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The Social Acceptance of Renewable Energies and Climate-Neutral Electricity Mixes in Bavaria

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Abstract

Social acceptance presents a significant barrier to the development of renewable energy (RE) despite widespread support for the energy transition. While there is a substantial body of literature addressing the social acceptance of individual technologies, there is a notable gap in research that examines multiple RE technologies within a single study across various acceptance dimensions. Furthermore, there is limited investigation into preferences for future energy/electricity mixes. To address these gaps, this research aims at exploring socio-political, community, and market acceptance of key technologies crucial for achieving a climate-neutral electricity supply in Bavaria, while also investigating preferred future electricity mixes. This study applied a mixed-method research approach that combines desk research with quantitative and qualitative empirical data collection. The emphasis of the empirical research is a survey among the Bavarian public (n = 376) providing insights into public acceptance, while interviews (n = 5) offered assessments of stakeholder and political acceptance. The findings indicate that the recent energy crisis has shifted the primary motivation for the energy transition in Bavaria from climate protection to energy independence, while also increasing acceptance levels across all dimensions. Assessing the acceptance of individual technologies, roof-mounted photovoltaic (PV) systems received the highest acceptance score, followed by hydropower, wind energy, bioenergy, and lastly, ground-mounted PV. Regarding future electricity mixes, the "Balanced Development" scenario, which features a balanced mix of several renewables alongside significant energy imports, received the highest acceptance. Other scenarios that emphasise the development of a single technology to achieve a high share of renewable electricity generation or that rely heavily on imports saw significantly fewer votes. This scenario is also viewed as the most advisable from a market stakeholder perspective. Political preferences emerged as the strongest influence on attitudes toward renewable energy technologies, perceived concerns associated with those technologies and future electricity mixes. Individuals aligned with right-leaning or conservative parties tend to be supportive of bioenergy and hydropower. In contrast, those identifying with environmentally oriented or socially left parties are more likely to accept solar PV and wind energy. These preferences also shape attitudes toward future electricity mixes, with the former group favouring scenarios with less solar and wind development, while those in the latter category prioritise scenarios with more extensive RE development. The most accepted forms of supplementary electricity supply to complement domestic renewables are future technologies and electricity imports.

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1 Introduction

The drastic reduction of greenhouse gas emissions, mainly CO2 and CH4, from the use of fossil fuels in the energy sector is widely considered absolutely essential to ensure avoiding a catastrophic climate crisis (Lieber & Dobers, 2019). Decarbonisation pathways ensuring that global warming is limited to below 2°C, as ratified by the majority of the world community through the Paris Agreement, require immediate and formidable actions (Milani et al., 2024). A central pillar of international and national climate protection policy frameworks is the development of renewable energy (RE) sources allowing the transition away from fossil fuels (Leibenath & Lintz, 2017). Germany, the largest emitter of energy-related emissions in the European Union (Eurostat, 2023), acknowledges the critical importance of RE development through the *Erneuerbare-Energien-Gesetz* (EEG) (2023), which mandates a substantial increase of solar, wind and bioenergy. While legislations like the *EEG* underscore the political will to decarbonise the energy system, realising the ambitious governmental targets can be regarded as a very challenging undertaking.

1.1 Problem statement

Besides the technical and economic hurdles (Ruddat & Sonnberger, 2019; Zoellner et al., 2008) as well as the complexity of spatial planning and permitting processes (Ruddat, 2022), social acceptance is regarded as one of the most significant barriers to RE development, repeatedly causing delays in the construction and operation of RE plants (Segreto et al., 2020; Wüstenhagen et al., 2007). For the context of Germany, Dratsdrummer et al. (2023) describe the acceptance of renewables as a bottleneck of a successful energy transition. At first, social acceptance being a major hurdle might seem counterintuitive as general acceptance levels are on high levels with three-quarters of the population generally supporting the energy transition (RIFS, 2022) and 81% supporting further development of RE (AEE, 2023). However, despite widespread support and the well-documented overall benefits of transitioning from fossil fuels to RE (Segreto et al., 2020), the transformation of the energy system is accompanied by criticism, contentious conversations as well as local opposition (Hübner et al., 2023). This phenomenon can be attributed to a multitude of reasons including the negative consequences at the local level, such as the visual alteration of landscapes (Vuichard et al., 2022; Kirchhoff et al. 2022) or the potential impact on nature and human well-being (Hübner et al., 2023), which raise significant concerns. In Bavaria, the largest federal state of Germany, numerous instances reported in recent newspaper articles have highlighted citizen mobilisation against PV and wind energy projects, resulting in delays, downscaling or in many cases cessation of RE developments (Storch, 2024; Bluhme & Wilhelm, 2023; Treffler, 2024; Weinberg, 2024; Jeroma, 2024). In light of the increase in RE capacity required to meet established climate goals, it can be anticipated that this issue will gain even greater significance as a growing number of individuals encounter the consequences of local RE development (Mautz et al., 2008). While acceptance currently mainly influences RE development on a local scale, neglecting this aspect of the energy transition has the potential to impede the energy transition and result in failure to meet climate protection goals (San Martin, 2023).

1.2 Knowledge gap

While in the initial phases of renewable energy development, the matter of social acceptance has been largely overlooked, in more recent years there has been a surge in scholarly research examining this crucial area (Devine-Wright et al. 2017; Bianchi & Ginelli, 2018). Although there have been a considerable number of publications on social acceptance investigating different technologies (Peñaloza et al. 2022, Karytsas & Polyzou, 2021; Enevoldsen & Sovacool, 2016) in varied geographical contexts (Ingold et al., 2019; Liebe & Dobers, 2019), there remains a significant amount of ground to be covered on this subject.

Firstly, this research seeks to address the lack of scientific analysis of social acceptance of relevant renewable energy technologies - i.e. wind energy, solar PV, hydropower and bioenergy - in Bavaria. While Langer et al. (2016) focused on the factors most influential for the acceptance of wind energy within this geographical context, the study does not address the acceptance of other renewable energy sources, nor does it allow comparing the social acceptability of wind energy to these other technologies. Furthermore, the authors specifically suggest that future analysis should combine quantitative and qualitative methodologies to enhance the quality of results. So far there has been no study investigating and comparing the acceptance of all relevant renewable energy supply technologies in the context of Bavaria or Germany using a mixed-method approach. Secondly, Devine-Write et al. (2017) critique the limited scope of empirical acceptance studies, noting that only a few studies have incorporated more than one of the dimensions of social acceptance as defined by Wüstenhagen et al. (2007). This study seeks to address this critique by incorporating all three aspects of social acceptance meaning socio-political acceptance, community acceptance and market acceptance for renewable energy technologies. Thirdly, this research incorporates an innovative approach by not only investigating the acceptance levels of different renewable energies as well as decisive drivers of technology acceptance but also the social acceptance of different decarbonized electricity. While numerous studies at the macro, meso and micro levels demonstrate the technical feasibility of the energy transition through the development of various potential pathways, they do not elaborate on the societal impacts this fundamental transition will encompass, nor do they address whether these pathways will receive social acceptance (Wiese et al. 20, FfE, 100% E). Although there are two notable examples of scientific research, namely Bertsch et al. (2016) and Miniard et al. (2020), also incorporating the acceptability of future power generation/energy mixes in their research design, there are distinct differences between these studies and the approach of this research. Firstly, neither of the two studies investigates climate-neutral electricity mixes, which is a fundamental assumption of this study. In particular, Bertsch et al. (2016) investigate the acceptance of three mixes with different levels of RE generation, power-to-gas and fossil fuel electricity generation, but do not examine the preferred composition of renewable energy sources. Miniard et al. (2020) put the focus on the public perceptions of current and future energy mixes and the role of partisan difference. In their study participants could assign percentage values to each energy source without being constrained to a total of 100% and disregarding the technical potentials of each energy source. Overall, this research responds to the call of Wiese et al. (2022) who advocate for further investigations into the sustainability implications of possible pathways to achieve climate neutrality.

1.3 Research objective

By addressing these gaps in existing scientific literature, this research aims to generate knowledge on the social acceptance of relevant renewable energy sources and plausible future electricity mixes required for decarbonizing the electricity sector in Bavaria. Moreover, it seeks to understand the factors influencing different preferences and beliefs. The goal is not to simply offer straightforward solutions or attempt to “overcome opposition” (Aitken, 2010), but to investigate what the most socially acceptable electricity mix and developments of different renewable energies are and how attitudes are influenced by socio-demographic characteristics. This approach can support the development of a foundation for the “best possible energy system for a society” (Wiese et al., 2022:12). To reach this aim, this research set out to answer the following primary research question and its associated subquestions:

1. How socially acceptable are different renewable energies and plausible future electricity mixes for achieving a climate-neutral energy system in Bavaria, and how can different attitudes be explained?
   a. What are the potential pathways for Bavaria to achieve a climate-neutral electricity system, and what are the associated land use requirements for renewable energy developments?
   b. What is the current state of socio-political and market acceptance of different renewable energy technologies and future electricity mixes, and what pivotal factors exceed influence on community acceptance in Bavaria?
   c. How do perspectives on renewable energy technologies and preferred future electricity mixes diverge among Bavarian citizens, and what is the extent of the influence of socio-demographic and political factors on their social acceptance?
   d. How does the provision of additional information concerning the scale of renewable energy development and potential spatial distribution impact acceptance levels of various future electricity scenarios?

To answer these questions a mixed-method research approach combining quantitative and qualitative methods will be applied. As the first step, desk research will be used to develop plausible pathways for the Bavarian electricity system to become carbon neutral. These developed scenarios will be used in the second phase of the research as part of a survey, which provides data on the social acceptance of relevant renewable energies and desired future electricity mixes by members of the public. In parallel interviews with different stakeholders will be conducted to gain detailed knowledge about aspects of the social acceptance dimensions which can only be partly covered by the questionnaire. Additionally, these interviews help to validate and contextualise the results from the quantitative research part. Using this multiphased approach will allow answering the research question and respective subquestions, which can be regarded as being both scientifically and societally relevant. From a societal perspective research on the acceptance of transformation processes can be highly beneficial as it can highlight significant issues that need to be addressed at the institutional level (Wolsink, 2018). Research in this area can help to inform policies and guide an acceptable and sufficient transformation process. Furthermore, project developers and investors can leverage the insights from this study to enhance local acceptance and ensure a more equitable distribution of benefits and drawbacks. In addition, the approach of this research can be regarded as highly relevant for the academic context as it provides an innovative approach to social acceptance studies by investigating plausible future electricity mixes using a mixed-method approach. This research can serve as a baseline for future studies investigating social acceptance and contributes to the field of ex-ante acceptance studies in the context of the energy transition (Prosperi et al., 2019).

2 Theory

2.1 Theoretical background

A valuable systemisation of academic work on social acceptance of renewable energy was developed by Batel (2020) who describes three waves of research, which will be outlined in the following paragraphs. Before the 1990s the matter of social acceptance of renewable energy technologies had been mostly neglected by politicians, developers, local authorities and researchers alike, as surveys demonstrated high levels of general support by communities (Bianchi & Ginelli, 2018). However, as the first utility-scale wind farms began to develop, local acceptance issues of renewable energy technologies began to arise, making successful project implementation challenging (Batel, 2020). This discrepancy between high general support and low success rates due to local opposition was referred to as "the social gap" (Bell et al., 2005) and can be considered the starting point of academic research on this topic.

In the first wave of research on RE acceptance a common explanation of this phenomenon was the not-in-my-backyard (NIMBY) syndrome, which assumed that individuals would reject the siting of renewable energies in their vicinity similarly to other large infrastructure projects, such as waste incinerators or nuclear power plants, due to their intrusive nature and perceived environmental impacts (Sovacool, 2014). This initial wave of academic research can be characterised by a strong normative stance, seeking to find ways to reduce opposition (Batel, 2020).

The second wave of research, which Batel (2020) describes as the criticism approaches, challenges this viewpoint of using Nimby as an explanation, arguing that it is based on the assumption that opposition towards renewables derives from selfishness, ignorance and irrationality. During this phase, research changed the objective towards examining which socio-psychological and community factors influence acceptance of RE technology developments (Batel, 2020). A significant contribution in this second wave was the publication by Wüstenhagen et al. (2007), which is still considered a landmark in this field and helped formalize the study of social acceptance of renewable energy innovation and technologies (Batel, 2020).

The third wave of research on social acceptance of renewable energies is characterised by publications having a critical perspective on ideological, theoretical or methodological approaches within existing acceptance literature (Batel, 2020). Regarding ideological aspects, papers such as Aitken (2010) take issue with the prevailing paradigm of needing to overcome opposition, arguing that it reproduces the flaws of the existing neoliberal capitalist system. Furthermore, this wave of research places greater emphasis on the role of power disparities and seeks the adopt new conceptual and rational frameworks that go beyond recognized research frameworks.

This research falls within the category of the second wave of research on the social acceptance of RE technologies. The primary objective of this research is to generate insights which can inform policymakers rather than contribute to the further academic understanding of social acceptance as a scientific concept. While such research can be highly valuable for the further development of the academic concept of social acceptance of emerging technologies, the question remains how to translate these findings to the application level. Through the innovative approach of evaluating the acceptance of future electricity mixes, this study can simultaneously form the foundation for future critical research.

2.2 Conceptualization

Given the substantial body of research employing diverse methods and drawing from various disciplinary perspectives on the topic of social acceptance, it is crucial to clarify the term *social acceptance* in the context of this study. This research will base its understanding of social acceptance on the definition of Upham et al. (2015), who describes it as "a favourable or positive response (including attitude, intention, behaviour and – where appropriate – use) relating to a proposed or in situ technology or socio-technical system, by members of a given social unit […]" (Upham et al., 2015:107). This conceptualisation views acceptance as encompassing both attitudinal as well as behavioural dimensions, in contrast to the distinction between acceptance as a behaviour and acceptability as an attitude as proposed for example by Huijts et al. (2012).

This understanding of acceptance of acceptance as a two-dimensional notion was also applied in the research project *Akzeptanz Erneuerbarer Energien und sozialwissenschaftliche Fragen*, which led to the publications by Zoellner et al. (2008) and Schweizer-Rieß et al. (2008), who pioneered the research on the social acceptability of renewable energies in Germany. By using an environmental-psychological mixed-method approach, the authors investigated public acceptance of large ground-installed PV systems, biomass plants and wind turbines in four different regions of Germany. Schweizer-Rieß et al. (2008) differentiated between the attitudinal and a behavioural dimension and further dichotomised these dimensions into positive and negative categories, creating a comprehensive four-field schema of different acceptance types:

- **Protest** (negative attitude of the acceptance object, willingness to translate into protest action)
- **Rejection** (negative attitude towards the acceptance object, no resulting action)
- **Approval** (positive attitude of the acceptance object without corresponding action)
- **Support** (positive attitude towards the acceptance object, in combination with supportive actions or intentions)

This conceptualisation of different acceptance types was expanded to also include consideration as an additional type of acceptance. The reasoning for this will be laid out in the methods section.

2.3 Theoretical framework

To study the acceptance of renewable energies effectively, it is advantageous to differentiate between different classifications of acceptance based on the context (Dratsdrummer et al., 2023). A very prominent theoretical framework has been developed by Wüstenhagen et al. (2007) which differentiates between three dimensions of social acceptance, namely socio-political, community and market acceptance. The conceptual framework from Wüstenhagen et al. (2007) describes each level as follows: socio-political acceptance characterizes the most general and aggregated form of acceptance. This level refers to the attitude and behaviour of the general public, policymakers, civil society organisations, experts, etc., to a set technology on a country, state or regional level. Acceptance of energy infrastructure or facilities at the local level - i.e. community acceptance - refers to the reaction of communities including local authorities, stakeholders and citizens to a particular proposed or developed energy infrastructure. Market acceptance encompasses the reaction of actual and potential end-users and consumers towards the RE technology meaning the process of market adoption of an innovation. This technology can be either a supply or demand-side energy application with this research focusing on the supply side of renewable energies i.e. the power generation sector. Later

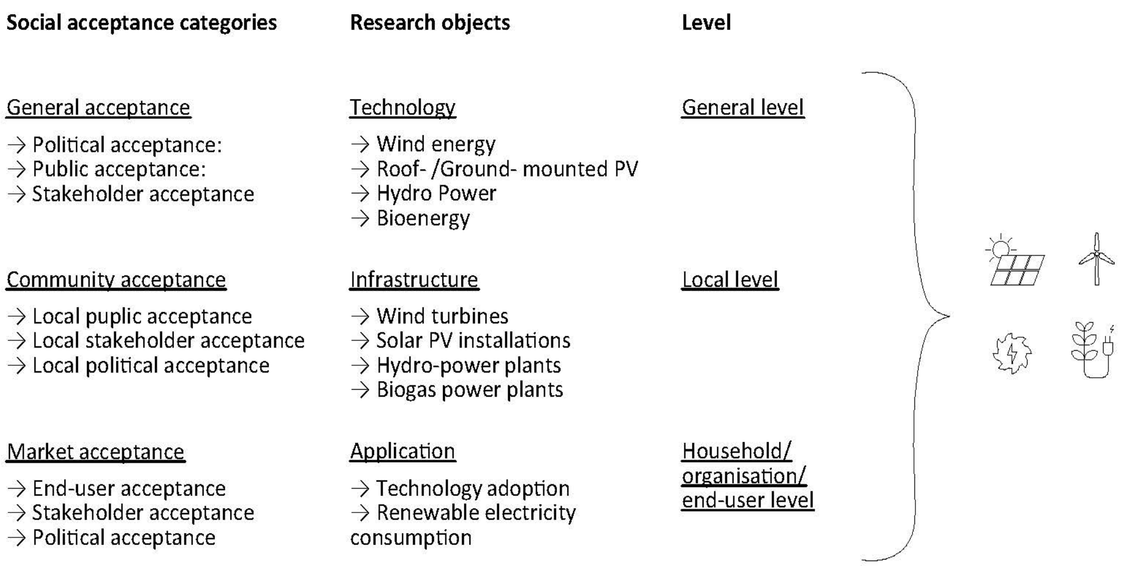

Figure 1: Theoretical framework; adapted from Upham et al. (2015)

research by Upham et al. (2015) further developed this classification by Wüstenhagen (2007) to describe social acceptance as a multi-actor phenomenon on three different levels as depicted in Figure 1. This research will use the conceptualisation of Upham (2015) as a theoretical framework. The terms socio-political and general, as well as community and local acceptance, are regarded as synonyms and will be used interchangeably.

