlsruhe Institute of Technology

Duration: since 01/2006 (ongoing)

The Center for Disaster Management and Risk Reduction Technology (CEDIM) is an interdisciplinary research center of the Karlsruhe Institute of Technology (KIT) in the field of disaster management. The main goal of CEDIM is to advance our scientific understanding of natural and man-made hazards, and to develop disaster management solutions for the early detection and reduction of the related risks.

Facing the increasing probability of extreme events and their tremendous possible impacts on societies, it is inevitable to investigate their impacts on current and future energy, mobility and information systems. This is also more than valid, facing the aspect that through the network character of those systems, extreme events lead to cascading effects along its system parts. That is why, natural disasters can have also severe impacts far away from their place of origin. The current globalization and strong interconnectedness around the world is also increasing this aspect. To assess the indirect impacts of natural events, two subprojects were implemented, dealing with supply chain vulnerability under consideration of global interconnectedness (IIP) and changed consumer mobility requests in the aftermath of a disaster (ECON).

CoBiVal – Cooperation in Bioeconomy Value Chains

Raphael Heck, Simon Glöser-Chahoud, Tobias Zimmer

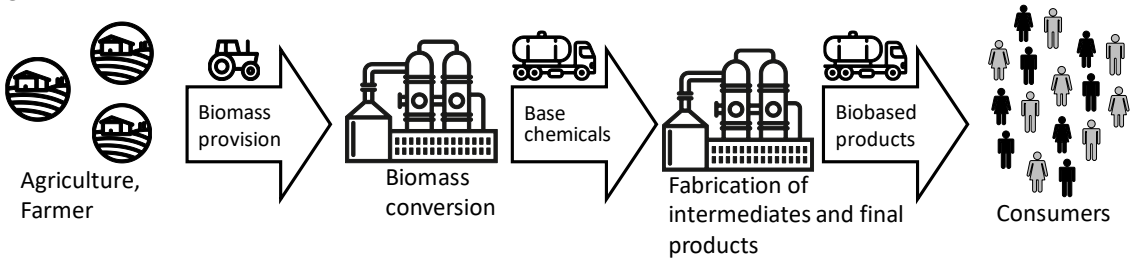
Funding: Federal Ministry of Education and Research

Duration: 2019 - 2022

Despite technical feasibility and, in some cases, a positive assessment of economic viability, bio-based processes and value chains are only implemented very slowly or not at all in practice. Classical obstacles are a lack of incentives for all actors involved in the value chain such as unequal distribution of risk or profit, high entry costs or path dependencies and a lack of flexibility. Social acceptance and general public perception of new bio-based products and technologies are also of central importance with regard to the practical implementation of innovations in a bioeconomy. Last but not least, every process, every renewable resource or raw material and every potential value chain has technical, economic and social specifics that have to be taken into account when performing a holistic evaluation.

The present research project aims at a systematic investigation and evaluation of bio-based value chains taking into account the incentives and obstacles of all actors involved. In particular, the availability of suitable biomass in sufficient quantity and quality is of central importance when establishing innovative utilization pathways. This requires new forms of cooperation and business models between agriculture and industry, which are systematically examined in this project. For this purpose, empirical studies will be carried out through expert interviews and surveys. Based on the gathered insights, optimization and simulation approaches taking into account the decision of individual actors in the value chain will be developed in order to enable a quantitative assessment of potential value creation in alternative bioeconomy value chains.

The aim of the project is primarily to identify and evaluate measures, concepts and business models with which actors can be motivated to participate in bio-based value chains in order to establish the bioeconomy as an integral element of a sustainable industrial society.



	Problem	Research question
I	Distribution of investment, risk and outcome among supply chain partners	Which share of risk and reward is acceptable for all partners in the value chain?
II	Coordination and cooperation in bioeconomy supply chains	How can transaction costs in value chains be reduced by cooperation and exchange of information?
III	Integration and implementation of bioeconomy value chains	How can the implementation and market entrance of bio-based technologies be facilitated and accelerated?
→	**Increase the participation of agents and potential partners in bioeconomy value chains**	

biomaBW – The biomass mobilization and marketing app for Baden-Württemberg

Andreas Rudi, Raphael Heck

Partner: Landesanstalt für Landwirtschaft, Ernährung und Ländlichen Raum Schwäbisch Gmünd; Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg

Funding: State Ministry of Rural Affairs, Food and Consumer Protection

Duration: 2020 - 2021

Motivation

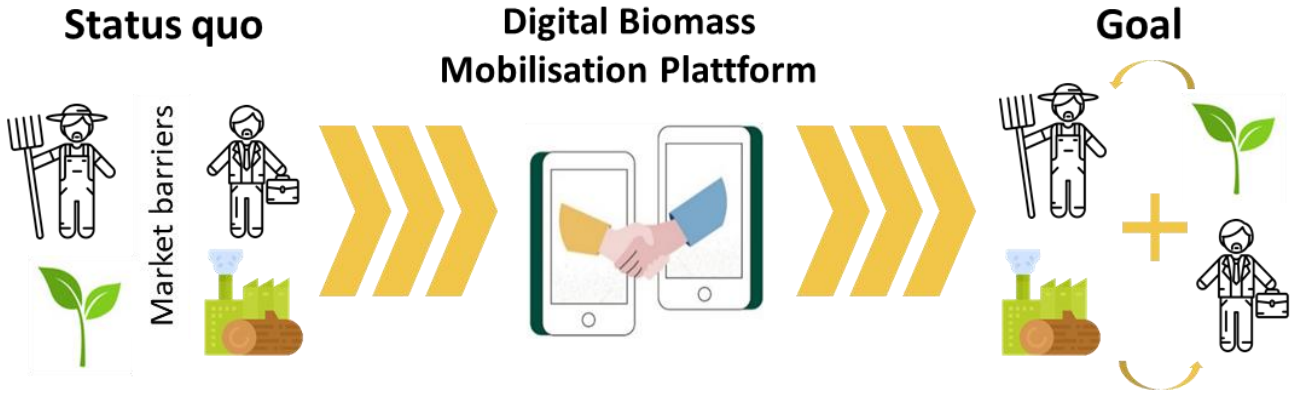
Small-scale land structures, fluctuating quantities, and trade barriers make efficient mobilization and marketing of biogenic raw materials difficult. A digital platform can uncover untapped potential and redirect existing potential. Actors in biobased value chains are thus enabled to manage raw materials and material flows intelligently, which increases efficiency, creates transparency and promotes the establishment of new utilization concepts, in particular by making forestry and agricultural (residual) materials accessible and marketing them centrally.

Solution approach

Stakeholders along biobased value chains were surveyed on the acceptance, use and participation in a digital biomass mobilization platform. Based on interview and survey results, the following were identified as the key benefits of a central platform: Creating market transparency (for new players), expanding distribution opportunities (for small players), and outsourcing trade activities (for established players). In general, experts are in favor of a platform, but point to low and fluctuating biomass volumes. Technical feasibility and economic viability are demonstrated in a business case and a platform dummy.

Outlook

A digital platform can bring actors together and thereby support the intelligent mobilization of regional biomass. This promotes a novel utilization of potentials in innovative bioeconomy concepts. The capacity for innovation is increased because actors are offered a platform to trade raw materials efficiently, to exchange information and to bring supply and demand together centrally. After the proof of feasibility, the realization of the biomass mobilization platform should be pushed in future follow-up projects.



Bringing together stakeholders in biobased value chains through a digital biomass mobilization platformform

DeMoBat – Industrielle Demontage von Batteriemodulen und E-Motoren zur Sicherung wirtschaftsstrategischer Rohstoffe für die E-Mobilität

Sandra Huster, Sonja Rosenberg, Simon Glöser-Chahoud

Partner: Fraunhofer Institut für Produktionstechnik und Automatisierung (IPA), Clausthal Research Center for Environmental Technologies (CUTEC), KIT Institut für Produktionstechnik (wbk), Hochschule Esslingen, BTU Cottbus – Fachgebiet Physikalische Chemie , Mercedes Benz AG, Siemens AG, Silberland Sondermaschinenbau GmbH, Greening GmbH & Co. KG, Erlos GmbH, acp systems AG, CTC battery technology GmbH

Funding: Ministry of the Environment, Climate Protection and Energy Sector Baden-Württemberg

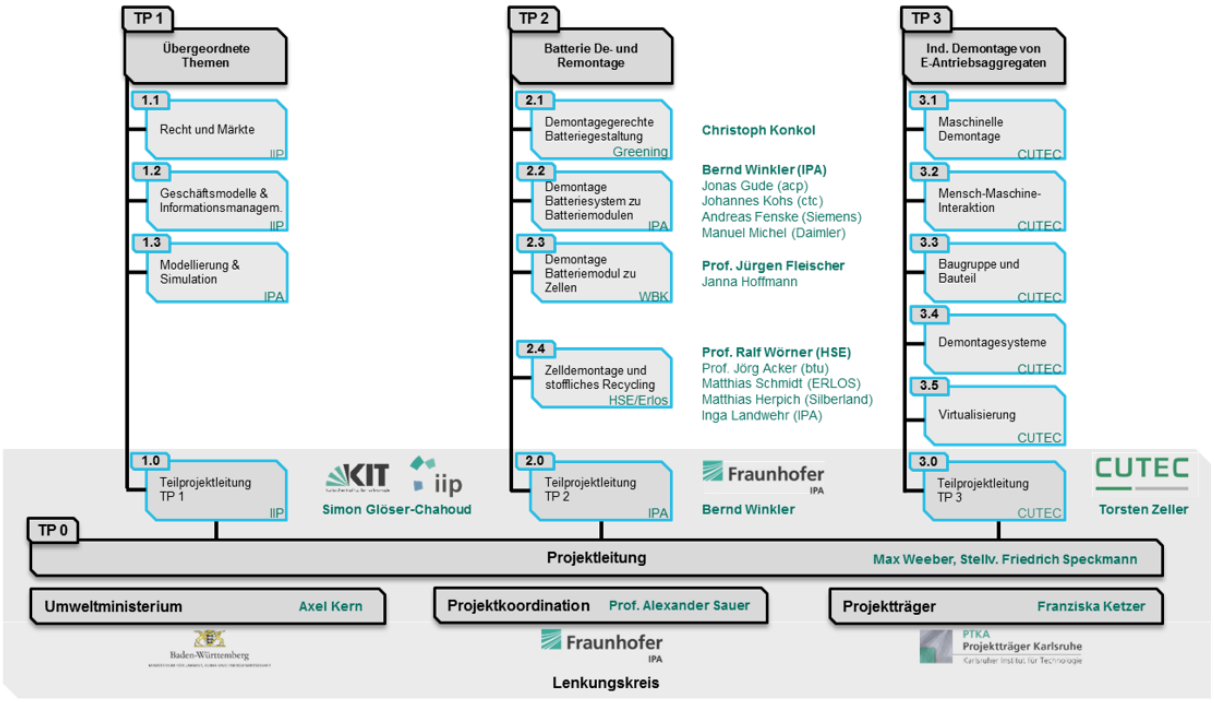
Duration: 12/2019 - 2022

The joint project DeMoBat aims to develop industrial disassembling processes for traction batteries and drive trains of electric vehicles. These processes are considered as a prerequisite for a resource-efficient and sustainable design of closed-loop supply chains for electro-mobility.

Traction batteries represent a key cost factor of electro-mobility and cause significant environmental impacts during production, which is why their most efficient and long-term use is a crucial element of the sustainable design of electro-mobility.

The targeted disassembly of battery packs into individual modules and subsequent cell level enables condition-specific uses of the battery modules or cells. A disassembling allows on the one side reassembling for second use applications, such as energy storages or automotive spare parts. On the other side, high-quality recycling of the electrode active material can be reached. The same applies to electric motors, where the rare-earth permanent magnets and copper coils are valuable components.

