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## 15th Global Conference on Sustainable Manufacturing

## The regional and social impact of energy flexible factories

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**Abstract**

The change of electricity supply from conventional to renewable energy sources is a challenge for the whole society. This transition causes an increase of volatility in electricity supply and therefore threatens both, grid stability and, also, electricity price stability. Besides cost-intensive countermeasures such as grid expansions and power-to-X storage technology, the incentivized change in electricity use (energy demand flexibility) is a promising approach. Today, when it comes to production matters, energy is considered as a resource which is immediately available on demand. In contrast, future scenarios draw a picture, in which electric energy will become a resource that requires planning and control. Energy flexible factories will be an important part of our society with an important ecological and social impact. The paper presents a transdisciplinary approach to shape a sustainable electricity supply in the discourse with regional stakeholders from a technical, ecological and social background.

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**Keywords:** energy flexibility, model region, transdisciplinary research, desing thinking

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**1. Introduction**

Global greenhouse gas emissions continue to grow. In 2015, participants of the UN Climate Change Conference in Paris agreed to pursue efforts to limit the temperature increase to 1.5 degrees Celsius above pre-industrial lev-

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els [1]. Germany, one of the top five countries in renewable power generation [2], has claimed to take a worldwide lead in climate protection [3]. In 2016, renewable energies already reached 31 % of the German electricity mix [4]. The expansion target for renewable energies, imposed by the Germany federal government, amounts 80 % up to the year 2050 [5]. This ambitious project will enable a gradual withdrawal from Germany's nuclear energy programme by 2022 and to reduce its greenhouse gas emissions by 80 to 95 % until 2050 compared to 1990 [4]. The change in German energy policy, that is called *energy transition*, addresses complex interrelations between heterogeneous actors from the technical, political, legal and societal sector.

One of the biggest challenges for the energy transition is the intermittent nature of photovoltaic and wind power systems, which constitute the largest share within the German renewable electricity generation [5]. Uncontrollability and difficult predictability of solar radiation and wind conditions threaten the balance between electricity supply production and demand. Consequently the grid stability in central Europe is challenged. Besides cost-intensive solutions of grid expansions and power-to-X storage technology, demand side management (DSM) is a promising approach for utilizing flexibility in electricity demand to balance fluctuating energy availability [6]. Thereby, DSM was originally defined as “the planning and implementation and monitoring of [...] activities designed to influence customer use of electricity in ways that will produce desired changes in the [...] load shape, i.e., changes in the time pattern and magnitude of [...] load” [7]. Palensky and Dietrich [6] divide DSM further into Energy Efficiency, Time of Use, Demand Response (DR) and Spinning Reserve. For purpose of simplification, we summarize Time of Use and Demand Response by the term *energy flexibility*, describing the ability of a manufacturing company to adapt the production to short-term changes in electrical energy provision with least possible loss in time, effort, costs and performance [8,9]. It induces changes in electricity demand through incentives such as varying electricity prices that are an important measure to encounter fluctuating energy availability [10]. Especially the industrial sector, which is by far the largest electricity consumer with a share of 47 % of the total German net electricity consumption in 2016 [11] has a high potential for energy flexibility. Although there are some companies in the industrial sector that already participate in energy flexibility markets, e.g. balancing power markets, most of the capability of energy flexibility remains unused. Recent studies assess the potential of DSM in German industries between 1.8 and 15 GW [12,13].

Apart from monetary incentives and technological enablers to leverage this potential, ecological and social aspects of energy flexibility have to be considered in order to achieve a broad public acceptance. For this reason a subproject of the project *SynErgie*, funded by the German Federal Ministry of Education and Research (BMBF), aims for prototyping a new form of cooperation between society and the energy flexible factory with transdisciplinary research (TR) and design thinking. “TR deals with problem fields in such a way that it can grasp the complexity of problems, take into account the diversity of life-world and scientific perceptions of problems, link abstract and case-specific knowledge and develop knowledge and practices that promote what is perceived to be the common good” [14].

