Karlsruhe Institute of Technology

Institute for Industrial Production

Annual Report 2022

Chair of Business Administration, Production and Operations Management




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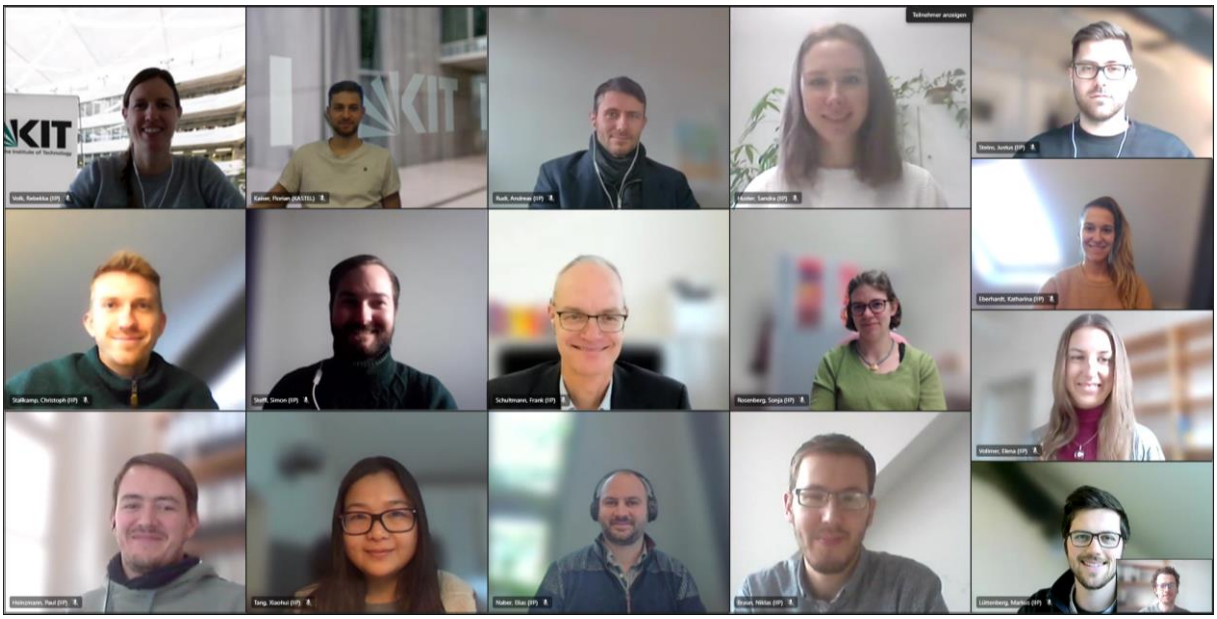
Preface

This annual report of the Chair of Business Administration, Production and Operations Management at the Institute for Industrial Production (IIP), Karlsruhe Institute of Technology (KIT) reflects our main activities during the year 2022. 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 25 researchers, 4 administrative staff and a several student assistants.



[1]

During 2022, we worked on 29 third party funded research projects. We published 15 peer-reviewed journal papers, numerous articles in conference proceedings and book chapters. 4 PhDs and 1 Habilitation were completed. Teaching activities resulted in around 600 exams and about 90 bachelor and master theses were supervised. The Corona pandemic still affected parts of our activities in 2022, in particular our international collaborations, however, we managed to continue and broaden 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 screenshot has been taken in 2022 with most of the team members of the Chair. All pictures in this report have been taken considering the infection protection laws at the time.

Sustainable Value Chains

Head of research group: Andreas Rudi

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).

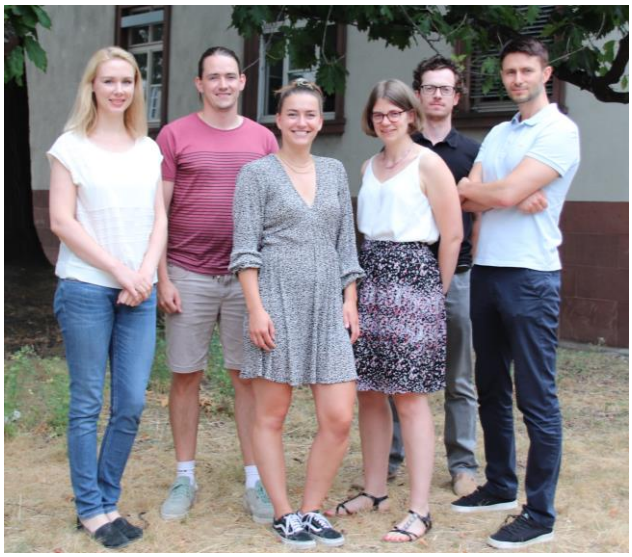
To cope with the related manifold problems, different approaches from economics, engineering as well as environmental and social sciences are implemented, adapted and enhanced. Methods and models are developed based on the regarded problems and transferred to specific applications.

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 (techno-economic analysis)
- 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.): Sandra Huster, Paul Heinzmann, Nina Treml, Sonja Rosenberg, Raphael Heck, Andreas Rudi, Xiaohui Tang (missing in the picture).

Risk Management

Head of research group: Florian Kaiser

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, empirical approaches and data analytics as well as simulations.

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.

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 as well as data analytical works within the research group engineering secure systems.

Furthermore, in 2022 a novel Project started which is on the analysis of alternative storage strategies of public emergency food supply (ALANO).

The year 2022 was driven by change. The former group leaders Miriam Klein and Florian Diehlmann left the IIP. The Risk Management Research Group deeply thanks them for their commitment as group leaders and wishes them all the best for the future. Florian Kaiser took over the role as the research group leader.

In December Rebecca Wehrle successfully completed her PhD with a thesis on ” Criticality of infrastructure networks under consideration of resilience-based maintenance strategies using the example of inland waterways”. Furthermore, also in December Florian Kaiser successfully completed his PhD with a thesis on “Holistic Cyber Risk Quantification and Management”. The Risk Management Research Group warmly congratulates Mrs. Wehrle and Mr. Kaiser 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-and resource-efficient technologies and renewable/sustainable policies, as well as their potentials regarding the built environment. Especially we work in the fields of circular economy, decommissioning and dismantling of nuclear facilities, sustainable urban development, energy resource and emission/waste efficiency in industrial processes, buildings and urban districts and the use of renewable energies in buildings.

To offer decision support for different planning activities on consumer/user or producer perspective, building level, district, regional or national level, several optimization models have been developed and employed. Among others the AWOHM model for energetic retrofits of buildings, the namares model for sustainable urban development, the ECCO models for site-specific greenhouse gas quantification in value chains and the ResourceApp MogaMaR and 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 optimization models for scheduling deconstruction projects taking into account resource constraints, uncertainties, and material flows. While the ResourceApp model is focusing on residential and non-residential buildings, MogaMaR and NukPlaStoR are address nuclear power plants and facilities.. The MogaMaR/NukPlaRStoR model is licensed by our project partner RODIAS GmbH as a software product called OPTIRA since mid 2020. Furthermore, we work on the planning and decision support model namares for a sustainable urban development on district level. In 2022 a second funding phase (namares 2.0) has been successfully acquired.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 biobased composites (research projects ReGrow and Willow Weave) to autoclaved aerated concrete (research project REPOST) and 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.): Humberto Patarca, Marco Gehring, Christoph Stallkamp, Justus Steins, Niklas Braun, Rebekka Volk, Elena Vollmer, Elias Naber, Simon Steffl (missing in the picture: Zoe Mayer, Mihir Rambhia, Daniel Wilkinson).

Research Projects

AI4EOSC – Artificial Intelligence for the European Open Science Cloud

Elena Vollmer, Dr. Rebekka Volk

Partners: Agencia Estatal Consejo Superior De Investigaciones Científicas M.P. (CSIC), Steinbuch Centre for Computing at the Karlsruhe Institute of Technology (KIT), Ustav Informatiky, Slovenska Akademia Vied (IISAS), Universitat Politecnica De Valencia (UPV), Predictia Intelligent Data Solutions Sl, Laboratorio De Instrumentacao E Fisica Experimental De Particulas (LIP), Istituto Nazionale Di Fisica Nucleare (INFN), Instytut Chemii Bioorganicznej Polskiej Akademii Nauk (PSNC), Microstep-Mis Spol Sro, Wielkopolski Osrodek Doradztwa Rolniczego W Poznaniu (WODR)

Funding: European Union (EU)

Duration: 2022 – 2025

The AI4EOSC project aims to deliver an enhanced set of services for the development of Artificial Intelligence (AI), Machine Learning (ML) and Deep Learning (DL) models and applications. These services will allow for advanced features such as distributed, federated and split learning; provenance metadata; event-driven data processing services or provisioning of services based on serverless computing.

The project will focus on tools to provide AI, ML and DL services by integrating real life use cases to aid in the design process and showcase the afore-mentioned functionalities. AI4EOSC bases its activities on the technological framework delivered by the DEEP-Hybrid-DataCloud H2020 project. The DEEP platform is a production-ready system that is being effectively used by researchers in the EU to train and develop ML and DL models.

The AI4EOSC consortium has been assembled to ensure a balanced and complementary set of partners with backgrounds in research, development, technology and innovation. The consortium comprises several of the most active institutions in terms of development, implementation, deployment and operation of distributed pan-European e-infrastructures as well as experienced and highly innovative SMEs with a untapped potential in the field of AI. It consists of 10 partners from academia (including the project coordinator CSIC, KIT, IISAS, UPV, LIP, INFN and PSNC) and industry (Predictia, MicroStep-MIS and WODR).

The IIP joins this endeavour by providing a use case on automated thermography, centered around thermal images of city infrastructure (such as buildings and the ground above district heating networks). These will form a basis to test the platform's functionality and proficiency in incorporating new AI-based models to - in this case - detect thermal bridges on buildings and common thermal anomalies. If possible, new platform services such as federated learning can be showcased using the provided data and AI-model(s).

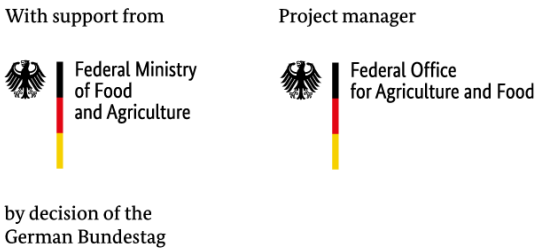
The project kick-off took place in October 2022 at the coordinating university in Santander, Spain. During the course of the event, the project was introduced and planned procedure was discussed on how the current DEEP platform will be improved. The division of the workload into seven work packages was outlined, each work package presenting its key aims and current status. This included an overview of IIP's use case in automatic thermal image analysis as part of workpackage number 6. Since then, regular meetings have taken place and the development of user stories, epics and use case requirements for the first deliverable are well underway. Further recent work focused on setting up a pipeline for training the AI-model(s) that are to be provided as part of the use case.