While the other research partners are primarily working on technical solutions for disassembling, IIP is responsible for coordinating sub-project 1. In this context, IIP evaluates raw material markets, business models, legal framework conditions, and logistics concepts, as well as capacity and sequence planning of the disassembling processes from a techno-economic perspective.



Development and evaluation of biobased value chains for Baden-Wuerttemberg

Andreas Rudi, Raphael Heck

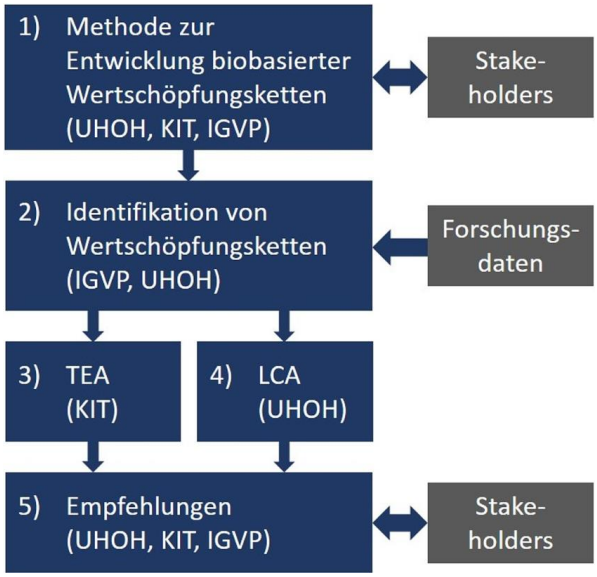
Partner: University of Hohenheim, University of Stuttgart

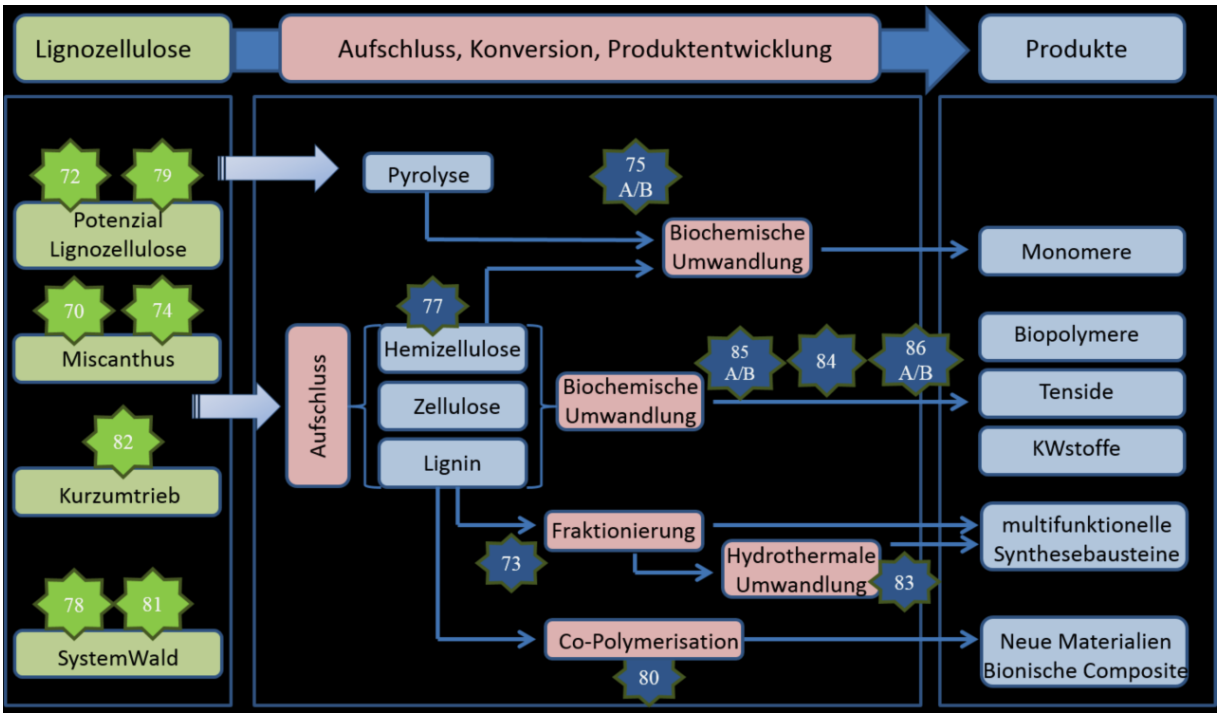
Funding: Ministry of Science, Research and the Arts

Ministerium für Wissenschaft, Forschung und Kunst Baden-Württemberg

Duration: 10/2018 - 02/2021

For the development of new bio-based products, a large number of possible process steps are available. The combination and evaluation of these possibilities is a complex undertaking, especially if process steps are to be taken into account in the trial phase. In addition to the technical feasibility, the ecological evaluation and the economic realization possibilities have to be considered with regard to the overriding goals of the bioeconomy. This project aims to develop a methodological approach that is suitable for creating bio-based value chains and analyzing them from a techno-economic and ecological perspective. Five steps are undertaken:





Entwicklung von Rückbau- und Recyclingstandards für Rotorblätter

Dr. Rebekka Volk, Simon Steffl

Partner: THINKTANK Industrielle Ressourcenstrategien, Institut für Technische Chemie (ITC) am KIT, Fraunhofer-Institut für Chemische Technologie (ICT), Baumeister Rechtsanwälte, Composites United e.V.

Funding: Umweltbundesamt (UBA)/
Federal Environment Agency (UBA)

Duration: 2020 - 2021

Wind turbines are a decisive component in achieving the goals of the energy turnaround in Germany. The number of onshore wind turbines has more than tripled in the last 20 years. In addition to the numerical development, their continuous increase in size and, closely related to this, the increasing complexity of the material composition, is of great importance. The height of wind turbines and their rotor diameters influence the possibility of a uniform energy yield and allow the development of new areas for energy conversion. This leads to the expectation that, within the scope of technical possibilities, the height and especially the rotor diameter will continue to increase in the future.

Due to their operating life and the reduction in EEG payments, wind turbines are increasingly being dismantled due to decommissioning or repowering, and this trend is expected to continue. The possibility of rebuilding disused plants in emerging markets will be made more difficult in future by their increasing size. It can therefore be assumed that new generation turbines will have to be recycled mainly in Germany. The pressure and the necessity to develop conclusive dismantling and recycling concepts for Germany's wind power plants will therefore increase considerably.

In a previous study commissioned by the Federal Environment Agency (UBA) a first, conclusive and complete dismantling and recycling concept was developed. Conceptual proposals for high-quality and complete plant recycling were developed and organisational obligations were assigned to manufacturers, operators and owners.

Figure 1: Wind park

From the perspective of high-quality recycling, composite materials - carbon fibre reinforced (CFRP) or glass fibre reinforced (GFRP) plastics - are a particular challenge. The composite materials are mainly found in the rotor blades, making them a key component in the dismantling of wind turbines. In the case of the rotor blades, it is often unclear which materials were used because of the large number of makes. Especially with longer rotor blades, one must always expect to find layers of CFRP. In the UBA study mentioned above, these composite materials play only a minor role. In the next few years, however, the increasing proportion of CFRP-containing waste will pose a particular challenge for health and environmental protection reasons during dismantling, shredding and processing, and as a disruptive factor for the established recycling of CFRP and due to the ultimate lack of safe disposal. Here, too, the organisational responsibility for the highest possible quality recycling plays an important role.

EU-Tender

"Technical assistance to assess the potential of renewable liquid and gaseous transport fuels of non-biological origin (RFNBOs) as well as recycled carbon fuels (RCFs), to establish a methodology to determine the share of renewable energy from RFNBOs as well as to develop a framework on additionality in the transport sector."

Simon Glöser-Chahoud, Manuel Ruppert, Paul Heinzmann, Uwe Langenmayr

Partner: Guidehouse, Fraunhofer ISI, ESA², TU Wien

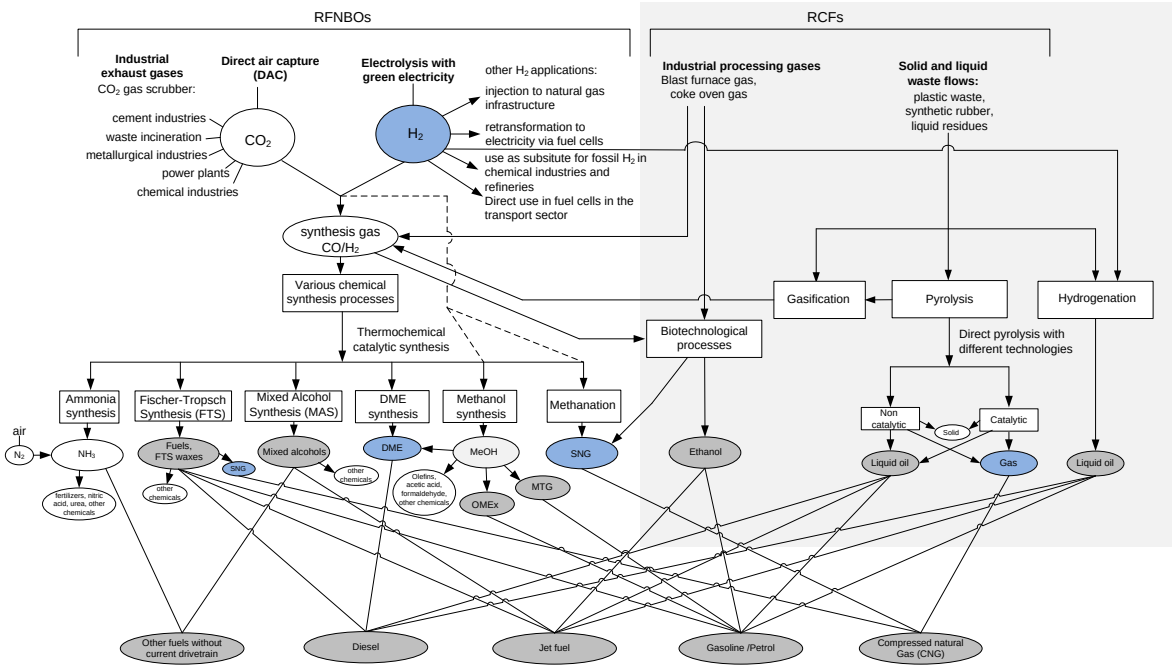
Funding: European Commission, DG ENER

Duration: 07/2020 – 07/2021

The general objective of the contract research is to obtain detailed information on the potentials of renewable fuels of non-biological origin (RFNBOs) and recycled carbon fuels (RCFs) in the EU from 2021 onwards. Producers of RFNBOs need a framework enabling to provide evidence that the renewable electricity used in the production of their fuel is of renewable origin. Subsequently the project develops a general framework to measure the additionally of electricity in the EU transport sector, which is required in the revised version of the Renewable Energy Directive (RED II).

The specific objectives of this contract research are to assist the Commission in:

- Assessing the potential of renewable liquid and gaseous transport fuels of non-biological origin as well as recycled carbon fuels, as defined in REDII, over the period 2020 to 2050 in the transport sector in the EU (task 1).
- Development of detailed rules by which producers of renewable liquid and gaseous transport fuels of non-biological origin can provide evidence that they are using renewable electricity in the production of their fuel in order to establish the methodology under Article 27, paragraph 3, subparagraph 7 of REDII (task 2).
- Developing a framework on additionality in the transport sector and the identification of different options to determine the baseline for EU Member States in accordance with Article 27, paragraph 3, subparagraph 3 of REDII



Leuchtturmprojekt Kreislauf für Kunststoffe

Dr. Rebekka Volk, Christoph Stallkamp

Partner: Institut für Technische Chemie (ITC) am KIT, Audi AG, VW Originalteilelogistik (OTLG)

Funding: THINKTANK Industrielle Ressourcenstrategien, Land Baden-Württemberg

Duration: 01/2020 - 06/2022

Worldwide, the production of plastics is increasing and with that the dependence on crude oil and secondary plastics. The amount of plastic waste has also increased in recent years. The German recycling figures remain at a constantly low level. In contrast, there have been considerable changes in the market for plastic waste: Changed import regulations in China influence the price, supply and demand structure, and Germany and the EU are calling for further steps towards a circular economy by tightening the political framework conditions. This is reflected in an increase in recycling quotas for plastic packaging.