3 Methods

To evaluate all three dimensions of social acceptance of renewable energy technologies and the future electricity mix in Bavaria, the decision was made to conduct mixed-method research combining quantitative and qualitative research methods. The following chapter will describe how the different scenarios enabling a climate-neutral Bavaria were developed using desk research and how the survey and interviews were designed to gather empirical data to allow answering the set research questions.

3.1 Desk research: scenario development and corresponding maps

As mentioned before, the decision was made to focus on developing future scenarios for the generation of electricity using climate-neutral technologies. In order to develop these scenarios first the potentials of each renewable source were evaluated. In the second step, these findings were used to design five different scenarios and visualise them.

3.1.1 Potentials of renewable energy development in Bavaria and future electricity demand

To evaluate the social acceptance of future electricity mixes, various plausible scenarios to reach climate neutrality were developed through desk research for later implementation in the survey. As a starting point, the renewable energy supply of Bavaria in 2023 was investigated using statistical data from the Bavarian State Ministry of Economic Affairs, Regional Development and Energy (Stmwi, 2023) to assess the current importance of each RES. Currently, the most important RE sources in Bavaria are solar energy, hydropower, bioenergy and wind energy (Stmwi, 2023). Due to the very limited role geothermal energy plays in the current electricity supply system and the limited development potential, this technology was excluded from further investigations. Based on this initial assessment, solar PV, wind energy, bioenergy and hydropower were regarded as relevant RE sources to achieve climate neutrality in Bavaria. For hydropower, it should be noted, that the growth potential is very limited, as most potential sites have already been developed (Stmwi, n.d). However, there are no current plans to decommission existing power plants on a larger scale, meaning all scenarios estimate hydropower to remain at a level comparable to today. Consequently, only wind, solar and bioenergy can be considered as RES with significant growth potential. After deciding which technologies to investigate further, the potential of these three technologies was assessed for Bavaria by reviewing official documents, NGO reports and academic papers in order not to overestimate any RES in the further scenario-building process. For solar PV a distinction was made between roof-mounted and ground-mounted systems.

The maximum potential for solar PV on roofs is estimated to be around 52,8 TWh according to Miehling et al. (2021). The authors performed a GIS analysis to calculate the floor plan area of buildings in Bavaria to be 977 km². Based on an exemplary PV module with 335 W and 4.99 m²/kW, a total area of 266 km² would be needed to achieve this PV potential. For ground-mounted solar PV, no specific technical potential could be derived from existing literature. Considering the vast area of more than three million hectares used for agriculture in Bavaria (DESTATIS, 2022), which could theoretically be converted into solar farms, the theoretical potential would be around 3,000 TWh when estimating area requirements of 0.9 ha per GWh. When assuming five percent of agricultural areas would be used for PV systems (including agri-PV) the technical potential would be around 150 TWh. Although the assumption of five percent does appear quite large at first, it has to be considered that around 14% of the agricultural and forest areas in Bavaria are currently used for growing biomass for energy purposes (Stimwi; n.d.). Regarding the potential for wind energy, Miehling et al. (2021) assume an electricity generation potential of 216,85 TWh considering a minimum distance of 1000 meters to the next settlement. Consequently, the technical potential would be significantly greater than the calculated value. Nonetheless, it is highly unlikely that spatial planning requirements will be reduced to below 1,000 meters given the current regulatory framework. For bioenergy, the value of 87.72 TWh was based on the calculation from the AEE (2010) which includes energy plants, wooden biomass, straw, waste wood, animal excrement and organic waste. For hydropower it can be stated that the potentials are almost fully developed in Bavaria (Miehling et al., 2021), meaning no significant changes in the electricity generation from this source can be expected. To ensure that the scenarios which will be developed reflect an achievable value, it is necessary to take into account that the technical potential figures exceed the economic and realisable potential. Therefore, the values for the scenarios must be adjusted downwards. An overview of the different potentials per technology is provided in Table 1.

Table 1: Overview of relevant renewable energy technologies and associated potentials

Technology	Technical Potential	Source
Solar PV (roof-mounted)	52,8 TWh	Miehling et al. (2021)
Solar PV (ground-mounted)	> 150 TWh	Own assumption
Wind energy	> 216.85 TWh	Miehling et al. (2021)
Bioenergy	87.72 TWh	AEE (2010)

In the second step, a baseline for future electricity demand was established at 180 TWh, which each scenario had to reach using a different technology mix. This value was adopted from one scenario of an in-depth study on the future energy system of Bavaria which was published by the *Forschungsstelle für Energiewirtschaft* (FfE) (2023). This scenario assumes a substantial reduction in final energy use mainly due to the renovation of residential buildings as well as the electrification of transport, residential heating and industrial processes, which would allow Bavaria to reach climate neutrality until 2040.

3.1.2 Development and Visualization of Scenarios

Based on the potentials of each RE source and the assumed electricity demand of 180 TWh, five plausible supply mixes were developed with one being based on the FfE (2023) study. It must be mentioned that the scenarios are simplified, as they were designed to investigate the preferences of Bavarian citizens and do not emphasise cost-effectiveness or optimal technological feasibility. Each scenario incorporates varying assumptions concerning the role of energy imports and relevant RE sources. The assumption for hydropower is, that electricity generation will remain equivalent to current levels. The first scenario, Energy import, aims to minimise the development of renewable energies in Bavaria and associated environmental effects, relying mainly on electricity imports and climate-neutral energy carriers for electricity generation. The second scenario *Balanced Development* was adopted from the FfE (2023) study and assumes substantial developments of wind energy and solar PV, yet still requires significant imports to meet the demand. The remaining three out of five scenarios are focused on maximising the development of one respective RES in Bavaria i.e. solar PV, wind energy and bioenergy to minimise the reliance on energy imports. For the wind energy and PV scenarios, the electricity demand of Bavaria will be met through RE technologies developed in Bavaria using the substantial potential for further advancements.

For this study, the decision was made to create maps for each scenario to make them more tangible compared to simple bar charts. The first step after calculating the future electricity generation needed for each technology in each scenario was to determine the energy yield per unit of area. An overview of the assumptions is shown in Table 2. Although the source mentioned where used to calculate the energy density, in most cases the units had to be converted to ensure comparability within the table.

Table 2: Overview of energy densities of relevant renewable technologies

Technology	Energy density [year]	Source
Solar PV (roof-mounted)	102 kWh/m²,	StMWi (n.d.a)
Solar PV (ground-mounted)	109 kWh/m²	FfE (2023)
Wind energy	21 kWh/m²	Own calculation
Wind energy (direct)	3450 kWh/m²	Own calculation
Biomass (agriculture)	4.5 kWh/m²	FfE (2023)
Biomass (forest)	1.5 kWh/m²	FfE (2023)

The energy atlas of the StMWi (n.d.-a) states that typical roof-mounted PV systems in Bavaria require approximately 7.5 m² of surface area per kW of installed capacity. Assuming a capacity factor of 8.77% (FfE, 2023), this translates to spatial requirements of around 102 kWh/m² per year. This rather conservative value results from the assumption that efficiency gains and an increasing number of non-south-facing PV panels balance each other out. For ground-mounted PV systems, the FfE (2023) study projects significant efficiency improvements over the coming decade from 52.5 kWh/m² (2021) to 166 kWh/m² (2050). When comparing this assumption to values reported in other studies (Ioannidis & Koutsoyiannis, 2021), the assumed value seems to be an optimistic projection. Therefore, for this study, a more conservative value was adopted by selecting the median value of 109 kWh/m². For wind energy, spatial requirements were determined based on the diameter of a representative turbine. According to the energy atlas (StMWi, n.d.-b), the installed capacity of newly developed wind turbines in Bavaria is 5MW with a diameter of 160 meters. Based on the assumption that wind turbines should be placed five times the diameter away from each other to prevent losses in yield (StMWi, n.d.-b), each turbine area requires approximately 50 ha. According to the FfE (2023) study a capacity factor of 23.6% can be presumed which results in the spatial requirements of 12 kWh/m². The direct spatial requirements of wind energy are 0.3 ha per turbine (StMWi, n.d.-b). This estimate includes space allocated for the foundation, crane pad and construction paths. Lastly, the values for the energy density of biomass in Bavaria were adopted from the FfE (2023) study.

For each developed scenario a map was composed using ArchiCAD. The primary goal of the scenarios' visualisation is to effectively convey the scale of RE development. ArchiCAD allows the manual placement of symbols with a specific surface value which can be used to calculate the area requirements of various renewable energy systems. The end result provides a more organic and tailored look, similar to illustrations made by Sijmons et al. (2014), compared to the automated spatial analysis using GIS software. The process was initiated by creating a base map by manually transferring the outlines of Bavaria, its cities, highways, large water bodies, nature conservation areas, and forest areas from the standard map of the energy atlas (StMWi, n.d.-c) onto a blank canvas.

In a further step, geographical data on existing sites of wind energy, ground-mounted PV systems and hydropower plants of the energy atlas were categorised using Excel and visualised using ArcGIS Pro. The generated GIS map included wind turbines (excluding small wind turbines), large ground-mounted PV systems (> 1 MW) and hydropower plants (> 5 MW). Existing wind turbines were visualised in ArcGIS using a circle representing an area of 50 hectares, corresponding to the representative turbine. Ground-mounted PV systems were visualised as rectangles with the area of the symbol being dependent on the installed capacity of the PV farm. For hydroelectric power stations, a symbol was used which is constant in size regardless of the installed capacity as spatial requirements of hydropower strongly depend on the site characteristics. After generating the map with the existing RE sites in ArcGIS, they were manually transferred to the canvas in ArchiCAD.

Bioenergy was not included in the map as no geographical information could be retrieved. Furthermore, roof-mounted PV systems were also not included, as they can be regarded as too small to be visible on a map of Bavaria and were also too numerous to be placed manually. However, next to the map, a square representing each RE source was inserted which illustrated the total area requirements today and the projected requirements in the scenario. This also allowed for easy comparability between the different RE sources in regard to area requirements and total electricity generation.

After creating the base map, which depicts existing RE systems, each scenario map was developed. For the expansion of wind energy, the potential area analysis which was published by the StMWi (n.d.-d) was used to identify suitable areas for wind energy development. Although this analysis does not include an exhaustive assessment of every potential site, it adheres to Bavaria's spatial planning regulations and considers environmental factors such as minimum wind speeds or ground conditions. The process of placing symbols representing an individual turbine was repeated until the total area of wind turbine symbols summed up to the calculated spatial requirements of each scenario. Attention was paid to prevent overlap between the circles of each turbine, to ensure that the determined distance between turbines of five times the diameter is maintained. Furthermore, these circles not only assist in maintaining the minimum distance between turbines but also highlight areas where the turbines will be visually prominent, helping to better understand their impact on the environment (Ioannidis & Koutsoyiannis, 2020). For ground-mounted PV systems, the only strict condition for further development was, that they must be developed on agricultural areas as they cannot be placed in settlements, forests or on infrastructure. Equivalent to wind energy, the process of marking PV areas was repeated until the total inserted area matched the calculated area for each scenario. Preference was given to agricultural areas near highways, as the landscapes are already impacted and development in these sites is financially supported through the EEG. Regarding hydro energy, no changes were applied compared to the base map as the electricity generation remained constant.

3.2 Quantitative research: survey

The central focus of this research was gathering quantitative data on the social acceptance of renewable energies by Bavarian Citizens through a survey. In this section, first, the structure of the questionnaire will be explained, followed by a description of how the survey was distributed and lastly how the results were analysed.

3.2.1 Questionnaire structure

The survey was developed using Qualtrics XM and consisted of a total of 34 questions. Although asking additional questions to generate deeper insights was taken into consideration, lengthening the survey posed the risk of increasing the number of people cancelling the survey since it would require more time to complete it. During the pretest, the survey took participants around 15 minutes, which was considered the optimal duration to strike a balance between being too time-consuming and providing insufficient data. The majority of questions in the survey provided a Likert scale as answer options to cover all parts of the spectrum.

The survey was divided into four distinct sections, with the first section aiming at gaining knowledge on the participants' demographic and personal characteristics i.e. their gender, age, place of residence, educational attainment and preferred political party. Additionally, one question asks participants how they became aware of the survey to account for potential biases, such as significant numbers of entries from members of citizens' initiatives against renewables.

The second part, including 9 questions, was tailored to investigate the general attitude towards the energy transition while also testing previous academic findings regarding socio-political, community and market acceptance. For instance, participants were asked about their views towards the current pace of the energy transition in Bavaria to assess socio-political acceptance. To examine previous findings regarding community acceptance, one question addressed the importance of involving local actors in RE development projects in the vicinity of the participants. Furthermore, to give an example of how market acceptance was investigated, a question was included on willingness to accept higher prices for renewable energy supply, and if so, to what extent.

The third section encompasses thirteen questions to evaluate the acceptance of roof & ground-mounted PV systems, wind energy, hydropower and bioenergy in Bavaria. Before asking how people perceive the respective technology, a short text introduces the technology including information on its benefits and drawbacks. These informational texts were written using criteria mentioned in academic literature as having an influence on acceptance levels of a given technology as well as personal knowledge. This method can be described as an Informed-Choice questionnaire (De Best-Waldhober et al., 2009) which is aimed at providing participants with the requisite knowledge to form an educated judgment. After the short introductory information, respondents were asked about their acceptance towards the respective technologies using the categories of *protest*, *rejection*, *approval* and *support* as described in section 2. Furthermore, an extra category, *consideration,* meaning their attitude and behaviour depend on the circumstances and site characteristics, was introduced for participants who were undecided about a technology. For each of those categories per technology, an example was provided illustrating what behavioural and attitudinal dimensions of this option refer to. For instance, in the case of wind energy *protest* could mean negatively assessing wind energy and participating in a citizens' initiative against the development should the opportunity arise. Conversely, support could represent a positive evaluation of the technology and participating in a citizens' energy cooperative if feasible. Additionally, respondents were asked which aspects they were concerned about regarding technology. Similar to the informational text, the multiple-choice answers were based on findings from existing literature, while also allowing participants to use text entries if their concerns were not covered with one of the options. The third question for each technology was then aimed at whether the participants would like to see further developments of this technology in Bavaria using a four-point Likert scale from strong agreement ("Yes, definitely") to strong disagreement ("No, existing sites should be deconstructed").

The final section of the questionnaire investigated the social acceptance of future electricity mixes. This part was introduced with a bar chart showing the five plausible scenarios accompanied by an informative text explaining every scenario. Afterwards the respondents were asked which scenario they preferred. Next up, the maps of every scenario were presented to the participants along with a short explanation, followed by the question of whether the spatial requirements matched their expectations and whether they would like to change the selected scenario based on the additional information. Next up, participants were shortly informed about the additional energy required for achieving a fully climate-neutral energy sector in Bavaria (e.g. to supply the remaining electricity demand or to synthesise kerosine for aviation fuels and energy carriers for industrial applications) and asked to choose which supplementary energy sources (i.e. electricity imports, synthetic energy carrier imports, nuclear power, carbon capture and storage or future technologies) should be developed. Lastly, this section included a question investigating participants' preferred origins for electricity/energy imports.

3.2.2 Survey distribution

The goal of achieving a representative sample across Bavaria, considering demographic factors, geographic distribution, and individual attitudes towards the energy transition can be regarded as a major challenge for this study. Previous studies in Germany utilised existing data from representative phone surveys as their survey data (Ruddat & Sonnberger, 2019; Liebe & Dobers, 2019). However, for this research, this approach is not suitable as it does not allow the inclusion of tailored questions, especially regarding the acceptance of future electricity mixes. Therefore, collecting primary empirical data was essential for addressing the research questions effectively. Due to monetary constraints financial compensation for completing the survey, as offered by Miniard et al. (2020), was not feasible. Additionally, using these sorts of compensations results in the risk of participants responding without adequate consideration or randomly selecting answers to receive the set benefit.