ALANO - An analysis of alternative storage strategies of public emergency food supply

Florian Kaiser, Katharina Eberhardt, Markus Lüttenberg

Funding: Federal Ministry of Food and Agriculture (BMEL), Federal Agency for Agriculture and Food (BLE)

Duration: 2022 – 2024



In light of past experience in emergency food preparedness and taking into account the lessons learned from the COVID-19 crisis, this research project will examine whether and how adjustments can be made to the design of public food storage and household food storage, in order to be well prepared for future crisis situations.

The aim of the project is to analyze existing and alternative strategies for public emergency food storage. This is done by a multi-stage investigation, in which first the status quo is identified and analyzed. For this purpose, a detailed cost-benefit analysis will be prepared. This is intended to show the current costs of public food stockpiling in peacetime and the benefits in the event of a supply crisis for the scenario's "pandemic", "blackout" and "defense case". In a next step, alternative supply strategies will be evaluated and compared to the status quo.

The findings of the research project are to be integrated into the future design of the state's emergency food preparedness system. The systematic cost-benefit analysis and the identification of alternative situation strategies as well as the consideration of private food storage provide a comprehensive assessment of potential measures.

On June 14, 2022, the kick-off event of the ALANO project took place. At this event, the project was presented and the expectations of the project were coordinated with representatives of the BMEL and the BLE. In addition, various content-related points of the individual sub-goals were discussed and questions clarified. Subsequently, the content-related processing of the work packages began. In addition to initial literature research and model considerations, planning also began for the expert workshop, which will take place in February 2023. As part of this work, initial interviews with key stakeholders in the field of emergency food preparedness were also conducted. Moreover, preparations were made to conduct an empirical study on food stockpiling in private households.

CEDIM – Center for Disaster Management and Risk Reduction Technology

Marcus Wiens & group members

Partners: 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).

CARE-o-SENE – Katalysatorforschung für nachhaltige Flugzeugtreibstoffe

Working package 4 : Impact Assessment aus techno-ökonomischer und ökologischer Perspektive

Paul Heinzmann, Andreas Rudi

Partners: Sasol Germany GmbH; Helmholtz-Zentrum Berlin für Materialien und Energie (HZB); University of Cape Town, Department of Chemical Engineering (UCT); Fraunhofer Institute for Ceramic Technologies and Systems (IKTS); INERATEC GmbH; Karlsruher Institut für Technologie (KIT), Institute for Catalysis Research and Technology (IKFT)

Funding: Federal Ministry of Education and Research (BMBF)

Duration: 2022 - 2025

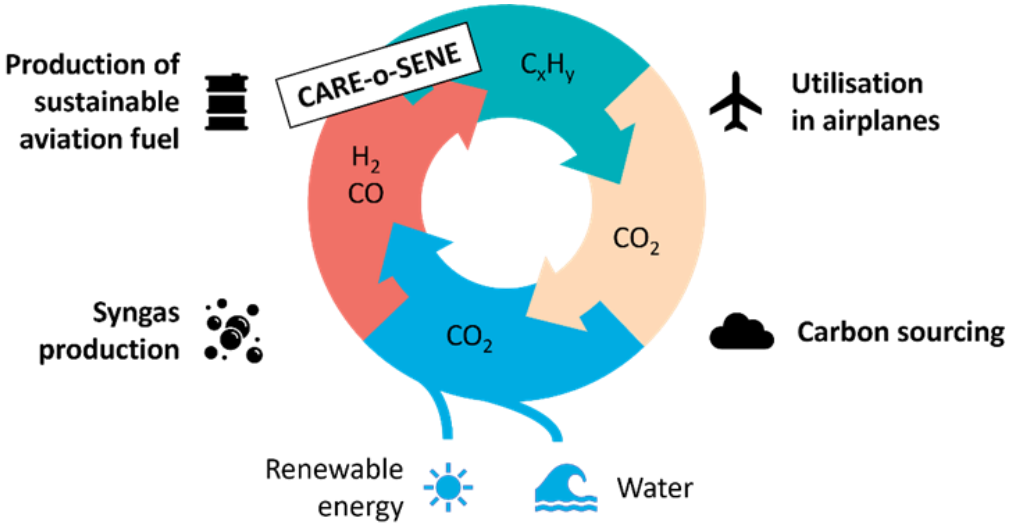
The energy transition requires the substitution of fossil fuels with carbon-neutral alternatives. Power-to-Liquid (PtL) processes might be the future key to a sustainable decarbonization of hard to abate sectors, such as the aviation sector.. The CARE-o-SENE project focuses on the process of converting renewable hydrogen and CO_2 to sustainable aviation fuels (SAF) by utilizing Fischer-Tropsch (FT) processes. FT process derived synthetic paraffinic kerosene (FTSPK) show well demonstrated benefits and high greenhouse gas emissions reduction potential.

To achieve the expected rapidly growing medium to long term demand of SAF, a competitive, reliable FT catalyst with high conversion efficiencies and yields to the desired kerosene product fraction are key success factors.

Therefore, the goal of CARE-o-SENE is the accelerated and knowledge-based development of Fischer-Tropsch catalysts for the highly efficient and sustainable production of green SAFs in relevant volumes for the transformation of the aviation sector. The project aims atthe scale-up of a promising catalyst (TRL 4) targeting a reduced usage of metals, a higher activity, selectivity and longer lifetime, leading to economic and environmental benefits. Additionally, new FT catalysts (TRL0/1) will be developed and analyzed, based on the combined knowledge and skills of the involved partners. .

For future application, development and improvement, understanding and quantifying the overall benefits that the improved catalysts, could have on the production of Sustainable Aviation Fuels (SAF), will be analyzed in an impact analysis in working package 4. This will include life cycle assessment as well as techno-economic evaluations to assess the feasibility of the whole production, application and recycling.

The overall goal of the project strongly complements the German "Hydrogen Strategy". The project will have significant benefits in establishing new, long lasting strategic partnerships and foster existing ones between the various German and South African companies and institutes.


Production of sustainable aviation fuel
CARE-o-SENE
C_xH_y
Utilisation in airplanes
H_2
CO
CO_2
Syngas production
CO_2
Carbon sourcing
Renewable energy
Water

CoBiVal – Cooperation in Bioeconomy Value Chains

Raphael Heck, Simon Glöser-Chahoud, Tobias Zimmer, Andreas Rudi

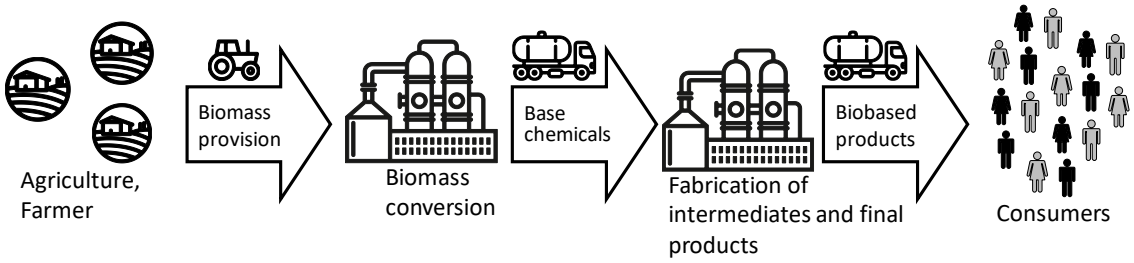
Funding: Federal Ministry of Education and Research (BMBF)

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**	

ReBioBW – Potentials of agricultural residues for the bioeconomy in Baden-Wuerttemberg

Raphael Heck, Andreas Rudi

Partners: Universität Hohenheim, the Departments of Bioeconomy, Production Theory and Resource Economics, Biobased Resources in the Bioeconomy

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

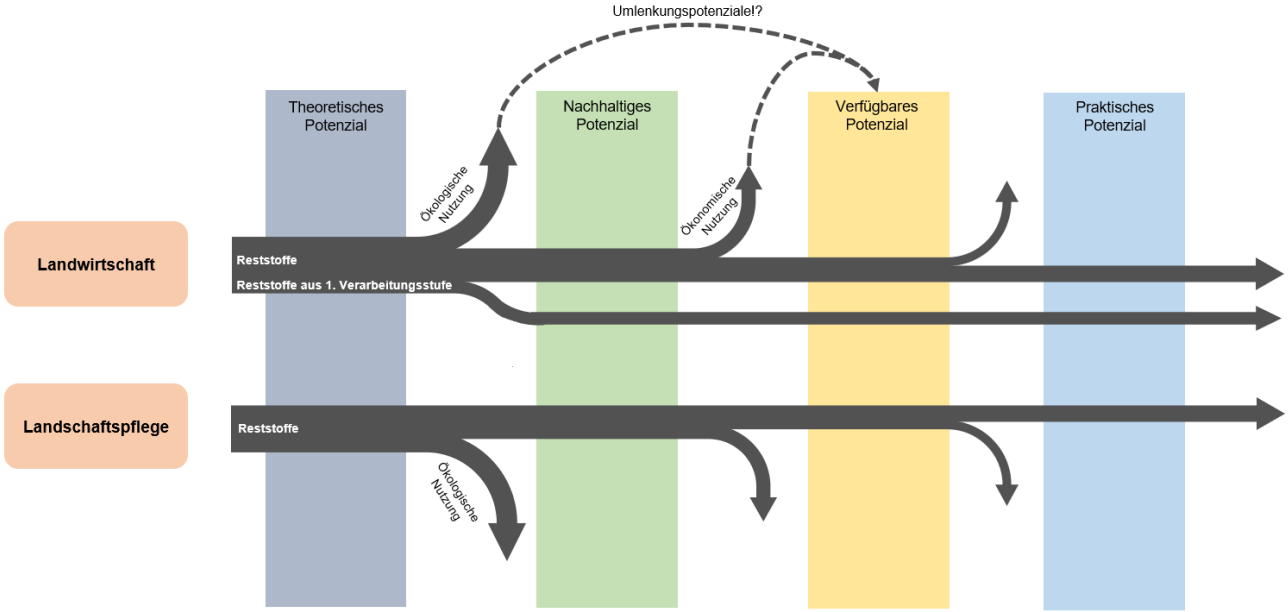
Duration: 2022 - 2025

By substituting fossil resources with renewable resources, the bioeconomy in Baden-Württemberg supports a climate-neutral economy. In order to avoid conflicting goals with food security, the focus is on agricultural residues. However, increased use of residues can cause conflicts of interest with existing use or climate protection if humus build-up and carbon storage in the soil are at risk. At the same time, the use of the residues offers opportunities for new regional value chains in rural areas. Realizing these opportunities and avoiding conflicting goals therefore requires a holistic evaluation of the residual material potential.

The aim of the ReBioBW project is to record the current and future potential of residues from agriculture and landscape conservation for the bioeconomy in Baden-Württemberg.