The establishment of a closed-loop economy for plastics offers the opportunity to improve competitiveness and resource efficiency. The finite nature of primary raw materials is countered and a reduction in energy consumption contributes to climate protection.

The aim of the project is to compare different recycling technologies regarding economic and environmental indicators and derive implications for a circular economy for plastics. The focus is on the waste fraction of lightweight packaging and its standard thermoplastics , as well as the automotive sector with its engineering thermoplastics.

In particular, the option of raw material recovery of currently unused plastic waste fractions as raw materials for chemical recycling processes are investigated. A special focus lies on the pyrolysis of plastic waste to provide feedstock for the petrochemistry and to replace fossil raw materials (crude oil). The assessment includes a assessment of the recycling paths by mapping the waste volume in Germany.

Figure 2: Sorting of lightweight plastic packaging waste

On basis of a national model for Germany, the following desired effects of potential actions should be investigated: (1) the reduction of the use of fossil raw materials, (2) the reduction of greenhouse gas emissions, and (3) economic advantages compared to the current status quo.

Figure 3: Pyrolysis condensate from different plastic waste fractions

The project is located in the THINKTANK Industrial Resource Strategies at KIT, which was established by the state government of Baden-Württemberg in cooperation with industry and science. Its focus is the holistic view on technological-strategic questions of resource efficiency, resource use, and resource policy.

The assessment of chemical recycling options is performed in cooperation with the Institute of Technical Chemistry (ITC) at KIT. At the ITC, the

selected material flows are investigated, experiments are performed and data is collected on chemical recycling options, and thus the technical feasibility is demonstrated.

Audi and Volkswagen OTLG support the subproject "Chemical recycling of plastics from automotive engineering" by providing plastic components that are no longer needed as well as data for the assessment. The successful cooperation in the subproject "Chemical recycling of plastics from automotive engineering" lead to the subsequent project "PlasticLoop" together with Audi, Volkswagen OTLG, lyondellbasell and KIT/ITC. Here, the focus is on the proof-of-concept and assessment of chemical recycling of automotive shredder residues.

Lignocellulose Biorefinery for the Bioeconomy in Baden-Wuerttemberg

Andreas Rudi, Raphael Heck, Simon Glöser-Chahoud

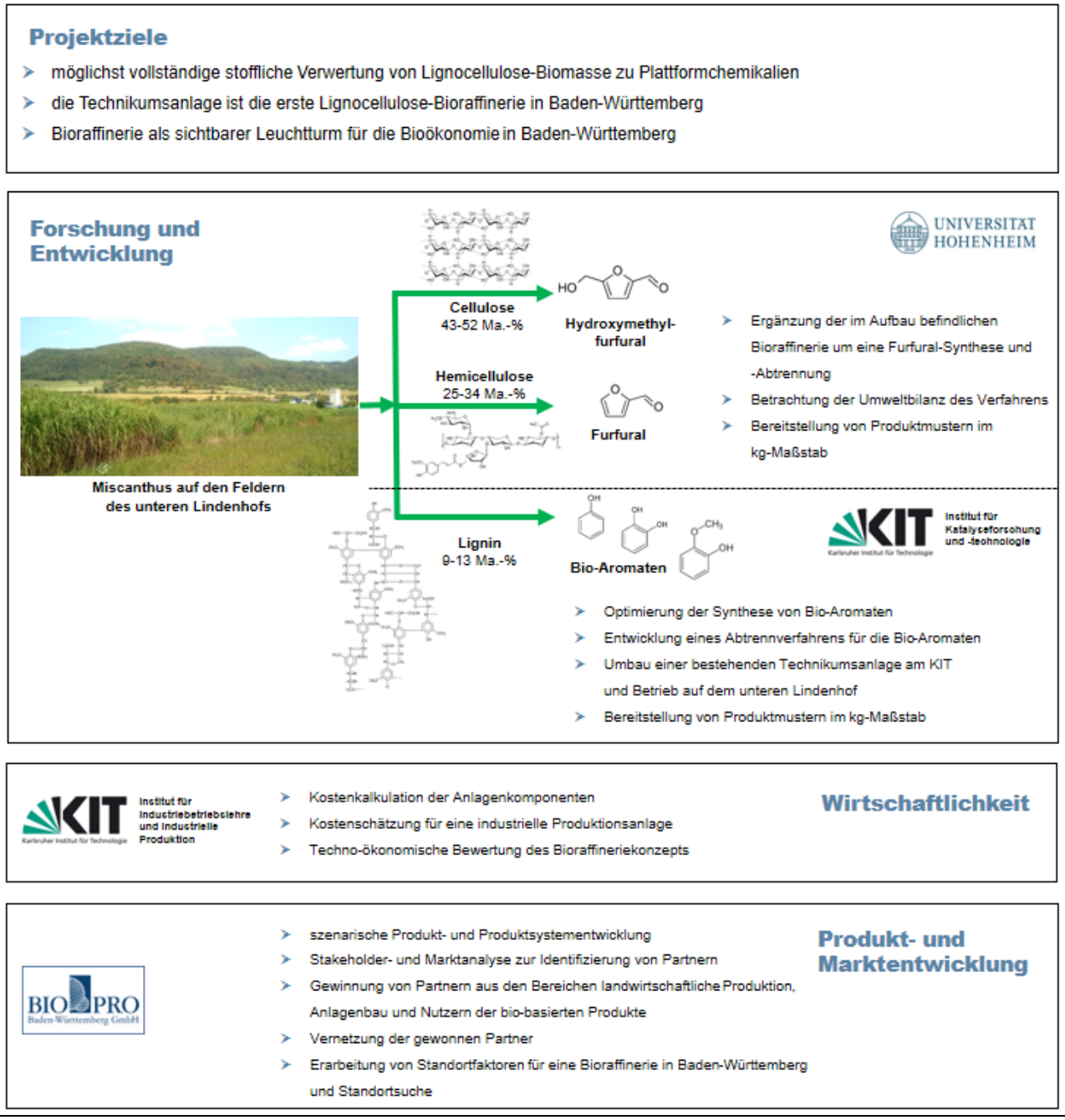
Partner: Institut für Katalyseforschung und -technologie (IKFT-KIT), University of Hohenheim, BIOPRO GmbH

Funding: Ministry of Science, Research and the Arts

Ministerium für Wissenschaft, Forschung und Kunst Baden-Württemberg

Duration: 10/2018 - 09/2020

The aim of the project is to set up and operate a complete lignocellulose utilisation chain in the biorefinery pilot plant "Bioraffinerie-Technikum" on the site of the "Unterer Lindenhof" experimental station at the University of Hohenheim. Within the framework of a modular plant, the complete recycling of lignocellulosic biomass into platform chemicals will be demonstrated.



namares
– Resource management in urban districts in the context of sustainable urban development

Dr. Rebekka Volk, Elias Naber

Partner: Karlsruhe city administration (Stadtplanungsamt und Amt für Umwelt- und Arbeitsschutz der Stadt Karlsruhe), Smart Geomatics Informationssysteme GmbH, Netzwerk für Planung und Kommunikation Sippel.Buff, KIT – Lehrstuhl Ökologie und Ökonomie im Wohnungsbau (ÖÖW), KIT - Institut für Angewandte Geowissenschaften (AGW), KIT - Kompetenzzentrum für Materialfeuchte (CMM)

Funding: BMBF - funding code: 033W111A

Duration: 04/2019 - 06/2022

The project aims at developing a support tool for urban resource management, which enables city administrations and other actors to monitor the use of natural resources (here: land, water, materials) at district level and to establish active resource management. To manage (natural) resources efficiently, their use must be measured and evaluated. On this basis, the need for action can be identified, measures can be designed and targeted goals can be monitored. For this purpose, an assessment scheme with relevant fields of interest and subordinate indicators will first be developed. Subsequently, interrelationships and effects of resource use in the urban district are modelled and consequences and conflicting goals for different actors are examined. With the base of this scientific knowledge a GIS-based software tool will be developed, implemented and tested in an urban case study district in the city of Karlsruhe. This will be accompanied by transdisciplinary approaches and a guideline enabling the transfer of project results.

The desired project result is a capable GIS-based web tool for accounting and monitoring resource consumption in urban districts, which is aimed at municipal decision makers and interested citizens. The tool and an accompanying guideline should enable the transfer of the results and support sustainable decision-making processes in district management and sustainable urban transition processes.

In 2021, the modeling and integration of roof and façade areas in the inventory and potential analysis as well as the techno-economic-ecological assessment of land use represented important milestones. Additional measures added to the assessment include: extensive and intensive green roofs, energy use of roof surfaces (photovoltaics and solar thermal), ground and façade-based vertical greening, and energy use of façade surfaces using photovoltaics (see Figure 1). For these analyses, 3D building/urban models in detail level LOD2 are used, which are available for most cities and municipalities in Germany. Furthermore, the functionality and user guidance in the prototypical web application was tested by the project partners and the feedback was incorporated in the prototype. Due to the corona pandemic, the project faced some delays. Nevertheless, in addition to the virtual project meetings, a backyard tour took place in the NaMaRes project area Innenstadt-Ost Karlsruhe as part of the anniversary event "50 years of urban development funding" of the city of Karlsruhe. During this tour, the possibilities for unsealing and greening in existing districts were discussed with interested owners and the NaMaRes project was presented.

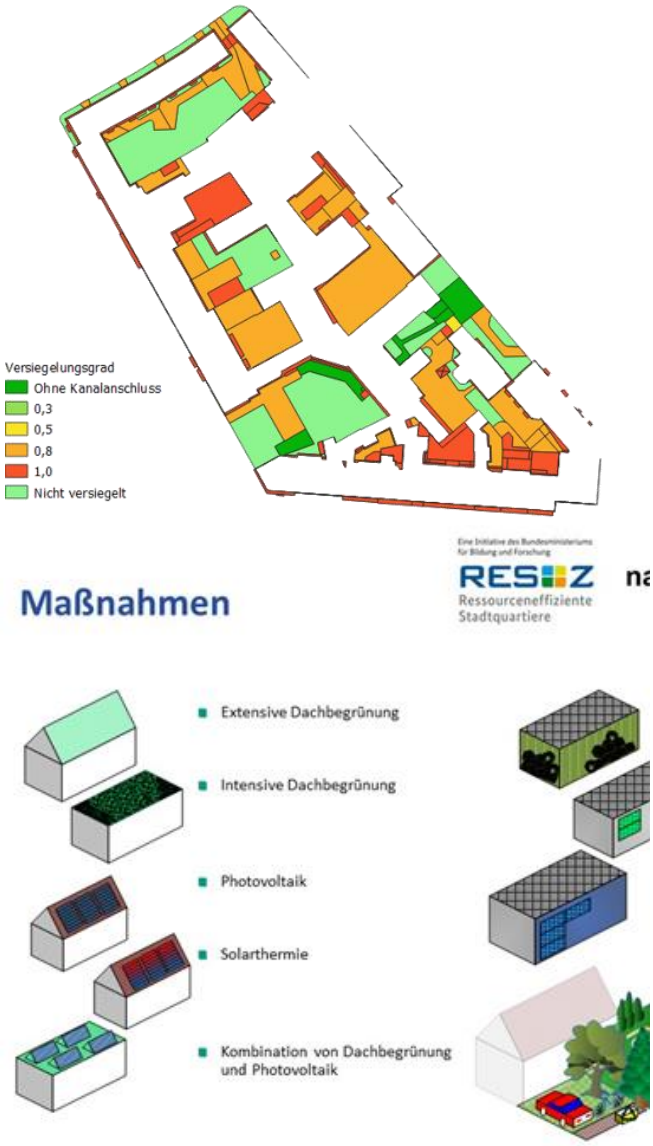


Figure 4: Measures modeled in the NaMaRes project

The project is accompanied by working groups within the research program RES:Z funded by the Federal Ministry of Education and Research. We particularly contributed to the working groups "digitalisation" and "indicator development".