SynErgie has the objective to conceptualize, develop and implement a digital market platform for the trading of energy flexibility within the industrial sector. This is why the project team pursues a bottom-up-approach by taking one region into a closer examination and transferring the results to other regions. In the context of the SynErgie project, the aim of the so-called *energy flexible model region Augsburg* is therefore to take a holistic perspective on energy flexibility in a regional context to uncover the local obstacles for energy flexibility with regard to ecological and social aspects. Thus, a holistic perspective must integrate the impacts on all technological, ecological and social stakeholders and it demands for a collaboration of those stakeholders from different disciplines and backgrounds. Stakeholders like scientists, plant operators, plant employees or conservationists must perform a transdisciplinary discussion process to uncover and assess different problem areas that emerge from a regional integration of energy flexibility. This offers a basis to develop appropriate measures that utilize and increase energy flexibility and to transfer the knowledge gained into other regions and therefore on a national level. In order to contribute to the transdisciplinary efforts of SynErgie and the energy flexible model region Augsburg, the authors aim for working on the following research objective:

*Designing and illustrating a transdisciplinary approach to utilize (industrial) energy flexibility  
with respect to technological, ecological and social restrictions.*

The paper presents the transdisciplinary dialog process in the energy flexible model region Augsburg, which is also a guideline for regional and national efforts within the SynErgie project. Thus, in Section 2, Augsburg as energy-flexible model region is introduced in detail. In Section 3, impacts of energy flexible factories within the transdisciplinary dimensions technosphere, soziosphere and ecosphere are illustrated. Section 4 gives an overview of the transdisciplinary approach and the methodology. Section 5 presents the research project's progress and intermediate results. Section 6 concludes with an outlook.

## 2. Introducing the energy-flexible model region Augsburg

The introduction emphasized the importance of a regional approach to balance electricity supply and demand by utilizing and increasing industrial energy flexibility. Therefore, it is necessary to build up a regional platform at distribution grid level to synchronize renewable energies in the region with the energy demand by using them most efficiently. To analyse the impact of energy flexible factories, the region around the German city Augsburg has been chosen as a model region. The following subsections will present key facts of the region and a first overview of energy flexible factories with their social and ecological impacts.

### 2.1. The regional structure of Augsburg

Augsburg is a German city with nearly 300.000 inhabitants in the city and 600.000 inhabitants in its surrounding region. Augsburg serves as capital of the district Swabia and is the third largest city of Bavaria. The industrial sector includes small, medium and large companies [15]. The five most important business areas are mechatronics and automation, fiber composite, information technologies, logistics and environment [16]. Therefore, manufacturers of the following sectors are important regional employers: machinery and equipment, rubber and plastic products, chemicals and chemical products, pulp, paper and paper products [17]. From an energetic point of view Bavaria and especially Augsburg offer a heterogeneous mixture of industrial energy consumers, including energy-intensive companies (see Figure 1). However, many companies are not directly located in the city. Hence, we broaden our scope onto the surrounding region of Augsburg, the so-called *economic region Augsburg*. Thereby, the city of Augsburg is characterized by a high electricity demand and low renewable electricity supply, while the surrounding regions have a low electricity demand and a high capacity of renewable energies, particularly photovoltaics. Within that scope the overall annual electrical energy demand of households and industries is 4.600 GWh, whereby the industry in the economic region Augsburg contributes about 74 % [18].

