Karlsruhe Institute of Technology

Institute for Industrial Production

Annual Report 2019

Chair of Business Administration, Production and Operations Management




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Preface

This annual report from the Chair Business Administration, Production and Operations Management at the Institute for Industrial Production (IIP), Karlsruhe Institute of Technology (KIT) highlights our main activities during the year 2019. Our three research groups "Sustainable Value Chains", "Risk Management", and "Project and Resource Management in the Built Environment" have carried out numerous projects on a regional, national and international level covering a broad range of topics. The team of the Chair consists of about 20 researchers, 4 administrative staff and a several student assistants.

During 2019, we worked on 21 third party funded research projects. We published 14 peer-reviewed journal articles, numerous conference proceedings books and book chapters and 3 PhDs were completed. Teaching activities resulted in around 900 exams and about 110 bachelor and master theses were supervised. Various international collaborations and international staff exchanges completed our activities.

We hope that this report triggers your interest in our activities. We look forward to future collaboration around our research and teaching activities.

Prof. Dr. Frank Schultmann,

Chair of Business Administration, Production and Operations Management

Sustainable Value Chains

Head of research group: Dr. Simon Glöser-Chahoud

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

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

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

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

Typical methods in use are:

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

Members of the research group (from t.l. to b.r.): Marina Maier, Simon Glöser-Chahoud, (Kira Schumacher,) Andreas Rudi, Tobias Zimmer, Sonja Rosenberg.

Risk Management

Head of research group: Dr. Marcus Wiens

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

In 2019, the risk research group continued its work in the field of applied risk and crisis management with a strong focus on cooperation, supply chain risk management and risk management for critical infrastructure. Strongly linked to the DFG-ANR-project INCA a new project – the Crossborder Risk Academy – started in 2019. The trinational French-Swiss-German project was initiated by the French fire department in Strasbourg (SDIS 67) with over 30 project partners comprising research institutes, public authorities and emergency response agencies as well as private firms and critical infrastructure providers. Within this project, the risk research group contributed to the two working groups "intercultural risk management" and "cross-border cyber threats". In the area of applied risk and crisis management, the research in the DFG-ANR-project INCA advanced. Also in 2019 (as already in 2017 and 2018) the project consortium had the opportunity to present interim project results to the participants of the disaster assistance-working group and the industrial accident working group of the Upper-Rhine conference. In the NOLAN-project, which deals with the design & analysis of a public-private partnership for crisis management (public-private emergency collaboration: PPEC), the consortium extended the range of stakeholders (associate project partners) by the Federal Association for the Critical Infrastructure Protection (BSKI) and the German Trade Association (HDE), which both comprise a large network of relevant stakeholders. Interim-results of the NOLAN-project were presented and discussed on Stakeholder-workshops and national safety & security conferences. In the area of critical infrastructure protection, the BMBF-funded projects PREVIEW and KASTEL advanced in 2019. In PREVIEW, the project consortium establishes a holistic risk management framework in order to measure and improve the resilience of the German waterway (canal) system. In 2019, first results were published and discussed on stakeholder workshops and conferences. In the KASTEL-project, which deals with cyber risk management from an economic perspective, the risk research group established a contact to the Society for the Promotion of Research Transfer (GFFT), which has the main objective of closing the gap between the risk management need of (industrial) firms on the one hand and excellent academic research on the other. This contact will contribute to an efficient knowledge exchange and validation of our KASTEL-research results in the future. In 2019, a former research associate and Ph.D. student of the group, Thomas Münzberg, has successfully passed his doctoral exam. Thomas' Ph.D. thesis deals with a vulnerability assessment of critical infrastructure – in particular hospitals and health care facilities – in the context of a long-lasting power blackout. In October 2019, Florian Diehlmann visited the Humanitarian Lab at the MIT (Cambridge, USA) for two weeks, presented the projects and research areas of the group and had a fruitful exchange of ideas and knowledge about ongoing projects in the field of humanitarian logistics. Florian's research visit was financially supported by the networking grant of the Karlsruhe House of Young scientists.

The outlook for 2020 indicates a further convergence of research topics of the group, namely the application and modelling of strategic and behavioral factors of risk management cooperation and critical infrastructure analysis.

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

Project and Resource Management in the Built Environment

Head of research group: Dr. Rebekka Volk

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

To offer decision support for different planning activities on consumer/user perspective, building level, district, regional or national level, several optimization models have been developed and are employed, in particular the AWOHM model framework, the ResourceApp building inventorying tool and robust project planning as well as the MogaMaR/NukPlaRStoR model for optimized nuclear decommissioning project planning. AWOHM is a simulation model for the German residential building stock, the building stock's energetic quality and technical equipment as well as its owners and residents. AWOHM is used to identify economically feasible retrofit options and the resulting national greenhouse gas emissions. This is a transferable model for national-scale energy systems, which mainly employs publicly available data and census data.

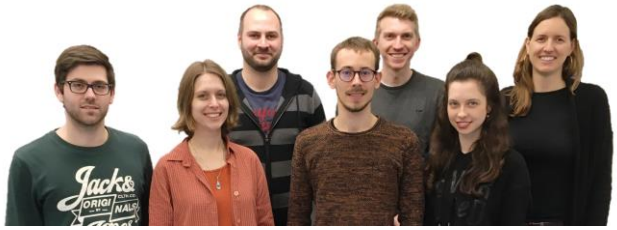
The ResourceApp, MogaMaR and NukPlaRStoR models are linear optimization models for robust project planning under uncertainty (particularly deconstruction and decommissioning of buildings and structures), and are employed to analyse time-optimal or cost-optimal project planning. While the ResourceApp model is focusing on residential and non-residential buildings, MogaMaR and NukPlaStoR are addressing nuclear power plants and facilities.

Furthermore, we work on the sustainable urban development on district level with the city administration Karlsruhe. Key aspects are the sustainable and efficient resource usage and management focusing on land use, water and materials. Another project is identifying heat losses in urban districts via automated processing of drone images.

As well, we analyse current and emerging technologies and supply chains with respect to more resource efficient (recyclable and/or CO_2-reduced) building materials and products, ranging from aerated concrete and cement to different types of plastics. In these projects, we analyse production methods, new production technologies and assess the whole supply chain for decision support.

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,
- project management optimization methods.



Members of the research group (from l. to r.): Justus Steins, Sophia Schambelon, Elias Naber, Marco Gehring, Christoph Stallkamp, Zoe Mayer, Rebekka Volk.

Research Projects

CEDIM (Center for Disaster Management and Risk Reduction Technology)

Marcus Wiens & group members

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

Funding: Karlsruhe Institute of Technology

Duration: since 01/2006 (ongoing)

The Center for Disaster Management and Risk Reduction Technology (CEDIM) is an inter-disciplinary 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).

Cooperation in Bioeconomy Value Chains (CoBiVal)

Simon Glöser-Chahoud, Tobias Zimmer, Raphael Heck

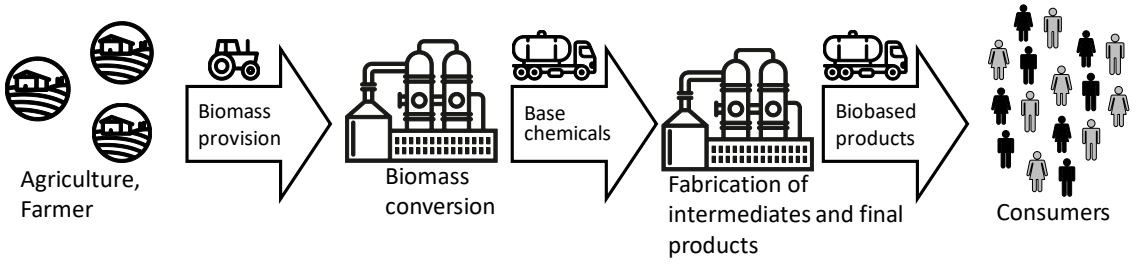
Funding: Federal Ministry of Education and Research

Duration: 2019-2022

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

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

Development and evaluation of biobased value chains for Baden-Wuerttemberg

Andreas Rudi

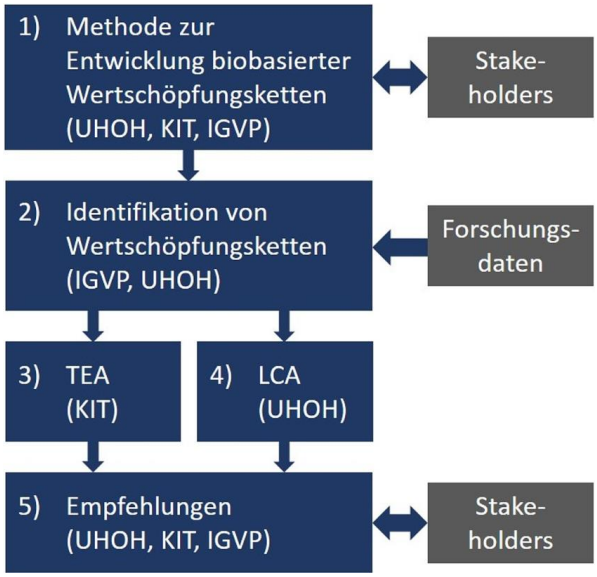
Partner: University of Hohenheim,University of Stuttgart