NOLAN

Florian Diehlmann, Markus Lüttenberg, Katharina Eberhardt, Marcus Wiens

Partner: 4flow AG, TU Dresden

Funding: Federal Ministry of Education and Research – BMBF.

Duration: 2018 - 2022

Emergency care falls within the remit of the public sector. Nevertheless, private companies have a large number of resources (including skills) at their disposal, which can be very helpful in providing emergency support to the suffering population in the event of a crisis. In the NOLAN project, the option of a public-private partnership in crisis management is being systematically investigated for the first time.

The project partners are experts in the areas of risk and crisis management, emergency logistics, supply chain management and public law. Together with dialogue partners from the private and public sectors, the partners investigate the possibilities for the effective and practical design of a "Public Private Emergency Collaboration" (PPEC).

The overall objective of the project is to improve the supply security of an urban population with essential goods in crises. The aim is to develop concepts for efficient cooperation between private actors in commercial supply chains (i.e. retail, logistics, CI-operators) and state actors (i.e. public response agencies). For an escalating crisis event in urban areas, a holistic concept of emergency logistics – scalable in escalation stages – is developed which focuses on the cooperation of private actors in commercial supply chains and on state actors in emergency supply, taking into account the findings from humanitarian supply chains.

The focus is on the supply of vital, discrete goods such as food, medicines and bottled drinking water. Methodologically, a distinction can be made between two different approaches. On the one hand, the supply chains of public authorities and private companies are modelled and the interaction of the supply chains simulated and optimized. Parallel to this, a game theoretical analysis of the cooperation is carried out with the objective to determine factors of a stable cooperation together with an efficient and fair division of risk and responsibility in a PPEC.

Due to the acute need for research related to the Covid-19 pandemic, the project was extended for one year, until February 2022.

At the beginning of this year, a digital expert workshop was held. Here, lectures were alternated with various interactive sessions, with the content focus on the COVID-19 pandemic. Thus, natural disasters as a stress factor in supply chains were discussed holistically from production to logistics and trade. Risk perception and public acceptance were included in the considerations of ways to increase resilience.

In September, the Logistics Research Group at the University of Hasselt was visited. In addition to working on joint studies, the meeting focused on knowledge exchange regarding public-private cooperation in crisis management.

At the end of November, a digital transfer workshop was held with experts, where project results were presented, a lively panel discussion took place and interactive sessions were conducted.

Presentations were made digitally at the World Food Convention in July and INFORMS in October. In addition, an experiment conducted within the project on the influence of safety stocks on company reputation was presented at the GfeW Annual Conference on Experimental Economics in Magdeburg in September.

Furthermore, project meetings with the project partners from Berlin and Dresden took place digitally. In bilateral discussions, project results and modelling assumptions were validated with the project partners from public authorities and the private sector. Furthermore, in collaboration with the project partners and international colleagues, publications in the context of crisis management were continuously advanced.

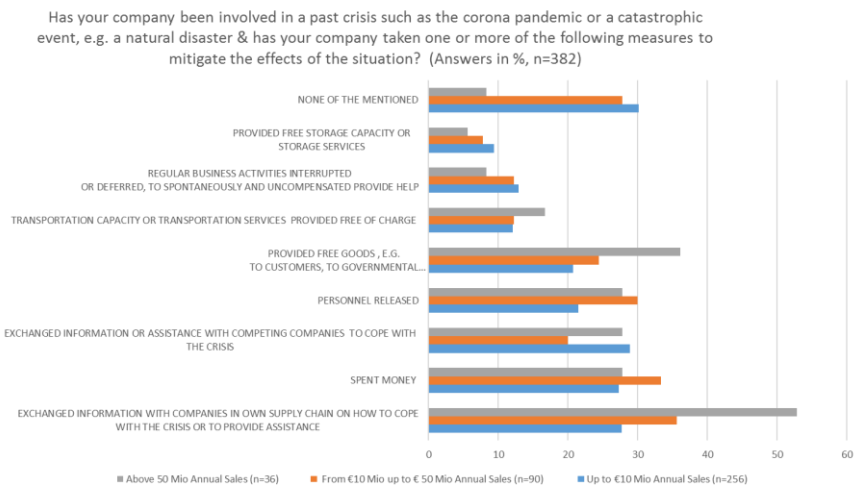


Figure 5: Responses from company representatives (n=382) working in the field of essential goods (food, beverages, medicine)

NukPlaRStoR – Development of a user-friendly cost-optimizing planning tools for nuclear dismantling projects taking into account material flows for resource planning

Dr. Rebekka Volk, Marco Gehring, Niklas Braun

Partners: RODIAS GmbH; VPC Nukleare Dienstleistungen GmbH

Funding: BMBF - funding code: 15S9414A

Duration: 07/2019 - 12/2022

International organizations expect that the dismantling of nuclear plants is becoming a national and international focus of the energy and dismantling industries. Completed and still ongoing dismantling projects of nuclear plants show that dismantling is technically safe. However, there exists a considerable potential for optimization and cost savings in the project management of nuclear dismantling. This is particularly evident with regard to the extreme time and cost deviations from the original planning of some current nuclear decommissioning projects. A major reason for these deviations is that the planning of nuclear dismantling projects represents a major challenge due to low empirical values and the large scope (many dismantling steps, many actors involved, long project duration, complex permits, complex material and waste flows, etc.). Currently, existing project planning tools do not completely cover the requirements of nuclear dismantling projects.

The aim of the NukPlaRStoR joint project is to develop a user-friendly planning tool that is specifically tailored to the needs of nuclear dismantling projects. The planning of nuclear dismantling projects is thus considerably simplified. The planning tool should enable the calculation of an optimized plan (with regard to costs and in compliance with safety regulations) containing all tasks to be performed as well as all material flows occurring during the decommissioning. Since the available space inside nuclear facilities is very limited, an additional layout model is developed to optimize the positioning of workstations and material storages within the power plants that will be dismantled. The goal is to avoid dead-lock positions and reduce the transportation effort during the dismantling process.

The NukPlaRStoR project started in June 2019 with a kick-off meeting in Karlsruhe. In the following months, IIP and RODIAS GmbH have created a first prototype of the user-friendly planning tool in close collaboration. The development was supported by VPC Nukleare Dienstleistungen GmbH with know-how from nuclear dismantling. Since mid 2020, RODIAS GmbH offers the planning tool as a software product called OPTIRA. OPTIRA is designed as an add-on to conventional project planning software that enables the automated optimization of especially large and complex projects of any kind. The models and methods developed at KIT/IIP are integrated as an independent program library and carry out the mathematical optimization. On the part of RODIAS, extensive user and application interfaces, program control as well as data management and visualization were added on the way to the now available final product. Additionally, the IIP implemented a first running prototype of the layout model in Python. In the further course of the NukPlaRStoR project, the developed models and methods will be refined in cooperation with the project partners.

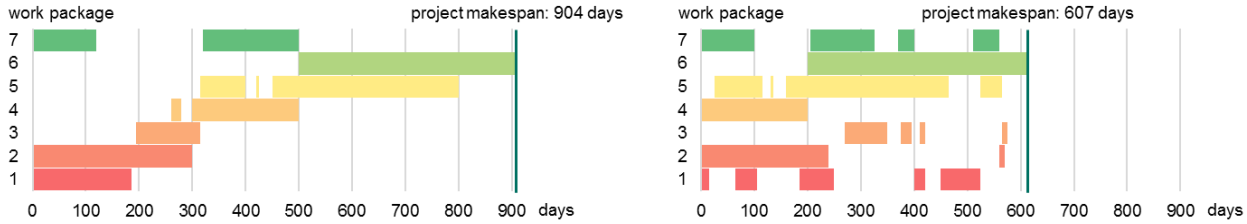


Figure 6: Gantt charts of an original project schedule (left) and the corresponding optimized project schedule (right) using the NukPlaRStoR planning tool

Piloting the native ethanolic extraction of rapeseed (EthaNa); Subprojects 5: Economic and ecological accompanying research in the joint project (EthaNa)

Andreas Rudi, Simon Glöser-Chahoud

Partner: Fraunhofer-Zentrum für Chemisch-Biotechnologische Prozesse CBP, Fraunhofer-Institut für Grenzflächen und Bioverfahrenstechnik IGB, Fraunhofer-Institut für Verfahrenstechnik und Verpackung IVV, Forschungsinstitut Futtermitteltechnik IFF, B+B Engineering GmbH, Thywissen GmbH, AVA Anhaltinische Verfahrens- und Anlagentechnik GmbH, Miccra GmbH, VetterTec GmbH, tti Magdeburg GmbH

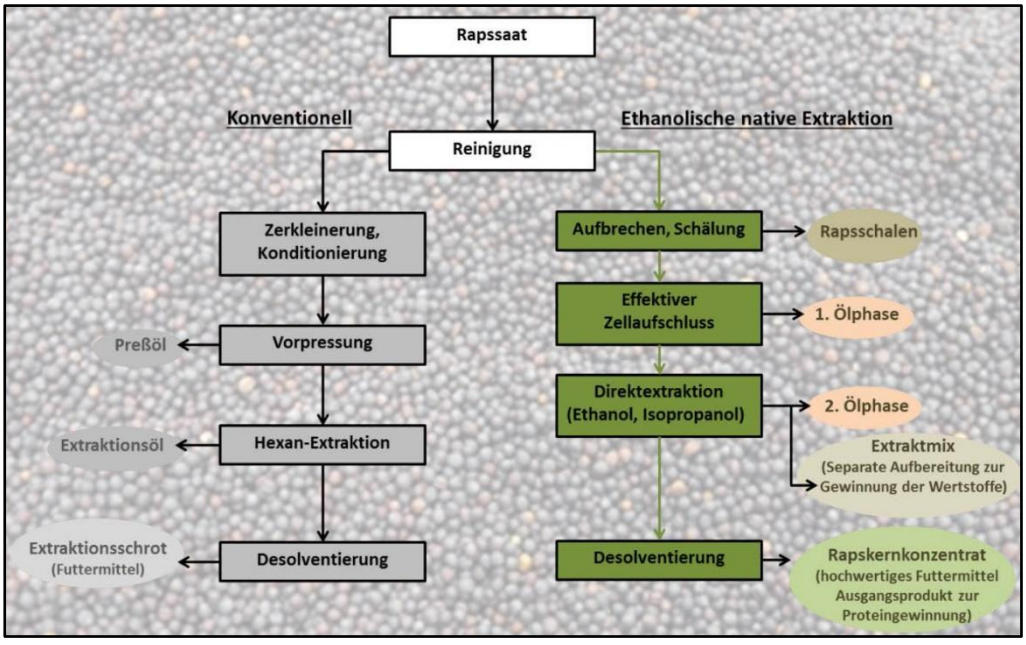
Funding: German Federal Ministry of Food and Agriculture (BMEL)

Federal Ministry of Food and Agriculture

Duration: 09/2017 - 08/2021

The aim of the project is to develop an innovative refining process of canola seed in order to obtain highly efficient, economical, high-quality products. Compared to extraction processes with the solvent hexane, which were customary up to now, the EthaNa-refining processes might enable a significant qualitative improvement of the products rape oil and rape kernel concentrate. In addition, new highly valuable substances which have not yet been derived from rape seed are isolated. This will open up further sales markets in future and increase overall sales revenues from the oleaginous seed. The EthaNa concept is a fully integrated process for rape seed refining. Direct extraction with alcohol makes it possible to obtain high-quality plant-oil and proteins as primary products. Within the framework of the overall project, the IIP is dedicated to the evaluation of the relevant economic and ecological aspects of the individual sub-processes as well as the overall process. It forms an essential basis for industrial application and marketing of the developed concept. Economic and ecological evaluation models for the concept are used and evaluations are carried out in parallel. For this purpose, methods from material and energy balancing (e. g. process engineering simulation), investment and operating cost estimation as well as life cycle assessment (e. g. Life Cycle Inventory of the entire value-added chain) are applied.