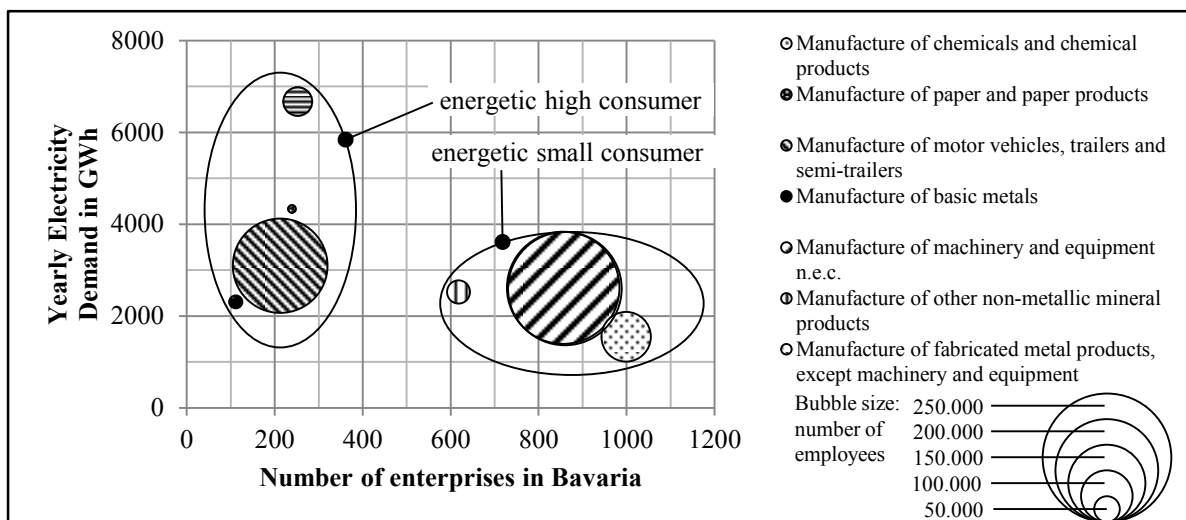


Figure 1: Classification of regional industrial energy consumer [19]

## 2.2. Regional change in energy policy

The regional turnaround in energy policy is affected by the Bavarian renewable expansion targets. Therefore the prospective changes are presented in the following subsection. The regional climate protection concept of the economic region Augsburg includes the objective to decrease CO<sub>2</sub> emissions by 55 % until 2030 in comparison to 2009. Measures to reach this ambitious objective include both an increase of energy efficiency and a rising share of renewable energies [20]. In the last years, the installed capacity of renewable energies in Bavaria has been extended from 5 GW up to 15 GW, which nowadays represent 50 % of the power generation portfolio. Accordingly, 40 % of the electrical energy supply in Bavaria is provided by renewable energies. The remaining part is covered by 43 % from nuclear and by 17 % from fossil power plants (see Figure 2). As stated in the introduction, the existing nuclear power plants will be successively turned off until 2022.

As the nuclear power plant in Gundremmingen, which is located close to Augsburg will be shut down until 2022, there will be a local gap in electricity supply. In short-term, this gap cannot be covered by transporting wind power from the north of Germany or pump stored power from Austria, as transmission grid capacity is limited. In addition, conventional electricity supply from France and Czech Republic may become limited in terms of time and volume. For this reason, regional energy sources have to be used in a most effective way to guarantee the security of supply, by taking into account that the supply volatility in the distribution grid level will increase through the use and the expansion of renewable energies. In order to incentivize the industries to offer energy flexibility and to enable a prioritization of local balancing measures, the current power market design needs to be challenged.

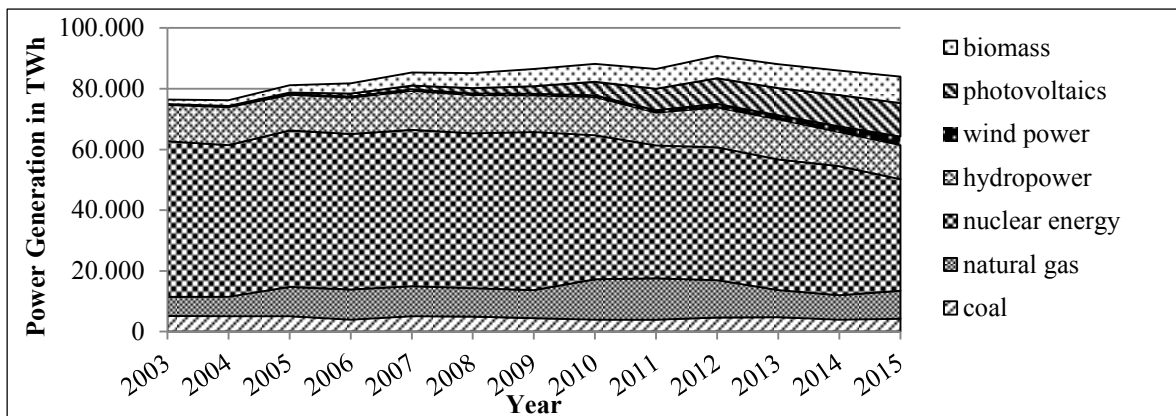


Figure 2: Mixture of the energy supply in Bavaria (2003-2015) [19]

## 3. Impact of energy flexible factories

Due to their large impact on Augsburg's energy demand, energy flexible factories may significantly contribute to grid stability[21]. To realize this energy flexibility potential, factories need to be integrated into a smart grid on a regional and a national level. Thereby, manual or automated changes in the load profile can be performed between the grid and production. Thus, energy flexibility in production has the potential to contribute to the power system's stability.