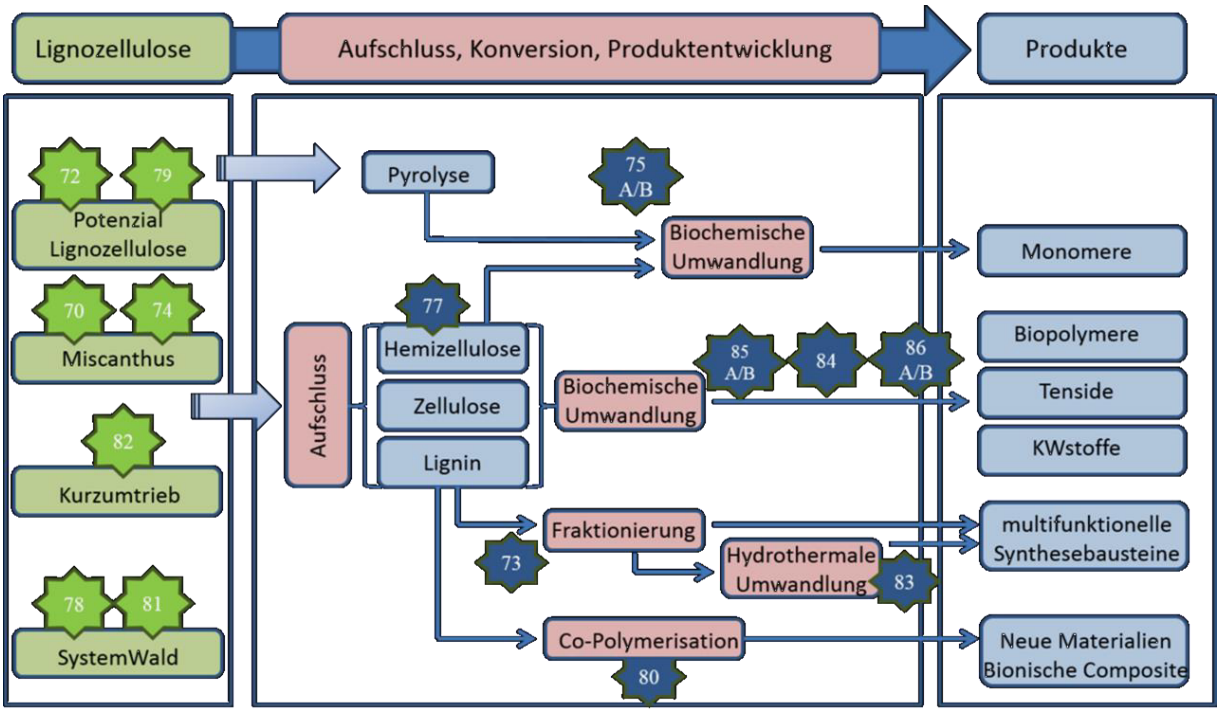
Funding: Ministry of Science, Research and the Arts

Ministerium für Wissenschaft, Forschung und Kunst Baden-Württemberg

Duration: 10/2018 – 09/2020

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





Development of an economic approach for decision support in a circular economy orientated production

Sonja Rosenberg, Marina Maier

Partner: AUDI AG, UMICORE, Scholz Recycling GmbH

Funding: THINKTANK Industrielle Ressourcenstrategien

Duration: 05/2018 – 03/2019

Up to today, Original Equipment Manufacturers (OEM) have hardly any incentive to invest in recycling and dismantling friendly products. One of many reasons is that expected earnings through recovery in the future cannot be allocated directly to higher costs in the early stages of a products life cycle, such as development and production. Thus, it is common practice for OEM business models to focus solely on producing and selling while achieving a profit based on a margin. If performed, other companies execute the dismantling and recovery processes and receive the earnings.

With the increasing digitalization and changing consumer behavior OEM rethink their business models and tend to focus more on product service systems. Furthermore, increasing technology allows new forms of cooperation along supply chains and lifecycles of products. These developments create the possibility of new circular economy based business models.

In order to evaluate and identify which circular economy based business models should be chosen for a specific product, decision support is needed.

Thus, the aim of this project is to develop an evaluation tool that allows the economical investigation of alternative business models and recovery options. The developed method is tested for specific use cases in the automotive industry. Afterwards, further use cases in other industries are implemented to show the general applicability.

Emergency Management and Evacuation

Farnaz Mahdavian

Funding: Graduate Funding from the German States

Duration: 2017 - 2020

The first objective of the research project is to gain a deeper understanding of the chain of events during a disaster and to improve human behaviour and reactions particularly regarding evacuation. To this end, extensive research on different natural disasters in several countries has been carried out to outline the key lessons concerning evacuation from various hurricanes and floods in major worldwide events. The analysis revealed both successes and failures in warning and evacuation.

The evacuation process can be viewed from two perspectives. The first is related to government decision-making, to early warning systems and to the relevant authorities' protocols for issuing an evacuation order. The second is whether people in the affected area decide to evacuate or not depending on whether or not they have received an evacuation order. In principle, evacuation needs to be carried out in an immediate and urgent manner, which requires fast decision-making on all levels. However, crises are characterized by a high degree of uncertainty and delay and the need to evacuate is often only realized after the disaster has escalated.

For the government reaction part, a decision model for disaster evacuation was designed using the Bayesian Updating method, which captures government decision-making during the event of a flash flood. In this scenario, the government receives a noisy signal (a disaster warning) about an upcoming extreme weather event and faces a choice between announcing an evacuation order, either severe or extreme, or keeping silent. The objective of the dynamic model is to analytically compare the outcomes and various costs of different decisions based on different levels of information and identify the optimal decision paths. "Cost" in this context is defined as adverse consequences for life and health as well as a loss of trust or credibility in governmental announcements.

The second part of the research analyses society's perception and attitude towards crisis events based on a questionnaire. To this end, a set of hypotheses about the influence of risk attitude, disaster experience and trust is established. A special focus is on country comparisons.

The target sample includes people who were living or working in the affected area in Germany, Iran, and United Kingdome. Key questions elicitate the levels of risk awareness, knowledge, attitude to disaster and preparedness in different countries as well as the role of trust among people and between people and government in emergency reaction. The objective is to to learn which factors influence people's decisions and reactions immediately following a disaster. The insights out of this survey can help the government to improve preparedness, warning and evacuation order.

Energieleitplan Karlsruhe (ELP)

Rebekka Volk, Elias Naber

Partner: Green City Experience GmbH

Funding: Stadt Karlsruhe

Duration: 2018 - 2019

In the course of the new and integrated climate protection concept of the city of Karlsruhe, together with the Green City Experience GmbH we consult the environmental city department and the respective working group in the city. In this project, our work focuses on the data analysis and design of an "Energieleitplan" (energy-use plan) for the whole city. The "Energieleitplan" is meant to serve as an internal, GIS-based tool to collect and develop all information needed to provide basic information for energetic questions of urban development and energetic solutions on district and city level.
As an internal working tool, the energy-use plan should enable quick orientation, for example, which energy sources are suitable or available for new planning. In addition, it should provide strategic assistance, e.g. by identifying neighbourhoods that are considered to be urgent for a rehabilitation initiative ("redevelopment hot spots") or by designating areas that have sufficient potential for connection to a potential district heating network. The energy-use plan should be developed in parallel with the climate protection concept, so that, if possible, initial results can already be used for the planning of measures (for example, to determine further district-specific remediation initiatives).
The project started in May 2018 and results were handed over in November 2018. The consulting accompanied the project until project closing in February 2019.

Furthermore, we contributed in different working commissions of the city administration of Karlsruhe (AK Klimaschutzkonzept, AK Energie and AK Stadtentwicklung) between January and October 2019.

INCA Project

Miriam Klein, Marcus Wiens

Partner: University of Wuppertal, ARMINES - Mines Paris Tech, University of Paris-Dauphine

Funding: German Research Foundation (DFG), French National Research Agency (ANR).

Duration: 03/2017 - 02/2020

In the INCA project, the crisis scenario of a long-term power failure in the German-French border region is investigated with the objective to enhance cross-border resilience. First, direct and indirect consequences of a power failure for the population are mapped by scenarios. The ensemble of resulting crisis situations represents a stress test for societal resilience as it pushes the emergency procedures to their limits (e.g. energy backup generators are only designed for a short-term usage). Hence, the main aspect is the efficient identification and treatment of casualties by finding an optimal distribution of the available medical resources by efficient integration of cross-border capacities. Hence, a strong focus is on the cross-border cooperation of authorities who are responsible for crisis management as well as the forces involved in crisis management. A second focus of the project is on volunteer management in the cross-border context. During past crises it was observed, that volunteer helpers not just act as members in voluntary aid organizations, but spontaneously come together and offer their know-how. As a result, the usual coordination is limited or even completely eliminated such that this trend requires analysis. One further focus of investigation is the inclusion of voluntary spontaneous helpers into the crisis management procedures since their different backgrounds, experiences and motivations are seen as a huge potential for an improved disaster resilience.

To achieve these goals, an agent-based model is developed, as this method is suitable for mapping the complex interplay of the individuals and the dynamics of their behavior. Agent-based modelling is particularly well-suited for depicting a crisis scenario, as each actor has limited information that he gains by sharing with other agents. Additionally, not all alternative courses of action are known and not all resulting effects are predictable due to the complexity. Nevertheless, decisions must be taken under uncertainty and the project will support this process from a scientific point of view. Here, special features of the cross-border region as culture and language, which may facilitate or complicate crisis cooperation, are considered. Therefore, in the modelling of the communication process, there has been inserted an additional trust variable between sender and receiver of a message. Depending on the relationship of trust between the two agents, the incoming information is evaluated and processed. Using a scenario-based approach, the impact of trust in the dynamic process of crisis management can be measured and compared with other factors of influence such as different languages. Using this approach it is possible to accurately represent the peculiarities of the border region which take into account positive factors of so-called border identity. The solution of the model should be robust despite changes in the scenario, since crises and their course are not known in advance.

Dr. Anouck Adrot (University of Paris-Dauphine) and Dr. Marcus Wiens presented parts of the work to the crisis management working group of the Upper-Rhine-Conference in Colmar. At a mid-term project meeting which took place at the University Paris Dauphine, the INCA-team discussed the current progress of the work with Prof. Louise Lemyre, University of Ottawa und Prof. Stephen Platt, Cambridge Architectural Research Ltd. Miriam Klein presented the preliminary results from an empirical study about people's willingness to help in a crossborder-context at the Crossborder Risk Academy.