EthaNa Process



PREVIEW

Rebecca Wehrle, Marcus Wiens

Partner: 4flow AG, TU Dresden, Bundesanstalt für Wasserbau (BAW), antwortING

Funding: Federal Ministry of Education and Research – BMBF.

Duration: 2018 - 2022

Around 2.5 million containers are transported annually on the German waterways. On the one hand, the waterways are of outstanding importance for the functioning of the economy. On the other hand, the infrastructure of the artificial federal waterways, including canals and locks, is outdated. Floods or possible terrorist attacks also pose a threat to the waterway infrastructure. Furthermore, it is not known what consequences the failure of individual critical elements of this system may have for other transport infrastructures, the economy and the population in the affected regions.

The PREVIEW project investigates the possible consequences of the failure of critical water transport infrastructure structures for other transport infrastructures, logistics, neighbouring industries and the population of the regions concerned. The overall objective of the project is thus to increase the resilience of the waterway infrastructure in Germany. To this end, adverse consequences will be analysed and processed on the basis of three exposure scenarios as natural events, technical or human failure and hostile attacks. For the first time, the entirety of the hazards for the population as well as for transport logistics and the economy will be analysed. The resulting findings will be used to draw up contingency plans in order to effectively counter these hazards.

The results of the project will be incorporated into a simulation model, which illustrates possible hazardous situations using the example of the West German canal network. This enables end users to visualize the vulnerability of the infrastructure, the local communities and industries. Logistic models also make it possible to assess the economic impact of damage events in canals. The results benefit the end users and can then be transferred to the entire waterway infrastructure.

In 2021, two digital project meetings and regular telephone conferences took place, which ensured close cooperation with the project partners from Berlin, Cologne and Karlsruhe and focused on the common goal of further work.

In order to ensure the transfer of knowledge from previous work, a closing event took place in September 2021, at which the present research results of the project were demonstrated. These include a GIS-based web application for monitoring resilience-based maintenance planning, among others. The closing event was held as an interactive, hybrid format with interested parties from research, business and authorities. In addition, the project could be extended cost-neutral by six months so that the works can continue until February 2022.

The continuous validation of the research results was pursued through publications and conference participation within the framework of the joint project. An article in the International Journal of Disaster Risk Reduction was accepted and further research results are currently under review. A contribution to the EURO 2021 conference was made and Rebecca Wehrle attended the Pharma Logistics Masterclass at the University of Antwerp.

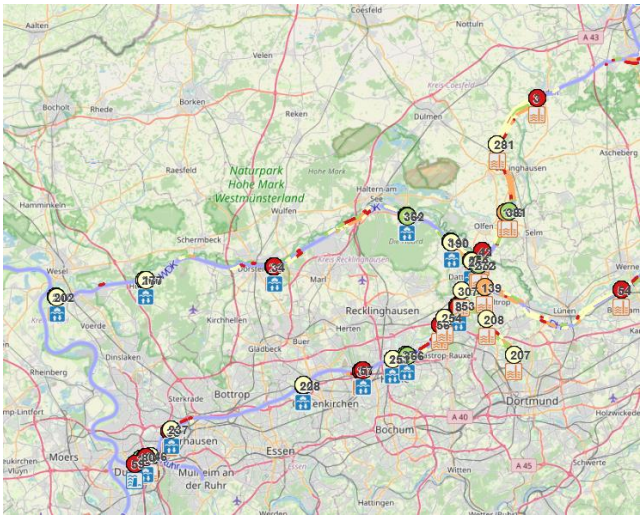


Figure 7: Excerpt of the developed GIS-based web application that allows to monitor a resilience-based maintenance strategy. Construction elements and their depicted assessed risk then are concluded to a prioritization order.

reFuels – rethinking fuels

Simon Glöser-Chahoud, Paul Heinzmann, Uwe Langenmayr, David Pflegler

Partner: Institut für Kolbenmaschinen (IFKM), Institut für Katalyseforschung und -technologie (IKFT), Institut für Mikroverfahrenstechnik (IMVT), Engler-Bunte-Institut (EBI), Institut für Technikfolgenabschätzung und Systemanalyse (ITAS) and numerous industry partners

Funding: Ministry of Transport Baden-Württemberg

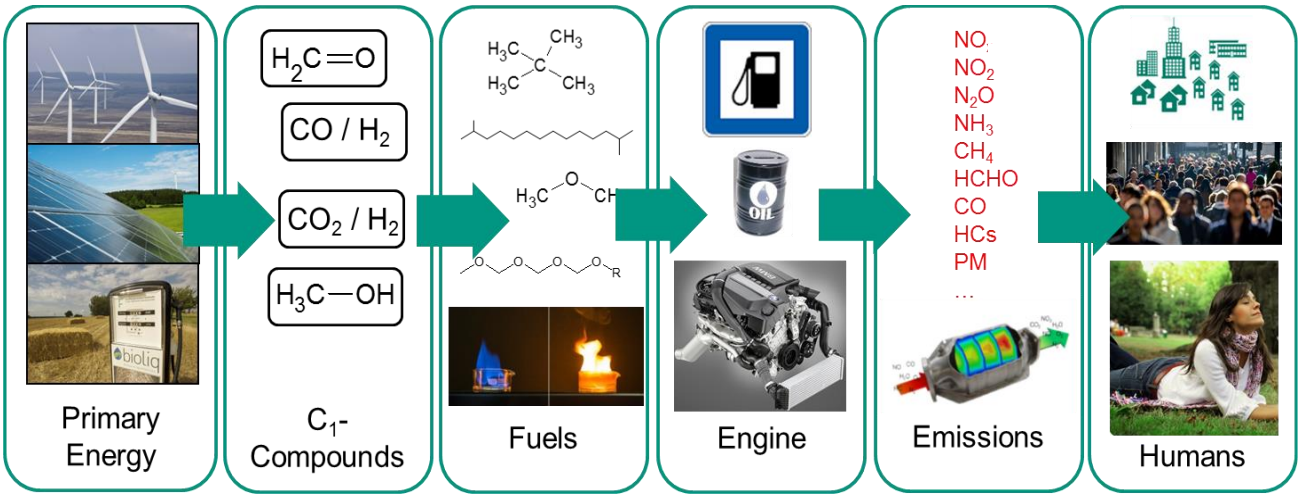
Duration: 2019 - 2022

The utilization of renewable produced fuels (reFuels) is one of the main actions beside electric mobility on the way to a CO2 neutral transportation sector. These fuels use carbon-containing residues of agriculture and forestry, as well as industry and municipality waste in combination with hydrogen produced from the electrolysis process for chemical synthesis.

The project consortium comprises several institutes of the KIT and other partners from the industry. The aim of the project is to assess the complete value chain, from production of the fuels to the application of these fuels in vehicles.

The Institute for Industrial Production, on the one hand, examines the impact of the production processes on the energy system of Baden-Württemberg and Germany. The focus of this task is the assessment of the additional flexibility of these processes, the CO2 savings in the mobility sector and the increasing integration of renewable energy sources. On the other hand, a techno-economic analysis of the different production processes is conducted. This task aims to deliver deeper understanding of investment volumes and the cost structure of different process constellations. This includes aspects of logistics and necessary infrastructure, which have an additional impact on the final integration costs of the processes. Finally, the implementation of a pilot plant at the facility of one project partner will be simulated and assessed.

The project results support deeper insights on reFuels, their production processes and useful applications. Furthermore, they help to further decrease the greenhouse gas emissions in the mobility sector.



REPOST

– Autoclaved aerated concrete recycling cluster: Development of new options for circular economy

Dr. Rebekka Volk, Justus Steins

Partner: Xella Technologie- und Forschungsgesellschaft mbH, Otto Dörner GmbH, KIT - Institute for Technical Chemistry

Funding: BMBF - funding code: 033R249B

Duration: 06/2019 - 05/2022

"REPOST" has set itself the goal of creating the basis for a high-quality and economical recycling management of autoclaved aerated concrete (AAC). New and competitive products for masonry construction are to be created from post-demolition AAC. In addition to direct material recycling, alternative recycling methods - e.g., the production of clinker substitutes - are also being investigated. The project is funded within the framework of the funding measure "Resource-efficient recycling management - Innovative product cycles (ReziProK)" by the Federal Ministry of Education and Research (BMBF).

AAC is a building material that has been known and proven for almost 100 years. The recycling of AAC fresh from production, which occurs as cuttings or breakage during production, has been practiced for decades. In contrast to this, post-demolition AAC often contains accompanying materials that make high-quality recycling difficult, which is why AAC is usually disposed in landfill after use. Decreasing landfill capacities, legal obligations for the recyclability of products as well as the conservation of primary materials therefore make it essential to find recycling alternatives for this demolition material. REPOST aims at the reduction of primary raw materials in the production of AAC by recycling post-demoliton AAC at the same or comparable quality level. This concept differs from conventional building material recycling. In the statistics, around 90 percent of mineral construction waste is recycled, but mostly as low-value and one-off downcycling in road construction.

Figure 8: Aereated concrete waste to be recycled

The REPOST work plan is based on the life cycle of a recycled AAC block and begins with the dismantling and sorting/preparation of AAC from the existing stock. The secondary raw material obtained is to be used directly as an additive for new masonry products. In 2020 and 2021, we quantified the expected AAC waste in Germany until 2050. The results show a sharp increase of waste volumes in the following decades which further motivates the establishment of recycling options.

AAC contains a large proportion of deacidified lime, which was produced using a high amount of energy and high CO_2 emissions. Where recycling within a closed cycle is not possible, a thermal conversion into dicalcium silicate, a main component of cement clinker, is investigated. The aim is to partially replace the primary raw materials cement or lime in the production of AAC with a recycled product that causes lower CO_2 emissions and energy consumption during its manufacture. With the involvement of demolition and processing companies, business models focusing on location, capacity and logistics are being developed for the new recycling options over the entire life cycle.