Using statistical data, the theoretical potential is calculated as the absolute volume of residues and minus the quantities for humus build-up, the sustainable potential. A representative survey among farmers is intended to provide information on the current use of the residues in order to determine the economically available potential. Qualitative surveys among companies and farmers show hurdles and framework conditions for calculating the practical potential. By developing a regional bioeconomy sector model and coupling it with an agricultural operating model, the knowledge gained is used to estimate the economic and ecological effects of residue use and future residue potential against the background of economic, social and political drivers. The surveys are accompanied by knowledge transfer along the value chain of agricultural residues in order to close knowledge gaps with regard to the nature, demand and supply and to increase the practical potential.

The project is being carried out in close coordination with the Baden-Württemberg Ministry of Food, Rural Areas and Consumer Protection and is based on the state strategy for sustainable bioeconomy.



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

Sandra Huster, Sonja Rosenberg, Simon Glöser-Chahoud

Partners: 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 (MUKE)

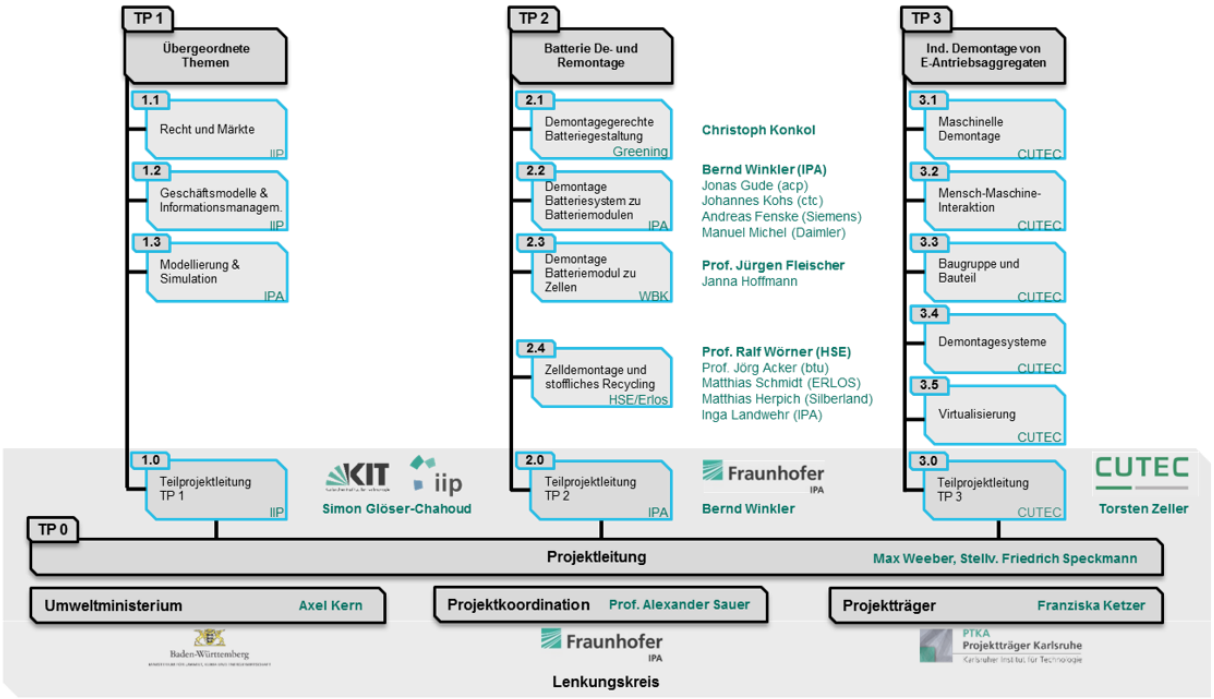
Duration: 12/2019 – 03/2023

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.



E-Akteur – Akteursbeziehungen in der kreislaufwirtschaftlichen Wertschöpfung von E-Fahrzeugbatterien

Sandra Huster, Andreas Rudi

Partners: Fraunhofer Institute for Manufacturing Engineering and Automation IPA

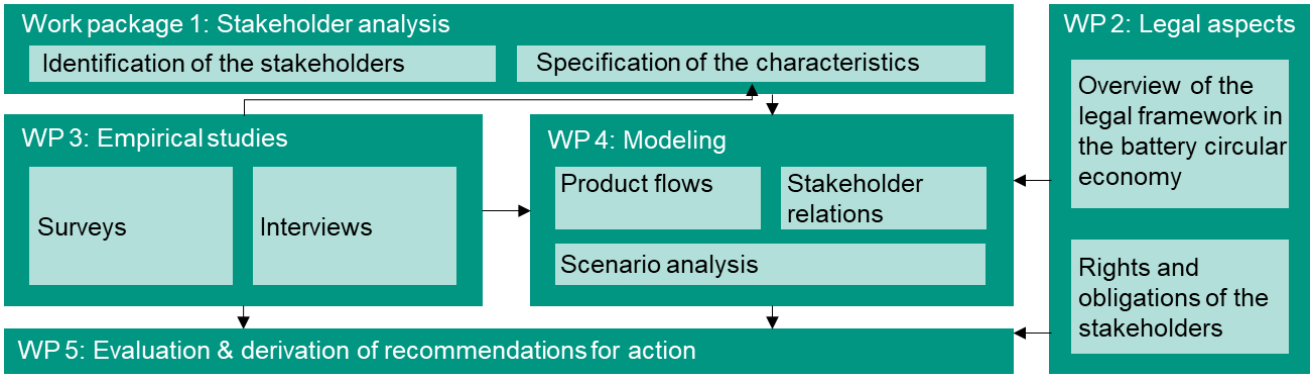
Funding: Ministerium für Wirtschaft, Arbeit und Tourismus Baden-Württemberg (MWAT)

Duration: 11/2022 - 12/2024

Due to the increasing spread of electric vehicles, it is foreseeable that many e-vehicle battery systems will reach the end of their first phase of use in vehicles soon. To meet the challenge of recycling these battery volumes in a resource- and environmentally-conscious manner, a wide variety of recycling solutions are being researched.

Industrial recycling capacities are also already being established. Other options for handling batteries in a recycling-friendly manner, such as repurposing them or remanufacturing them for reuse in the vehicle as a replacement battery before final recycling, are also being discussed, but to a much lesser extent. This also reflects in the public and scientific debate, which focuses primarily on recyclers and manufacturers of vehicles and batteries. Other players, such as logistics service providers, remanufacturers, core brokers, and customers, receive less attention, although presumably, all players influence how batteries will be recycled in the future. It is currently unknown how those above and other stakeholders for used traction batteries will interact with each other and what factors decide which recovery path a battery system will take after initial use. In order to build an efficient, collaborative, circular economy value network for future EoL battery streams in Baden-Württemberg, it is considered necessary to understand the interests and interactions of the stakeholders. This will help identify how incentives for collaboration can be set on the part of policymakers, and barriers can be reduced to create an environment in Baden-Württemberg that is attractive for battery circular economy companies.

The project will first identify and describe the relevant players. Empirical studies will help to understand the interests of the stakeholders. Thus, one goal of this research project is a transparent survey and description of the stakes, incentives, and barriers of the stakeholders involved in circular economy value creation. The findings on the stakes will then be used to parameterize innovative modeling approaches. In these models, the physical battery material flow is to be represented, but also behaviors of the stakeholders involved are to be mapped with the help of agent-based modeling. The models will be used to analyze, on a scenario basis, how different basic conditions affect the recovery pathways of traction batteries. The empirical studies and the scenario analysis will be used to derive options for steering battery flows toward different end-of-life paths.



Entwicklung von Rückbau- und Recyclingstandards für Rotorblätter

Dr. Rebekka Volk, Simon Steffl

Partners: 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 – 2022

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: Wind park

From the perspective of high-quality recycling, composite materials like 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 Entwicklung von Rückbau- und Recyclingstandards für Rotorblätter, 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.

Use and management of finest particulate anthropogenic material flows in a sustainable circular economy ("FINEST")

Dr. Rebekka Volk, Daniel Wilkinson

Partners: Helmholtz-Zentrum Dresden-Rossendorf (HZDR), KIT-ITC Helmholtz Centre for Environmental Research (UFZ), Helmholtz-Zentrum Berlin für Materialien und Energie (HZB), TU Bergakademie Freiberg, Universität Greifswald

Funding: Helmholtz Association of German Research Centres under the "Helmholtz Sustainability Challenge"

Duration: 07/2022 – 07/2027

FINEST aims to develop a combined pyrolysis- and rotary-kiln based recycling process for creating high value products from the waste of external thermal insulation composite systems (ETICS) based on expanded polystyrene (EPS) and its mineral adhesions. Recycled cement clinker bricks and styrene are potential products of the FINEST project. These products are expected to partially replace their virgin counterparts, reducing construction and other sectors' environmental impact.

ETICS are multilayer insulation systems applied to building facades, walls, and roofs to reduce heat transmission and exchange, lowering energy demand and costs. They consist of a base coat, EPS insulation (such as EPS), anchors, a base coat, a reinforcement mesh, and a finishing coat. The layers are held together with adhesive. ETICS have been in use since the 1960s and have an approximate lifespan of 60 years. To improve buildings' energy efficiency, ETICS are being increasingly installed and the amount of waste from ETICS will increase.

One of the common insulating materials included in ETICS is EPS, a low-density fossil-fuel-based plastic. Its production has a large environmental footprint but, installed as an insulating material, it reduces energy consumption during building operation. Currently, waste EPS is typically burned for heat recovery and the material value is lost. The layers contain valuable minerals, metals and plastics bound together. The exact composition and quantity of each component varies from building to building. ETICS are difficult to separate mechanically and contain diverse, high-value materials that can be used in a circular economy.

The FINEST project is structured into three sub-projects which address plastic, mineral and metal fine particulates. In sub-project 1, UFZ, UG and HZB focus on developing processes for recovering microplastics whereas the focus of sub-project 3 (TU BAF) is on recovering metal fines. The mineral components of EPS-based ETICS are KIT's focus (sub-project 2). KIT IIP is responsible for the life cycle assessment and techno-economic assessment of the new recycling process with respect to minerals . Our emphasis is on demonstrating the potential for sustainability and avoiding risks to the environment. In addition, the optimum number and location of decentralised treatment facilities in Germany will be evaluated.

FINEST will establish and maintain a research school for training 28 postgraduate students. This includes the provision of internships to build connections with industry. PhDs will be prepared for leadership roles in industry and academia through a tailored doctoral programme. Knowledge will be transferred to industry through careers, which will be achieved through a central transfer desk at HZDR which is connected to industry clusters and organizations.