KASTEL

Florian Kaiser, Marcus Wiens

Partner: Institute for Applied Computer Science and Formal Description Methods (KIT), Institute for Anthropomatics and Robotics (KIT), Institute for Automation and Applied Computer Science (KIT), Institute for Program Structures and Data Organization (KIT), Institute for Theoretical Computer Science (KIT), Institute for Telematics (KIT), Research Center for Computer Science (KIT), Center for Applied Law (KIT), Institute for Public Law (Goethe University Frankfurt a.M.)

Funding: Federal Ministry of Education and Research (BMBF)

Duration: 05/2018 - 04/2022

The main objective of the Competence Center for Applied Security Technology (KASTEL) is to develop methods and concepts for secure IT systems of the future as a university-based competence centre. The focus here is on a holistic approach and application orientation. To this end, various aspects of Smart Environments, which are characterized by a variety of networked sensors and actuators, will first be investigated. Networked production (industry 4.0) is also considered to be an application case in the economy. Furthermore, the security of networked critical infrastructures will be investigated.

KASTEL is researching on a system theory for the continuous adaptation to strategic, evolving attackers, as well as to tools and methods that consider security, implement security consistently and make security verifiable.

The research group Risk Management deals within this Project with economic risk management. Risk management generally includes the systematic analysis of internal organizational risks and the development of measures to reduce risks for the purpose of long-term protection of the organization and the society. The handling and control of IT risks requires not only that organizations have the necessary technologies and processes, but also that these are economically sensible and feasible. Economically oriented risk management is therefore becoming increasingly important due to the ever-stronger linkage of industrial value chains in terms of information technology and the associated growing effort required to protect these structures from attacks and technical errors. Economic risk management refers not only to the economic efficiency of IT risk management, but also to the economic consequences of a failure of IT systems (e.g. business interruption). With a view to the development of scalable and quantifiable safety concepts, it is possible to consider material and immaterial consequences in the risk assessment. In addition, an economic risk analysis also considers the behaviour of the actors as well as the opportunity costs of risk-reducing measures and thus the conflicting objectives of security investments.

The research group has started to develop a framework for the holistic assessment of cyber risk as well as first quantitative assessment approaches. Furthermore, the group analyzed their advantages and disadvantages compared to current national and international standards regarding cyber security. An industrial demonstrator was developed for this purpose, which can be used for simulation and analysis. By transferring the knowledge gained by the in-depth research to organizations and society, the research can help increase cyber security. In particular, participation in corporate network initiatives and in research transfer companies should prove to be particularly relevant. Thereby, among other things an innovative KPI-system shall be developed to increase the research impact.

Lignocellulose Biorefinery for the Bioeconomy in Baden-Wuerttemberg

Andreas Rudi, Simon Glöser-Chahoud

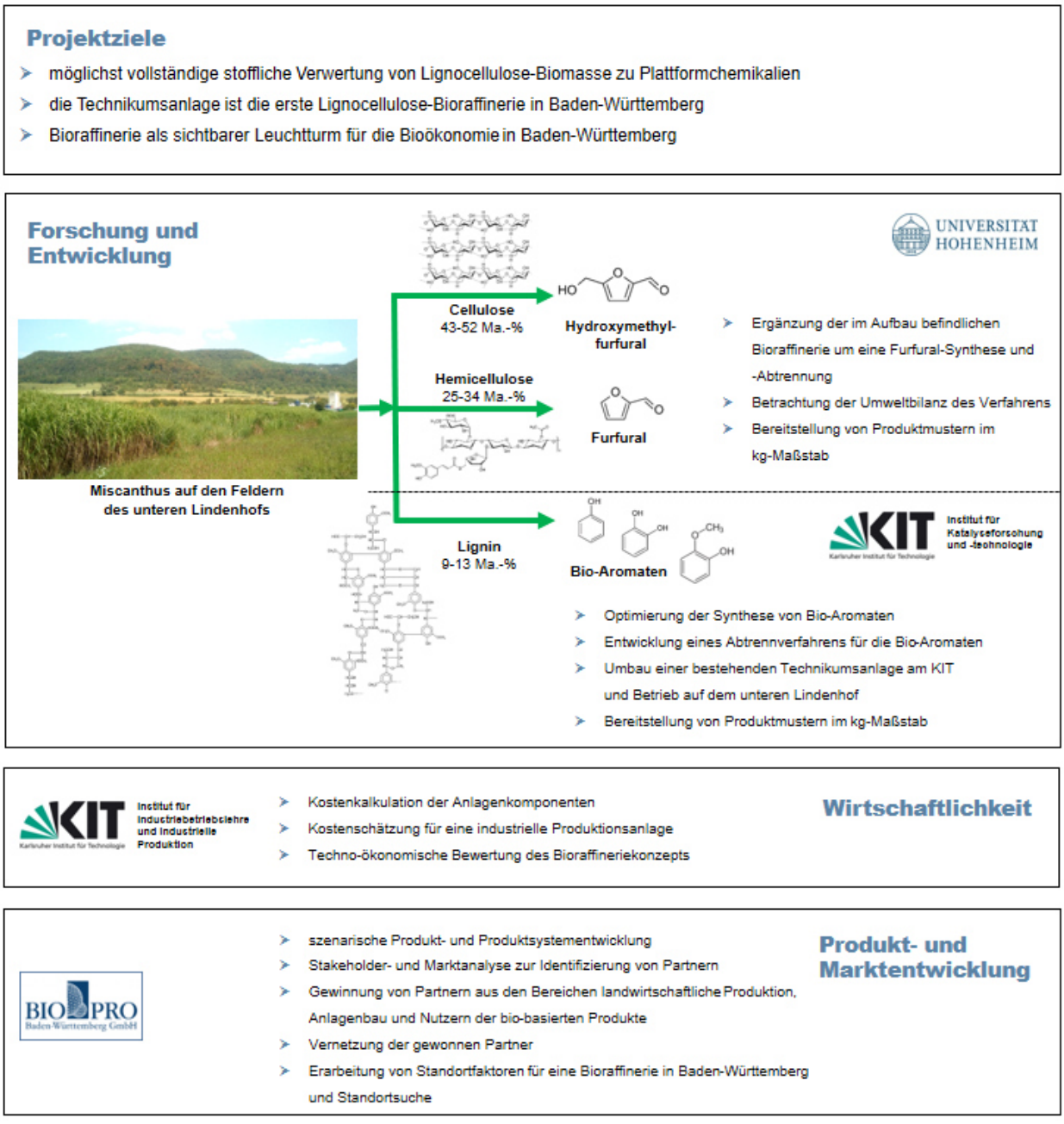
Partner: Institut für Katalyseforschung und -technologie (IKFT-KIT), University of Hohenheim, BIOPRO GmbH

Funding: Ministry of Science, Research and the Arts

Ministerium für Wissenschaft, Forschung und Kunst Baden-Württemberg

Duration: 10/2018 – 09/2020

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



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

Dr. Rebekka Volk, Sophia Schambelon, Elias Naber

Partner: Karlsruhe city administration (Stadtplanungsamt der Stadt Karlsruhe, Amt für Umwelt- und Arbeitsschutz), 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 - 03/2022

The aim of this project is to develop a support tool for urban resource management, which enables city administrations and other actors to monitor the use of natural resources (here: land, water, materials) at district level and to establish active resource management. To manage (natural) resources efficiently, their use must be measured and evaluated. On this basis, the need for action can be identified, measures can be designed and targeted goals can be monitored.

The overall aim is to account and visualize resource use in urban areas and its possible consequences for various actors in order to fill blind spots in the planning process. For this purpose, an assessment scheme with relevant fields of interest and subordinate indicators will first be developed. Subsequently, interrelationships and effects of resource use in the urban district are modelled and consequences and conflicting goals for different actors are examined. With the base of this scientific knowledge a GIS-based software tool will be developed, implemented and tested in an urban case study district in the city of Karlsruhe. This will be accompanied by transdisciplinary approaches and a guideline enabling the transfer of project results.

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

Work on the project started in April 2019, whereas the official kick of meeting took place in the beginning of June 2019 in Frankfurt. Since then the project was accompanied by workshops within the research initiative RES:Z (resource-efficient urban districts for the future) funded by the program FONA by the Federal Ministry of Education and Research. These workshops promoted the exchange of various projects on the topics "digitalisation" and "indicator development" and will be followed by other meetings in 2020. As the case study quarter is currently affected by urban redevelopment, the projects visions were presented to the public at an official event in July 2019. The NaMaRes project team developed an open set of indicators to assess resource use in urban districts, which will be tested in 2020 on a case study in the district Innenstadt-Ost in Karlsruhe.

NOLAN

Florian Diehlmann, Markus Lüttenberg, Marcus Wiens

Partner: 4flow AG, TU Dresden

Funding: Federal Ministry of Education and Research – BMBF.

Duration: 2018 - 2021

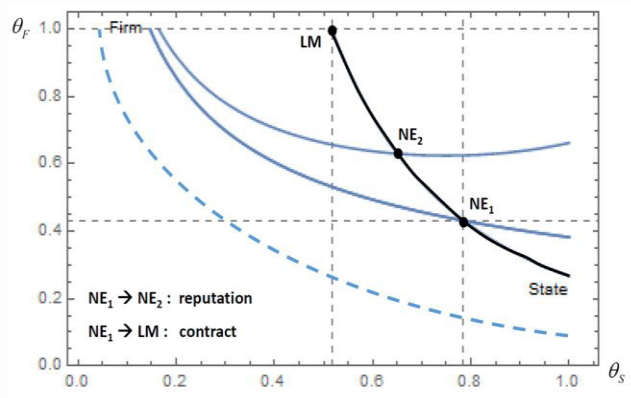
Emergency care falls within the remit of the public sector. Nevertheless, private companies have a large number of resources (including skills) at their disposal, which can be very helpful in providing emergency support to the suffering population in the event of a crisis. In the NOLAN project, the option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

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

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

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

The 2nd NOLAN expert workshop took place in May 2019. Dialogue partners from the private and public sectors reported on their experiences. Furthermore, current interim results of the project partners were presented and concrete aspects worked out in small groups, which represent important input data for the modelling in the project. At project meetings in Dresden, Karlsruhe, and Berlin, further steps were defined in the project and interim results were recorded. Some of these interim results were then presented by Marcus Wiens at the European Disaster Management Congress in Berlin. Other conferences, such as the Fuel Safety Conference in Bonn or the closing event of the KIRMIN project, also funded by the BMBF in the field of safety research, were also attended. The exchange with the representatives there provided the team with further insights.