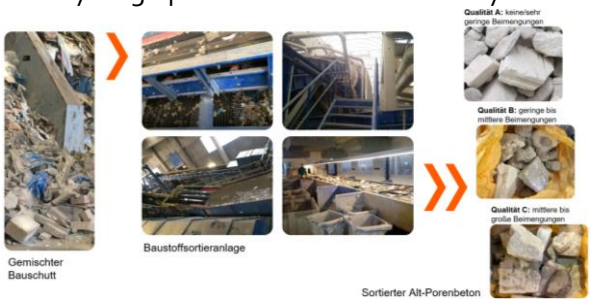


Figure 9: Provision of old aerated concrete in various grades of purity

SPECK – Systemic optimization of the meat value chain using the example of pig farming through the development and embedding of digital tools

Nina Treml, Simon Glöser-Chahoud

Funding: Federal Ministry of Agriculture and Food, Federal Agency for Agriculture and Food

Duration: 2021 - 2024

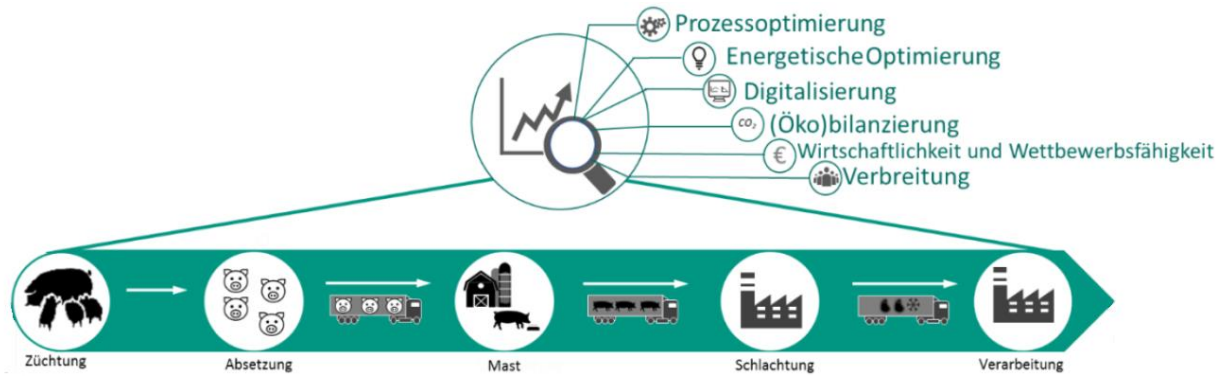
Agriculture and especially animal husbandry are currently facing major challenges, such as ensuring food quality and enabling sustainable value chains. To address these challenges, regional and global food security, animal welfare, efficient use of raw materials, climate and environmental protection and their interactions play a prominent role.

In order to address the challenges of product quality and sustainability, the digitalization of food value chains seems necessary so that relevant data can be generated and analyzed. Within the research project SPECK (Systemic optimization of the meat value chain using the example of pig farming by developing and embedding digital tools), the research group Sustainable Value Chains is working together with the University of Kassel, the research group critical information infrastrucures (cii) of the AIFB at the Karlsruhe Institute of Technology and partners from industry.

The aim of the research project is to optimize the meat value chain by developing and embedding digital tools as well as the process analysis of the technological status quo of market participants along the value chain and, based on this, the ecological assessment of the value chain using life cycle assessment methodology.

The scope of the IIP includes the preparation of Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) along the value chain. Further, the development of animal welfare and meat quality indicators based on the LCA methodology is aimed at. The approach of the IIP is based on the following sub-objectives:

- Identification of the value chain links of pork production and inventory analysis of the data necessary for LCA
- Balancing (LCA and LCC) of the value chain links in the context of the LCA methodology on the one hand considering the industry partners, on the other hand a "standard" case in Germany mapped through case studies
- Sensitivity analysis of different parameters within LCA/LCC
- Increasing the transparency of ecological burdens in the context of pig production in Germany
- Discuss possibilities of transparent and uniform presentation of meat quality and animal welfare aspects



TFTEI – Technical Secretariat of the Task Force on Techno-Economic Issues

Simon Glöser-Chahoud

Partner: Interprofessional Technical Centre for Studies on Air Pollution (CITEPA), Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)

Funding: French Environment and Energy Management Agency (ADEME)

Duration: since 2002 (ongoing)

Since 2002, DFIU and CITEPA (France) form the Technical Secretariat of the former Expert Group on Techno-Economic Issues (EGTEI), now Task Force on Techno-Economic Issues (TFTEI). The work is primarily funded by the French environmental agency ADEME under the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP). Between 2002 and 2008 several sector specific background documents with techno-economic information about air emission abatement techniques have been developed and revised. This information is considered in the Integrated Assessment Models (IAM) RAINS and GAINS, developed by the International Institute for Applied Systems Analysis (IIASA) in Luxembourg, Austria. Both models have been applied for the derivation of emission abatement strategies on UNECE and EU level.

After EGTEI focused on technical background documents for the revision of the Gothenburg Protocol and investment and cost calculation for emission abatement in large combustion plants in recent years, the work has been honoured in December 2014 by promoting the former Expert Group into a Task Force that is a constant part of the Working Group on Strategies and Review (WGSR). The current work focuses on VOC abatement in order to support the revision of the BREF STS and on emission abatement in the aluminium and cement sector. Furthermore, an information platform (the so-called Clearing House on Abatement Techniques) is built up and hosted by TFTEI. The results of the TFTEI activities shall be of use for the convention and its members, but particularly for the EECCA-region, where mission abatement strategies are currently developed.

THINKTANK "Industrial Resource Strategies"

Rebekka Volk, Simon Glöser-Chahoud, Frank Schultmann

Partner: AUDI AG, Badische Stahlwerke GmbH, Carl Zeiss AG, Daimler AG, Robert Bosch GmbH, Scholz Recycling GmbH, SchwörerHaus KG, Umicore AG & Co. KG, German Chemical Industries Association (VCI) Baden Württemberg, Zeller+Gmelin GmbH & Co. KG.

Duration: 01/2018 - 12/2022

In February 2018 the THINKTANK "Industrial Resource Strategies" was set up at the Karlsruhe Institute of Technology (KIT). This THINKTANK is a pioneer institution between policy, industry, and science to develop ideas and answers on questions concerning resource and raw material efficiency. The efficient usage, as well as the recycling and reuse of (raw) materials, have a high priority, especially in a Federal State like Baden Württemberg that only has a few natural resources, but is at the other hand a well-developed production location. Therefore, ideas and concepts to reduce its dependency on raw material imports and geopolitical crises should be developed within the THINKTANK.

Four institutes of the KIT are involved in the THINKTANK, among others the Institute for Industrial Production (IIP). Within the THINKTANK, we will work on topics such as circular economy, resource efficiency alongside the entire supply chain. The circular economy framework will be applied holistically to achieve a more efficient material selection, to increase the collection and recycling rate, and to decrease the resource input. Furthermore, the impacts of important technical and social trends and transformation processes on resource demand and efficiency will be analysed.

Five pilot projects have been defined to set up the work of the THINKTANK. Those projects deal with questions in trending areas such as blockchains and digitalization, closed loops supply chains, circular economy and the 2nd life cycle of products.

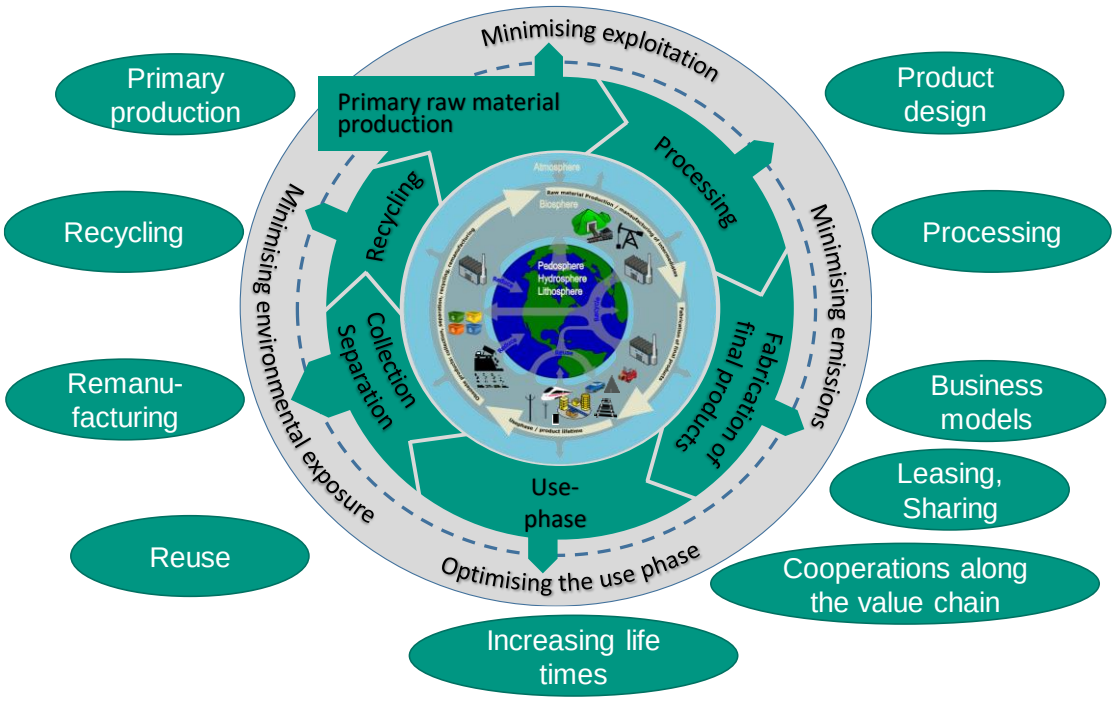


Figure 10: Circular Economy from a systemic perspective as a key element of research activities within the ThinkTank Industrial Resource Strategies

Urban heat losses and detection of thermal bridges

Dr. Rebekka Volk, Zoe Mayer, Yu Hou

Partner: University of Southern California, Air Bavarian GmbH

Funding: DAAD, Landesgraduiertenförderung Baden-Württemberg

Duration: 03/2018 - 12/2022

Figure 11: Drone experiments at KIT campus north and in the city area Karlsruhe (© KIT, Rebekka Volk)

The main objective of this project is the data collection and processing of drone data with the aim to identify urban heat losses – both in buildings and infrastructures.

For this, we collected thermal data of buildings and heat distribution networks in Karlsruhe at Campus North, Campus South and in the inner-city area in 2018 and 2019. The data collection was scheduled in January and March 2019 and accompanied by research fellow Yu Hou from the university of Southern California. During the experiments, we successfully completed day and night drone flights in Karlsruhe at several heights, with different flight paths, camera angles and flight patterns. Furthermore, further experiments were undertaken to calibrate the different thermal cameras in use and to measure indoor temperatures and temperature distributions.

The processing of the data revealed significant heat losses especially from non-retrofitted buildings (windows, facades, chimneys, roofs) but also visualized heat losses in the infrastructural network (see Figure). The research group deals within this project with the identification of heat losses in buildings and district heating networks to design and assess change measures from a technical, economic and ecological point of view.

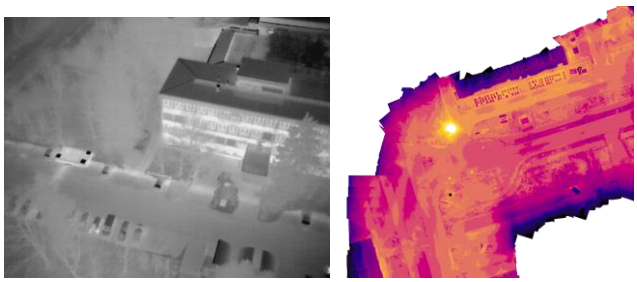


Figure 12: Thermal images with visible damages (©Rebekka Volk)

Most recent developments were presented both in conferences (ISARC conference in May 2019, Banff, Canada) and published in several scientific journals.

Awards

In June 2021, the model for optimized project planning developed in the NukPlaRStoR project was awarded the 3rd prize at the KIT NEULAND innovation competition in the category Transfer Prize. The innovation competition takes place annually and offers KIT scientific employees the opportunity to present their innovative ideas and projects to a company jury, which then evaluates them. More information about the award ceremony can be found here.

Simon Glöser-Chahoud received this year's "Gert-von-Kortzfleisch Prize" awarded by the German System Dynamics Society (DGSD) together with his co-authors for their approach for modelling the dynamic behaviour of commodity markets. The awarded paper published in "System Dynamics Review" can be found here, more information about the award and the online ceremony can be found of the website of the DGSD.