However, as manufacturing companies are individual socio-economic systems in a regional context, technical, social and ecological aspects have to be considered. Therefore, three spheres are defined which integrate the individual interests of the different stakeholders in the context of industrial energy flexibility and support the creation of solutions and guidelines for a successful implementation within the region. This approach is illustrated in Figure 3.

The *technosphere* comprises industrial companies, utility companies and service-companies (e.g. IT) with the objective of formulating and utilizing flexibility measurements throughout the different industries. Second, the *sociosphere* unites labor unions, regional municipality, utility companies and citizen groups as a think tank, which elaborates a local energy transition agenda and its impact to quality of life, work and the energy market situation

within the region. Thereby, a municipal statement towards energy transition objectives, the Regional Target Scenario, flexibility measures, which companies in the region may use for energy flexibility (e.g. weekend production) are formulated and discussed. Finally, the *ecosphere* merging interest groups like ecological activists, governmental and non-governmental environment institutions in order to assess the impact of possible energy flexibility measures on the regional environment. All spheres work on their own solutions and guidelines. The three spheres are mutually integrated in a collaborative procedure where preliminary results are shared and combined in common meetings such as decisions for further actions. Using insights of the technological, social and ecological attitude towards energy flexibility, technically realistic flexibility levels are joined with socio-ecological guidelines. As a result, appropriate energy flexibility measures are identified for each factory that meets the individual requirements of the respective stakeholders. Hence, factories are able to utilize their energy flexibility potential within the region and therefore contribute proactively to the local and national energy transition.

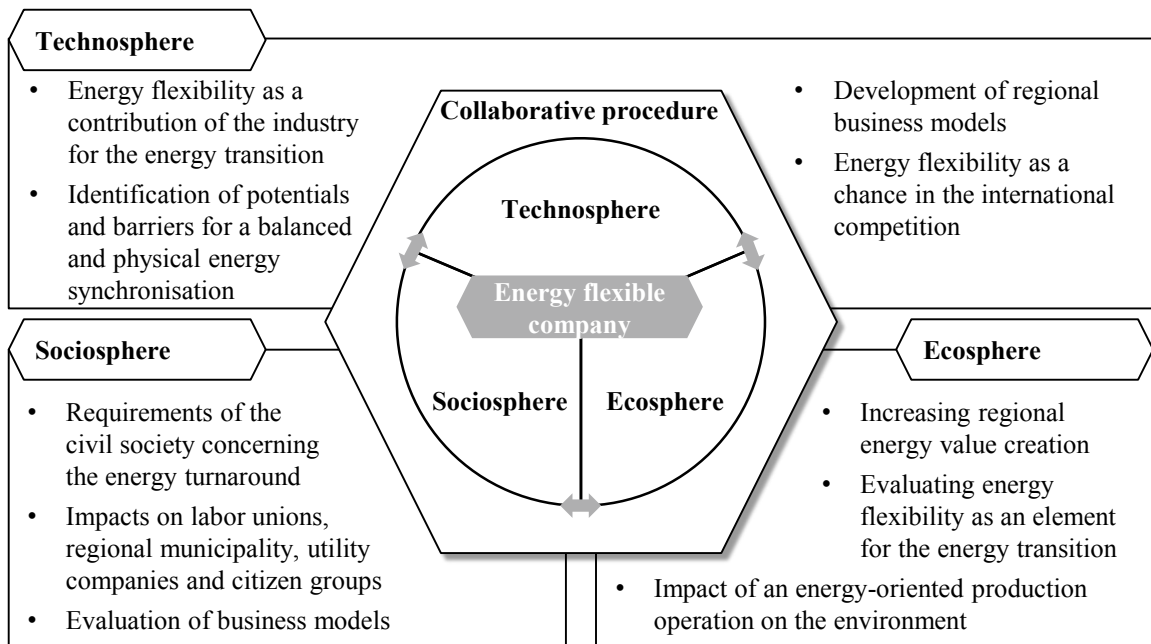


Figure 3: The collaborative procedure and the three spheres of the energy flexible model region

#### 4. Approach and methodology

As shown, the German energy transition poses many technical and societal challenges. These can be understood and tackled best by a transdisciplinary approach: “Transdisciplinarity is a reflexive research approach that addresses societal problems by means of interdisciplinary collaboration as well as the collaboration between researchers and extra-scientific actors; its aim is to enable mutual learning processes between science and society; integration is the main cognitive challenge of the research process” [22].