IntWertL – Intelligente Wertschöpfungsnetzwerke für Leichtbaufahrzeuge geringer Stückzahl

Sonja Rosenberg, Sandra Huster, Nina Treml, Andreas Rudi

Partners: KIT-IMI, Fraunhofer IPA, DLR, bwcon, many small SME from BW, further associated partner (cities)

Funding: Federal Ministry for Economic Affairs and Climate Action (BMWK)

Duration: 2022-2025

The mobility sector is currently undergoing a transformation, which must be evaluated in terms of the economic, ecological and social dimensions of sustainability. Global competitive pressure is increasing sharply, and sustainability and climate protection are transforming from an additional benefit to an obligatory goal. Classic individual mobility is increasingly being questioned by society. Concept lightweight construction offers new forms of mobility. Vehicles can be optimized for a specific application (use case) and be resource-saving alternatives compared to the classic series-produced vehicle. While there are numerous prototypes of such use-case specific mobility, the introduction into the market often fails due to the high costs associated with pre-series and small series production.

The project therefore aims to build a digital engineering and production platform for small and medium-sized enterprises that enables manufacturing companies and engineering service providers in cooperative approaches to offer complex products in small quantities to increase their global competitiveness. Distributed engineering and production lowers barriers to launch such lightweight vehicles. Small companies can thus become integrators/OEMs themselves. The engineering and production platform is initially designed for specific use cases of lightweight vehicles. To ensure that the developed platform can withstand the challenges of practical use, the commitment of potential users is of particular interest. That is why the active participation of more than twenty SMEs from Baden-Württemberg is not only encouraging for the project work, but also shows that the industry sees strong economic potential in the development of the platform. Leichtbau BW GmbH and bwcon are responsible for the overall project coordination and lead the knowledge transfer. In addition to the industry partners, KIT, represented by IMI (Institute for Information Management in Engineering) and IIP, Fraunhofer IPA and DLR are involved in the project as scientific partners. The project is rounded off by associated municipalities, which contribute their knowledge about the future mobility behavior of end customers to the project.

The IIP will carry out the ecological evaluation within the project. Among other aspects, this includes the development of a concept to derive the ecological benefits of the developed lightweight engineering and production platform. Furthermore, it will be investigated how the platform can be extended in order to be able to take ecological aspects into account when using the platform.

EthaNa – Piloting the native ethanolic extraction of rapeseed (EthaNa);

Subprojects 5: Economic and ecological accompanying research in the joint project

Andreas Rudi, Simon Glöser-Chahoud

Partners: 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

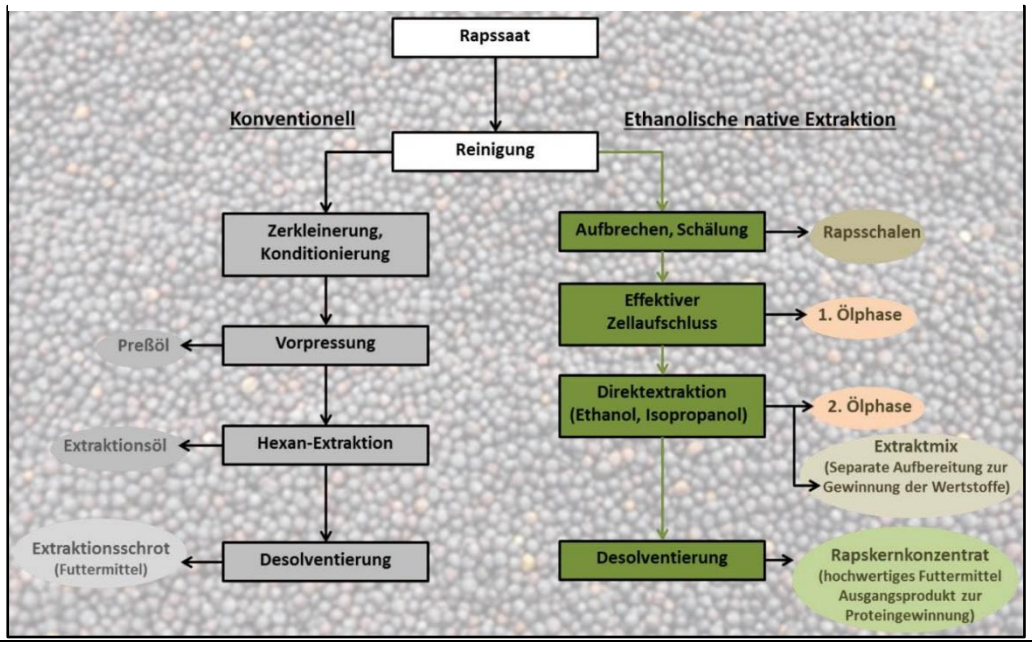
Funding: German Federal Ministry of Food and Agriculture (BMEL)

Federal Ministry of Food and Agriculture

Duration: 09/2017 - 11/2022

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. Project page: https://ethana.de/

EthaNa Process



Leuchtturmprojekt Kreislauf für Kunststoffe

Dr. Rebekka Volk, Christoph Stallkamp

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

Funding: THINKTANK Industrielle Ressourcenstrategien, Land Baden-Württemberg

Duration: 01/2020 - 12/2022

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 the mapping of the waste volume in Germany.

Figure: 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: Pyrolysis condensate from different plastic waste fractions

The project is funded 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.

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

Dr. Rebekka Volk, Elias Naber

Partners: 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 NaMaRes project successfully ended in June of 2022. Moreover, successive funding was acquired to continue the research of NaMaRes in the follow-up project named namares 2.0.

Increasing societal interest calls for more sustainable, climate-friendly, climate-adapted, biodiverse, and resource-efficient urban development. Existing districts, in particular, face the challenge of utilizing the available resources (here: land and soil, water, ecosystem services/biodiversity, and primary raw materials) in a low-impact manner to become future-proof and to develop, evaluate, and advance the implementation of integrated solutions for more efficient urban resource use. Integrated, resource-efficient neighborhood development and urban transformation is a process in several steps with 1) an analysis of the initial situation with identification of the need for action, 2) a formulation of concrete goals, 3) an analysis, evaluation, and prioritization of possible measures, and 4) planning and implementation of these measures including success control, long-term monitoring, and continuous improvement.

Very few cities currently have comprehensive data on district-level resource inventories and suitable planning and assessment tools to address the challenges in sustainable development.

The NaMaRes project aimed to develop and prepare methodological principles and recommendations for action and to develop (digital) tools for an integrated planning and transformation process at the district level toward resource-efficient existing districts. The results are a software application, the documentation of basic principles and suitable indicators, and guidelines on water, materials, area, and ecosystem services in urban development. The software application uses existing urban data on building (LOD2 model) and on sealing, greenry and open spaces. These are processed accordingly so that potentials for nine different improvement or intervention measures on the ground, roof, and facade areas can be calculated. For each measure, specific technically realizable potentials are calculated. Then a comprehensive assessment of the measures is conducted. The assessment results can be called up for each building, subarea, parcel, building block, or neighborhood. This allows for identifying potential improvements ('hot spots') of resource efficiency in the existing districts. The indicator set assesses technical, economic, and ecological aspects, such as intervention-design, ecosystem services, or maintenance cash flows.

The research results from NaMaRes show that data availability and urban data processing can be improved. The software application was developed using the example and requirements of the redevelopment area in Karlsruhe's Innenstadt-Ost. There, considerable potential for a sustainable redevelopment could be identified for the nine measures investigated. The foci of the study were soil desealing of privately ownereal estate and utilizing building surfaces for climate change adaptation.

Further reading on specific results:

https://publikationen.bibliothek.kit.edu/1000147805

https://publikationen.bibliothek.kit.edu/1000149416

https://publikationen.bibliothek.kit.edu/1000148530

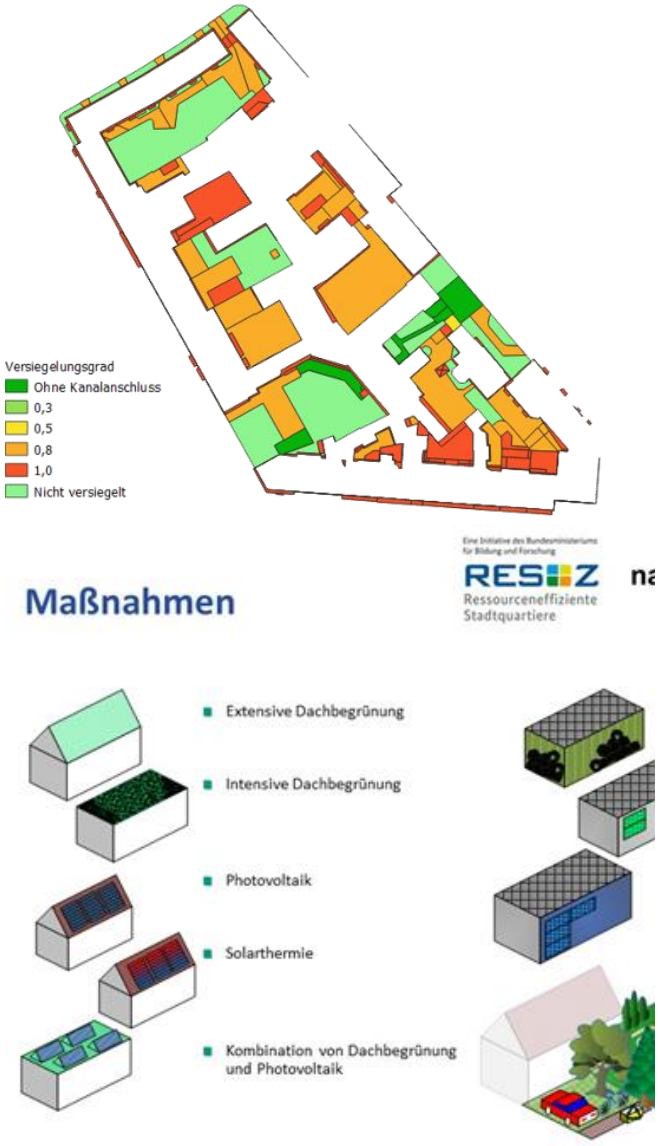


Figure: Measures modeled in the NaMaRes project

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

Namares 2.0 – Urban resource management on the district level

Dr. Rebekka Volk, Elias Naber

Partners: City of cologne, Environment and Energy Agency Karlsruhe County, Institute for Environmental Science and Geography at the University of Potsdam, Smart Geomatics GmbH. The project is coordinated by IIP.

Funding: BMBF - funding code:

Duration: 07/2022 - 06/2024

Namares 2.0 is the successor of NaMaRes with a partly new project consortium. For our further research and development efforts in urban resource management, we successfully obtained funding from the German Federal Ministry of Education and Research (BMBF). The project supports the implementation of the flagship initiative Future City of the BMBF1 framework program "Research for Sustainable Development - FONA3" within the guideline "Resource Efficient Urban Neighborhoods for the Future" and on the topic of "Sustainable Urban Land Management."