Given these considerations and limitations, the decision was made to focus on contacting administrative bodies on various governance levels of Bavaria to request assistance with the distribution of the survey. Reaching out to authorities of the state of Bavaria provides a more nuanced approach compared to, for example, environmental protection organisations. The goal of this first stage was to contact stakeholders who could use their means of communication to inform a wide range of actors about the research project. As part of the initial outreach, all seven administrative districts (*Regierungsbezirke*) and the Bavarian State Ministry of Economic Affairs, Regional Development and Energy were contacted to inform them about the research project and request their assistance in distributing the survey. Additionally, each partner of the team energy transition (*Team Energiewende*) of the StMWi (n.d.), which encompasses various organisations, companies and networks working on energy-related topics, as well as the Bavarian State Office for the Environment (Landesamt für Umwelt), was contacted. Furthermore, the Bavarian Association of Municipalities (Bayrischer Gemeindetag), the Association of Bavarian Counties (Bayrischer Landkreistag) and the Bavarian Association of Cities (Bayrischer Städtetag) were approached to request whether they could forward the information of the ongoing study to their members.

Despite initial efforts, this first stage of enquiring for assistance did not yield significant results due to various constraints. Therefore, in the second phase of outreach, the decision was made to contact each county and city of Bavaria, encompassing a total of 96 stakeholders, to broaden the reach (see Fig. 2). In most cases the enquiry was sent to the respective climate protection representative. Addressees were asked whether they were interested in supporting the study by distributing it through their website, newsletter or official journals. In return, they were offered the data set which encompasses data of Bavaria as well as for their administrative area through the postal code. Furthermore, the members of the county's offices were asked if they could notify municipalities in their administrative area about the ongoing research to increase the number of possible recipients. The idea of writing an email to each municipality in Bavaria was abandoned, as this would necessitate contacting more than two thousand individual stakeholders. However, in some cases, the counties advised approaching each municipality in the county's area with the message that the research project was supported by the county's climate protection representative. This approach was subsequently adopted for these cases. In addition, notable support was contributed by an initiator of the mayor's appeal "together successful renewable" (Zusammen erfolgreich erneuerbar), who proposed including a reference to the research project in the municipalities official journal. Even though this phase of research took considerable effort in writing emails and making phone calls, it did prove to show better results compared to the first stage.

After all stakeholders of the second phase were contacted, the number of participants did not yet meet the set requirements. Therefore, as an additional form of outreach, all 147 citizens' energy cooperatives in Bavaria listed in the online database *Netzwerk Energiewende* were contacted with the request to share the questionnaire with their members. Oftentimes, the request was denied due to statutory restrictions on sharing third-party content. To compensate for the generally more positive attitude towards RE in citizens' energy cooperatives, which can be assumed as they actively support renewable energy development, the decision was made to also contact several citizens' initiatives against RE. This approach would help to acquire a more representative data sample reflecting various attitudes towards RE. Despite these efforts, the willingness of members from these initiatives to participate in the survey was fairly limited. A visual overview of the approach for distributing the survey can be found in Figure 2.

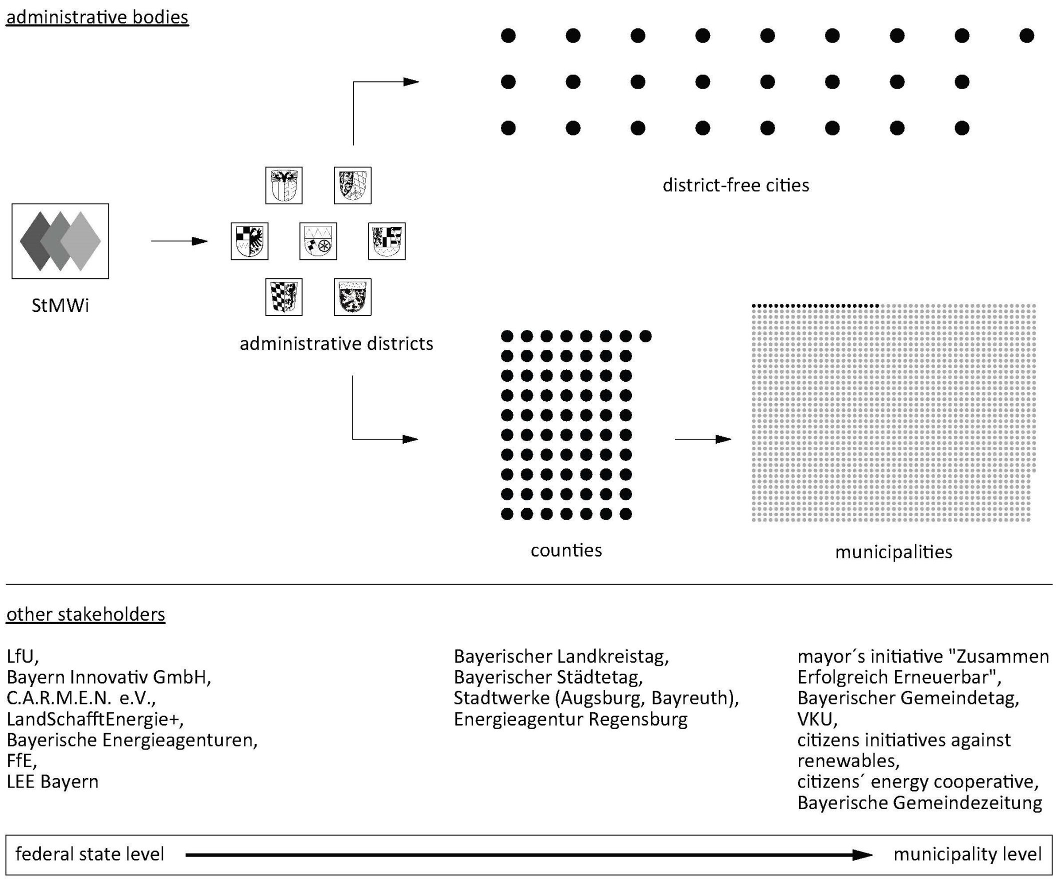

Figure 2: Illustration of the two-layered survey distribution process, where all administrative bodies and key stakeholders involved in the Bavarian energy transition mentioned here were contacted. These stakeholders, spanning across multiple governance levels, were asked to assist with the distribution.

3.2.3 Statistical analysis

After completing the data collection, the data set was processed using Excel. A total of 525 individuals participated in the survey. Participants, who did not finish the survey were excluded from the data set. Additionally, the postal code of several respondents did not correspond to any location within Bavaria, which is why these submissions were also removed from the sample. In the last processing step, any participant who finished the survey in less than five minutes was expelled as this can be regarded as insufficient time to answer all questions with adequate consideration. In total, this left the data set to consist of 376 individual participants.

The initial data analysis, focusing on frequencies, was conducted in Excel. Questions with multiple response options required further processing, as all selected choices were initially included in a single cell, making further analysis unfeasible. In the next step, the data sample required further processing in SPSS, transforming the nominal answers of the Likert-scale questions into ordinal values. This transformation allowed each variable to be assigned a specific value based on the distribution of results. For example, in assessing acceptance categories of renewable energies, participants could select from a 5-point scale, with values ranging from 1 (“Protest”) to 5 (“Support”). In this case, a value higher than 3 would indicate rather positive acceptance levels of the respective technology. This approach enabled the calculation of mean acceptance levels, facilitating easier comparability. This method was also applied to questions evaluating the perceived importance of a variable, using a Likert scale ranging from 1 (“Not important at all”) to 5 (“Very important”).

Following the initial processing and descriptive analysis, further statistical analysis was conducted using SPSS. In this phase, the correlation between socio-demographic factors (i.e. gender, age, educational level) and political affiliations with different variables was examined using the Chi-Square test of independence. It is important to note that the geographical information was excluded from the correlation analysis as there was a significant correlation between administrative districts and political preference, which would have skewed the results. The political bias observed in some of the administrative districts can be attributed to the distribution method. Additionally, statistical correlations between different variables were analysed where suitable, such as the correlation between technology acceptance and preferred scenarios. A confidence level of 95% was applied, corresponding to a significance level (α) of 0.05. This is the commonly applied threshold for determining statistical significance (Loftus, 2022). Accordingly, if the Chi-Square test produced a p-value less than 0.05, the null hypothesis—stating that there is no significant association between the variables—was rejected in favour of the alternative hypothesis, which suggests a significant correlation exists. Furthermore, Cramer’s V was used to assess the strength of the correlation. The Cramer's V is a widely used strength test to assess data when a significant Chi-square result has been obtained (McHugh, 2013). The interpretation of various effect sizes, as shown in Table 3, follows the IBM (2024) standard, consistent with the approach used by Rodriguez-Segura et al. (2023). Further investigations of the cross tables comparing observed and expected values were used to explore the direction of these correlations.

Table 3: Interpretation of Cramer's V, source IBM (2024)

Effect size (ES)	Interpretation
≤ 0.2	The result is weak. Although the result is statistically significant, the fields are only weakly associated.
0.2 < ES ≤ 0.6	The result is moderate. The fields are moderately associated.
> 0.6	The result is strong. The fields are strongly associated.

To obtain more representative results for Bavaria, key findings have been weighted according to the political preferences of the Bavarian population. The reasoning behind this is that statistical analysis has shown the significant impact of party preferences in the context of social acceptance of renewable energies and future electricity mixes. As the sample data has a significant bias towards environmental parties, adjusting the results ensures that the central results of this research are more representative of the regional political landscape. To weigh the results based on political preference, first, all political parties mentioned in the dataset were categorized into six groups: right-leaning, conservative, liberal, environmentally oriented, socially left, and others. For each category, the corresponding percentage value was calculated by summing the election results of the parties that fall within that category based on the most recent election data. Participants who selected a party which can be categorised as "other" such as satirical parties with no clear agenda as well as participants, who did not mention any political preference, were excluded. In the next step, crosstabs were used to determine the distribution of responses within each political category. These distributions in percentage values were then multiplied by the proportion of the political category and the total number of Bavarian citizens. Finally, the weighted results were calculated by summing up the responses for each answer within each political category.

3.3 Qualitative research: interviews

The inclusion of interviews in the research framework can be justified by two key reasons. First of all, the interviews allowed gaining further knowledge about aspects which the survey did not cover. Especially in regard to stakeholder and political acceptance, conducting interviews was essential to be able to assess all aspects of the applied theoretical framework. While the survey data can be used to assess public acceptance on the general level, local public acceptance and end-user acceptance, there are several acceptance dimensions which could not be addressed by solely using the survey as a means of gathering empirical data. Secondly, the interviews could be used to validate and further explain the findings of the survey. This can help ensure that the data does not get misinterpreted and provide crucial context.

Based on these objectives several interview partners were selected. To assess political acceptance at both the general and market levels, interviewing political stakeholders could be evaluated as beneficial for generating insights. To capture a broader spectrum of views, representatives from both a conservative party and an environmental-orientated party were approached. In particular, this was the Bavarian party *CSU,* which has been the governing party for almost 70 years consecutively, and the largest environmental-orientated party in Bavaria *Die Grünen*. Unfortunately, only a member of the *Die Grünen* party agreed to participate in an interview for this study and due to a limited time frame, no replacement could be arranged. Therefore, in some cases this study refers to official statements of the governing party, to present a complete picture. Since stakeholders in the acceptance framework from Upham (2015) refers to organisations not having official political aims but with a specific interest in the outcome, including the perspective of an industry or economic association to get insights into their sector provides great benefit for evaluating social acceptance. For the context of Bavaria, the *vbw – Die bayerische Wirtschaft* was an appropriate choice as this voluntary, cross-industry, central advocacy group represents 160 members organisations, including employers and business associations across sectors such as industry, construction, retail trade, banking, forestry, agriculture and various service industries. Furthermore, given that the energy transition as well as climate change have a significant impact on local ecosystems, the decision was made to also include the perspective of an environmental organisation in this study. More specifically the BUND Bayern, the largest environmental association in Bavaria, was selected as a suitable interview partner. Regarding community acceptance, local political acceptance can be best integrated by interviewing a local politician. For this purpose, an interview was conducted with the mayor of Speichersdorf, a municipality which is very active in renewable energy development and can be regarded as a best-practice example for the local implementation of the energy transition. Lastly, conducting an interview with a project developer for renewable energies can provide further insights into local stakeholder acceptance as well as market stakeholder acceptance. Here, GP Joule was selected as a suitable interview partner as this company is active in all parts of the energy value chain including the development and operation of wind turbines, PV farms, district heating networks, electrolysers and charging stations for electric vehicles making them an expert in integrated energy system solutions. An overview of all conducted interviews in provided in Table 4.

All interviews were conducted using MS Teams and four out of five were recorded. In the next step, all interviews were transcribed using MS Word. In the following step, the transcripts were coded based on the different categories of theoretical framework i.e. general, community and market acceptance using the text highlight feature of MS Word.

Table 4: Overview interview partners and associated acceptance category

Acceptance category	Interviewee	´interview length (min:sec)
Local political acceptance	Gemeinde Speichersdorf	52:07
General/market stakeholder acceptance	Vbw – Die bayerische Wirtschaft	40:31
General/local political acceptance	Die Grünen	55:17
General/local stakeholder acceptance	BUND	29:28
General/local/market stakeholder acceptance	GP Joule	54:51

4 Results

4.1 Pathways enabling a climate neutral electricity sector in Bavaria

4.1.1 Scenario description

The assumptions and calculations detailed in Chapter 3 lead to five pathways for achieving a climate-neutral electricity supply in Bavaria, as illustrated in Figure 3. The projected increase in electricity demand to a total of 180 TWh by 2040 can be attributed to growing demand due to the electrification of industrial processes, residential heating and the transport sector as well as a surge in required electrolysers to produce hydrogen in Bavaria. The following paragraphs will briefly describe each scenario. As the will be no significant changes to hydro power, it will not be specifically mentioned in each scenario description.

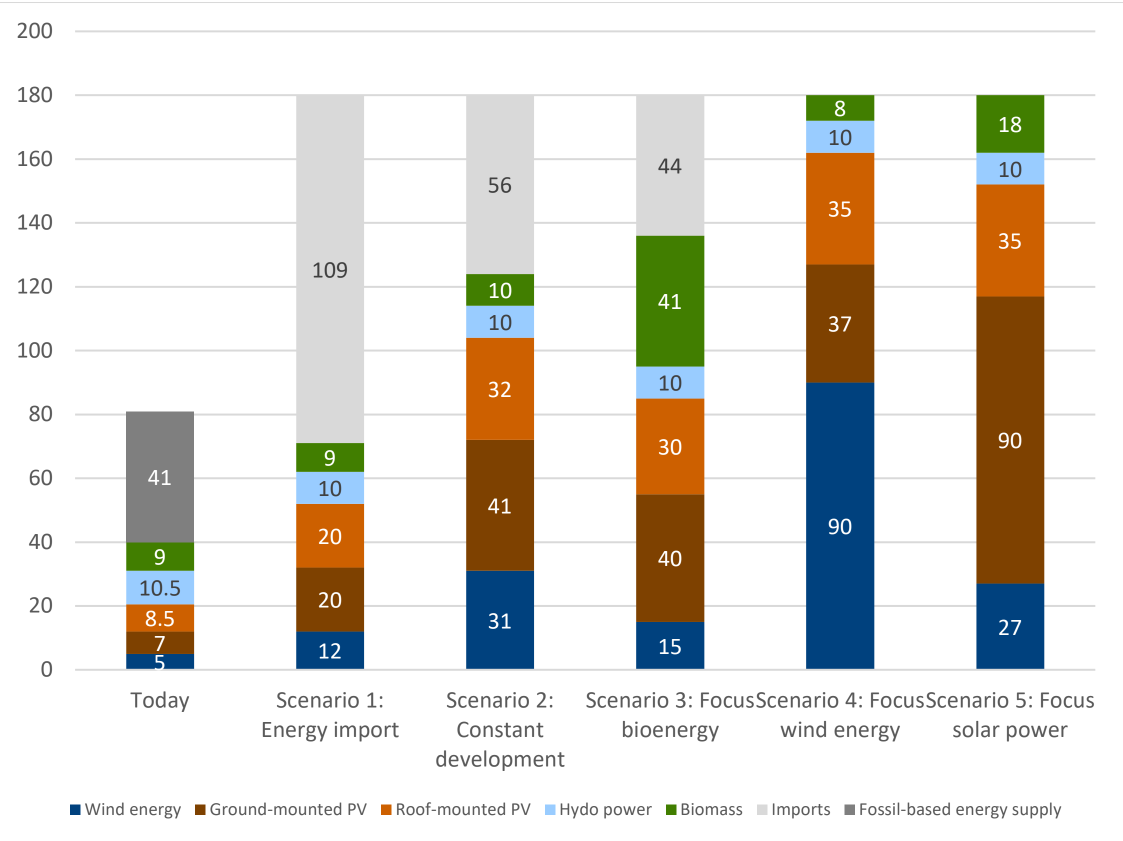

Figure 3: Scenarios enabling a climate-neutral electricity supply in 2040 [in TWh]

Scenario 1 is called *Energy Import* and assumes a very strong reliance on imports of electricity. In addition, significant amounts of imported climate-neutral energy carriers in power plants will be necessary. Bioenergy is maintained at today's level, while the electricity supply from solar PV will increase gradually on rooftops as well as in open spaces. However, this increase in PV is less substantial compared to other scenarios. Regarding wind energy, no development of further sites was assumed and the increase in electricity supply will only be achieved through the repowering of existing turbines. The need for energy storage systems would be rather small.