The transdisciplinary approach for the energy flexible model region includes the following three phases Co-Design, Co-Production, Co-Communication and Transdisciplinary Re-Integration (see Figure 4). At the Co-Design societal as well as technological problems are discussed within the different research spheres (i.e. the sociosphere, ecosphere and technosphere). The goal is to establish a mutually shared understanding, to frame the problem, and to derive specific research questions. During the phase Co-Production scientific knowledge (like new technologies) and societal knowledge (how to’s, values) are gathered together to produce valuable solutions. Finally, the phase Co-Communication and Transdisciplinary Re-Integration represents a remarkable challenge, integrating the different perspectives in the cluster meetings twice a year. The results of the generated knowledge have to be fed back into the scientific and societal practice. This requires an agora to deliberate and reflect with stakeholders and citi-

zens. The Regional Target Scenario for Augsburg is an important interface which needs to be defined during the research progress. It consists of a shared vision of all partners and citizens for the renewable electricity mix and its flexible use of the industry in the region Augsburg.

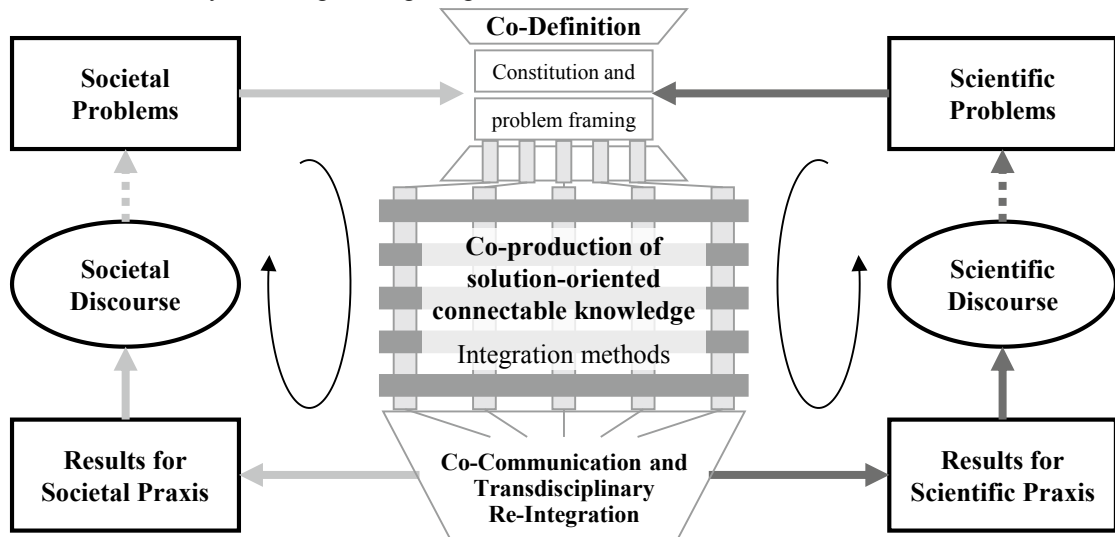


Figure 4: Transdisciplinary Research Approach [23]

Transdisciplinarity means that scientist and practitioners from industry, politics, administration, NGOs and citizens contribute to the research process design and to the implementation of solutions. It is important for the overall participatory process to define roles and responsibilities as well as the decision and feedback architecture. To ensure a high-quality cooperation, the transdisciplinary approach is combined with a human-centred design methodology.

Design is a way of assessing and creating services and products, focusing on their usability, usefulness and engagement to the people creating and using them. This enables to understand, define, develop and evaluate relevant knowledge with stakeholders from different affected sectors. The chosen research design is oriented on the *Double Diamond Model*

[24] which differentiates between two main phases: 1) *Problem Area* and 2) *Solution Area*, with a divergent and convergent phase for each area. The theoretical base builds on successive phases, as illustrated in Figure 5. Solution area is the connection between the Regional Target Scenarios and the factories.