The objectives of this second research phase are the continuation and further development of the namares software (from phase 1 NaMaRes) and the digital support of an integrated planning and transformation process on the district level for the transformation of existing districts into resource-efficient urban districts. The enhanced namares model will be used in the project in multiple urban areas in Cologne, Bruchsal and Bretten and it will integrated into municipal planning processes. Moreover, it is planned to make the academic model open-source for further scientific exchange and development and develop a commercial product (webtool with GUI) at the same time for easy user interaction. The role of the municipal partners in namares 2.0 is the use and test of the software. Moreover, the project partners will provide feedback on the development process in co-design workshops to further enhance the software. The academic partners will continue the academic development and plan to publish scientific publications. In the first half year of the project, promising advancements in data preparation and automatic tree detection were made.

NOLAN

Markus Lüttenberg, Katharina Eberhardt, Florian Kaiser

Partners: 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, which finally ended in August 2022 after more than four years, the option of a public-private partnership in crisis management was 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 investigated the possibilities for the effective and practical design of a "Public Private Emergency Collaboration" (PPEC).

The overall objective of the project was to improve the supply security of an urban population with essential goods in crises. The aim was 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 – was 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 was 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 were modelled and the interaction of the supply chains simulated and optimized. Parallel to this, a game theoretical analysis of the cooperation was 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.

At the beginning of this year, results of the NOLAN project were presented within a project meeting of the Thünen Insitute, which focused on the food security for animals. Furthermore, in June, within a joint project meeting with colleagues from the project BASIC, which are dealing with the supply of cash in Germany, various crisis scenarios and possibilities to collaborate, have been discussed. A Presentation was held in July at the EURO in Espoo, Finnland.

A Presentation was held in July at the EURO in Espoo, Finnland.

Furthermore, project meetings with the project partners from Berlin and Dresden took place digitally, as well as one last project meeting in person took place in July in Dresden and Freiberg. 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.

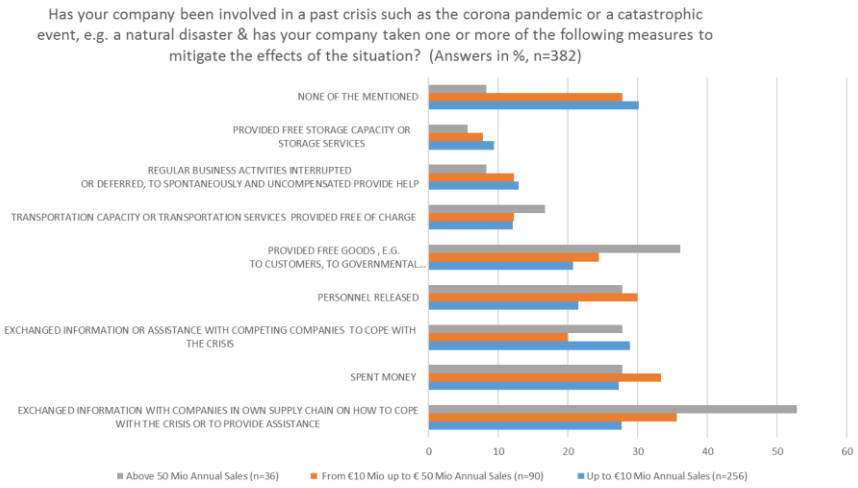


Figure: Responses from company representatives (n=382) working in the field of essential goods (food, beverages, medicine)

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; Dornier Nuclear Services 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 prototype of the user-friendly planning tool in close collaboration. The development was supported by Dornier Nuclear Services 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 running prototype of the layout model in Python and develops extensions for it. The NukPlaRStoR project was successfully completed in December 2022.

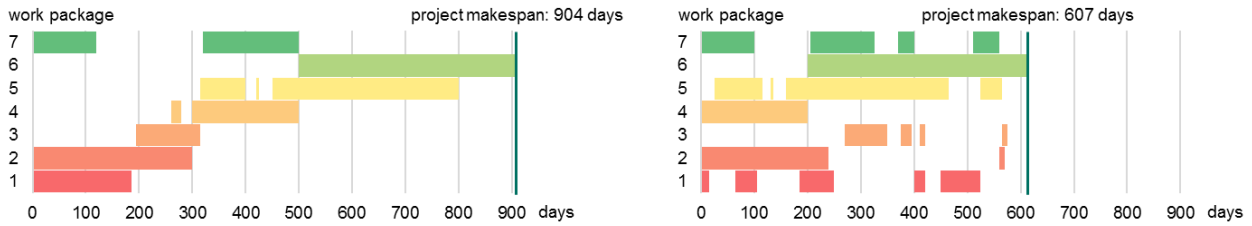


Figure: Gantt charts of an original project schedule (left) and the corresponding optimized project schedule (right) using the NukPlaRStoR planning tool

PREVIEW

Rebecca Wehrle, Florian Kaiser

Partners: 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 investigated 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 was thus to increase the resilience of the waterway infrastructure in Germany. To this end, adverse consequences were 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 is analysed. The resulting findings can be used to draw up contingency plans in order to effectively counter these hazards.

The results of the project were incorporated into a simulation model implemented as web-GIS application, 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 2022, 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 2022, the project was completed after a cost-neutral extension and after a final event had already taken place in September 2021 to enable a continuous transfer of knowledge.

The continuous validation of the research results was pursued through publications and conference participation within the scope of the research project. For example, one paper was published in the journal *Water* and one in the journal *Progess in Disaster Science*. Further research results are currently in the review process.

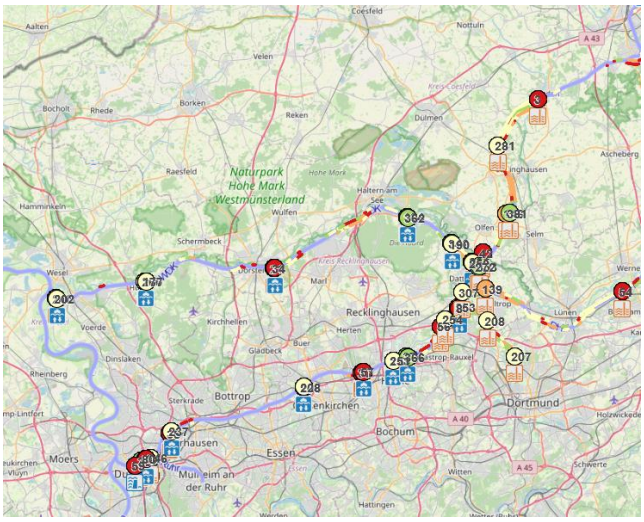


Figure: Excerpt of the developed GIS-based web application that allows to monitor a resilience-based maintenance strategy. Construction elements and their depicted assessed risk then are concluded to a prioritization order.

Ref4Fu – Refineries for Future: Erneuerbare Kraftstoffe aus Grünen Raffinerien der Zukunft

Working package 4: Techno-economic and ecological assessment of renewable fuels

Paul Heinzmann, Andreas Rudi

Partners: Institut für Kolbenmaschinen (IFKM), Institut für Katalyseforschung und -technologie (IKFT), Institut für Mikroverfahrenstechnik (IMVT), Engler-Bunte-Institut (EBI)

Funding: Förderprogramm Nachwachsende Rohstoffe (FNR), Federal Minsitry of Food and Agriculture (BMEL)

Duration: 2022 - 2025

The REF4FU project, in cooperation with 5 research and 6 industrial partners, aims to develop, validate and evaluate sustainable refinery concepts with which the future demand for liquid fuels can be generated on the basis of sustainable raw materials. From green methanol, Fischer-Tropsch hydrocarbons and pyrolysis oil, the fuels that are customary in road, air and ship traffic today and that are likely to be required in the future are to be produced, tested and evaluated using scalable technologies. The technologies required for this should be verified at least in TRL 5. The refinery concepts derived from this are evaluated with regard to technical, ecological and economic characteristics and their flexibility for future fuel requirements and possible synergy and optimization potentials are determined. Finally, an overall assessment is made against the background of the regulatory framework and the feasibility of the refinery concepts developed.

The results of the analyzes and models shall demonstrate the potential of synthetic, green fuels. For this purpose, the system mentioned must first be implemented and tested on a pilot plant scale. Furthermore, the results of the cost and profitability analysis are used to support the decision-making process with regard to the optimization of the system constellations, the usefulness of the planned synergies and the profitability of the overall concept. The developed supply concepts and calculated GHG reduction potentials serve as a scientific representation of the possible contribution of synthetic fuels/biogenic fuels in sustainable road, air and shipping traffic.

In Working package 4 a techno-economic and ecological evaluation of the fuels is carried out. The focus of the work is on the flow chart simulation, the economic evaluation and the derivation of synergy and optimization potentials.

reFuels – rethinking fuels

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

Partners: 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

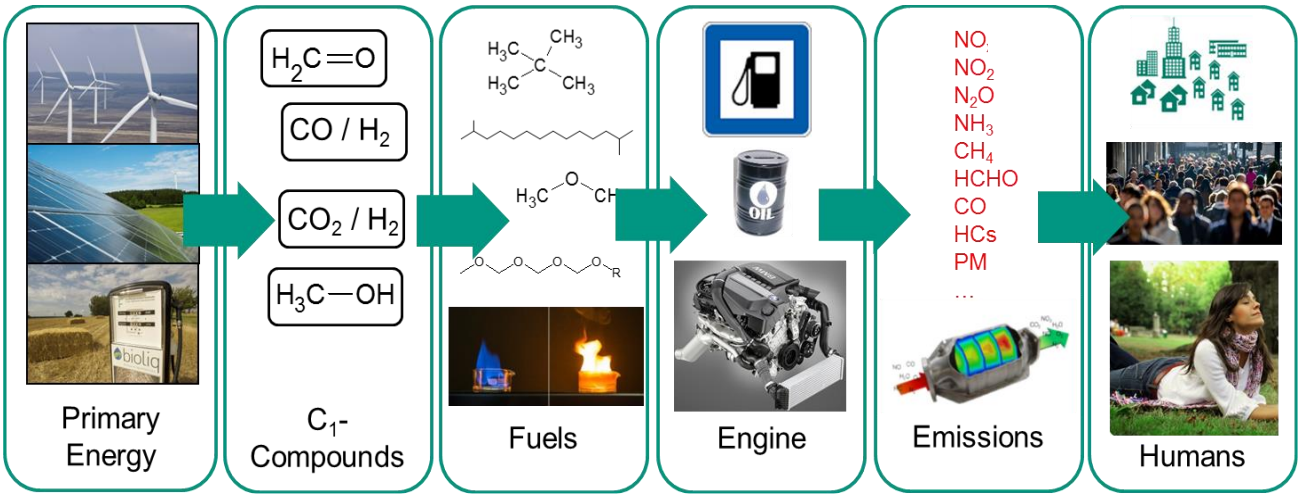
Duration: 2019 - 2022

The utilization of renewable produced fuels (reFuels) is one of the main actions beside electric mobility on the way to a CO_2 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 CO_2 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. The project ended in 2022 and the results were presented at the final event at the site of the industrial project partner Mineralölraffinerie Oberrhein. The project results and the the final report are published on the project website. Project page: https://www.refuels.de/