The second scenario *Balanced Development* is based on the FfE (2023) study and assumes substantial increases in both wind energy and solar PV, with a slight decrease in bioenergy due to a growing focus on peak load and more demand for biomass in the industrial sector. This scenario still requires imports of electricity and/or energy carriers for power generation to meet the projected demand. As solar PV makes up a large portion of electricity generation substantial developments of electricity storage would be necessitated.

The *Focus Bioenergy* scenario aims at maximizing the utilization of biomass for power generation, while still considering the growing demand for biomass in industrial applications. As the FfE (2023) study assumes a demand of 40 TWh in the industrial sector to replace fossil fuels, an additional 40 TWh for electricity generation will mean that this scenario maximises the use of available biomass. The increase of solar PV is comparable to the second scenario, in contrast to the development of wind energy which is mostly limited to repowering of existing turbines. Similar to the previous scenario, focus bioenergy will require imports, although not as much. Compared to other scenarios the need to develop storage systems will be significantly smaller, as biogas plants can be operated flexibly similar to natural gas power plants.

As the name implies, the fourth scenario prioritises wind energy extensively. This strong focus on wind turbine development allows this scenario to meet 100% of the electricity demand of Bavaria using domestic electricity generation. However, this scenario will only be feasible if the existing spatial planning regulation of 10H is abandoned. Even though this regulation has already been softened, it still represents the strictest standard for wind turbine development in Germany. Additionally, solar PV has to be developed on a scale comparable to the *Balanced Development* scenario. As wind energy is less volatile compared to solar energy this scenario necessitates moderate storage development.

Scenario 5 maximises power generation from PV systems to a point where 100% of the electricity demand can be met with domestic supply. The development of wind energy is comparable to the *Balanced Development* scenario. Electricity generation from bioenergy will double in size compared to today's level and will focus on meeting peak demand and covering periods of minimal wind and solar radiation, the so-called "*Dunkelflaute"*. Regardless of the increase in bioenergy power plants, this scenario will entail enormous electricity storage expansion.

4.1.2 Scenario maps

The scenario maps display potential locations for wind turbines, ground-mounted PV systems and hydropower stations for the specific scenario in the year 2040. The maps were designed to get an understanding of the necessary scale of RE development for each scenario, and do not represent actual siting decisions. The legend of the map shows the spatial requirements of each relevant renewable energy source, comparing current levels with the projection for the target year (See Figure 4-8).

The energy import scenario is depicted in Figure 4. The calculated area required for wind energy increases from the baseline of 404 km² to 582 km². Although the number of turbines remains constant, the average diameter of wind turbine blades will increase due to repowering. As more modern wind turbines are larger, the area required will expand as well, based on the applied calculation method. Equally, the area directly occupied increases as the foundation of larger turbines needs to be bigger in size as well as the needed crane pad and construction paths. From the baseline value of roughly 2.4 km² resembling 0.0043% of agricultural and forest area, the area needed increases to 3.8 km², which is comparable to 0.0062% of the area used for agriculture and covered forests. For ground-mounted PV systems, the total area needed sums up to 183 km² in the scenario, which is a substantial increase from the baseline of 95 km². The increase in required area for roof-mounted systems is slightly higher and is equivalent to 195 km² which resembles 19.96% of the total building floor plan area. Lastly, the area for biomass remained constant at the baseline at 1333 km² agricultural area (4.29% of the total area) and 2000 km² forest area (8.02% of the total area).

The *Balanced Development* scenario is depicted in **Error! Reference source not found.**. The calculated area for wind energy increases significantly from the baseline of 404 km² to 1504 km² due to the sixfold growth in electricity generation from wind energy. Equivalently, the area directly occupied by wind turbines increases from the baseline value to an area of 9 km², which is comparable to 0.0160% of the area used for agriculture and covered by forests. For ground-mounted PV systems, the total area required sums up to 375 km². The area with roof-mounted PV systems also rises substantially, amounting to 312 km², equivalent to 31.93% of the total building floor plan area. Lastly, the area for biomass in the scenario is equivalent to 1481 km² of agricultural area (4.77% of the total area) and 2222 km² of forest area (8.91% of the total area).

In Scenario 3, the *Focus Biomass* scenario shown in **Error! Reference source not found.** illustrates the increase of area needed for wind energy to 728 km². The area directly occupied by wind turbines therefore also increases from the baseline value of 2.4 km² (0.0043% of agricultural and forest area), towards 4.3 km², which corresponds to 0.0078% of the area used for agriculture and covered forests. For ground-mounted PV systems, the total area needed sums up to 366 km². The required area for roof-mounted systems rises to 293 km², equivalent to 29.94% of the total building floor plan area. The area for biomass increases sharply to 6074 km² of agricultural area (19.55% of the total area) and 9111 km² of forest area (36.55% of the total area).

The *Focus Wind* scenario, as shown in Figure 7, is based on the assumption of a drastic increase in electricity generation from wind turbines, which shows in the calculated area as the area needed increases from the baseline of 404 km² to 4368 km² which resembles a more than tenfold increase. Even though in this scenario the development of wind energy is immense, the directly occupied area sums up to 26 km² (0.0466% of the area used for agriculture and covered forests), which is still a fraction of the land use of other RE sources in this scenario. Nonetheless, it becomes evident that the scale of wind turbine development would have a very significant impact on the character of the Bavarian landscape. Ground-mounted PV systems would occupy an area of 339 km². The required area for roof-mounted systems also rises, amounting to 341 km², equivalent to 34.93% of the total building floor plan area. The area for biomass decreases slightly to 1185 km² in agricultural areas (3.82% of the total area) and 1778 km² in forest areas (7.13% of the total area).

Scenario 5 F*ocus PV* (Figure 8) requires an area of 1310 km² for wind energy. The area directly occupied by wind turbines grows to 8 km², which corresponds to 0.0140% of the area used for agriculture and covered forests. For ground-mounted PV systems, the total area needed sums up to 824 km² which is still substantially smaller than the land needed for bioenergy in every scenario. The required area for roof-mounted systems remains the same at 341 km², equivalent to 34.93% of the total building floor plan area (8.58% of the total area) and 4000 km² of forest area (16.05% of the total). Lastly, the area for biomass increases to 2667 km² of agricultural area e total area).

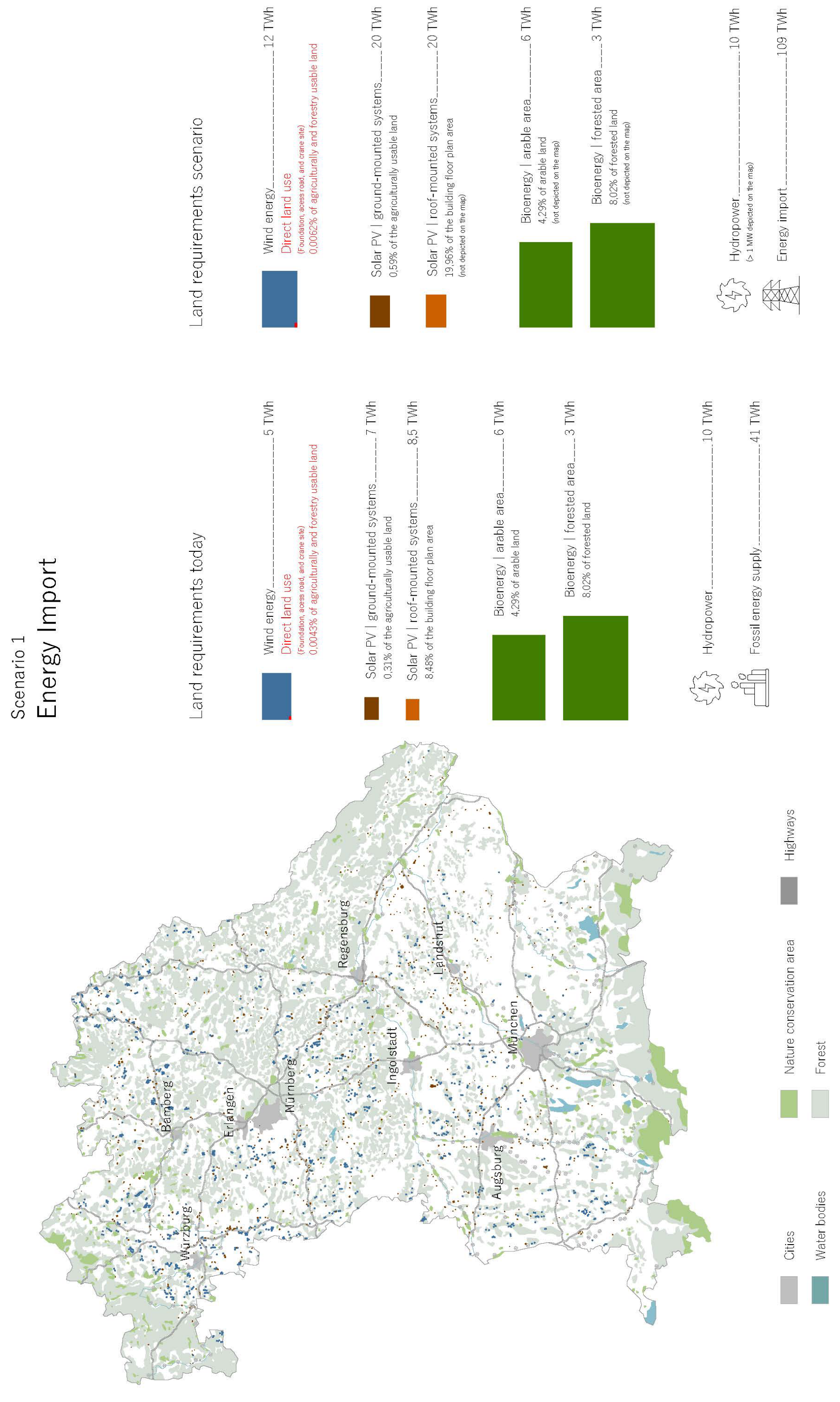

Figure 4: Scenario map "energy import" (for higher quality see Appendix 1)

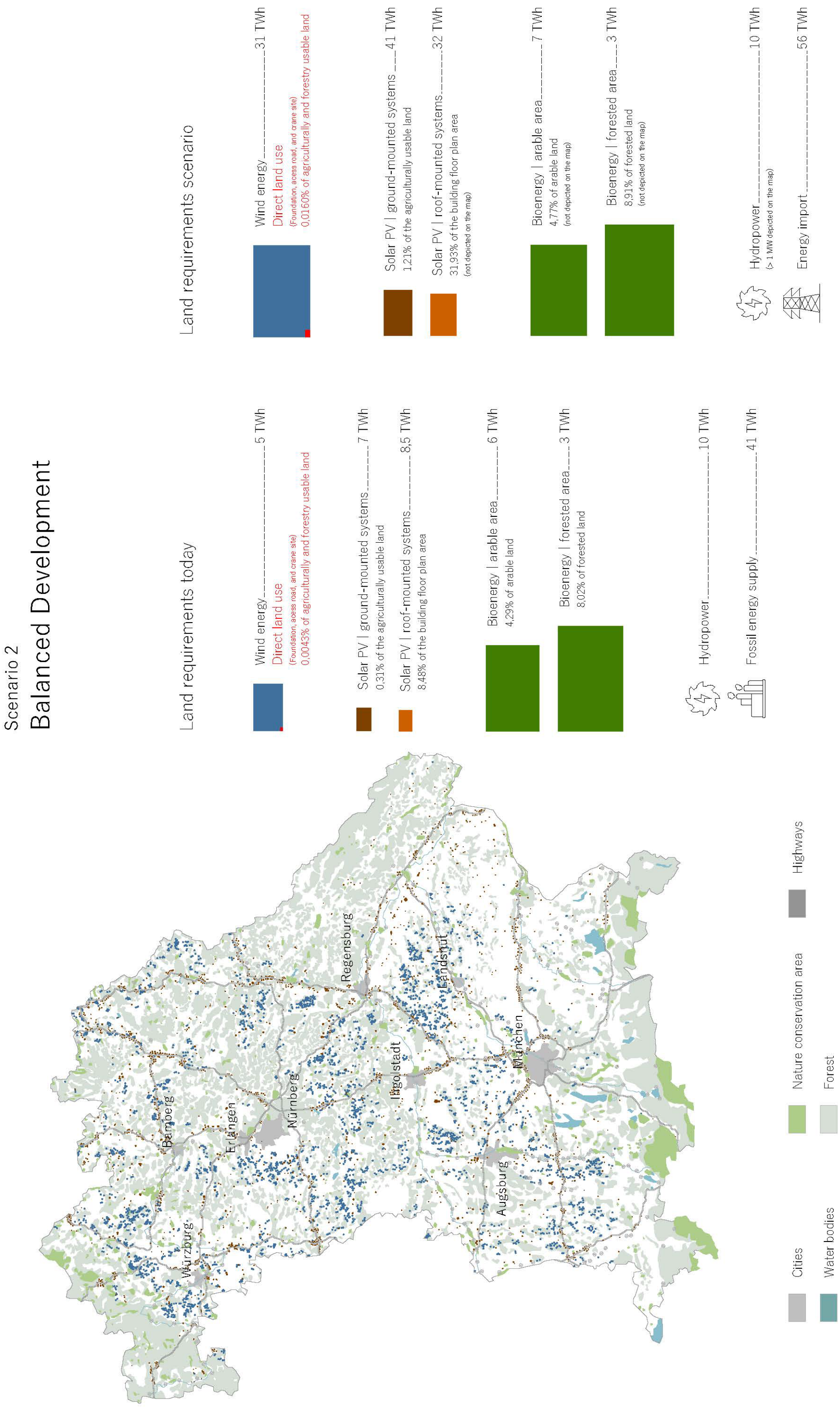

Figure 5: Scenario map "Balanced development" (for higher quality see Appendix 1)

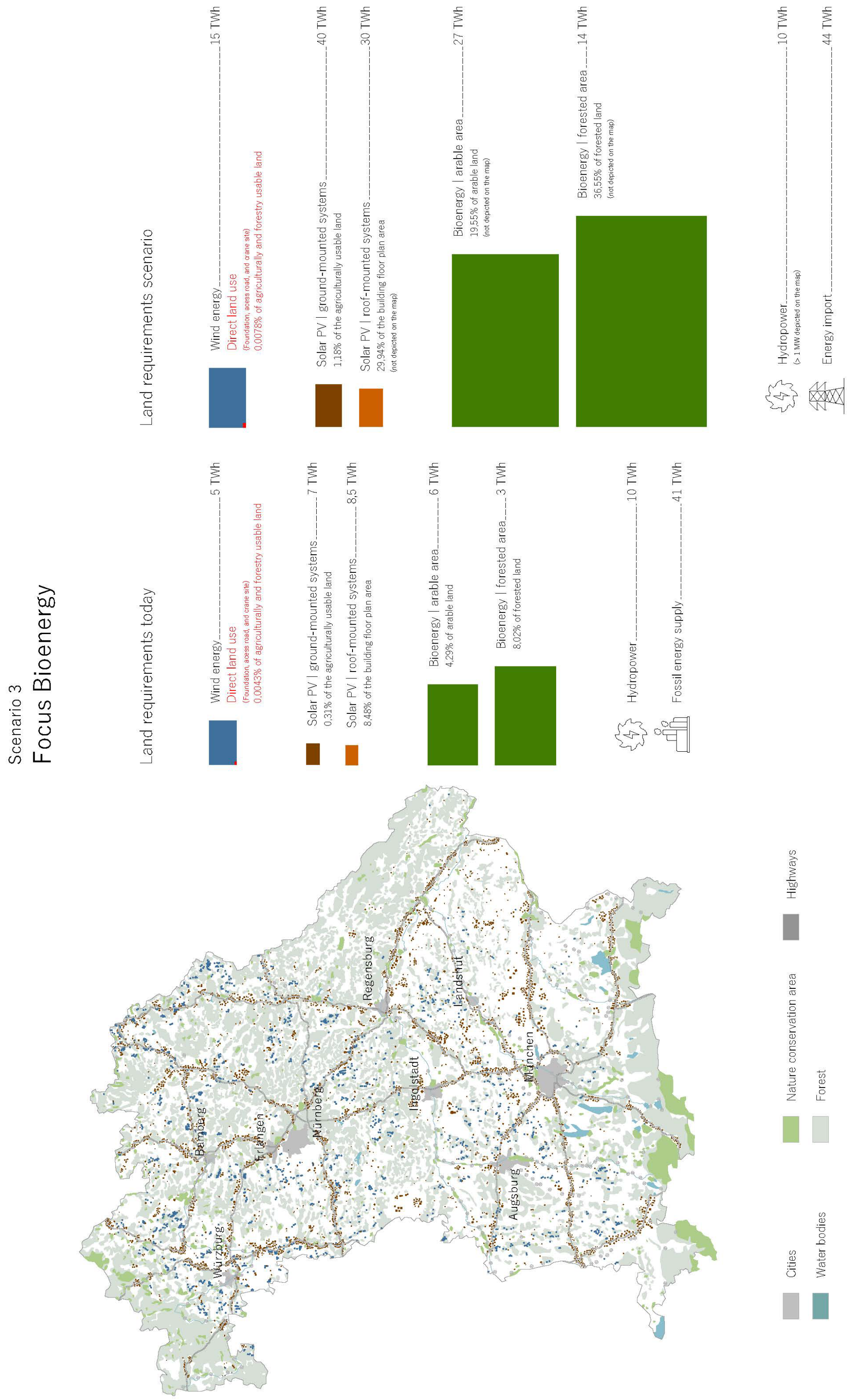

Figure 6: Scenario map "Focus Biomass" (for higher quality see Appendix 1)