The underlying design principles are implemented by different methods throughout the entire process. The process is based on the principles of transdisciplinary research and are conducted with a human centred design approach. To guarantee valid results that build on one another, the research process is divided into three phases:

- Phase 1) Co-Definition: Setting the foundation for cooperation, creating a shared understanding of process and roles, collecting stakeholder demands and worries concerning the energy flexible factory  
Co-Define: Defining main challenges and opportunities, summarizing insights in regional target scenario for Augsburg
- Phase 2) Co-Production: Developing ideas and prototypes for fields of action and business models within the context of the energy flexible factory
- Phase 3) Co-Communication & Transdisciplinary Reintegration: Testing and synthesizing pathways for an energy flexible factory in Augsburg and transfer to other regions

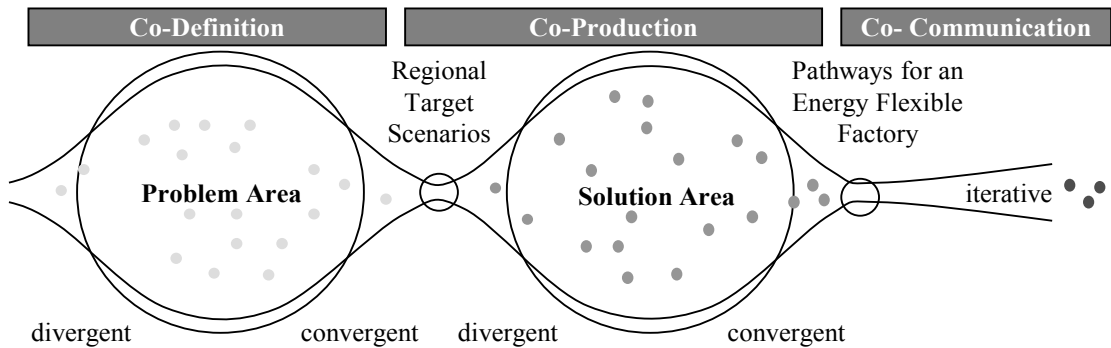


Figure 5: Process design for the energy flexible model region Augsburg (based on [24])

## 5. Progress and intermediate results

So far, the phase of Co-Definition has been approached from various angles: Stakeholders have been engaged, Understanding, has been approached, in which the kick-off workshops of the entire cluster and each sphere have been conducted. In order to collect data and knowledge within the four relevant sectors (science, industry, politics and civil society) the regional stakeholders were asked for related topics, challenges and opportunities. Based on these knowledge-maps the four groups have synthesized their needs and interests with regard to the energy flexible factory. For this purpose *Persona Profiles* were used to develop a *Position Map* displaying the parties that will benefit or lose and support or hinder the developments at the moment. First results are the following identified challenges and topics: social innovations, establishment of the economic framework, political support to foster the transition and adoption of the regulatory framework.. Questions regarding the implementation of the research project in companies and markets, the tasks of the research agenda, the achievement of societal acceptance for the project approach as well as the question of fairness in the transition process and the development of new roles and positions in different stakeholder groups were outlined. One question, the stakeholder focus on, is how to cope with the ambiguity between economically viable solutions and affordable costs for all consumers.

The complex process synchronization between the different research spheres (the sociosphere, ecosphere and technosphere) has been specified in order to develop a mutually shared understanding of feedback and co-communication structures throughout the entire process. This transdisciplinary research approach is needed as a basis for co-producing the Regional Target Scenario for Augsburg.

## 6. Discussion and outlook

Reflecting the cooperation so far, knowledge integration can be mentioned as the biggest challenge, especially regarding the process facilitation and coordination in transdisciplinary research. The evaluation of the project is outlined by the following three dimensions [23]:

- 1) Cognitive-epistemic dimension: The differentiation and linkage of disciplinary knowledge bases, as well as practical real-world knowledge is still underdeveloped. This means that the limits of one's own knowledge have to be clarified and methods and building theories need to be developed and strengthened in the process.
- 2) Social and organizational dimension: The participating researchers' interests and activities are going to be more and more transparent and mutually reasonable. All partners are aware of the challenges and willing to learn.
- 3) Communicative dimension: The different linguistic expressions and communicative practices are perceived. One goal of the project is to develop a common discursive practice in which mutual understanding and communication is possible. This will be a significant step for a mutually shared understanding for the challenges of the energy transition.



The results of the three-year research project will be crucial for the transfer of the energy flexible industry into other regions in Germany. The experiences and findings within the Augsburg region will be a first prototype and an important step for the success of the energy transition in Germany and Europe.

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