Completed PhD Dissertations and Habilitations

Habilitation Thesis: Resilient Systems – an Economic, Operational, and Behavioral Perspective

Priv.-Doz. Dr. Marcus Wiens

This treatise contributes to resilience research from an economic and business science perspective. The presented studies (eight companion articles) apply operational research methods as well as social or behavioral approaches. They include models for optimization and simulation, decision support systems adapted to complex problems, data generation, and formal analysis frameworks that take trade-offs and economic evaluations into account. The decision makers in these models are either professionals in the role of risk and crisis managers or the potentially affected people like CI-users. Professional actors are firms of a supply chain, CI-operators or government agencies.

The general topic of this treatise can be assigned to two overarching themes:

- *Economic assessment and risk optimization* of measures to improve the safety and security of Critical Infrastructure (CI) and to protect processes and operations for the supply of critical goods. The first two studies have a focus on operational resilience for supply chains of essential goods like food, water and medicine (Schätter et al. 2019; Löffel et al. 2020). These approaches also borrow from the field of humanitarian logistics. Study A presents a decision support system for a double-risk scenario; hence it contributes to the intricate field of controllable versus uncontrollable uncertainty. Study B proposes an evaluation method to determine candidate regions for warehouses, which can be used by commercial firms in peacetime and from emergency actors during crisis time. It shows how these criteria can be integrated into an objective function, which leads to a collaborative approach. Both studies, A and B, improve the flexibility of operations and lower the hurdles for preparation engagement.

Regarding CI, studies C and D deal with the resilience of the energy system and the health system with respect to the risk of power blackout (Münzberg et al. 2017; Wiens et al. 2018). As these studies have an operational and techno-economic focus, methods from decision science and operations research are used here. However, some aspects also touch on aspects of risk perception and behavioral incentives. Study C develops a decision support system for municipal crisis managers that makes the risks to the community's critical facilities transparent. As the approach is based on the facilities and characteristics of the municipality, it takes the local knowledge and resources into consideration. The approach enables the identification of critical facilities and provides information on where public authorities need to expand their crisis preparation and where the self-help capacity of the population needs to be strengthened. Study D describes exogenous and endogenous risks of the energy sector and compares the energy sector with the financial sector with respect to systemic risks. Due to the comparative perspective, the study provides insights into the nature of endogenous and behavioral risks. A further important finding refers to the need of stakeholder cooperation, in particular on an international level.

- *Strategic behavior and social interaction of decision makers* including their beliefs, expectations and their reaction to risks and incentives. One research area touches on borderland resilience as a special topic. Here, studies E and F address the question of how authorities and citizens of a border region can jointly manage risks through deepened cooperation (Klein et al. 2020a; Klein et al. 2020b). Key factors are multi-level coordination, but also social capital and trust. Study E provides an empirical survey on cross border attachment and borderland social capital, eliciting general and directed trust of citizens in a simultaneous

cross-regional and cross-country setting. Hence, this study refers above all to the success-factor of social connectedness. A further research question of this study was whether borderland social capital increases the people's willingness to help in a crisis – this contributes to the citizens' capacity for self-organization and also to preparation engagement. Study F refers to the same context (cross border crisis management) but uses an agent-based simulation to analyze and improve multi-level coordination. One level refers to coordinated search and rescue activities based on professional exchange and resource sharing between first responders and civil protection agencies of two countries. This requires both empowerment from a political or higher-order administrative level and the use of local knowledge and resources. The second level of coordination refers to the integration of spontaneous volunteers into the rescue operations. Hence, the contribution of study F covers the category stakeholder exchange and cooperation in all of its forms.

Studies G and H have a focus on flood risk resilience (Mahdavian et al. 2020; Wiens et al. 2020). Used methods are empirical surveys, agent-based modelling as well as game theory. Study G is an empirical survey on people's risk perception, risk preparedness, their willingness to follow evacuation orders and their trust into public advice in two flood-prone locations in Germany and UK. Dealing with risk perception, the study contributes to a better understanding of risk and uncertainty in the context of flood risk. In addition, it also provides insight into aspects of empowerment (in particular perceived responsibility) and preparation engagement. Study H is a decision theoretic and game theoretic model, which focusses on flood risk communication and people's compliance. Similar to study G, the factors effective communication and risk expertise are of high relevance here.

Summary and conclusion

The management of crises and the establishment of disaster resilience in the sense of higher robustness, flexibility and adaptability of technical, economic and social structures are highly demanding and complex tasks. Based on formal models and empirical research, this treatise analyzes selected problem areas, such as the disruption of critical infrastructures, supply shortages for essential goods and flood disasters, and proposes solutions from a primarily operational and economic perspective. Methodologically, the approaches include economic assessment and optimization models as well as decision-theoretic and behavioral approaches that also incorporate social expectations, such as public trust. The results show how a combination of innovative concepts, optimized planning and the consideration of social factors can increase the efficiency of supply and the effectiveness of emergency measures in the event of a crisis.

PhD Dissertation: Planning and modelling of costs and CO2-emissions along industrial supply chains – using the automotive industry as an example

Richard Müller

The dissertation is dedicated to the development of a decision support system for the planning and evaluation of sustainable industrial value chains and its exemplary application in case studies of the automotive and supplier industry (for example the metal and chemical industry). Complete information is rarely available for the planning of sustainable value chains, since supply chains have developed into very complex, non-transparent supply networks due to the globalization of the procurement market. The origin of the purchased products (for example, the supplier's plant) as well as the production processes used there and their environmental impacts are therefore mostly unknown. In addition, the transformation process to a sustainable, e.g. climate-neutral, company is associated with high, sometimes existence-threatening investments for the majority of companies. The key challenge for companies is to identify measures along the value chain that have the greatest possible effect on sustainability and at the same time are associated with the lowest possible costs, so that the company's success is not jeopardized at any point. However, companies generally lack the corresponding data, methods and evaluation systems.

The approach developed in this dissertation supports companies and their decision makers in planning climate-friendly and at the same time economic value chains. In this way, this thesis pursues the goal of making a significant contribution to the reduction of industrial GHG emissions, so that national and international greenhouse gas reduction targets can be achieved and man-made climate change is limited. The focus is on the value-added stages of material production, material processing/final product manufacturing, product use and end-of-life (for example, landfilling, energy recovery, recycling). Hybrid Life Cycle Assessment (LCA) models have been developed for the material production of steel, aluminium, and important chemical base materials, enabling material manufacturers to be compared for the first time on a plant-specific basis regarding to their GHG intensity. In this way, the carbon footprint of a product can already be reduced by selecting climate-friendly material manufacturers (suppliers). LCA models are also being developed for the other stages of the value chain and integrated into the decision support system. For the material processing/final product manufacturing stage, an accounting model is also being created that combines the material flow cost accounting and LCA methods. In this way, the manufacturing costs of a product are determined in parallel with the GHG emissions, which are used as an economic decision criterion. For decision making, the pareto-optimal configurations are determined among all combinatorically possible value chain configurations (materials, suppliers, manufacturing chains, product use types, and possible end-of-life activities). Based on the pareto-optimal configurations and the preferences of a decision maker, the optimal configuration of a value chain for a company is calculated by methods of multi-criteria decision analysis and a subsequent stability analysis, and the GHG avoidance costs in product manufacturing are quantified. The decision support system is applied to the example of a passenger car component. Different scenarios (e.g., drive technology and mileage of the car) and their impact on the planning of the value chain are examined.

PhD Dissertation: Techno-economic impact assessment of steel and aluminium production sites and supplier selection in the automotive industry

Andreas Schießl

The fast growing stakeholder interest in sustainability leads to an increased attention both on the ecological and social perspective of industrial companies and its products. While in the past the focus predominantly laid on the environmental impact of the product use phase, it recently shifted towards the manufacturing phase. Hence, both, focal companies and supply chain members are obliged to create and apply new strategies to reduce greenhouse gas emissions (GHG). From a purchasing perspective, the selection of more environmentally efficient suppliers is a possibility to significantly reduce CO2e emissions. Therefore, transparency is required in form of site-specific and comparable data on suppliers' environmental performance. This data is lacking and the detailed environmental performance criteria has not been integrated in supplier selection decisions yet.

In this dissertation a model is developed and applied to close the transparency gap and to integrate CO2e as an additional supplier selection criteria in decision-making. For this purpose, a multi-criteria decision analysis approach is developed to derivate criteria weights and a supplier ranking based on expert opinion and quantitative supplier performance data. As decision making based on expert consultation is associated with a certain level of subjectivity, a sensitivity analysis is performed to evaluate the robustness of the model and the results. By means of 'what-if' scenario simulations, the dynamic behavior of the model is further investigated to examine how decisions may change when CO2e is formulated and considered as a new criteria. In addition, a systematic and modular life cycle assessment (LCA) based approach is developed to enable an efficient evaluation and comparability of the sustainability performance of raw material suppliers on a production site level, based on publically available data. The model combines a bottom-up calculation of technical process flows with top-down reported site-specific CO2 emissions, and explicitly considers technical restrictions and trading of intermediate products.

The developed site-specific performance model is applied in two case studies for primary steel production sites in Europe and primary aluminum sites in Germany. The results, which were validated with industry experts, differ by 58% for the comparison between the most and least efficient production site for steel and by 9% for the examined aluminum production sites and show an opportunity to reduce GHG emissions by selecting more environmentally efficient suppliers. The combined, integrated CO2e assessment and decision support model is subsequently applied on an automotive case study for the selection of the most adequate supplier for a powertrain part from an environmental and economic efficiency perspective. The results show that in some cases the integration of the CO2e performance can have a significant impact on the ranking of the most preferable supplier, despite an initially investigated low importance of the new CO2e decision criteria.

PhD Dissertation: Facility Location Planning in Relief Logistics: Decision Support for German Authorities

Florian Diehlmann

Disasters have devastating impacts on societies, affecting millions of people and businesses each year. The delivery of essential goods to beneficiaries in the aftermath of a disaster is one of the main objectives of relief logistics. In this context, selecting suitable locations for three different types of essential facilities is central: warehouses, distribution centers, and points of distribution. The dissertation aims to improve relief logistics by advancing the location selection process and its core components.

Five studies published as companion articles address substantial aspects of relief logistics. Despite the case studies' geographical focus on Germany, valuable insights for relief logistics are derived that could also be applied to other countries. Study A addresses the importance of public-private collaboration in disasters and highlights the significance of considering differences in resources, capabilities, and strategies when using logistical models. Moreover, power differences, information sharing, and partner selection also play an important role. Study B elaborates on the challenges to identify candidate locations for warehouses, which are jointly used by public and private actors, and suggests a methodology to approach the collaborative warehouse selection process. Study C investigates the distribution center selection process and highlights that including decision-makers' preferences in the objective function of location selection models helps to raise awareness of the implications of location decisions and increases transparency for decision-makers and the general population. Study D analyzes the urban water supply in disasters using a combination of emergency wells and mobile water treatment systems. Selected locations of mobile systems change significantly if vulnerable parts of the population are prioritized. Study E highlights the importance of accurate information in disasters and introduces a framework that allows determining the value of accurate information and the planning error due to inaccurate information.

In addition to the detailed results of the case studies, four general recommendations for authorities are derived: First, it is essential to collect information before the start of the disaster. Second, training exercises or role-playing simulations with companies will help to ensure that planned collaboration processes can be implemented in practice. Third, targeted adjustments to the German disaster management system can strengthen the country's resilience. Fourth, initiating public debates on strategies to prioritize parts of the population might increase the acceptance of the related decision and the stockpiling of goods for the people who know in advance that they will likely not receive support.

Consequently, the dissertation provides valuable insights into disaster relief. Therefore, it offers the potential to significantly improve the distribution of goods in the aftermath of future disasters and increase disaster resilience.