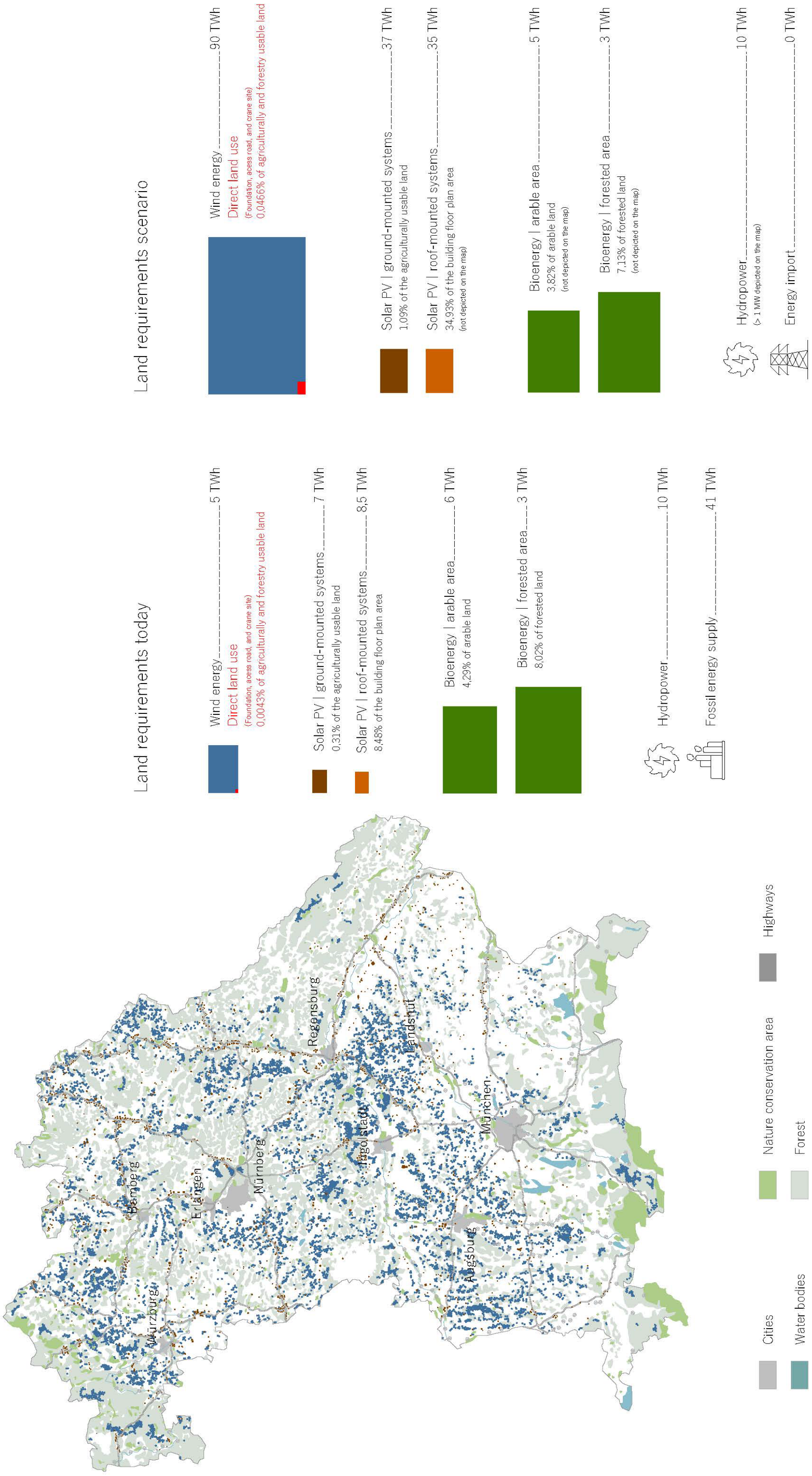

Figure 7: Scenario map “Focus wind” (for higher quality see Appendix 1)

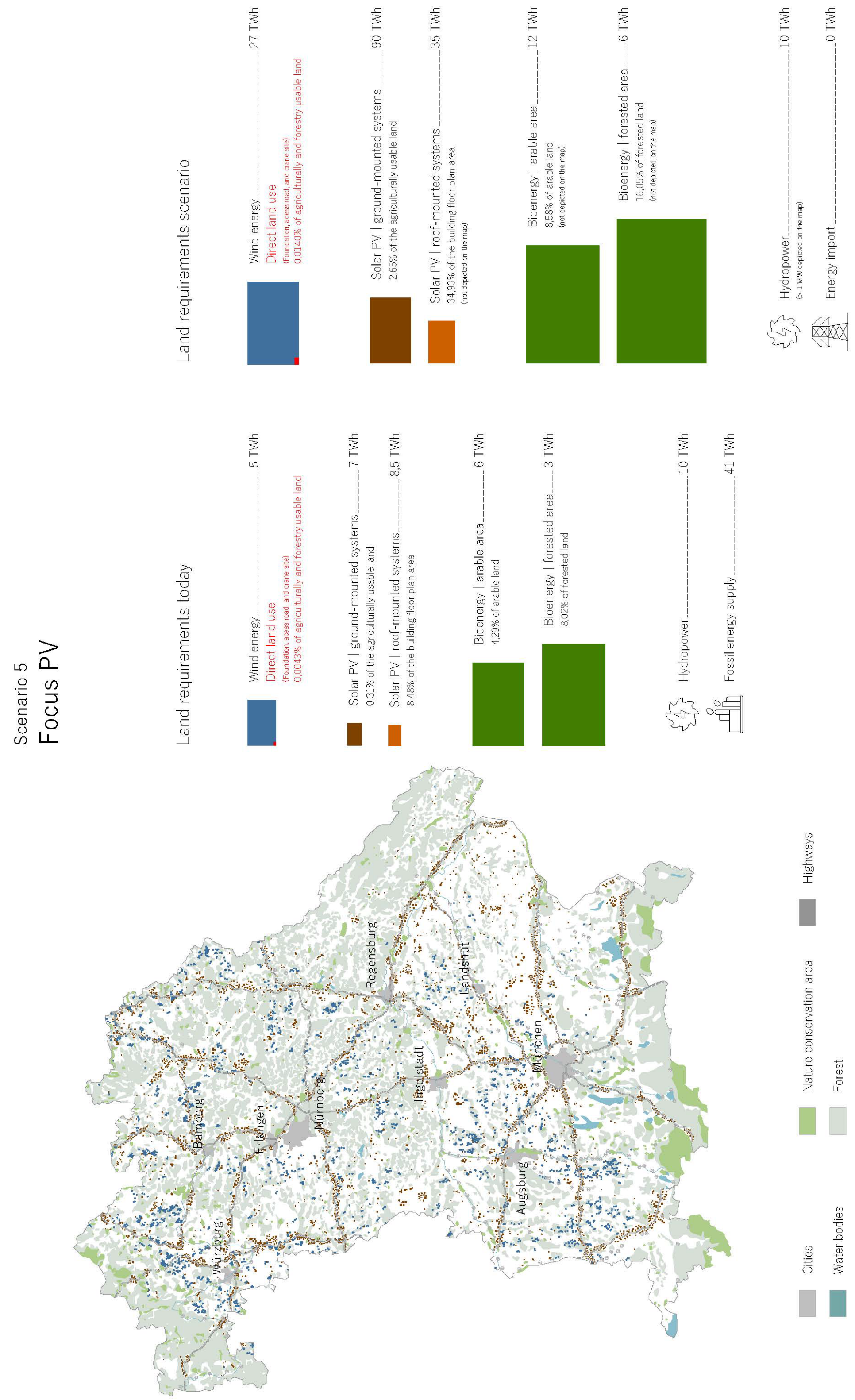

Figure 8: Scenario map "Focus PV" (for higher quality see Appendix 1)

4.2 Social acceptance of renewable energy technologies and future electricity mixes

The following sections will be structured according to the theoretical framework, focusing on the three main dimensions of acceptability: general acceptance, community acceptance, and market acceptance.

4.2.1 General acceptance

4.2.1.1 Energy transition and renewable energy development

When assessing political acceptance at the general level, there has been a noticeable increase in support from governing political actors for the transformation of the energy system. One primary factor contributing to the growing support for the energy transition was the energy crisis resulting from Russia's invasion of Ukraine. This event has further exacerbated the existing challenges of Bavaria's energy supply, which is increasingly dependent on imports and has already faced high electricity prices even prior to the war. This situation mainly resulted from the phase of nuclear energy, which Bavaria was heavily relying on, and very limited wind energy development over the past decade on the state level and several other reasons on the national level, which are outside of the scope of this research. These economic concerns seem predominant for Bavaria's governing conservative parties, who seek to accelerate the energy transition to mitigate the risk of outmigration of key branches of industry and avoid an economic downturn. Environmentally oriented parties acknowledge the economic importance of the energy transition while also emphasising the critical need to combat climate change.

Recently the Bavarian Energy Plan 2030 has been published, which demonstrates the political support for RE development by setting clear expansion targets for the electricity supply in 2030. The plan prescribes that electricity generation from renewables by 2030 must be doubled, compared to the 2020 baseline. In addition, it specifically mandates further increasing solar PV, wind energy and bioenergy to meet the target of 78 TWh by 2030.

Given the status quo of the energy transition, it is unsurprising that key economic stakeholders in Bavaria strongly support the energy transition as a necessary step to strengthen the region's industry and economic stability. Equivalent to political stakeholders, the energy crisis has catalysed a shift in perspective among industrial actors, highlighting the urgent need for developing domestic and decarbonized electricity generation as a means of ensuring long-term economic resilience. With rising carbon certificate prices and persistently high electricity costs, access to domestic and sustainable energy sources can be regarded as critically important for maintaining the competitiveness of Bavaria's industry and manufacturing sector. From the perspective of environmental stakeholders, the energy transition receives strong support as a critical strategy to combat habitat loss driven by climate change. While the localized impacts of renewable energy development, such as individual wildlife losses at wind turbines, should be carefully considered, the broader benefits of reducing greenhouse gas emissions far outweigh these concerns. This generally positive stance in favour of the energy transition also let to environmental organisations facing criticism from individuals focused on local ecosystems and the perceived negative consequences of RE development on their natural integrity. In this context it is important to consider that most existing ecosystems in Bavaria in their current form, cannot withstand warmer temperatures brought by climate change. In those arguments against RE development, alternative solutions to combat climate change, which can be associated with fewer environmental impacts, are oftentimes absent.

Based on a consensus in the interviews it can be stated that the acceptance of the energy transition among the general public in Bavaria is currently very high (see Appendix 2). Similarly to economic and political stakeholders' acceptance levels, the approval rates have seen a significant rise after the Russian attack on Ukraine and the subsequent energy crisis. Currently, the energy transition is perceived as a crucial political topic among Bavarian citizens, significantly influencing voters' party preferences with a majority stating that energy and climate policy is "very decisive" (51.5%) or "decisive" (32.8%) in the decision-making process regarding which party to support. Furthermore, survey results indicated that the majority would be in favour of an accelerated energy transition with 76.5% of total participants selecting the option "the energy transition should advance with a higher pace". Moving in this direction would be essential for meeting Bavaria's decarbonizing targets. 53 survey-takers (14.1%) find the current pace appropriate and 6.9% would prefer the energy transition to slow down. A very small proportion of respondents (2.4%) replied that the energy transition should be stopped. According to the survey, the primary reason for the energy transition is combating climate change, which was selected by 63.5% of participants, followed by increasing energy independence (23.7%) and decreasing availability of fossil fuels (6.4%). The options "there is no reason" and "other" were selected by 3.2% of respondents. This distribution of responses is depicted in Figure 9.

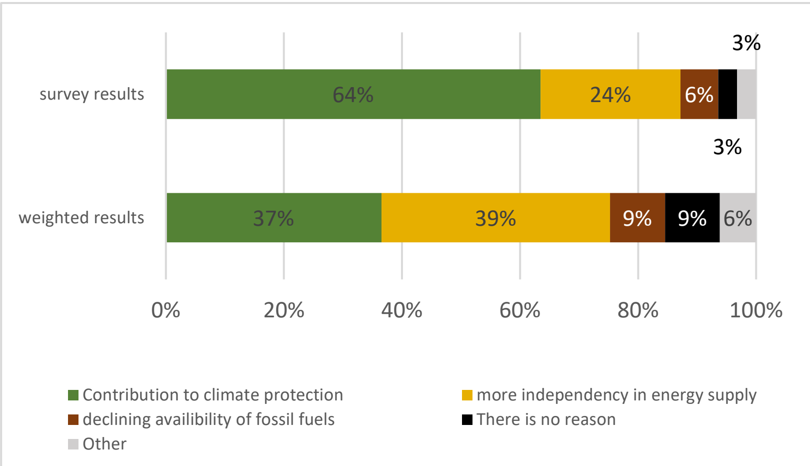

Figure 9: Primary reasons for the energy transition among survey participants in the survey sample and when weighted to account for the political bias of the sample to better represent the Bavarian population.

While these results shed a positive light on the acceptance levels of the energy transition, it has to be noted that these responses are significantly correlated to the political views of an individual. Individuals aligning with "environmentalist" parties perceive the energy transition as a more important political topic than those identifying with conservative or right-wing parties (p-value < 0.001, Cramer's V: 0.49). Similarly, the correlation between political preference and the attitude towards the pace of the energy transition is also significant (p-value < 0.001; Cramer's V: 0.49). Individuals identifying more as conservative or right-wing are significantly more critical regarding an accelerated pace of the energy transition. In addition, when asked about the most important reason for the energy transition the impact of political attitudes is even more prevalent (p-value < 0.001; Cramer's V: 0.73). For those who can be associated with a party of the "right" category, there is either no reason for the energy transition, which forms the majority, or the reasons are the declining availability of fossil resources and increasing energy independence. An interview partner noted that the current political zeitgeist, marked by the rise of right-wing parties, has also fostered scepticism towards the energy transition and questions its necessity. However, it was also mentioned that this opposition appears to be less influential and effective regarding the energy transition in Bavaria than in previous years. For individuals with liberal political views, energy independence and contribution to climate protection seem to be equally important. Participants who can be associated with an environmentalist party, show a very strong tendency towards climate protection as the main reason for the energy transition with 82% selecting this option. For respondents with "conservative" political views, the most decisive factor is achieving more energy independence. Interestingly, when weighing the sample of this study based on the last elections in Bavaria, increasing energy independence can be regarded as the most decisive factor for the energy transition (Figure 9). This aligns with the impression of one interviewee who mentioned that the "impacts of climate change are now becoming normality" and therefore exceed less influence on the acceptance level of the energy transition.

Figure 10 shows the perceived severity of challenges associated with the implementation of the energy transition and development of renewable energies. The technical implementation and social acceptance were identified as the primary concerns, with the majority of participants evaluating these challenges to be either "very high" or "high". Statistical analysis shows that there is no significant correlation between the rating of "technical implementation" and personal or demographic criteria. Nonetheless, when looking at the cross tables and expected values, a slight tendency of people with *conservative* and *right-wing* political attitudes, to rate this challenge higher can be observed. Social acceptance is generally perceived to be the most decisive challenge concerning the energy transition, with a mean value of 3.87 in the sample. The Chi-Square test shows a correlation (p-value = 0.002; Cramer's V: 0.18) between party preference and this variable. While *conservatives, liberals* and *right-leaning* generally perceive social acceptance to be a smaller issue, the environmental and social-left category perceives this category to be of great significance. The challenge of "economic effectiveness" appears to be perceived as less decisive, but equivalent to the previous variable, this depends significantly on the political attitude of respondents (p-value < 0.001; Cramer's V: 0.21). All participants who identify themselves with a right-leaning party, rate this aspect as "very high". Similarly, the conservative group also rates economic aspects higher than individuals associating themselves with other political categories. Conversely, people who fit in the environmental category rate issues to be of medium to low importance. Lastly, environmental impacts were rated as the least important of the four challenges with statistical analysis showing no significant correlations to participants' personal characteristics. However, there seems to be a slight tendency for those identifying with the environmentalist category to assign lower importance to this aspect, while more conservative and right-leaning individuals rate it as a greater concern. This result is somewhat counterintuitive, as it would be expected that individuals with a stronger environmental orientation to rate this issue as more critical. When accounting for the political bias of the sample the technical implementation is perceived as the greatest challenge with a value of 4.08, followed by economic efficiency (4.02), social acceptance (3.64) and ecological aspects (3.29).