ReGrow - Function-integrated lightweight structures for sustainable construction with local renewable raw materials

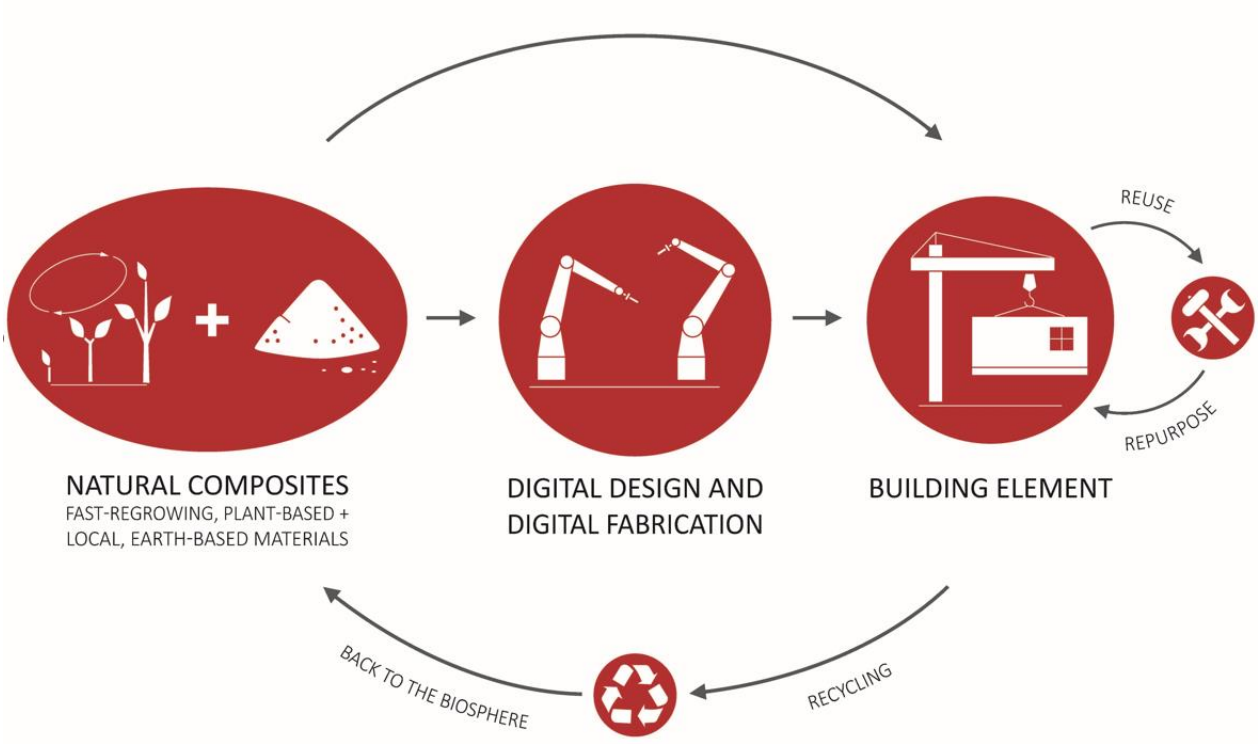
Dr. Rebekka Volk, Simon Steffl

Partners: KIT Professorships Digital Design and Fabrication, Building Physics and Technical Building Services, Design of Structures, Light Technology Institute, Institute of Microstructure Technology, FiBR GmbH

Funding: BIPL-Innovation Ministry for Nutrition, Rural Areas and Consumer Protection Baden-Württemberg

Duration: 2022 - 2023

The ReGrow project opens up new applications in the construction industry for rapidly and regionally growing renewable materials such as willow rods and flax fibres. The two robot-assisted 3D manufacturing processes specially adapted for renewable raw materials, willow braiding and free-form winding, are being used and assessed in this project. In addition to traditional timber construction, this expands and diversifies the range of locally available forestry and agricultural building materials, thus making an important contribution to the circular economy in the construction industry. This includes the development of a new type of construction and design repertoire and as well as the implementation of appropriate machine technology for the production of load-bearing components. Both technologies are combined in a complementary way to implement a modular concept for the production of functionally integrated building components with renewable raw materials. Within the framework of the project, a demonstrator will be implemented and shown at the "Bundesgartenschau 2023" in Mannheim. A central research building made of wound flax fibres will be used to create a shading and roofing structure that will provide a venue for lectures and exhibitions. In order to be able to evaluate this new approach to sustainable building technology in terms of its environmental effects, the project and corresponding manufacturing processes will be analysed within a life cycle assessment.



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

Dr. Rebekka Volk, Justus Steins

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

Funding: BMBF - funding code: 033R249B

Duration: 06/2019 - 12/2022

"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 fresh AAC, 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 % of mineral construction waste is recycled, but mostly as low-value and one-off downcycling in road construction.

Figure: 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. First, 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.

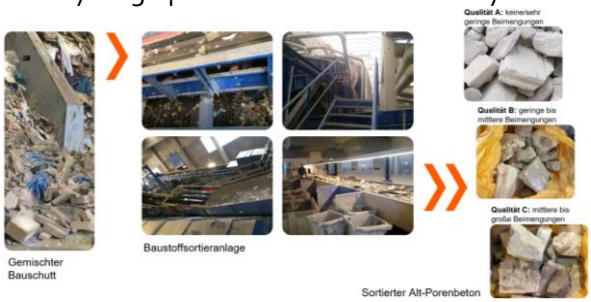


Figure: Provision of old aerated concrete in various grades of purity

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

Nina Treml, Andreas Rudi

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

Duration: 2021 - 2024

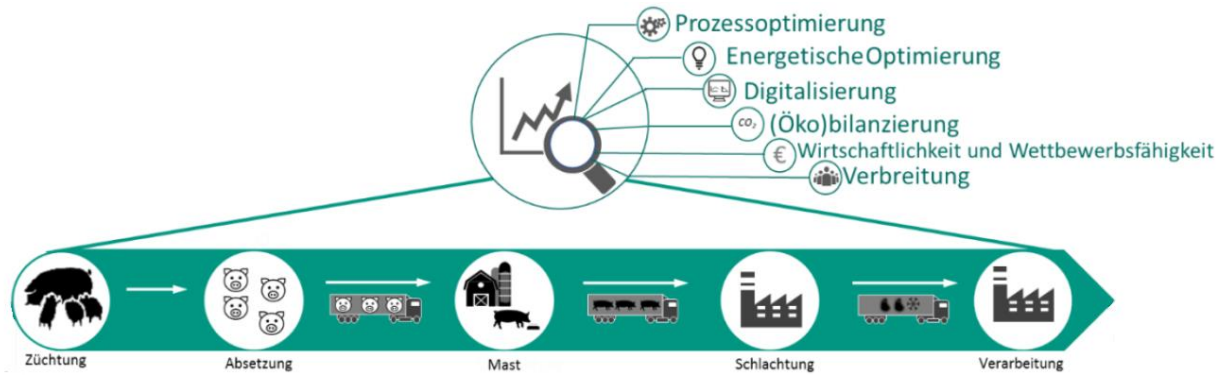
Agriculture and especially animal husbandry are currently facing major challenges, such as ensuring food quality and enabling sustainable value chains. To address these challenges, regional and global food security, animal welfare, efficient use of raw materials, climate and environmental protection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

Dr. Simon Glöser-Chahoud, Andreas Rudi

Partners: 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 HOLISCON

– Feasibility study for holistic concrete recycling–requirements, potential analysis *and recommendations for action*

Dr. Rebekka Volk, Elena Vollmer, Humberto Patarca

Partners:s KIT - Institute for Technical Chemistry (ITC), KIT – Institute of Concrete Structures and Building Materials (IMB)

Funding: BMBF - funding code: L7518017

Duration: 01/2022 - 12/2022

In Germany, cement production in 2020 caused more than 20 million t CO_2 equivalents, which represent up to about 3% of the total national CO_2 emissions (compared to 7% worldwide). As a core component of concrete, which is currently indispensable as a construction material, there is an urgent need to improve its environmental impact and sustainability. However, effective CO_2 savings in the field of cement or concrete production can only be achieved if more than just one-dimensional analyzes are carried out.

The aim of the project is therefore to take a holistic approach and optimize the sustainability of concrete so that as many components of the concrete as possible can be replaced by secondary raw materials. In cooperation with the Institute for Technical Chemistry (ITC) and the Institute for Concrete Structures and Building Materials (IMB) of KIT, the first step towards a broad application of concrete recycling is to be taken. A study to analyze the feasibility of such a project should examine the current state of the art of concrete and cement industry and describe the requirements and potential in order to derive recommendations for action.

With this approach, sustainability is not only considered in relation to climate neutrality, but also takes into account ecological aspects as well as durability, cost-effectiveness, recyclability and social acceptance. The study ranges from an inventory of the recycled concrete and the available secondary raw materials, to an analysis of the potential of the recycling system, to an evaluation of the feasibility of holistic concrete recycling. The construction material should not only be considered as a material in the production process, but its entire life cycle including all environmentally relevant processes should be examined - from the recycling of secondary materials to concrete production and transport to processing and use. In particular, different manufacturing, processing and recycling processes should be considered and compared with each other. With the the gained insights, a multi-criteria evaluation and the creation of a decision-supporting guide is aimed at.

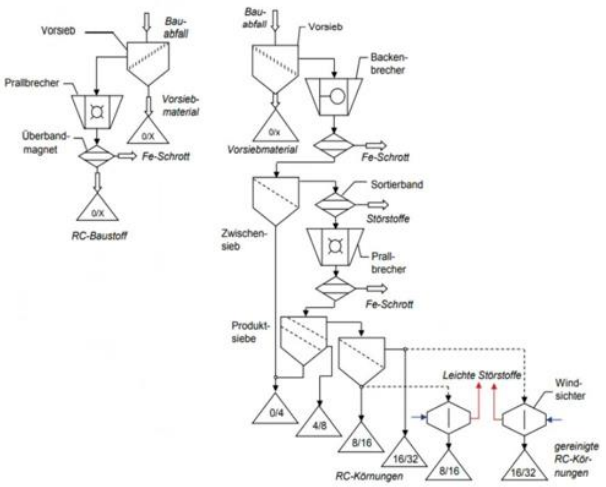


Figure: simplified process diagrams of a mobile processing plant for mineral construction waste (left) and a stationary processing plant (right)

THINKTANK "Industrial Resource Strategies"

Dr. Rebekka Volk, Dr. Simon Glöser-Chahoud, Frank Schultmann

Partners: 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.