PhD Dissertation: Cross-Border Collaboration in Disaster Management

Miriam Klein

When a disaster strikes, a rapid and coordinated response by the various crisis management actors is essential to limit the consequences. This interaction is made more difficult when the disaster affects multiple countries, as cooperation across national borders creates additional obstacles. In addition to different regulations and systems, cultural influences such as language barriers or lack of trust also play a crucial role. Although borderland resilience is of fundamental importance, it is still underestimated in the scientific literature.

The first part of this thesis presents an agent-based model to study inter-organizational collaboration during disaster response operations in a borderland. By extending communication protocols from the literature to a borderland context, the model analyzes the global dynamics resulting from local decisions. A scenario-based approach shows that while improved trust leads to significantly better coverage rates, reducing language barriers is even more efficient, especially when agents speak the other country's language directly rather than relying on a general lingua franca. The study of coordination shows that information flows along the hierarchical structure of organizations are most successful, while spontaneous collaboration through an established informal network of private contacts can further complement information exchange and provide an advantage in dynamic environments. Moreover, the involvement of spontaneous volunteers in disaster operations doubles the coordination effort. However, coordination across both dimensions, within disaster operations and across borders, leads to the best provision of resources to the affected population.

In a second part, this thesis presents a novel empirical study design based on transnational social capital and Weiner's motivational theory to quantify people's connections across national borders by taking regional connections within countries as a basis for comparison. Data collected through representative telephone interviews in Germany, France, and the French-German border region support the hypothesis that social capital and willingness to help across the French-German border is at least as high as regional social capital and willingness to help within each country.

Consequently, this work provides valuable insights for decision makers to reduce substantial barriers in cross-border disaster relief and thus, improve cross-border cooperation in future disasters. Implications for today's world in terms of globalization versus emerging nationalism and impacts of (natural) disasters are discussed.

Staff 2021

Head of the Chair of Business Administration, Production and Operations Management

Prof. Dr. Frank Schultmann

Administrative Staff

Liana Blecker (also working for the Chair of Energy Economics)

Corinna Feiler (also working for the Chair of Energy Economics)

Josiane Folk (also working for the Chair of Energy Economics)

Katrin Grauer

Heads of Research Groups

Dr. Simon Glöser-Chahoud – Sustainable Value Chains

Dr. Rebekka Volk – Project and Resource Management in the Built Environment

Dr. Marcus Wiens – Risk Management

Postdoctorial Researchers

Dr. Marina Maier

Research Associates and their PhD-topics

Niklas Braun: Logistics optimization in nuclear decommissioning projects

Marco Gehring: A Material Flow Based Optimization Tool for Planning Dismantling Projects

Raphael Heck: Cooperation and Competition in Bioeconomy Value Chains

Paul Heinzmann: Techno-economic optimization of e-fuel and hydrocarbon production taking into account plant flexibility and storage systems

Sandra Huster: Forecasting core supply and demand for reconditioned products under consideration of stakeholder preferences

Florian Kaiser: Holistic risk management for quantifiable and scalable IT-security

Markus Lüttenberg: Public-Private Emergency Collaborations from an Incentive-based Perspective

Zoe Mayer: Energy retrofits of single buildings and identification of heat losses on district scale

Elias Naber: Socio-Technical Modeling and Agent-based Simulation of Deep Energy Retrofits in the German Building Stock - Mitigating Emissions Caused by Cooling and Heating of Buildings

Mihir Rambhia: Urban Green Management

Sonja Rosenberg: Optimization of Closed-Loop Supply Chains with innovative Business Models for Traction Batteries of Electric Vehicles

Andreas Rudi: Evaluation and Modelling regional biobased value chains

Christoph Stallkamp: Circular Economy of Plastics in the case studies of lightweight packaging and automotive plastic waste

Simon Steffl: Assessment of end-of-life options of fibre-based materials

Justus Steins: Integrated, optimizing location, capacity and logistics planning including techno-economic as well as ecological assessment for recycling options of autoclaved aerated concrete

Nina Treml: Implementation of Life Cycle Assessment Methodologies in the Analysis of the Pig Value Chain in Germany

Elena Vollmer: Automation and software development for district heating system monitoring: analysing UAS acquired thermal images to detect network leakages

Rebecca Wehrle: Criticality assessment of transport infrastructure networks

Alexander Zienau*: Public-Private Emergency Collaboration in Logistics from a Business Perspective

Tobias Zimmer: Model-based assessment of mobile pre-treatment technologies in bioenergy value chains

*external researcher

International Collaboration and Exchange

Due to the Corona pandemic, several international research stays and further international activities of IIP staff were cancelled. However, IIP remains engaged in different international exchange activities.

Among others, this includes:

- Since the end of 2021, Prof. Schultmann is scientific spokesman of the TRENT platform and project (Transnational Competence Center for Environmental Technology and Research Jiangsu Baden-Württemberg)
- Workshops and participation to KIT's "China Round Table" and further activities within TRENT
- Topic lead within the virtual German-Chilean Institute for Eco-Industrial Development (IECO)
- German-Australian Cooperation

Teaching Activities

The Chair of Business Administration, Production and Operations Management offers several modules in the fields of Production and Operations Management, Risk Management, Project Management, Supply Chain Management and Logistics, and Sustainability. During 2021 around 700 student exams were completed and the chair has supervised 81 bachelor and master theses.

Anlagenwirtschaft / Planning and Management of Industrial Plants

Dr. Simon Glöser-Chahoud, Raphael Heck, Paul Heinzmann, Sonja Rosenberg

~120 students

This course familiarizes students with industrial plant management along the entire life cycle, starting with the initiation and erection up to operating and dismantling. Students learn how to deal with important methods to plan, realize and supervise the supply, start-up, maintenance, optimization and shut-down of industrial plants. A focus is also given to specific characteristics of plant engineering, commissioning and investment.

Grundlagen der Produktionswirtschaft / Introduction to Production Management

Prof. Dr. F. Schultmann, Dr. Rebekka Volk, Justus Steins, Christoph Stallkamp

~180 students

This course aims to make students familiar with basic concepts of industrial production economics and logistics. The main contents are the different strategic, tactical and operational production strategies and layouts, as well as planning and management methods. The terms and tasks of industrial production are defined and described by interdisciplinary and system approaches. Furthermore, warehouse location problems, operational site planning and production design problems as well as decision making are in the focus. Qualification aims are to enable students to describe the field, to reproduce and analyse decisive aspects and decisions in industrial production contexts, to know, model and solve key planning tasks of strategic production management and logistics.

Life Cycle Assessment

Prof. Dr. F. Schultmann, Dr. Marina Maier

~30 students

This course is a short introduction into the methodical field of Life Cycle Assessment (LCA). Within this course, the method itself is explained from different perspectives. Most of the course concentrates on the environmental aspect of LCA, however an overview of Life Cycle Costing Analysis and Social Life Cycle Assessment is included. At the end of the course, the research area of dynamic LCA is presented.

Logistics & Supply Chain Management

Dr. Marcus Wiens , Florian Diehlmann, Markus Lüttenberg

~70 students

Students learn the central tasks and challenges of modern logistics and supply chain management. They learn and apply methods of risk evaluation and risk management in supply chains like market forecasts, the Bullwhip effect and the difference between a lean and a robust supply chain. Further aspects comprise the analysis and development of efficient incentive-schemes and planning-tools relevant to procurement decisions, optimal location decisions, order management and supplier relationship management.

Produktions- und Logistikmanagement / Production and Logistics Management

Dr. Simon Glöser-Chahoud, Sandra Huster, Tobias Zimmer

~120 students

This course covers central tasks and challenges of operational production and logistics management. Systems analytically, central planning tasks are discussed. Exemplary solution approaches for these tasks are presented. Further practical approaches are explained. Students get to know the set-up and mode of operation of planning systems such as PPS, ERP and APS to cope with the accompanying planning tasks. Alongside to MRP II, students are introduced to integrated supply chain management approaches in Supply Chain Management.

Project Management

Prof. Dr. F. Schultmann, Dr. Rebekka Volk, Dr. Marcus Wiens, Marco Gehring, Sonja Rosenberg, Rebecca Wehrle

~60 students

This lecture introduces the basics of project management starting with a general introduction on projects and standards in the field. Then, scope management as well as time, cost and resource management principles are addressed and emphasised. Furthermore, aspects of risk, stakeholder and quality management are described and considered and, communication, negotiation, leadership and controlling in the project management context is examined. The lecture is deepened with practical exercises and complemented by a business game and a software tutorial. Furthermore, we are happy to have two invited talks this semester from employees of Campana & Schott (https://www.campana-schott.com/de/de/), an international management and technology consultancy with more than 300 employees in Europe, the US and Canada. The talks will cover the topics "The role of the project manager" and "Agile Methods of Project Management" from a practical perspective.

Risk Management in Industrial Supply Networks

Dr. Marcus Wiens, Miriam Klein

~50 students

Students learn methods and tools to manage risks in complex and dynamically evolving supply chain networks. Students learn the characteristics of modern logistics and supply chain management and learn to identify and analyse the arising risks. On the basis of this overview on supply chain management, the students gain knowledge about approaches and methods of industrial risk management. Key aspects include the identification of major risks, which provide the basis for the development of robust networks, together with risk reduction techniques like risk diversification, risk pooling and risk transfer. This provides the students profound knowledge for supply chain risk analysis and for the design of strategic and tactic risk prevention and mitigation measures for supply networks.

Supply Chain Management in the Automotive Industry

Prof. Dr. Frank Schultmann, Dr. Tilman Heupel (BMW AG), Hendrik Lang (BMW AG), Florian Kaiser

~100 students

Students learn concepts, methods and tools on various aspects of automotive supply chain management. Through concrete application examples of a globally operating automobile manufacturer, the students recognize challenges that are connected with the implementation of these solutions. The students learn theoretical concepts as well as their practical implementation in the context of value chains, procurement logistics, risk management, quality engineering, cost engineering and purchasing, and they can identify, analyse, and evaluate problems in these areas as well as design adequate solutions. At the end of the lecture, students are able to identify links in these fields and to classify them into the overall context of the value chain and the product development process of an automobile manufacturer.

Sustainable Production

Dr. Rebekka Volk, Dr. Julian Stengel (EnergieSüdwest AG)

~50 students

This course offers an introduction into the basics of sustainability and the linkage of sustainability to production and logistics. Main methods of lifecycle assessment (LCA), social LCA, material flow analysis and ecological accounting are presented. Examples of sustainability assessments and sustainable production systems illustrate actual challenges for the transformation of current production environments into sustainable structures. Also, integrated assessment models, environmental legislation, environmental management approaches and industrial ecology principles are presented. The students get an overview on different sustainability topics, methods, databases, software and legal background in relation to a sustainable consumption and production.

Teaching at the Chair for Business Administration, Production and Operations Management

BSc-Module
„Production Management"

- Introduction to Production Management (SS, 5,5 ECTS)
- Sustainable Production (WS, 3,5 ECTS)
- Logistics and Supply Chain Management (SS, 3,5 ECTS)

MSc-Module
"Planning and Management of Industrial Plants"

- Planning and Management of Industrial Plants (WS, 5,5 ECTS)
- Emissions and Environment (WS, 3,5 ECTS)
- Life Cycle Assessment (WS, 3,5 ECTS)
- International Management in Engineering and Production (WS, 3,5 ECTS)

MSc-Module
"Production and Logistics Management"

- Production and Logistics Management (SS, 5,5 ECTS)
- Supply Chain Management with Advanced Planning Systems (SS, 3,5 ECTS)
- Project Management (WS, 3,5 ECTS)
- Supply Chain Management in the Automotive Industry (WS, 3,5 ECTS)
- Risk Management in Industrial Supply Networks (WS, 3,5 ECTS)

Publications

Peer-Reviewed Journals

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