The graph to the left shows, which game-theoretical equilibria emerge, depending on the cooperative incentives of the two actors, state and company, in a crisis context.

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

Partner: Gesellschaft für integrierte Systemplanung mbH; VPC GmbH

Funding: BMBF - funding code: 15S9414A

Duration: 07/2019 - 06/2022

International organisations expect that the dismantling of nuclear plants is becoming a national and international focus of the energy and dismantling industries. Already completed and still ongoing dismantling projects of nuclear plants show that dismantling is technically safe. However, the operators of nuclear facilities as well as responsible dismantling companies point out that there is still considerable potential for optimisation and cost savings in the project management of the dismantling of nuclear facilities. 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. Based on the material flows, the planning tool should support logistical planning (e.g. transport and processing within the plant, conditioning) as well as container planning including final disposal documentation. Furthermore, the planning tool should be interfaced with other programs (e.g. for the visualisation of the calculated plan or for residual material tracking).

The joint project started in June 2019 with a kick-off meeting of the participating project partners in Karlsruhe. Subsequently, we began reviewing and analyzing the work breakdown structure of a real nuclear dismantling project in close cooperation with our industry partner VPC GmbH. Based on the retrieved data, a previously at IIP developed optimization method for cost-minimized project planning was tested. The optimization method is suitable for practical application, as the evaluation of the results considering various criteria has shown. Thus, the development of a user-friendly software prototype for the planning tool can now be launched in cooperation with our partner Gesellschaft für integrierte Systemplanung mbH.

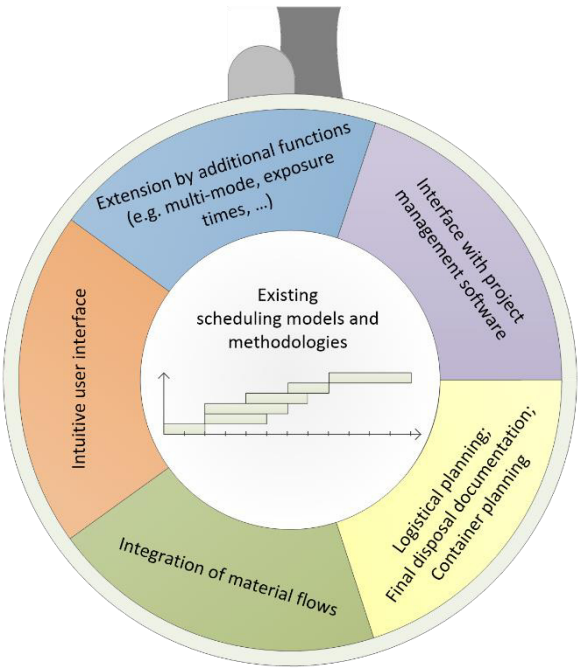


Figure: Provision of old aerated concrete in various grades of purity

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

Andreas Rudi, Simon Glöser-Chahoud

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

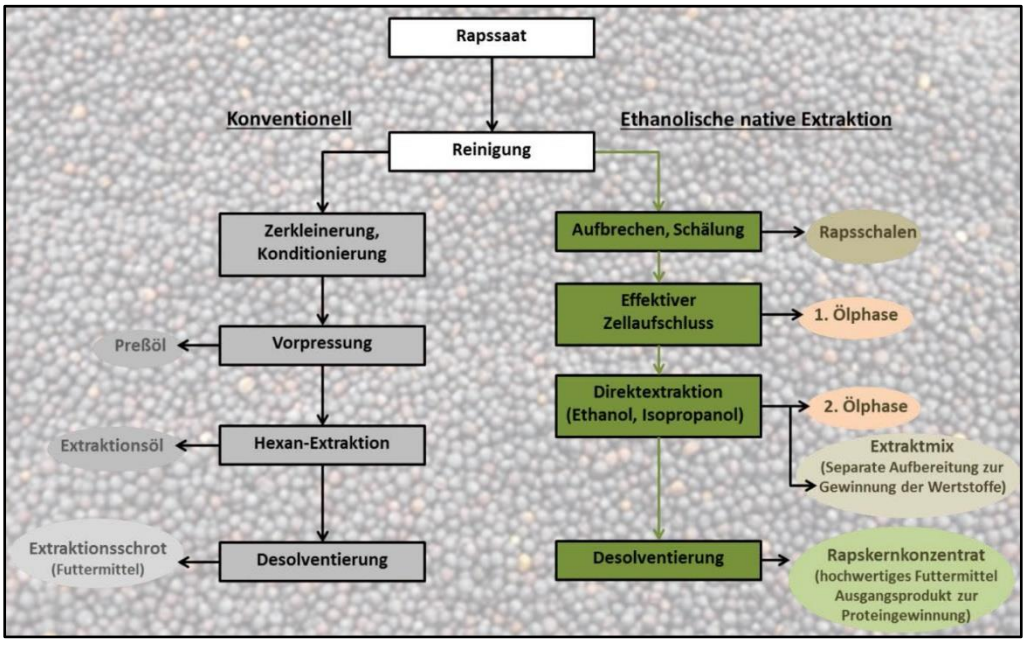
Funding: German Federal Ministry of Food and Agriculture (BMEL)

Federal Ministry of Food and Agriculture

Duration: 09/2017 – 08/2020

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

EthaNa Process



PREVIEW

Rebecca Wehrle, Marcus Wiens

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

Funding: Federal Ministry of Education and Research – BMBF.

Duration: 2018 - 2021

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

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

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

In addition to several internal project meetings, external expert knowledge was systematically gathered to gain relevant insights. Thus, the first expert workshop within the PREVIEW project took place in April 2019 with experts from science and industry. Special emphasis was placed on the validation and development of the scenarios to be developed in the project. In addition, a three-day excursion to the model region for the West German canal network contributed to the intended development of a holistic risk framework. The project activities thus supported the interdisciplinary and practice-oriented exchange between the project partners and experts from science and industry. First research results were presented at the Cambridge International Manufacturing Symposium in September 2019.

Figure: PREVIEW Excursion to the West German canal network in March 2019

Raw materials of strategic economic importance (r⁴)

Innovative technologies for resource efficiency – Provision of raw material of strategic economic importance

Sonja Rosenberg, Simon Glöser-Chahoud

Partner: Clausthal Research Center for Environmental Technologies (CUTEC), Fraunhofer Institute for Systems and Innovation Research (ISI), Federal Institute for Geosciences and Natural Resources (BGR), Pforzheim University (HS PF)

Funding: Federal Ministry of Education and Research (BMBF)

Duration: 2015 - 2019

Raw materials, such as indium, gallium, and rare earth elements are of strategic importance, while being scarce and thus, play a key role in future technologies and in Germany's transition to renewable energy. The started programme aims at increasing supplies for primary and secondary raw materials of strategic economic importance through research and development. Research areas cover primary and secondary resources comprised in 40 joint projects. Initiatives with focus on primary resource are associated to the exploration or the extraction and processing of raw materials. Meanwhile secondary resource projects deal either with recovery of raw materials or the recycling of end-of-life products.

Innovative Technologien für Ressourceneffizienz
Bereitstellung wirtschafts-strategischer Rohstoffe

The parties of the Germany-wide programme are interlinked by the research-supporting "r4-INTRA" integration and transfer project. "r4-INTRA" strengthens the innovation power of the projects by interconnecting parties and showing interdisciplinary synergies leading to a possible higher research efficiency. Performed potential analyses and evaluation of ecological and social benefits are used to derive recommended actions for future funding programmes.

Reallabor 131: KIT findet Stadt - Urban Transition Lab 131

Elias Naber

Partner: EIFER (European Institute for Energy Research), KIT-Institute for Building Design and Technology, Building Science Group

Funding: Ministry of Science, Research and the Arts Baden-Württemberg - IQF-Programm „Reallabore, BaWü-Labs, für eine Forschung für Nachhaltigkeit in Baden-Württemberg"

Duration: 10/2015 - 11/2016

The Urban Transition Lab focuses on four topics, identified as the bottom line of two different perspectives: the objectives of Karlsruhe's citizens which were developed in a participatory process on the one hand and the expertise of KIT on the other hand.

- Energy concept in the district Oststadt Karlsruhe
- Mobility and consulting
- Social networks and aspects of urban planning
- Sustainable consumption

Aside of surveys and various analyses of the building stock and the ownership structure, a model to calculate and assess energy demand and material stocks has been designed and applied on the Urban Transition Lab district. The results show that the combination of 3D building data and established methods increase certainty of model outcomes (see figures below). The comparison with other sources yielded good results and confirmed the validity of the model base data.

The project received two awards awarded by the Sustainability Council in 2017. The project closure ceremony of the project and the funding program took place in Karlsruhe on 27.04.2018.