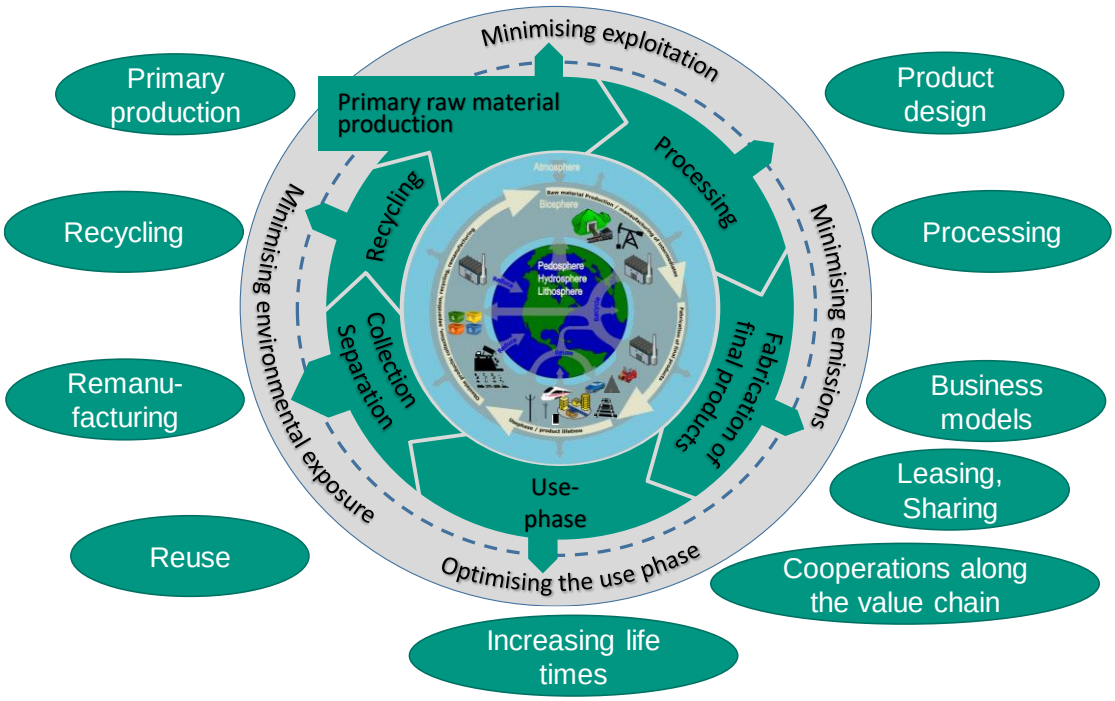


Figure: Circular Economy from a systemic perspective as a key element of research activities within the ThinkTank Industrial Resource Strategies

Urban heat losses and detection of thermal bridges

Dr. Rebekka Volk, Zoe Mayer, Yu Hou

Partners: University of Southern California, Air Bavarian GmbH

Funding: DAAD, Landesgraduiertenförderung Baden-Württemberg

Duration: 03/2018 - 12/2022

Figure: 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, 2019 and 2022. The latest data collection was scheduled in January and February 2022. 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 terrestrial experiments were undertaken with a hand-held camera to calibrate the different thermal cameras in use and to measure outdoor temperatures and temperature distributions of exterior building components.

As a result, we compared hand-held and drone-based thermography in a published study.

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) where research is still ongoing.

Within this project, the research group deals with the identification of heat losses in buildings and district heating networks via different neural networks to design and assess change measures from a technical, economic and ecological point of view.

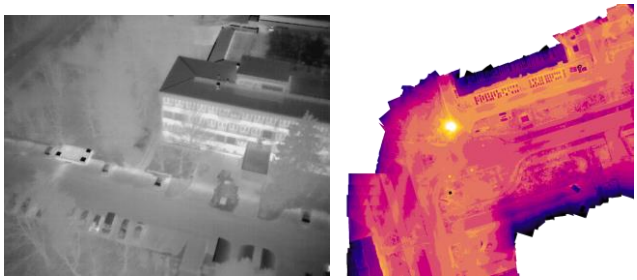


Figure: Thermal images with visible damages (©Rebekka Volk)

Most recent developments were presented both in conferences (ISARC conference in 2019, Banff, Canada, 9th ACM International Conference on Systems for Energy-Efficient Buildings, Cities, and Transportation – BuildSys '22 in 2022, sbe 2022 in Berlin) and published in several scientific journals (Automation in Construction, Remote Sensing, Computing in Engineering from the American Society of Civil Engineers (ASCE) International as well as in Building and Environment. Moreover, we published our dataset on the zenodo platform to enhance research in the field.

URBAN
– CO_2-reduced concrete by upcycling residues from concrete preparation and CCU

Dr. Rebekka Volk, Humberto Patarca

Partner: KIT - Institute for Technical Chemistry (ITC), KIT –Institute of Concrete Structures and Building Materials (IMB), Leibniz University Hannover (LUH) - Institute for building materials (IfB), Sika Deutschland GmbH, EHL AG, Holcim (Deutschland) GmbH

Funding: BMBF - funding code: 03EE5130C

Duration: 01/2023 - 12/2025

The aim of the project is to develop a highly CO_2-reduced, high-quality and resource-efficient concrete cycle for old, post-demolition concrete. For this purpose, a belite-based Portland cement clinker (RC clinker) with a low CO_2 footprint will be produced from concrete crushed sand for the first time. Released CO_2 can be separated in a concentrated manner and used for the technical carbonation of either mechanically processed concrete crushed sand as a substitute in cement or for carbonation hardening of coarse RC rock formation (CCU) using a new process based on a pressure autoclave.

Recycled cements with a greatly reduced CO_2 footprint are formulated from recycled bricks, Portland cement clinker and technically carbonated crushed sands as well as other substitutes. In order to enable its use in production, recipes for recycled concretes based on adapted superplasticizers and accelerator systems are developed from recycled cement and recycled aggregate (RC2). At the end of the project, plant tests will be carried out to demonstrate the high-quality concrete cycle using the example of concrete products and precast concrete elements.

The newly developed technical process is assessed and evaluated technically, economically and ecologically for different plant sizes and locations over the entire life cycle and compared with the state of the art. The aim is to reduce the cumulative CO_2 emissions of RC2 concrete by at least 40% compared to conventional recycled concrete.

In addition, regulatory boundary conditions are examined (e.g. Recycling Building Materials Ordinance, DIN-EN 197-1, legal classification of a plant for clinker production) in order to identify obstacles in the implementation of centralized or decentralized concepts.

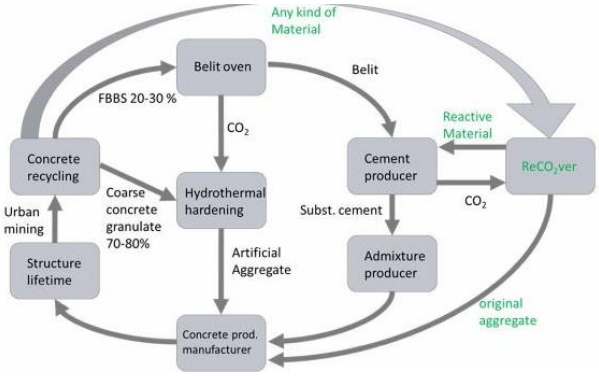


Figure: Circular flows (URBAN), supplemented with the material flows of the Sika project RECO2VER (green)

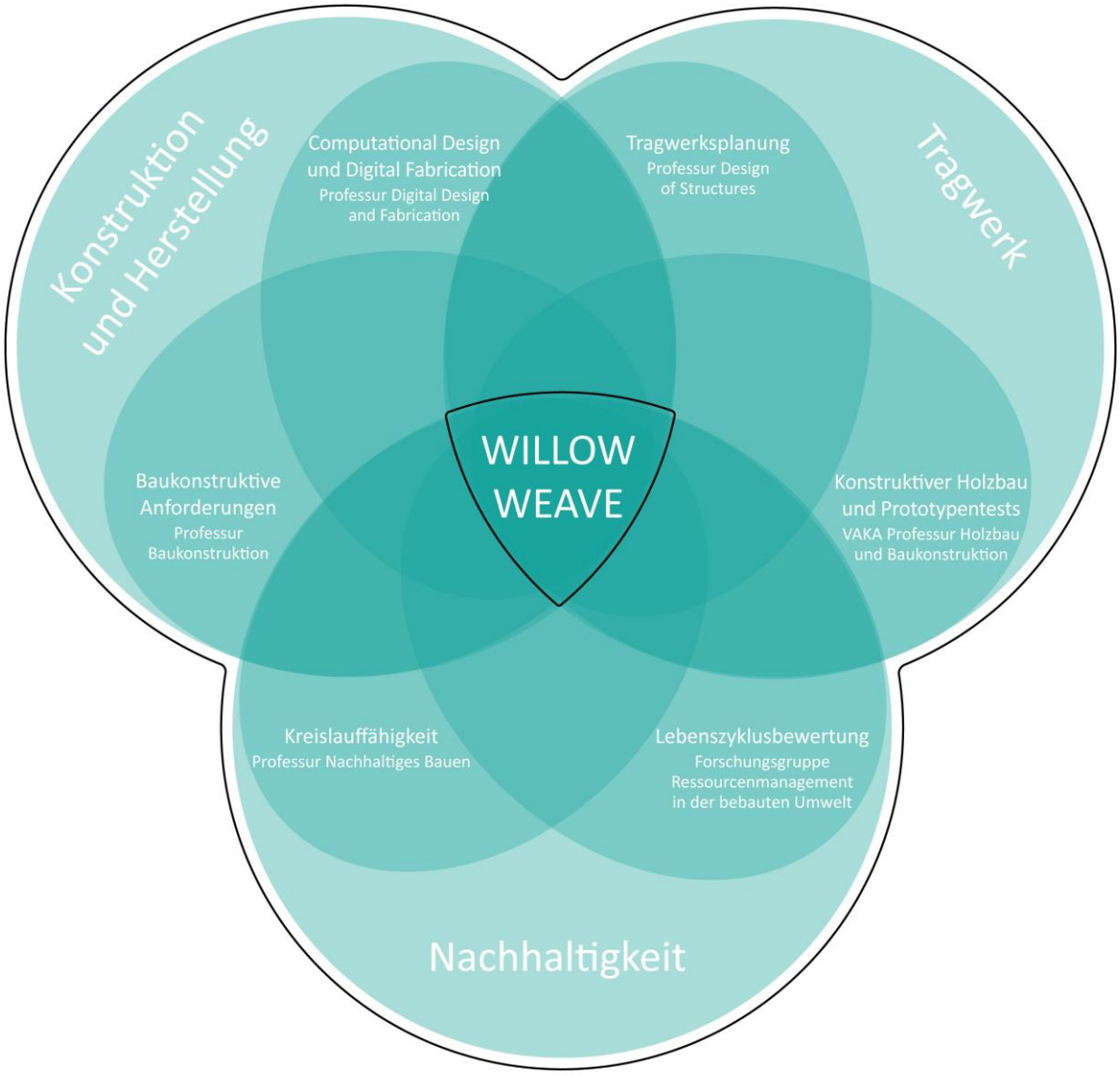
Willow Weave – Digital Circular Construction

Dr. Rebekka Volk, Simon Steffl

Partners: KIT Professorships: Digital Design and Fabrication, Design of Structures, Building Construction, Sustainable Building, VAKA Wood Construction and Building Design

Duration: 2022 - 2023

The KIT Future Fields stage 2 project "Willow Weave" contributes to the strategic development of the promising and socially highly relevant research field Digital Circular Construction as a Future Field at KIT. The pilot project aims for the combination of preliminary work. This is done through the holistic experimental research of an exemplary structural building component made of willow-clay composite on a 1:1 scale and its production process assessment. It promotes coordinated innovations in the fields of digital construction, sustainable construction, construction design, structural engineering, component testing, and life cycle assessment within the framework of an integrative co-design process.