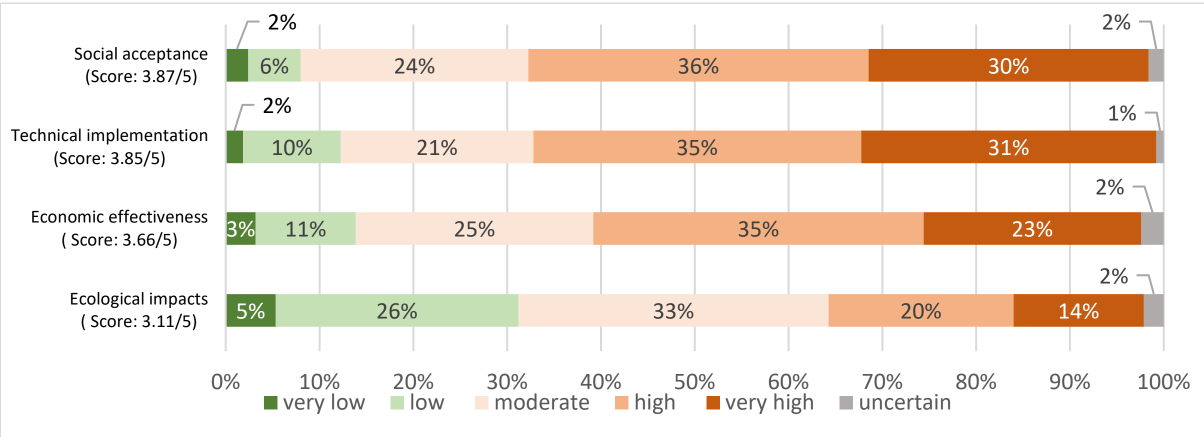

Figure 10: Perceived importance of challenges associated with renewable energy development

<u>Solar Photovoltaics</u>

Solar PV can be described as highly accepted by political stakeholders and is supposed to supply 40 TWh of electricity from ground-mounted and roof-mounted systems until 2030. Over the past years, the governing party strongly advocated for further development of ground-mounted and roof-mounted PV systems. This support has led to Bavaria having the highest amount of installed PV out of any federal state in Germany. In fact, the political acceptance of PV has been on high levels over the past decades with the first models of cost-covering remuneration starting back to the 1980s in Bavaria when the technology was developed as an alternative and additional form of electricity generation complimenting nuclear power. While the overall development can be described as already on a high level, all the interviewees agreed that further developments are essential for the decarbonisation of the electricity sector. A spokesman of an environmental organisation mentioned that its development can positively influence biodiversity when transforming agricultural areas from monocultures to ground-mounted PV systems. It was highlighted that especially the combination of PV with agricultural practices such as animal grazing can be associated with multifaceted benefits from an environmental and economic perspective.

When assessing the acceptance levels of the public, substantial variations exist between roof-mounted and ground-installed panels (Figures 11 & 12). Roof-mounted solar systems are the most accepted form of RE technology, with an average acceptance score of 4.75. Remarkably, only 4 out of 375 participants reported a negative attitude towards these systems and only one of them was willing to act on this attitude. In contrast, 311 participants indicated to have a positive evaluation of the technology while also showing an inclination to actively engage in the development of roof-mounted solar PV systems. The acceptance of this technology is significantly correlated to the political stance of an individual (p-value < 0.001; Cramer's V: 0.30). While the right and conservative categories show slightly lower acceptance levels, environmental-orientated individuals tend to rate this technology more positively. Even when weighing the sample depending on political preferences in Bavaria, roof-mounted PV systems still achieve an acceptance score of 4.56.

Ground-mounted PV systems show substantially lower acceptance levels compared to their roof-mounted counterparts achieving an acceptance score of 3.84 (Figure 11). Out of the five assessed renewable energy types, this resembles the second-lowest score. The category *support* is still the most selected option, although only being selected roughly half as much as often compared to the results for roof-mounted systems. The category *consideration* is selected the second most often with more than one-third of participants opting for this option. These results indicate that acceptance of the technology is oftentimes dependent on the specific site conditions. Furthermore, there is a significant correlation between political preferences and a more positive assessment of the technology (p-value < 0.001; Cramer's V: 0.25). The acceptance score of Individuals preferring environmental-orientated parties sums up to 4.11 which is substantially higher compared to the right-leaning (2.29) or conservative (3.42) group. However, a notable proportion of individuals with a conservative stance (33.9%) also selected *support* as acceptance type. When adjusting the data to reflect the political landscape of Bavaria, the most selected option would be *consideration* due to the large proportion of conservatives selecting this option (Figure 11). In fact, when assessing the acceptance of the technology after weighting the sample, this technology achieves the lowest rating out of all renewables with a score of 3.11.

Interestingly, there is also a significant correlation between age and the acceptance level of this technology (p-value < 0.001, Cramer's V: 0.20). In the younger age groups, the majority of participants selected *consideration* while also showing very low participant numbers negatively evaluating the technology. In contrast, among participants with an age higher than 40 *support* was the most selected option. However, individuals in the age group 40-70 also showed the highest number of participants having a negative stance towards this technology. This suggests that while younger individuals are more inclined to consider the context specifics, individuals with a higher age tend to have more polarised views, either positive or negative.

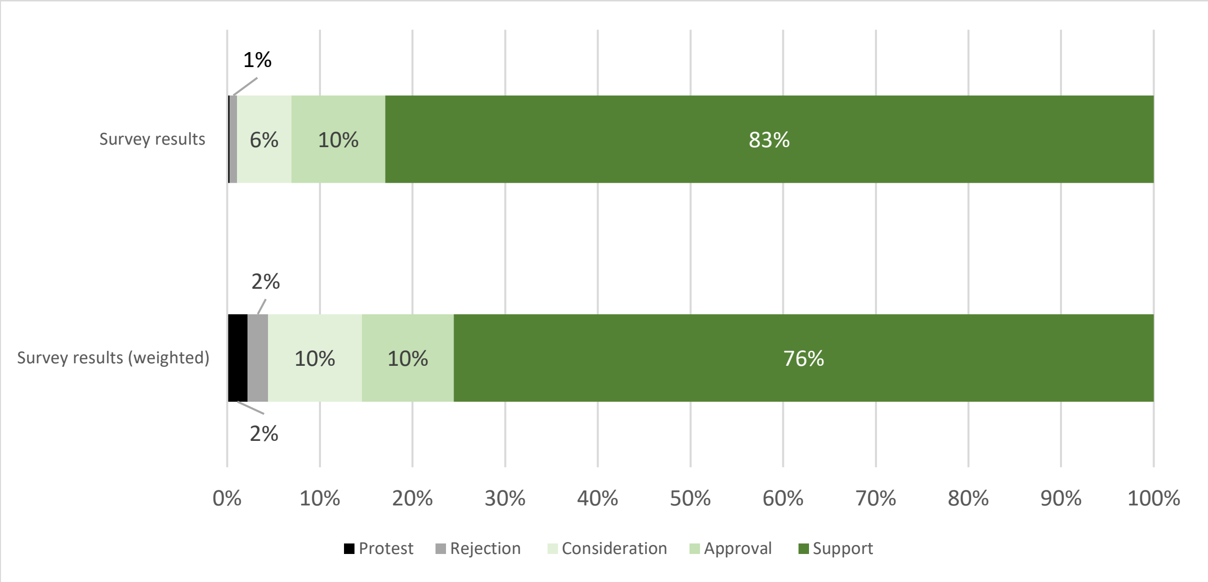

Figure 11: Distribution of acceptance types: roof-mounted solar PV; survey sample and weighted results to account for the political bias of the sample.

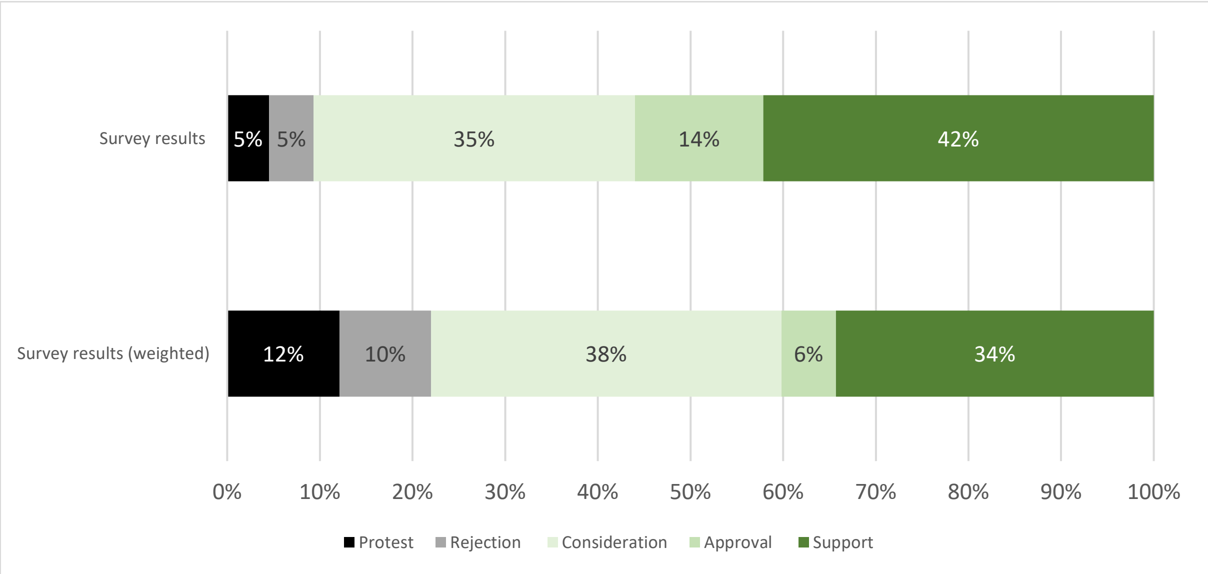

Figure 12: Distribution of acceptance types: ground-mounted solar PV; survey sample and weighted results to account for the political bias of the sample.

As the *consideration* category is frequently represented for ground-mounted solar panels it is of crucial importance to assess what respondents perceive to be considerable concerns for the development of solar PV. It must be noted that in the survey there was no distinction between the two application forms of solar PV. However, when considering the acceptance levels, it can be assumed that these challenges are mostly associated with ground-mounted PV systems especially as some of the options in the questionnaire only affect ground-mounted installations such as land use competition with agriculture.

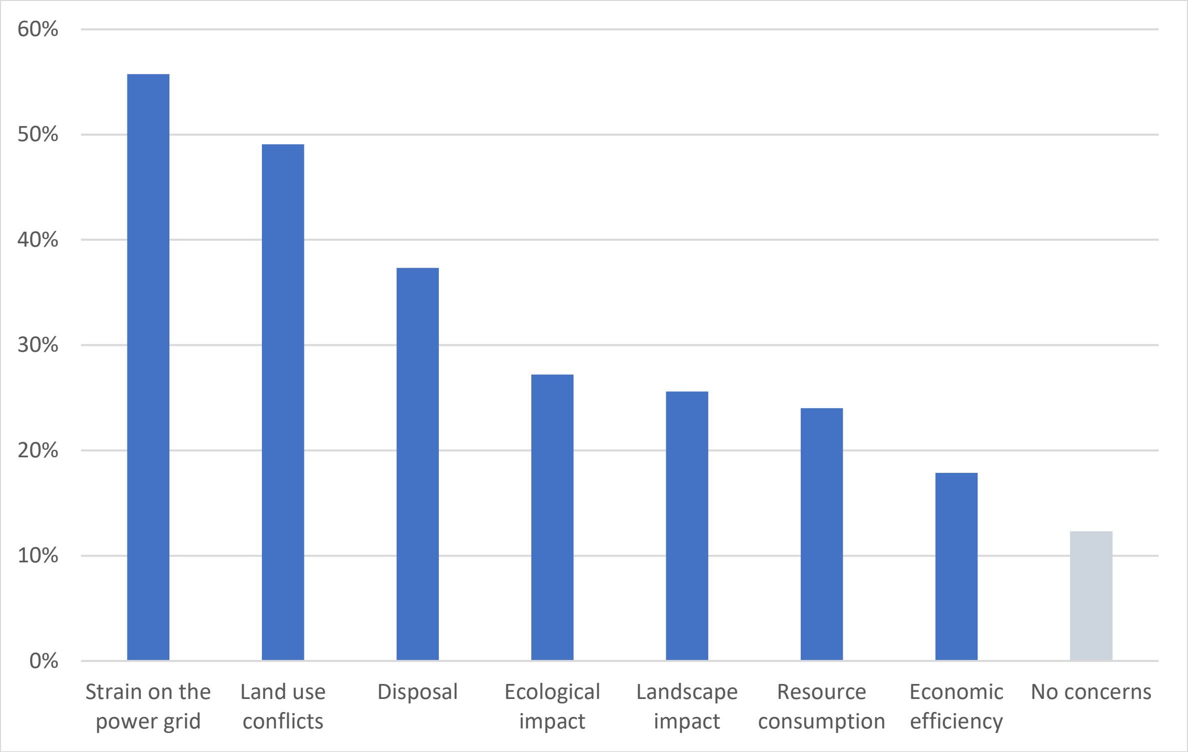

Figure 13: Concerns: solar PV development

Looking at Figure 13, it is apparent that most people see the *load on the electricity grid* resulting from the volatile nature of the technology and the *land use requirements* as the most critical aspects of PV development. In addition, almost half of the participants evaluated the disposal of PV panels as a significant issue. Other aspects such as environmental impacts, resource demand and impacts on the landscape were only selected at a moderate level. When it comes to solar panels most people rate their economic efficiency quite highly as this is the least selected issue regarding PV systems. One aspect that should not be overlooked is that even though the acceptance of solar PV is generally high, only a small number of participants have no concerns regarding this technology.

When further investigating correlations between the perceived challenges and socio-demographic characteristics, some interesting connections can be detected. Consistent with previous findings, the political party preference has an influence on the evaluation of the technology with significant correlations identifiable concerning the challenges of economic efficiency (p-value = 0.002, Cramer's V: 0.23) and impacts on the landscape (p-value < 0.001; Cramer's V: 0.32). The most significant concerns for right-leaning and conservative individuals are land use requirements (85.7%), while the former also see strain on the electricity grid (85.7%) as a hurdle for further development. Interstingly, environmental-orientated individuals also selected strain on the electricity grid most frequently (54.4%), showing that it is a concern across the political spectrum.

When it comes to the criterion age group, there is a weak link to the perception of the issue of disposal of PV panels (p-value = 0.045, Cramer's V: 0.20). Younger individuals see it as a more striking challenge compared to participants in older age groups. The criterion with the highest number of identified correlations is gender. One concern which men selected slightly more often is economic efficiency (p-value = 0.030, Cramer's V: 0.11), while women perceive the resource use for the production of panels (p-value < 0.001; Cramer's V: 0.191), the disposal of such (p-value = 0.002; Cramer's V: 0.16) and the ecological impact (p-value < 0.001; Cramer's V: 0.18), including those during mining processes for necessary material, as more striking issues. In regard to the educational level, respondents with a higher educational degree selected economic efficiency (p-value = 0.009, Cramer's V: 0.204) and challenges with disposal significantly less frequently (p-value = 0.043, Cramer's V: 0.18).

When participants were asked whether they would like the technology to develop further, the vast majority selected either "Yes, definitely" (68.5%) or "Yes, but mentioned concerns must be considered more carefully" (27.5%). Only a very small proportion stated that they think the current level is enough (2.7%) or that they would prefer existing sites to be deconstructed (1.3%). The responses are correlated with political preferences (p-value < 0.001, Cramer's V: 0.35) as well as the educational level (p-value < 0.001; Cramer's V: 0.18) with participants in the environmental category and higher educational degrees desiring more development.

Wind energy

The political acceptance of wind energy is one of the most crucial aspects in regard to the overall energy transition in Bavaria. Over the past ten years, the governing conservative party CSU has prevented further developments of wind energy through spatial regulation the so-called "10H rule", which can be regarded as the most restrictive regulation for wind energy in Germany. According to this rule, there must be a minimum distance of ten times the height of the proposed wind turbine between residential areas and wind turbines. Its implementation basically led to a standstill of wind energy development for over a decade as Bavaria has a very dispersed settlement structure. Furthermore, this regulation can be regarded as a "catalyst for organised wind energy opposition". More recently, political support for wind energy resurged again due to pressure from the federal government as well as economic and environmental stakeholders on the federal level, resulting in a weakening of the regulation. This also shows the high acceptance levels of environmental and industry stakeholders, with both of them advocating for a substantial increase in installed capacity. Furthermore, with the introduced changes to the 10H regulation project developers now see a large potential for the development of new projects. The current expansion target is developing between 800 and 1000 wind turbines to reach a total installed capacity of 6.6 GW. While the target for PV is formulated very clearly, this is not the case for wind energy as the Bavarian energy plan does not mention a precise target for electricity generation and the time frame for developing these wind turbines is not until 2030, but "in the coming years" (StMWi, 2023).