PROJEKT NACHHALTIGKEIT 2017

Ausgezeichnet durch den NACHHALTIGKEITSRAT
als besonderer Beitrag zur TRANSFORMATION

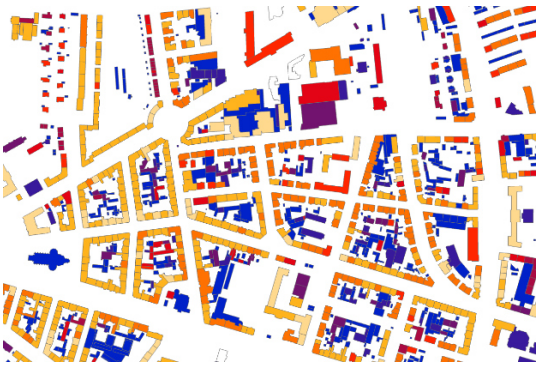


Figure: Spatial distribution of total energy demand of thermal energy. Values in kWh/($m^2_{A\_B}$*a)

Figure: Spatial distribution of total energy demand of electricity. Values in kWh/($m^2_{A\_B}$*a)

Figure: Distribution of steel in the Oststadt Karlsruhe. Values are in Mg/$m^2_{A\_B}$

reFuels - rethinking fuels

Simon Glöser-Chahoud, Paul Heinzmann

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

Funding: Ministry of Transport Baden-Württemberg

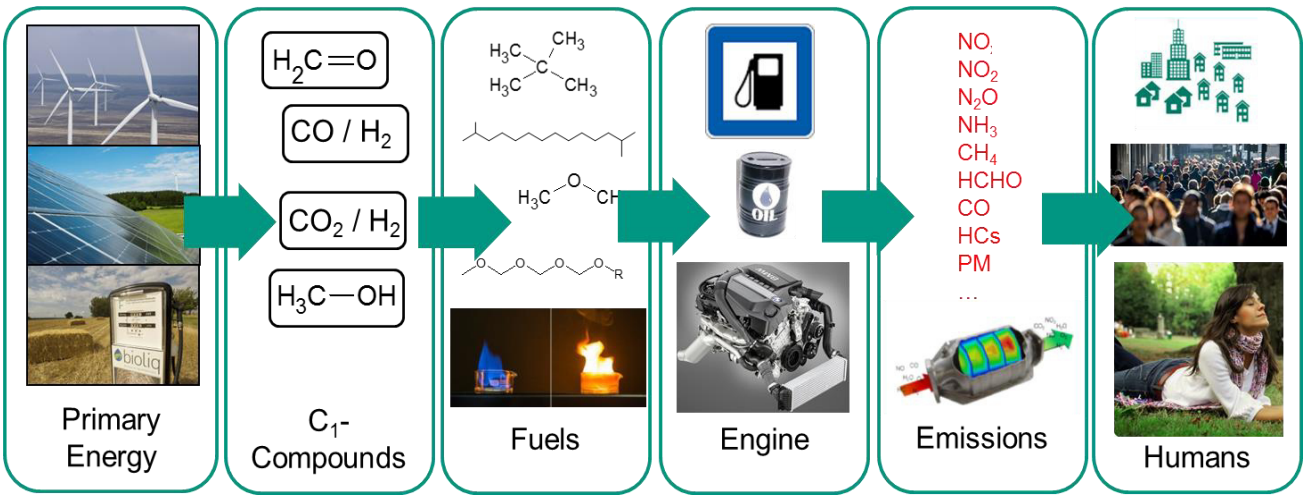
Duration: 2019 - 2021

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.



REPOST
- Resource management in urban districts in the context of sustainable urban development

Dr. Rebekka Volk, Justus Steins

Partner: Xella Technologie- und Forschungsgesellschaft mbH, Otto Dörner GmbH, KIT - Institut für Technische Chemie

Funding: BMBF - funding code: 033R249B

Duration: 06/2019 - 05/2022

"REPOST" has set itself the goal of creating the basis for a high-quality and economical recycling management of aerated concrete. New and competitive products for masonry construction are to be created from old aerated concrete. 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) which started the 11/12th of December 2019 with a kickoff meeting at DECHEMA-Haus Frankfurt.

Aerated concrete is a building material that has been known and proven for almost 100 years. The recycling of aerated concrete fresh from production, which occurs as cuttings or breakage during production, has been practiced for decades. In contrast to this, aerated concrete demolition material often contains accompanying materials that make high-quality recycling difficult, which is why aerated concrete is usually deposited 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 aerated concrete by recycling old aerated concrete at the same or comparable quality level. This concept differs from conventional building material recycling. In the statistics, around 90 percent of mineral construction waste is recycled, but mostly as low-value and one-off downcycling in road construction.

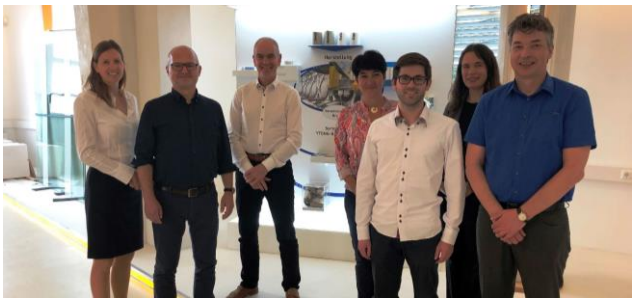


Figure: Kickoff meeting in Kloster Lehnin

The REPOST work plan is based on the life cycle of a recycled aerated concrete block and begins with the dismantling and sorting / preparation of aerated concrete from the existing stock. The secondary raw material obtained is to be used directly as an additive for new masonry products. Aerated concrete 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 cellular concrete with a recycled product that causes lower CO_2 emissions and energy consumption during its manufacture. With the involvement of building owners, demolition companies and processing companies, business models are being developed for the new recycling options over the entire life cycle.

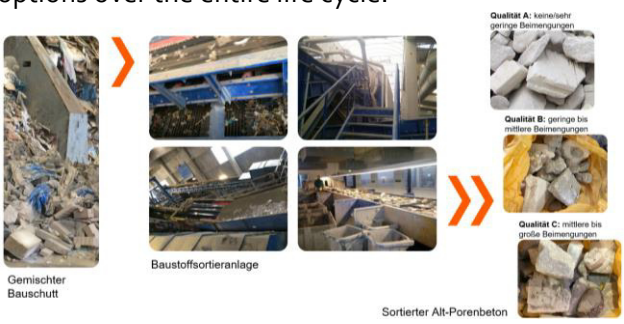


Figure: Provision of old aerated concrete in various grades of purity

Sustainable Supply Chain Management. Carbon accounting in the supplier network: A sustainable decision support model.

Richard Müller, Andreas Schiessl

Partner/Funding: Industry

Duration: 10/2016 - 02/2018

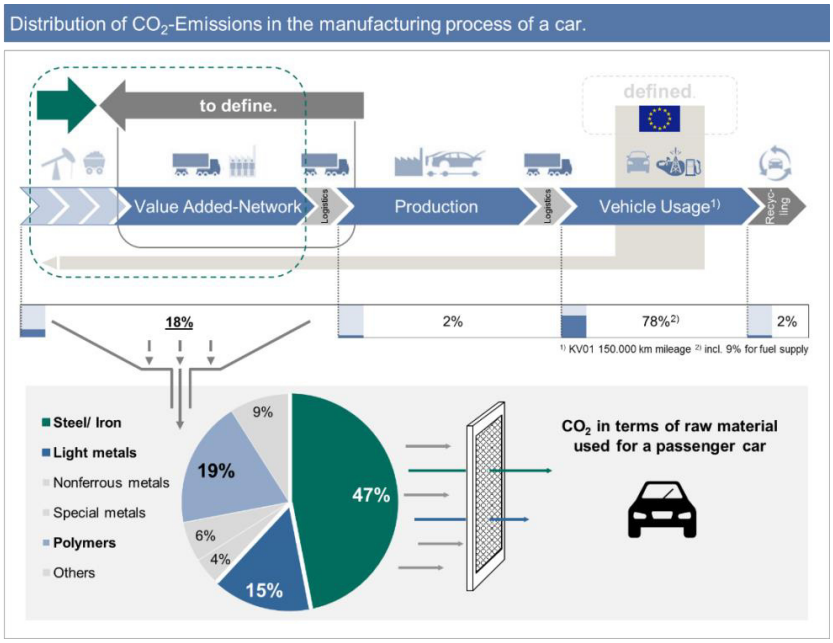
While end customers are increasingly demanding sustainable produced products, some manufacturers also expect future regulatory frameworks that contain, for example, explicit specifications on the carbon footprint of a product. For this reason, it is becoming increasingly important to not only understand the internal production processes as well as to control them with regard to environmental impacts, but also to include the upstream supply chain in the considerations.

However, the fact that the environmental impact of individual suppliers is not always known to the focal company (OEM) and sometimes more than 100 suppliers are considered for a certain product (e.g. reference product passenger vehicle/car), illustrates a certain difficulty. This lack of transparency and the high number of suppliers require the development of a methodology for a standardized assessment of the environmental impact of individual suppliers and for taking the generated data into account during the sourcing process.

The assessment of CO2e emissions for individual steel suppliers (integrated iron and steel mills) has already been successfully demonstrated in a previous project and a standardized method based on the use of publicly available plant-specific data (ECCO2 Steel - Evaluation Tool to compare CO2e emissions of the iron and steel industry) has been developed.

Steel was chosen as a reference product, since steel has the largest impact on the selected reference product – passenger vehicle, in terms of the quantity of the material needed and the according carbon emissions generated during the manufacturing process.

In this research project, the methodology of estimating greenhouse gas emissions at specific sites was transferred to other materials and extended in order to be able to record the CO2 footprint of a product in detail. For the automotive industry, this applies above all to light metals (aluminium) and plastics (e.g. polypropylene), which make up the second and third largest share of the vehicle after steel. With the goal of improving the long-term sustainability performance of companies, the tools developed (ECCO2 Steel, ECCO2 Alu and ECCO2 Plastics) enable CO2e emissions to be taken into account when selecting suppliers and further control of the environmental impact of a product.