Awards

Dr. 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

PhD Dissertation: Cyber Threat Intelligence based Holistic Risk Quantification and Management

Florian Kaiser

Technology has deeply penetrated modern society and economy and is omnipresent in daily life. The accompanying digitization, informatization, automation, mechanization and intelligence have led to new levels of convenience and productivity. However, the integration of technology brings with it new risks as well. Already today, cyber risks are one of the greatest risks to economic stability as well as prosperity. The importance of these risks will increase as digitization continues to advance. Despite this great importance for society and the economy, there is currently a lack of ability to manage them. Likewise, the reliable quantification of risks has been difficult so far, which represents essential obstacles for the development of secure systems.

The thesis aims to introduce new methods for quantifying cyber risks based on the use of cyber threat intelligence. In addition, the thesis aims to provide methods that can be used to support decision making regarding the efficient management of these risks. Special attention is given to the quantification and management of cyber risks in a holistic manner. This holistic approach takes into account the different domains of cyber attacks, which includes in particular the technical as well as the human and societal domain, and their interaction.

In the course of the dissertation different methods are presented, which serve the risk quantification. A set of methods is presented, which can be used to quantify the probability of an attack based on the results of a system monitoring (dynamic risk assessment). In addition, a static approach to risk assessment is pursued, which enables quantification of the probability of an attack based on game-theoretic methodology. Both approaches are based on cyber threat intelligence analysis. A key weakness of their analysis is the timeliness and informativeness for future attacks within a dynamically changing threat landscape. With the goal of minimizing these limitations, a methodology is presented that enables prediction of future attacks. Quantifying the impact of an attack is based on the analysis and simulation of a successful attack within Digital Twins. Finally, based on the risk quantification, a methodology for decision support is presented.

PhD Dissertation: Criticality of infrastructure networks under consideration of resilience-based maintenance strategies using the example of inland waterways

Rebecca Wehrle

Transportation infrastructures as backbone of modern, globalized, and networked societies ensure flows of people and goods and thus sustain social and economic prosperity. Concurrently, more and more infrastructure construction assets are facing the problem of systematic obsolescence due to deficient structural conditions, maintenance backlogs, and a lack of or misallocation of resources for the construction and maintenance of infrastructure buildings. This problem construct necessitates a resilience-based maintenance strategy for the asset portfolio. In particular, inland navigation as a mode of transport features large transport volumes and few redundancies. Combined with its increasing importance due to its comparatively high environmental friendliness, a predestined, yet in the literature underrepresented research subject results.

The dissertation aims to investigate essential factors of infrastructure management and thereby identify the potential for improvement in the complex construct of maintenance management and related areas. The emphasis is on enhancing the resilience of inland waterways as a complex System-of-Systems with all its interdependencies. Thus, a holistic risk and resilience assessment is essential and is underlined with the aspects infrastructure availability and business decisions and stakeholder communication and risk analysis which are addressed by seven studies published as companion articles.

Valuable insights can be gained for infrastructure management. In addition to the case study findings, general recommendations for infrastructure owners are derived. As a result, it can be stated that it is essential that maintenance strategies have to be more resilience-based than traditional strategies, which are mainly based on fixed time intervals for maintenance. Moreover, the application of both serious gaming and GIS visualization can help to enhance situation awareness and thus the resilience of infrastructure systems. An essential finding for which this dissertation provides methodological approaches is that considering the local area's attractiveness for business locations should receive more attention regarding investment decisions. Thereby a focus should be set on the realistic threat of relocations as response to deteriorating infrastructure conditions. Eventually, public debates should strengthen the knowledge about infrastructure and its funding, while deficits in alongside mechanisms in infrastructure funding must be encountered.

Consequently, this dissertation provides insights into the potential of infrastructure management. Mainly, it offers the potential to improve the resilience of the waterway transportation system and address stakeholders accordingly.

Habilitation Thesis: Resource Management towards a Circular Economy

Priv.-Doz. Dr. Rebekka Volk

The extraction and processing of non-renewable resources and their unsustainable utilization as well as the incineration or disposal of waste contribute to numerous local and global environmental problems. The transformation of current resource utilization to a more sustainable way in the sense of a circular economy is one of the major challenges of the 21th century. It includes a greatly reduced or no primary material and fossil energy input and new circular value chains with robust, consistent and economically reasonable processes and is a highly complex and demanding task.

Based on data-intense analyses, models and empirical research, this treatise analyses different aspects and proposes solutions from economic, environmental and operational perspectives in three selected problem areas: (1) the quantification and mapping of existing resources, (2) the assessment of technologies and resource management options and (3) the design and optimization of new circular value chains.

In problem area (1), two studies were performed. They aimed at predicting the expected waste volumes from post-consumer products and materials that are not covered by waste statistics. Both products and materials bear a non-neglectable potential to be recycled with innovative technologies and thus have the capacity to contribute to an increased material circularity and resource saving. The studies were either performed based on production statistics and lifetime assumptions, or on a plant inventory database and lifetime assumptions to derive the material volumes for potentially recyclable post-consumer products. In both studies, uncertainties on the expected product lifetimes have a strong influence on the results that remain fuzzy despite lifetime distributions and scenario analyses. And, in both studies the waste volumes are expected to strongly increase in the coming decade(s) and solutions are required to handle the materials in an environmentally friendly and economically reasonable way. Thus, these kinds of studies are an important step to quantify and visualize the expected material and waste streams that will have to be treated in the future.

The second problem area (2) comprises five data-intense studies on process and product assessment of the non-renewable materials of steel, aluminium, chemical intermediates, plastics and autoclaved aerated concrete with respect to different sustainability criteria and cost. The first three studies analyse the primary supply chain, manufacturing and procurement stages in a products' lifecycle, while the remaining two studies concentrate on the end-of-life stage of products and materials. We found that more information about supply chains and production sites are crucial for a more informed decision making that could be favourable to circular economy and sustainability principles. A further insight revealed that site-specific information is often confidential and approximations via publicly available information require a high effort for data collection, analysis and validation while at the same time a particular uncertainty remains. The problem of confidentiality might be partly solved with producer-specific or site-specific product declarations, production data management or new technologies such as distributed ledgers. But this will hamper public information and research on the environmental quality of products and production sites that are crucial for problem understanding, technology development, innovation and regulation.

The third problem area (3) addresses the design and optimization of new circular value chains and networks. Due to the complexity of the analysed systems and models and partly lacking data, assumptions on several model parameters were required. However, these were partly investigated by scenario analyses and were critically discussed. Particularly, validation of predictive material flow models is hardly possible. Here, only ex-post validations or comparisons with literature can provide insights into the quality of the model and its result. Consequently, future ex-post studies are required to check whether the material flow predictions have

been appropriate or not. All studies of this area face the challenge to find a trade-off between data availability, model complexity, solvability and computational effort.

Methodically, the approaches include environmental and techno-economic assessments, material stock and flow models, optimization models as well as multi-criteria decision models to enable well-informed decisions and to avoid problem shifting. The results show how a combination of innovative mixed methods and optimization can enable a more consistent resource management and support the informed decision-making and the transition to a more circular and sustainable economy.

Staff 2022

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

Andreas Rudi – Sustainable Value Chains

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

Florian Kaiser – Risk Management

Postdoctorial Researchers

Research Associates and their PhD-topics

Niklas Braun: Logistics optimization in nuclear decommissioning projects

Katharina Eberhardt: Analysis of alternative storage strategies of public emergency food supply

Marco Gehring: A Material Flow Based Optimization Tool for Scheduling 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

Markus Lüttenberg: Strengthening Resilience of Supply with Essential Goods through Public-Private Emergency Collaborations: Challenges and Incentives

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

Humberto Patarca: Concrete Recycling

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 of regional biobased value chains

Christoph Stallkamp: Economic and environmental assessment of chemical plastic recycling processes and their integration into the waste management system as a strategy for circular economy for plastics.

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

Daniel Wilkinson: Pyrolysis of polysterene and recycling of mineral fines

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 2022 around 600 student exams were completed and the chair has supervised 90 bachelor and master theses.

Anlagenwirtschaft / Planning and Management of Industrial Plants

Prof. Dr. F. Schultmann, 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, Niklas Braun, Simon Steffl

~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 und Prognosen der globalen Entwicklung

Prof. Dr. F. Schultmann, Dr. Julian Stengel

~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

Florian Kaiser , Katharina Eberhardt, 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, Nina Treml

~100 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, Prof. Dr. Marcus Wiens, Marco Gehring, Sonja Rosenberg, Rebecca Wehrle, Daniel Wilkinson

~50 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 include two invited talks from employees of Campana & Schott (international management and technology consultancy) and VSE AG (German power supplier). The talks cover the topics "The Role of the Project Manager", "Communication, Negotiation and Leadership" and "Agile Methods of Project Management" from a practical perspective.

Risk Management in Industrial Supply Networks

Florian Kaiser

~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, Humberto Patarca

~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 and Projection of Global Development (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 (SS, 3,5 ECTS)
- Risk Management in Industrial Supply Networks (WS, 3,5 ECTS)

Publications

Peer-Reviewed Journals

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Stallkamp, C.; Steins, J.; Ruck, M.; Volk, R.; Schultmann, F. (2022). Designing a Recycling Network for the Circular Economy of Plastics with Different Multi-Criteria Optimization Approaches. Sustainability, 14 (17), Article no: 10913. doi:10.3390/su141710913Volk, Rebekka; Steins, Justus J.; Kreft, Oliver; Schultmann, Frank (2023): Life cycle assessment of post-demolition autoclaved aerated concrete (AAC) recycling options. In Resources, Conservation and Recycling 188, p. 106716. DOI: 10.1016/j.resconrec.2022.106716.

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