When it comes to the public acceptance of wind energy, the interviews indicated that the 10H regulation resulted in tenacious concerns of the public as the image cemented itself that wind energy presents a danger to humans and wildlife alike. One interviewee noted, that for some individuals wind turbines are seemingly more dangerous than nuclear energy. Looking, at the results of the survey, it can be stated that public acceptance levels appear to have improved from their previously low levels. The survey data indicate high general acceptance of wind energy, achieving an acceptance score of 4.16, making it the RE source with the second-best rated RE technology in the sample (Figure 14). However, here it is important to further dissect the empirical data. In fact, wind energy has the highest number of respondents putting themselves in the protest category, although the total number of 21 (5.6%) can still be considered fairly small. Interestingly, the number of people selecting rejection (10) has the second lowest value out of all categories after roof-mounted PV, indicating that if people oppose wind energy, they are more likely to translate their attitude into action compared to other RE sources. The number of participants in the consideration category is fairly small compared to other technologies, which further hints towards a polarisation of attitudes and behaviour towards wind energy. Further supporting this hypothesis is that the number of respondents willing to actively support the technology (216) is significantly higher than those who put themselves in the approval category (54).

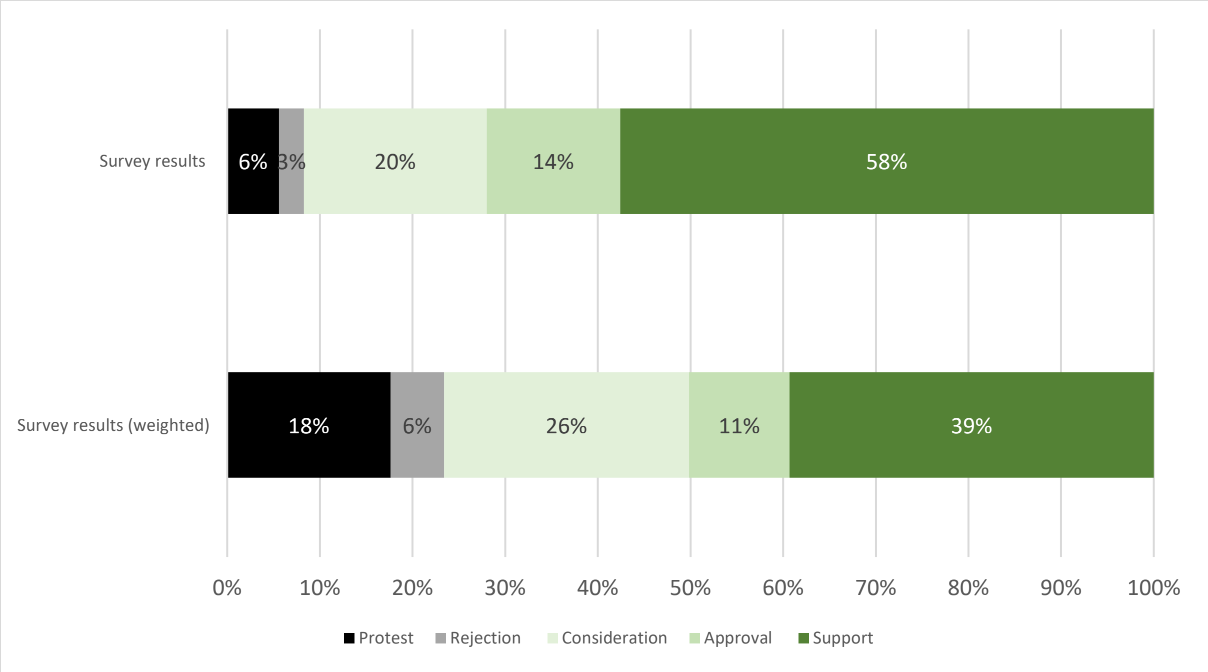

Figure 14: Distribution of acceptance types: Wind energy; survey sample and weighted results to account for the political bias of the sample.

The two parameter approval rating of the technology and political views show a relatively strong correlation explaining the mentioned polarisation of attitudes and behaviour (p-value > 0.001; Cramer's V: 0.40). Individuals with a conservative and especially those with right-wing political stances are substantially more critical regarding wind energy. For example, nearly three-quarters of right-leaning participants selected "protest", leading to an overall acceptance score of 1.71. Conversely, in the environmental-orientated category, almost three-quarters of those chose "support", achieving an acceptance score of 4.62. This indicates a significant dichotomy between the two groups. While conservative respondents evaluated wind energy more critically compared to the environmental, liberal or social party categories, the majority still selected a *consideration* (40.3%) or even *support* (32.3%) response. When weighing the results based on the political preferences in Bavaria, wind energy achieves an average score of 3.48, which represents the third-highest value. In addition, the results of the survey show a significant tendency of female participants to have a more nuanced perspective on wind energy they tend to select consideration more often and the categories *support* and *protest* less frequently compared to male participants (p-value = 0.004, Cramer's V: 0.16). Lastly, there is also a statistical link between the educational degree of respondents as those with a higher degree seem to view wind energy as more favourable.

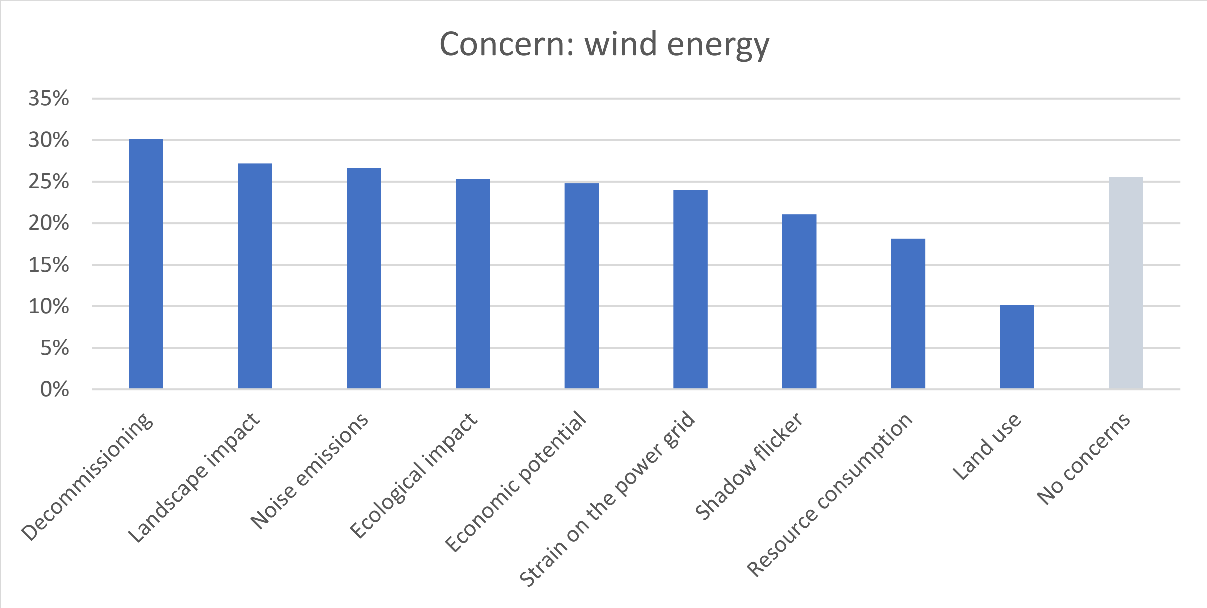

Figure 15: Concerns: wind energy development

The majority of perceived concerns about wind energy were selected approximately 80 to 100 times, showing a varied distribution of concerns (Figure 15). Solely looking at the frequency of each challenge does not provide valuable insights, which is why it is crucial to conduct a deeper statistical analysis of these results. Notably, almost every concern is correlated to the political preferences of participants. Surprisingly, concerns regarding the decommissioning of turbines achieved the highest rating with 113 participants selecting this option. This concern was the most selected concern by environmental-orientated individuals, although only 23.6% selected this option. In the practice of developing wind energy, this issue is brought up by members of the public less frequently as these results might suggest as stated by an interviewee. However, there seems to be an increasing concern about this aspect of wind energy as one interview partner could confirm. Investigating the political preferences of individuals selecting this option, it is evident, that this issue is mainly selected by members fitting in the environmentalist category. Therefore, the high frequency of this concern primary can be attributed to the bias of the data sample towards environmental-orientated parties.

Economic efficiency shows a comparatively strong correlation ($p < 0.001$; Cramer's V = 0.43) towards political preferences, as conservative, liberal and right-leaning participants are more prone to perceive this as a crucial challenge for the further development of wind energy. In fact, all participants in the right-leaning category and the majority of liberals (54.5%) evaluated this aspect to be an issue, making it the most selected challenge in these two groups. For conservatives, this was the second most selected issue, while only a minority of 11.3% of environmentally oriented individuals perceive this as a challenge.

Significant relationships can also be observed regarding landscape impact (p-value < 0.001; Cramer's V: 0.34), grid stress (p-value = 0.002; Cramer's V: 0.26), noise emissions (p-value = 0.001; Cramer's V: 0.26), shadow flickering (p-value < 0.001; Cramer's V: 0.31) and land use issues (p-value = 0.025; Cramer's V: 0.22) with right-wing and conservative individuals prioritising these problems and seeing them as more crucial in comparison to individuals with other political preferences. For example, among conservatives, 54% consider landscape impacts as an issue, making it the most frequently cited concern within this group. In contrast, individuals with social-left or environmentalist political views perceive it as an issue of lesser importance. The pattern of noise emissions is seen as a concerning issue by conservatives, right-wing participants, and interestingly, members of the social-left category. The latter group considers it their top concern, with 37% marking it as an issue. A total of 96 respondents reported having no concerns regarding wind energy. This option was most frequently chosen by environmentalists, with 37% indicating to have no significant concerns. In contrast, only a small fraction of conservatives (9.6%) and no right-leaning individuals reported having no concerns.

Age disparities are apparent in relation to the evaluation of ecological consequences (p-value = 0.003: Cramer's V: 0.242), with older individuals seeing it as more troublesome in comparison to younger individuals. For the variable landscape impacts, significant gender disparities are apparent with male participants prioritising them (p-value = 0.049; Cramer's V: 0.10), whereas women rate ecological concerns (p-value < 0.001, Cramer's V: 0.22), noise pollution (p-value = 0.009; Cramer's V: 0.13), resource use (p-value < 0.001; Cramer's V: 0.17), and disassembly (p-value < 0.001; Cramer's V: 0.18) as more troubling challenges. Perceptions are also influenced by educational level as those with higher degrees tend to see noise emissions (p-value = 0.001; Cramer's V: 0.24), shadow flicker (p-value = 0.011; Cramer's V: 0.20), and deconstruction (p-value < 0.001; Cramer's V: 0.24) as less problematic than those with lesser educational achievement.

Considering the high acceptance score of wind energy, it can be reasonably expected that participants would express strong support for further development of the technology. The results were indeed very positive with 257 (68.5%) "definitely being in favour of an expansion" of the technologies application and 103 respondents (27.5%) wanting further developments if the mentioned challenges will be considered more extensively. In total, 10 participants indicated that they believe the status quo is sufficient, and 5 expressed the desire to see existing turbines deconstructed. Further analysis reveals, that even when individuals put themselves in the protest category, they do not necessarily desire the deconstruction of existing turbines. The Chi-Square test also showed a significant correlation between the attitude towards further developments and political stance (p-value < 0.001; 0.42). Right-wing participants generally oppose further development, while conservatives are most likely to be supportive if concerns are adequately addressed. The majority of respondents of the other political categories were in favour of increased wind energy development.

Hydropower

Hydropower is a politically highly accepted form of renewable energy. This can partly be explained by the positive historical connotation as several of Bavarian's industry clusters could only develop through the development of hydropower. However, it was also acknowledged in the interviews that the potential for further development are limited, and possible increases will mainly stem from the modernisation of existing power plants and associated efficiency gains. This political attitude aligns with those of economic stakeholders, which underscore the benefits of the reduced volatility and the black start capability which is of critical importance in case of a blackout. From an environmental perspective, the development of new dams for hydropower should be refrained from as the remaining unaffected river streams can be described as especially valuable and the loss of these habitats therefore does not stand in relation to the small potential gains in electricity generation.

In terms of public acceptance, hydropower received a score of 3.91, placing it in the mid-range among evaluated technologies. This score is comparable to that of ground-mounted PV systems, although slightly higher. While the number of participants selecting support (144; 38.4%) and approval (94;25.1%) indicates a high acceptance level of the technology, a large proportion of respondents also chose consideration (110; 29.5%) (Figure 16). Negative acceptance categories are rather rare, with 13 participants (3.5%) putting themselves in the rejection category and 14 (3.7%) in the protest category. Interestingly, while other RE technologies showed significant correlations between acceptance levels and socio-demographic criteria such as age, gender, and especially political preferences, this is not the case for hydropower. Nonetheless, when assessing the scores of right-leaning individuals, it becomes evident that hydropower receives the highest rating among all renewable technologies, with the majority selecting *support* (57.1%) and *approval* (14.3%) as their acceptance categories. While the acceptance score of right-leaning individuals sums up to 4.14, making it the most accepted form in this socio-political category. In contrast, out of the 12 participants who selected *protest*, 11 indicated environmental-oriented parties as a preference, as well as 9 out of the 10 participants who selected *rejection*. When weighing the sample to represent the political preferences in Bavaria, hydropower achieves the second-highest acceptance rating with a score of 4.26.

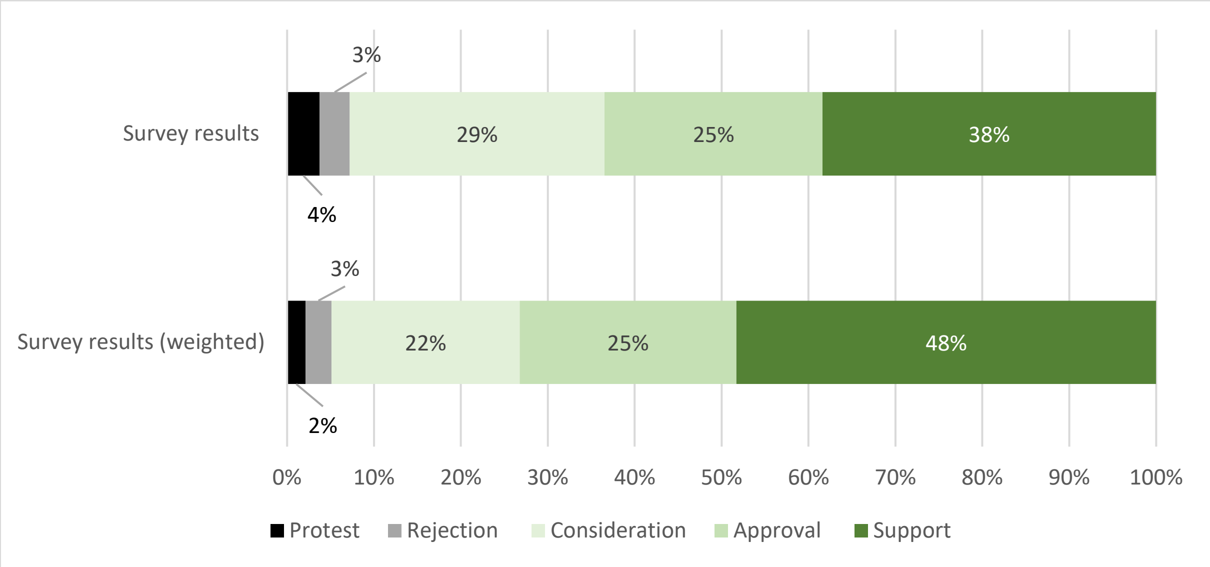

Figure 16: Distribution of acceptance types: Hydropower; survey sample and weighted results to account for the political bias of the sample.

Among all the evaluated technologies, hydropower is the one for which the majority of respondents (98) expressed no significant concerns. However, when specific concerns were evaluated, ecological impacts emerged as the primary issue (254 respondents), while other concerns, such as declining water quality (65) and the risk of dam rupture (50), were not perceived as significant by most participants. These concerns are significantly linked to personal characteristics. Political preference has a considerable impact on the perception of environmental issues, as individuals who can be associated with the environmental category (76.4%) are more inclined to view this aspect as a concern compared to the right-leaning (28.6%) or conservative (48.8%) category (p-value < 0.001; Cramer's V: 0.27). This contrasts with the findings for photovoltaic (PV) and wind energy, where individuals on the political right and conservatives more frequently identified ecological impacts as a significant concern. Furthermore, there is also a significant link between political affiliation and the probability of having no concerns with hydropower (p-value = 0.006; Cramer's V: 0.22). In particular individuals who lean towards the right and hold conservative views show a higher likelihood of not having any substantial issues with the technology. Gender disparities are apparent in the evaluation of water quality being an issue, with females being more inclined to view it as a concern in comparison to males (p-value < 0.001; Cramer's V: 0.21). Age is a factor which is significantly correlated to the perception of water quality being an issue (p-value = 0.004; Cramer's V: 0.24). Respondents in younger age groups (< 40) tend to be more concerned about water quality compared to older participants (> 40). In addition, older individuals are more prone to state that they have no noteworthy worries (p-value = 0.005; Cramer's V: 0.23). Education has an impact on individuals' perspectives about ecological concerns, as those with better educational qualifications are more likely to perceive ecological impacts as a concern (p-value = 0.049; Cramer's V: 0.173). Similarly, those with greater levels of education are less likely to indicate that they have no substantial worries about technology (p-value = 0029; Cramer's V: 0.19).