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

Simon Glöser-Chahoud

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

Funding: French Environment and Energy Management Agency (ADEME)

Duration: since 2002 (ongoing)

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

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

THINKTANK „Industrial Resource Strategies"

Marina Maier, Sonja Rosenberg, Simon Glöser-Chahoud, Rebekka Volk

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

Duration: 01/2018 - 12/2021

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.

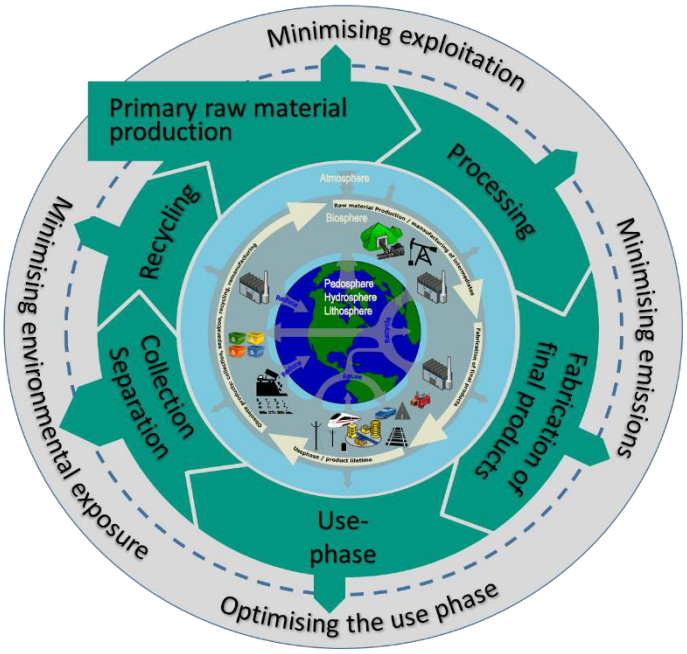


Figure: Finite resource flow according to the Circular Economy Concept

Urban heat losses

Dr. Rebekka Volk

Partner: University of Southern California, Air Bavarian GmbH

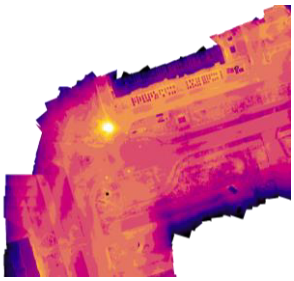
Funding: DAAD, Scholarship from Deutsche Wirtschaft

Duration: 03/2018 - today

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

For this, we collected thermal data of buildings and heat distribution networks in Karlsruhe at Campus North, Campus South and in the inner city area in 2018 and 2019. The data collection was scheduled in January and March 2019 and accompanied by a research fellow from the university of Southern California. During the experiments, we successfully completed day and night drone flights in Karlsruhe at several heights, with different flight paths, camera angles and flight patterns.

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. The research group deals within this project with the identification of heat losses, change measures and economic assessment.



We presented recent work in the project both in conferences (ISARC conference in May 2019, Banff, Canada) but also to the public, e.g. on the "Energiewendetag Baden-Württemberg" on 21st September 2019 in Stuttgart.

VOLLER ENERGIE!
Energiewendetage 2019

Completed PhD Dissertations and Habilitations

PhD Dissertation: "Public acceptance of renewable energies – an empirical investigation across countries and technologies"

Kira Schumacher

In the context of the so-called "energy transition", national energy systems are currently undergoing fundamental structural changes. This involves a rapid development of renewable energies, which means that new facilities are built or existing ones expanded. Moreover, the transformation of predominantly large-scale, mainly centralized electricity systems into smaller, at least partly decentralized generation units changes the geographic energy landscape and increases the number of contact points between society and plants. Consequently, it is more important than ever that new energy projects meet the acceptance of the general public. Otherwise, citizens' initiatives are capable to delay or stop projects which in consequence leads to cost increase or the collapse of the whole project.

Against this background, public acceptance of renewable energy innovations has become an important topic in energy research. Many studies address public acceptance through a case-based empirical lens with rather specific conclusions for individual technologies and in a given context. Comparison between studies is often difficult because of non-representative data and differences in the research designs. This compromises the generalizability of results and therefore the ability to provide meaningful guidance for the practice.

The thesis goes beyond existing studies by applying the same rigorous research design in four countries, which allows for comparative testing of various hypotheses from the research field across countries and technologies. The comparison adds significant explanatory power to the results, which can be assessed regarding their generalizability for other contexts. Based on this, recommendations for policy makers and project developers can be derived, which are applicable in different countries, including best practices and lessons learned which can be transferred from one country to another.

A noteworthy contribution of this thesis to the research field consists in the quality and comprehensiveness of the collected data. Applying a mixed methods research design, roughly 100 semi-structured interviews with bioenergy experts, three representative questionnaire-based surveys with more than 3,300 participants and 6 stakeholder workshops were carried out in Chile, France, Germany, and Switzerland. The three surveys cover around 70 variables on personal attitudes, beliefs, perceptions, and evaluations with respect to some of the most prominently discussed hypotheses in the area of acceptance research on renewable energy innovations. The hypotheses refer to acceptance levels, dispositions to act, acceptance dimensions, spatial proximity, previous experiences with renewable energies, explanatory factors for public acceptance, as well as the link between public acceptance, community energy, and energy autonomy. Moreover, the surveys focus on those renewable energy technologies which potentially evoke interactions with the general public due to their high degree of decentralization and potential local impacts which include large-scale ground-installed photovoltaic (PV) systems, small-scale PV rooftop systems, onshore wind energy plants, and bioenergy systems.

Kira Schumacher (2019): Public acceptance of renewable energies – an empirical investigation across countries and technologies, Dissertation, KIT Scientific Publishing, Karlsruhe. Doi: 10.5445/KSP/1000097148.

PhD Dissertation: "Planning and Modelling of Nuclear Dismantling Projects Considering Uncertain-ties – An Example for the Planning of Complex Projects"

Felix Hübner

Complex and large scale projects like nuclear dismantling projects often exceed the pre-defined project deadline and are often characterized by a cost overrun. Besides management problems, one of the main reasons for these deviations is the insufficient planning. Useful and applicable planning tools for the computer-aided optimization of nuclear dismantling projects are lacking.

Therefore, Felix Hübner developed a planning tool for complex and large scale projects in his PhD that exemplarily considers the special characteristics of nuclear dismantling pro-jects. The planning objective is the identification of a schedule at minimum costs on operative level considering uncertainties.

The experience data from finished projects is saved in a database (expert system). With the help of rule-based requests experience data from finished projects is used for the planning of a new project to reduce uncertainty. Nevertheless, uncertainties still prevail in complex project planning. Consequently, the planner can simulate a favored number of scenarios. For each scenario a schedule at minimum costs is calculated.
For the calculation of a schedule at minimum costs a mixed-integer linear programme (MILP) is set up that considers the special constraints of nuclear dismantling projects. With the help of the CPLEX-solver the calculation using the MILP with a warm start solution needs very long computation times or doesn't find a schedule for larger projects at all. Therefore, a new solution procedure was developed and applied.
Each of the optimized schedules is evaluated regarding its applicability in the other scenarios with the help of robustness measures. On the one hand, robustness measures from literature and on the other hand new developed robustness measures are applied.
The planner can use both the probability of applicability and the total project costs for each schedule to evaluate a preferred schedule. Additionally, sensitivity analyses help to find a preferred schedule.

Felix Hübner applied the planning tool to a case study of a complex and large scale nuclear dismantling project and hereby proved the applicability and usefulness of the planning tool.

Felix Hübner (2019): Planung und Modellierung des Rückbaus kerntechnischer Anlagen unter der Berücksichtigung von Unsicherheiten – Ein Beispiel zur Planung von Großprojekten / Planning and Modelling of Nuclear Dismantling Projects Considering Uncertain-ties – An Example for the Planning of Complex Projects, Dissertation, KIT Scientific Publishing, Karlsruhe, https://doi.org/10.5445/KSP/1000091848.

PhD Dissertation: "Development of a spatial-temporal vulnerability analysis for the initial crisis management of power failures"

Thomas Münzberg

This Ph.D.-thesis develops a spatial-temporal vulnerability analysis, which allows for a proper assessment of the urgency and the significance of power failure-related risks for a local authority on the basis of the characteristics of the critical infrastructures located there (such as hospitals, drinking water plants or dialysis clinics).
The vulnerability analysis is based on an indicator-based approach with modified multi-attribute analyses and on an approach for aggregating vulnerability indicators. Indicators are used to draw conclusions about the criticality and coping capacity of critical infrastructures to be considered and thus about the spatio-temporal risk potential of a (long-lasting) power failure. The subjectivity of the empirically collected indicator values is taken into account by means of a Monte Carlo simulation. Individual indicators are dynamized to consider temporal changes and a modified Delphi method is used to support group decisions.
The vulnerability analysis is embedded in the decision-making processes of demand planning and acute crisis management in Germany. Based on the results of the vulnerability analysis and its different spatio-temporal resolutions, the risk potentials and the locally individual power failure consequences in a local authority can be traced, making a demand-oriented dimensioning of precautionary and coping measures possible. Finally, this approach can also be used to promote security partnerships among providers of critical infrastructure providers.

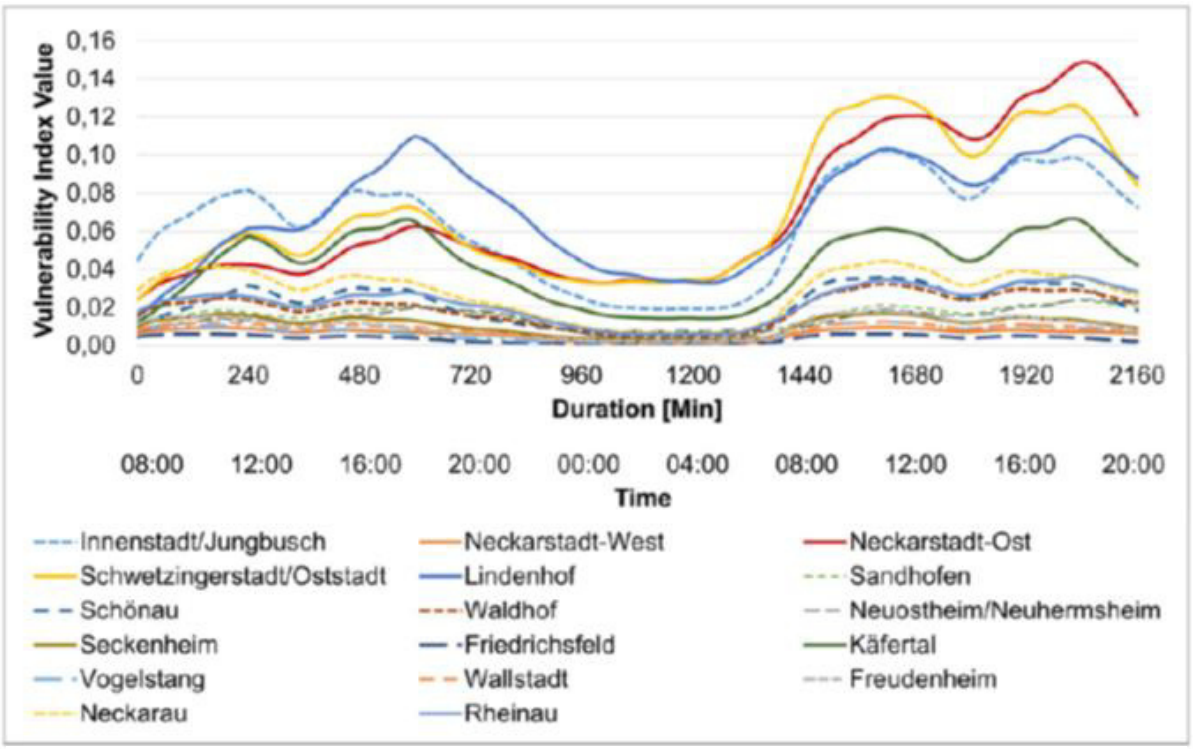


Figure: Vulnerability profiles of each city district for a reference power outage lasting two working days in the winter season starting at 8 o'clock.

Staff 2019

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

Prof. Dr. Frank Schultmann

Administrative Staff

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

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

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

Katrin Grauer

Heads of Research Groups

Dr. Simon Glöser-Chahoud – Sustainable Value Chains

Dr. Rebekka Volk – Project and Resource Management in the built environment

Dr. Marcus Wiens – Risk Management

Postdoctorial Researchers

Dr. Marina Maier

Research Associates and their PhD-topics

Mariana Burkhardt: Impacts of natural disaster on supply chain performance

Florian Diehlmann: Public Private Emergency Collaborations in Humanitarian Logistics from the Perspective of German Authorities

Marco Gehring: Mathematical project optimization in nuclear dismantling

Paul Heinzmann: Techno-ökonomische Analyse verschiedener Herstellungsrouten regenerativer Kraftstoffe

Felix Hübner: Planning and Modelling of Nuclear Dismantling Projects Considering Uncertain-ties – An Example for the Planning of Complex Projects

Sandra Huster: A quantitative approach for disassembly planning of electric vehicle batteries

Florian Kaiser: Holistisches Risikomanagement für quantifizierbare und skalierbare IT-Sicherheit

Miriam Klein: Social resilience and cooperation in cross-border crisis management

Markus Lüttenberg: Public-Private Emergency Collaborations from a game-theoretical perspective

Farnaz Mahdavian: Emergency Management and Evacuation Behavior

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

Thomas Münzberg*: Development of a spatial-temporal vulnerability analysis for the initial crisis management of power failures

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

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

Andreas Rudi: Modelling regional biomass-based value chains

Sophia Schambelon: Sustainable urban resource management

Carmen Schiel: Real Option Based Investment Strategies for Emission Abatement in Large Combustion Plants

Justus Steins: Techno-economic assessment of new aerated concrete recycling options and supply chain implications

Andreas Schiessl*: Environmental impact assessment in supplier selection

Heike Schmidt-Bäumler*: Risk-Based Maintenance Management System for Waterways Infrastructures

Kira Schumacher: Social acceptance of renewable energy installations in different national contexts – a comparative approach

Rebecca Wehrle: Criticality assessment of transport infrastructure networks

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

*external researcher

International Collaboration and Exchange

Location: Cambridge (MA), USA

Staff: Florian Diehlmann

Host: Dr. Jarrod Goentzel, Director of Humanitarian Supply Chain Lab (HSCL), Center for Transportation and Logistics (CTL), Massachusetts Institute of Technology (MIT).

Period: October 2019

Short description of stay: Since the colleagues at HSCL conduct research in the field of private sector engagement in the US, Florian got the chance to gain insights on a variety of fascinating aspects of public private emergency collaboration. Moreover, Florian shared his knowledge about German disaster management concepts in oral presentations and bilateral discussions. Furthermore, he had the opportunity to learn from the colleagues' about real world cases of collaboration from the US, where private engagement is further advanced than in Germany (mainly due to the higher frequency of disasters striking).

This research stay was funded by the Karlsruhe House of Young Scientists (KHYS).

Location: Karlsruhe, Germany

Staff: Ass. Prof. Dr. Stela Fucale Sukar (University of Pernambuco, Brazil)

Host: Dr. Rebekka Volk, Project and resource management in the built environment lab (PRM), Karlsruhe Institute of Technology (KIT).

Period: March 2019 – January 2020

Short description of stay: Associate Professor Stela Fucale from the University of Pernambuco, Brazil, visited the research lab of Rebekka Volk during 2019 for research exchange on construction and demolition (C&D) waste treatment and recycling in Germany. The fruitful exchange was based on oral presentations, bilateral discussions, multiple conference and site visits as well as participation in the institutes routines. Furthermore, she had the opportunity to learn from the colleagues' about real world cases of collaboration in Germany.

Figure: Talk at RecyclingAktiv 2019, Messe Karlsruhe

Figure: Site visit at Karlsruhe Wildpark Stadion

Location: Karlsruhe, Germany

Staff: M.Sc. Yu Hou, University of Southern California (USC) Los Angeles, USC Viterbi School of Engineering, Sonny Astani Department of Civil and Environmental Engineering.

Host: Dr. Rebekka Volk

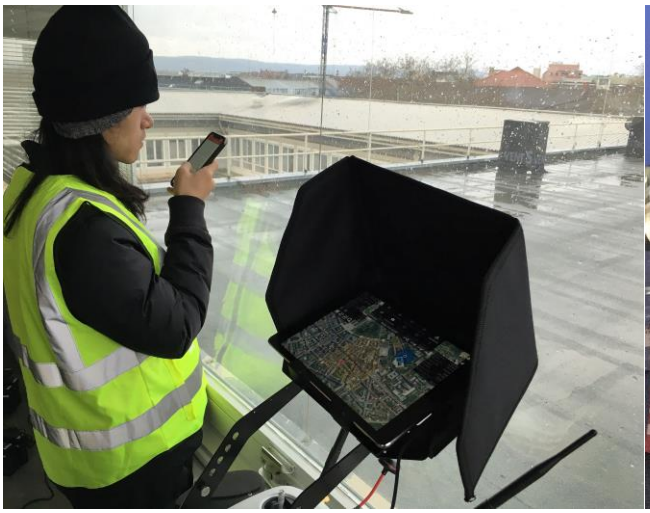
Period: Dec. 2018 – Jan. 2019 and Nov 2019 – Dec 2019.

Short description of stay: Between December 2018 and January 2019 and Nov 2019 – Dec 2019, M. Sc. Yu Hou completed a research visit at Institute for Industrial Production (IIP) at Karlsruhe Institut of Technology (KIT) in Karlsruhe. During that time Yu Hou further performed experiments and collected UAV based data in urban districts. He deepened the scientific collaboration with the employees and PhD students of PRM lab regarding sensors, drone surveys of neighborhoods, automated building detection and data processing, as well as the creation of thermal point clouds and the localization of energy losses.

The collaboration led to a first joint conference contribution on this topic on ISARC conference in May 2019 in Banff Canada. A second joint work is planned based on the results the research stay, funded by a DAAD grant.

USC Viterbi

USC University of Southern California



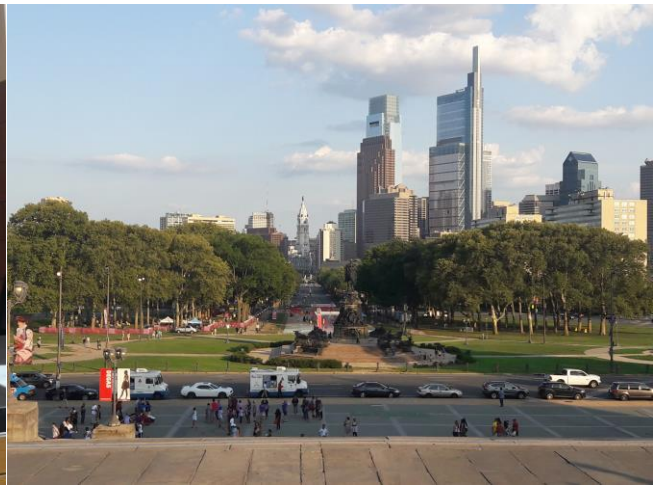
Location: Wharton School, University of Pennsylvania, USA

Staff: Dr. Marcus Wiens

Host: Prof. Dr. Steven O. Kimbrough

Period: July 2019

Short description of stay: Already since the year 2018, members of the risk research group have an ongoing research cooperation with the department of Operations, Information and Decisions at Wharton School in Philadelphia. The areas of cooperation with Prof. Dr. Steven Kimbrough are evacuation modelling and decision modelling in the context of agent-based simulations. During his stay in Philadelphia, Marcus Wiens worked together with Steven Kimbrough on a decision model, which integrates risk perception and group incentives in a "risk as public good"-problem. This approach allows policy makers to anticipate and address collective risk decisions of communities.



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 2019 more than 900 student exams were conducted and the chair has supervised 110 bachelor and master theses.

Grundlagen der Produktionswirtschaft / Introduction to Production Management

Prof. Dr. F. Schultmann, Dr. Rebekka Volk, Richard Müller, Elias Naber

~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.

Logistics & Supply Chain Management

Dr. Marcus Wiens, Florian Diehlmann, Markus Lüttenberg

~70 students

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

Produktions- und Logistikmanagement/ Production and Logistics Management

Dr. Simon Glöser-Chahoud, Andreas Rudi, Tobias Zimmer

~120 students

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

Anlagenwirtschaft/ Planning and Management of Industrial Plants

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

~140 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.

Project Management

Prof. Dr. F. Schultmann, Dr. Rebekka Volk, Dr. Felix Hübner, Dr. Kira Schumacher, Dr. Marcus Wiens, Marco Gehring, Sonja Rosenberg

~60 students

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

Risk Management in Industrial Supply Networks

Dr. Marcus Wiens, Miriam Klein

~50 students

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

Supply Chain Management in the Automotive Industry

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

~100 students

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

Sustainable Production

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

~50 students

This course offers and introduction into the basics of sustainability and the linkage of sustainability to production and logistics. Examples of sustainability assessments and sustainable production systems illustrate actual challenges for the transformation of current production environments into sustainable structures.

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 Analysis (WS, 3,5 ECTS)
- International Management in Engineering and Production(WS, 3,5 ECTS)

MSc-Module
"Production and Logistics Management"

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

Publications

Peer-Reviewed Journals

Diehlmann, F.; Zimmer, T.; Glöser-Chahoud, S.; Wiens, M.; Schultmann, F. (2019). Techno-economic assessment of utilization pathways for rice straw: A simulation-optimization approach. *Journal of Cleaner Production*, 230, 1329–1343. doi:10.1016/j.jclepro.2019.04.369

Glöser-Chahoud, S., Pfaff, M., Walz, R., & Schultmann, F. (2019). Simulating the service lifetimes and storage phases of consumer electronics in Europe with a cascade stock and flow model. *Journal of Cleaner Production*, 213, 1313–1321. doi:10.1016/j.jclepro.2018.12.244

Glöser-Chahoud, S.; Schultmann, F. (2019). Potential Contribution of Secondary Materials to Overall Supply – The Example of the European Cobalt Cycle. *Materials science forum*, 959, 11–21. doi:10.4028/www.scientific.net/MSF.959.11

Jacob, K.; Guske, A.-L.; Antoni-Komar, I.; Funcke, S.; Gruchmann, T.; Kny, J.; Naber, E.; Ruppert-Winkel, C.; Sauer, P. C.; Stumpf, K. H.; Volk, R. (2019). Governance for the sustainable economy: Institutional innovation from the bottom up? 2019. *Gaia*, 28 (S1), 204–209. doi:10.14512/gaia.28.S1.6 (peer-reviewed)

Meng, S.; Wiens, M.; Schultmann, F. (2019). Adversarial risks in the lab – An experimental study of framing-effects in attacker-defender games. *Safety Science*, 120, 551–560. doi:10.1016/j.ssci.2019.08.004.

Petig, E.; Rudi, A.; Angenendt, E.; Schultmann, F.; Bahrs, E. (2019). Linking a Farm Model and a Location Optimization Model for Evaluating Energetic and Material Straw Valorization Pathways – A Case Study in Baden-Wuerttemberg. *GCB Bioenergy*, 11(1), 304-325. doi:10.1111/gcbb.12580

Schätter, F.; Hansen, O.; Wiens, M. & Schultmann, F. (2019). A decision support methodology for a disaster-caused business continuity management, *Decision Support Systems*, 118, 10-20. doi: 10.1016/j.dss.2018.12.006

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Schumacher K.; Krones F.; McKenna, R.; Schultmann, F. (2019). Public Acceptance of Renewable Energies and Energy Autonomy: A Comparative Study in the French, German and Swiss Upper Rhine Region. *Energy Policy,* 126, 315–332. doi.org/10.1016/j.enpol.2018.11.032.

Volk, R.; Hübner, F.; Hünlich, T.; Schultmann, F. (2019). The future of nuclear decommissioning – A worldwide market potential study. *Energy Policy*, 124, 226–261. doi:10.1016/j.enpol.2018.08.014

Volk, R.; Müller, R.; Reinhardt, J.; Schultmann, F. (2019). An Integrated Material Flows, Stakeholders and Policies Approach to Identify and Exploit Regional Resource Potentials. 2019. *Ecological economics*, 161, 292–320. doi:10.1016/j.ecolecon.2019.03.020

Zarghami, S. A.; Gunawan, I.; Schultmann, F. (2019): Entropy of centrality values for topological vulnerability analysis of water distribution networks. *Built Environment Project and Asset Management* 9(1), 412-425. doi.org/10.1108/BEPAM-02-2019-0014

Zarghami, S. A.; Gunawan, I.; Schultmann, F. (2019). Integrating Topological and Hydraulic Attributes for Robustness Analysis of Water Distribution Networks. *International Journal of Industrial Engineering and Operations Management*, 1(1), 1-12

Zarghami, S. A.; Gunawan, I.; Schultmann, F. (2019). Exact Reliability Evaluation of Infrastructure Networks Using Graph Theory. *Quality and Reliability Engineering International*, 1-13 (online first). doi.org/10.1002/qre.2574

Conference Proceedings and Working Papers

Braeuer, F.; Kleinebrahm, M.; Naber, E. (2019). Effects of the tenants electricity law on energy system layout and landlord-tenant relationship in a multi-family building in Germany, 2019. SBE Graz 2019 Sustainable Built Environment D-A-CH Conference 2019 - Transition Towards a Net Zero Carbon Built Environment, 11 - 14 September 2019, Graz University of Technology, Austria, in: IOP conference series / Earth and environmental science, 323, Art.-Nr.: 012168. doi:10.1088/1755-1315/323/1/012168 (peer-reviewed)

Gast, J. & Wehrle, R. (2019). Application of the Concept of Supply Chain Reliability for an Availability Assessment of Inland Waterway Systems. *Proceedings of the 23rd Cambridge International Manufacturing Symposium*, Cambridge.

Hou, Y.; Soibelman, L.; Volk, R.; Chen, M. (2019). Factors Affecting the Performance of 3D Thermal Mapping for Energy Audits in A District by Using Infrared Thermography (IRT) Mounted on Unmanned Aircraft Systems (UAS) 2019. Modular and Offsite Construction (MOC) Summit / International Symposium on Automation and Robotics in Construction (ISARC), International Conference on Construction and Real Estate Management (ICCREM), Banff Alberta, Canada, May 21-24, 2019, Paper 66, University of Alberta, Edmonton (peer-reviewed)

Glöser-Chahoud S., Pfaff M. (2019). The role of unused storage phases (hibernation) in the overall lifetime of a mobile phone – an evaluation of simulation-based scenarios including their environmental impacts. 3rd Product Lifetimes and the Environment (PLATE) Conference, Berlin, Germany, Sept. 2019

Naber, E.; Lützkendorf, T.; Volk, R.; Schultmann, F. (2019). A survey of private landlords in Karlsruhe and their perception of deep energy retrofit, 2019. SBE Graz 2019 Sustainable Built Environment D-A-CH Conference 2019 - Transition Towards a Net Zero Carbon Built Environment, 11 - 14 September 2019, Graz University of Technology, Austria, in: IOP conference series / Earth and environmental science, 323, Art.-Nr.: 012165. doi:10.1088/1755-1315/323/1/012165 (peer-reviewed)

Books and Book Chapters

Hübner, F. (2019). Planung und Modellierung des Rückbaus kerntechnischer Anlagen unter der Berücksichtigung von Unsicherheiten – Ein Beispiel zur Planung von Großprojekten / Planning and Modelling of Nuclear Dismantling Projects Considering Uncertainties – An Example for the Planning of Complex Projects, Dissertation, KIT Scientific Publishing, Karlsruhe. doi.org/10.5445/KSP/1000091848.

Schumacher, K. (2019):.Public acceptance of renewable energies – an empirical investigation across countries and technologies, Dissertation, KIT Scientific Publishing, Karlsruhe. doi:10.5445/KSP/1000097148.

Volk, R. (2019). Betriebswirtschaft / Nachhaltigkeitsmanagement. 2019. Nachhaltigkeit interdisziplinär: Konzepte, Diskurse, Praktiken. Hrsg.: E. Zemanek, 180–197, UTB, Stuttgart, Kapitel 9, pp. 180-197, UTB/Böhlau, ISBN: 978-3-8252-5227-4, https://www.vandenhoeck-ruprecht-verlage.com/themen-entdecken/literatur-sprach-und-kulturwissenschaften/kulturwissenschaft/53239/nachhaltigkeit-interdisziplinaer-konzepte-diskurse-praktiken

Volk, R.; Müller, R.; Schultmann, F.; Rimbon, J.; Lützkendorf, T.; Reinhardt, J.; Knappe, F. (2019). Stoffffluss- und Akteursmodell als Grundlage für ein aktives Ressourcenmanagement im Bauwesen von Baden-Württemberg „StAR-Bau" - Schlussbericht des Forschungsvorhabens. 2019. KIT Scientific Publishing, Karlsruhe. doi:10.5445/KSP/1000086644, Band 32

Wiens, M.; Diehlmann, F.; Lüttenberg, M.; Schultmann, F.; Michalk, K.; Gromitsaris, A.; Schulte, M.; Zienau, A.; Breitbarth, E.; Gross, W. (2019). Wenn das Wasser knapp wird. Protector / Ausgabe Deutschland, 47 (7-8), 40–41.

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