Consistent with the support levels for hydroelectric power, the overall sentiment leans towards further development of the technology. A total of 144 individuals (38.4%) expressed definitive support for further developments, while 135 participants (36,0%) indicated conditional support if the mentioned concerns will be considered more carefully in the project development. Looking at differences based on political views the Chi-Square test showed a significant link (p-value < 0.001; Cramer's V: 0.42). In fact, 6 out of 7 right-leaning respondents expressed strong approval for expanded hydroelectric projects. Similarly, both conservative and liberal participants are in favour of more development in this sector. In contrast, all seven respondents advocating for the dismantling of existing hydropower infrastructure belong to environmentalist groups. Additionally, gender differences were observed, with men showing significantly more support for hydroelectric expansion compared to women.

Bioenergy

Currently, a very strong support for bioenergy by the governing political party can be observed. Despite bioenergy already making up the largest share of renewable sources used in the energy supply, including transport and heating, the party still advocated for the need to further develop of energetic use of wooden biomass and energy plants. To be more precise, the aim is to increase electricity generation by 15% while reaching a minimum installed capacity of 2.2 GW by 2030 (StMWi, 2023). Furthermore, an additional directive subsidising biogas processing plants and the replacement of natural gas using biomethane has recently been passed. This aligns with the perspective of a central economic stakeholder, who perceives this energy source as underestimated and recommends further development. While these political and economic stakeholders have a positive view of this technology, there are also opposing perspectives on the same level. Even though there is potential for further development it must considered carefully how bioenergy is integrated in the energy system. It can be observed that the current application of biogas power plants is not supporting an economically effective energy transition, primarily due to the lack of flexibility in operational plants. During periods when wind and solar meet 100% of electricity demand, bioenergy plants continue to operate, which results in negative electricity prices. Simultaneously, operators of bioenergy plants receive strong financial support even for electricity generated during those periods. Therefore, it would be advisable to incentivise flexible operation or at minimum integrate these into district heating networks, rather than promoting economically inefficient practices. The transition of operational modes towards meeting peak-time electricity supply could play a central role in balancing intermittent electricity generation from solar and wind. However, it must be considered that this requires further investment in biogas storage and additional turbines at existing biogas plants.

In addition, from an environmental point of view, the further development of bioenergy can be seen critically, as the vast majority of biomass for energy purposes is harvested from monocultures. Therefore, transitioning away from current practices towards more environmentally sound practices should be the aim. One solution could be the plantation of cup plants (*Silphium perfoliatum*), as they provide a vital food source for insects and, unlike corn, help minimize soil erosion due to their deeper roots. To maximise the ecological benefits the use of insecticides should also be refrained from or at minimum reduced.

When assessing acceptance levels of bioenergy in Bavaria today, it is overall viewed as more positive than negative (Figure 17). However, in comparison to other renewable sources, bioenergy has the lowest acceptance rating in the sample, with a score of 3.3. Notably, this technology stands out as the only one where support is not the most frequently selected option. Instead, 177 of the participants selected consideration making it the most popular choice by a substantial margin. Even though there are also a large number of individuals assessing the technology negatively (52), the proportion of participants willing to translate negative attitude into action is also very small with only 8 participants selecting this option. Overall, a substantial part of the sample evaluated the technology positively (82), with a considerable number (56) willing to support further developments. Further statistical analysis also reveals correlations between acceptance levels of biomass and socio-demographic characteristics. When accounting for political bias in the sample and weighing the results to represent Bavaria more closely, the acceptance score increases slightly to 3.45, making it the second-lowest value. Similar to hydropower, it is observable that right-leaning individuals (3.71) perceive this technology as more acceptable than those identifying with environmental-orientated parties (3.28). In fact, for the latter group, it is the least accepted technology. Interestingly, the acceptance score is very similar to wind energy, but while wind energy is subject to more polarised views with a higher proportion of individuals selecting *support* and *protest*, bioenergy is perceived as more nuanced with the majority selecting *consideration*.

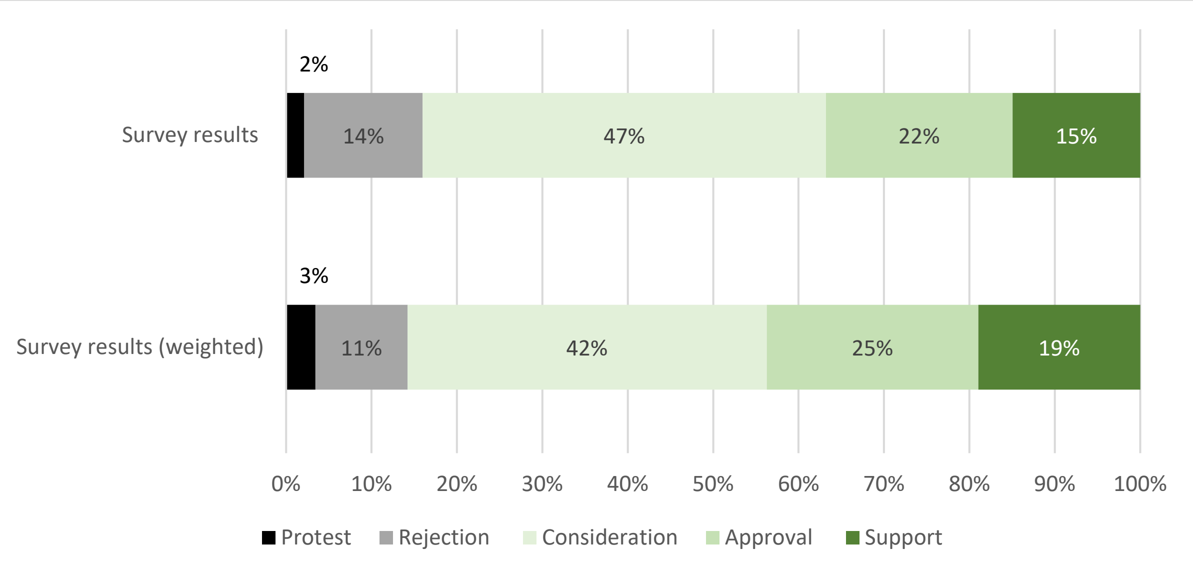

Figure 17: Distribution of acceptance types: Bioenergy; survey sample and weighted results to account for the political bias of the sample.

Given the large proportion of respondents selecting consideration, it makes sense that only a small fraction of respondents indicated having "no concerns" towards bioenergy (Figure 18). Compared to other renewable energy sources, only 19 participants, equivalent to 5% of the total sample, selected this option, making it the lowest among all technologies. Examining the frequencies of the perceived challenges, four issues were selected by over 50% of participants. Interestingly, out of the different environmental impacts, the primary concern is not the impact on flora and fauna but rather soil conditions. Additionally, issues related to land use conflicts, particularly with food production, and the extensive land requirements are causes of concern. In contrast, changes to the landscape was selected by a relatively low number of participants. This is particularly noteworthy given the previous negative assessments of the impact of bioenergy production on the landscape.

Interestingly, bioenergy was the first form of renewable energy which faced heavy criticism and a substantial decline in public acceptance as described by an interview partner. As the number of biogas plants in Bavaria increased substantially alongside monocultures of corn and rape seed an increasing number of citizens complained about the proliferation of those monocultures influencing the Bavarian landscapes. This process was regarded as the "Vermaisung der Kulturlandschaft". Although this issue was heavily debated in public media around 2010, this issue seems to have diminished in significance within the public discourse. Today it is rarely discussed and also the least mentioned concern for bioenergy, suggesting that people have become accustomed to these agricultural practices.

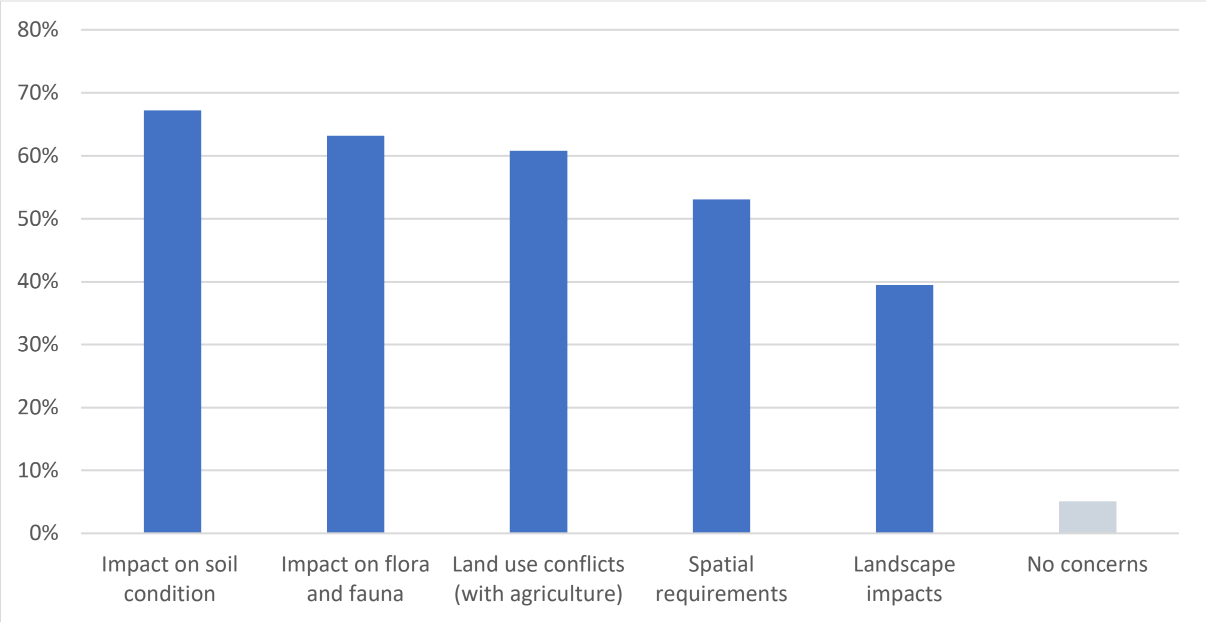

Figure 18: Concerns: Bioenergy development

In regard to challenges associated with bioenergy, there are notable statistical correlations. Party affiliation significantly influences perceptions of bioenergy's impact on flora and fauna (p-value < 0.001; Cramer's V: 0.30), with right-leaning (28.6%) and conservative (41.9%) participants expressing concerns less frequently compared to individuals identifying with environmental-orientated (70.8%) and social-left (77.8%) parties. This trend can also be observed regarding perceived issues with soil conditions (p-value < 0.001; Cramer's V: 0.27) and area requirements (p-value = 0.005; Cramer's V: 0.22), with environmentalists showing greater signs of worry while right-leaning, conservative and interestingly left-leaning individuals report this issue less frequently. The probability of selecting "no concern" is statistically significantly lower when identifying with right-leaning or environmental-orientated parties, compared to conservatives and liberals who show this attitude more frequently (p-value = 0.008; Cramer's V: 0.21). Gender also plays a role, as women tend to express more concern about the impacts on flora and fauna compared to men (p-value = 0.015; Cramer's V:0.13). Age differences are evident in perceptions of landscape changes, with younger participants significantly less concerned (p-value = 0.034; Cramer's V: 0.20). Similarly, individuals with higher levels of education tend to perceive this aspect as less significant, whereas individuals with a lower educational background report concerns in this category more frequently (p-value = 0.03; Cramer's V: 0.18).

Even though bioenergy has the lowest acceptance score out of all RE sources, the majority of respondents of the survey advocate for further developments. However, most participants (194, 51.7%) note that it is of crucial importance that these developments consider the aforementioned challenges with care. The number of individuals selecting "Yes, definitely" when asked if they want to see an increase in electricity supply from bioenergy sums up to 43, which equals 11.5%, making it a minority in the sample. On the other side, an even smaller proportion of respondents (20, 5.3%), would like to see existing plants being dismantled. In comparison to other RE sources, the highest number of participants (118, 31.5%) selected that they think the current level of development is sufficient. The only statistically significant correlation between the further development of bioenergy and personal characteristics is political preferences as right-leaning and conservatives tend to be more in favour than those in the environmental category (p-value = 0.039; Cramer's V: 0.16).

4.2.1.2 Future electricity mixes

Figure 19 shows the preferred electricity mixes of members of the Bavarian public. Interestingly, the *Focus wind* scenario scored highest in the sample with a total of 156 votes which resembles 41.6% of all participants. The *Balanced Development* scenario is the second highest-rated scenario in the sample with 116 individuals preferring this option. The third most frequently selected scenario was *Focus PV* with a total of 73 individuals (19.5%) evaluating this scenario as the most favourable. The two scenarios energy import and Focus Bioenergy received an equal number of votes and overall, a very low rating. Both scenarios were selected by 13 individuals each of which is equivalent to 3.5% of the total sample. Statistical analysis reveals that the selection of the scenario is dependent on the educational background as those with higher degrees have a tendency to prefer scenarios 4 & 5. However, the robustness of these findings is limited as half of the cells in the cross table have a value below 5. The substantial influence of political preferences on favoured scenarios will be addressed in a subsequent section, which explains Figure 20.

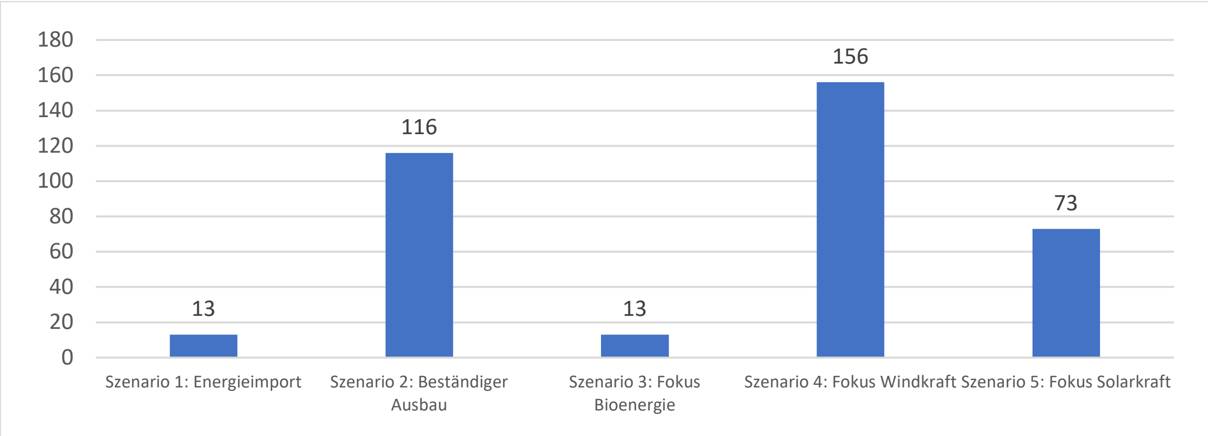

Figure 19: Preferred future electricity mixes among the survey participants

When reviewing the additional information in the form of the map and the associated spatial requirements, the majority of respondents indicated that the spatial requirements were in line with their expectations (198; 52.8%). In contrast, 59 participants reported that they would have expected smaller area requirements. Additionally, 51 respondents indicated that they would have expected larger area requirements. A total of 67 participants expressed that they were undecided about their perception of the spatial requirements, which presents on considerable proportion. The reasons for the frequent occurrence of this answer can be only speculated. It may suggest that these participants found the substantial amount of information consisting of five scenario maps overwhelming or were unwilling to spend additional time evaluating the scenario maps, as this information was presented toward the end of the survey. Notably, there was no correlation between these perceptions and the respondents' age, gender, levels of education or previously selected scenarios.

The goal of the maps was to make the impact of the selected scenario more tangible and to allow participants to critically reflect on their decision considering the spatial requirements of each RE source and respective scenarios. When participants were asked if they would like to change their selection after being confronted with the spatial requirements of their scenario as well as those of the other scenarios, the vast majority, 83.7% (314 participants), stated that they would stay with their original choice. These numbers show that for the majority the visual representation of the scenario and associated land use requirements did not affect their preference. Only a small proportion indicated the willingness to reconsider their decision. Among those indicating the willingness to change their scenario selection, most participants opted towards the solar scenario (Scenario 5) instead of their original choice. Most of these participants had initially selected the wind scenario (12) or *Balanced*

Development (6). This suggests that these participants show a desire for high levels of electricity generation from renewable sources, but the substantial amount of wind energy was perceived as too extensive. However, these scenarios were also the most frequently selected scenarios which is why evaluating only absolute values does not provide the complete picture. In fact, four out of five scenarios have a similar rate of reconsideration lying between 11.5 and 15.5%. Scenario 5 achieves a lower reconsideration rate with 6.9% changing the preferred scenario. Interestingly, statistical analysis shows no significant correlation between the previously selected scenario and willingness to change. In total, 5.1% of participants felt that none of the shown scenarios matched their expectations, and 1.3% did not provide an answer.

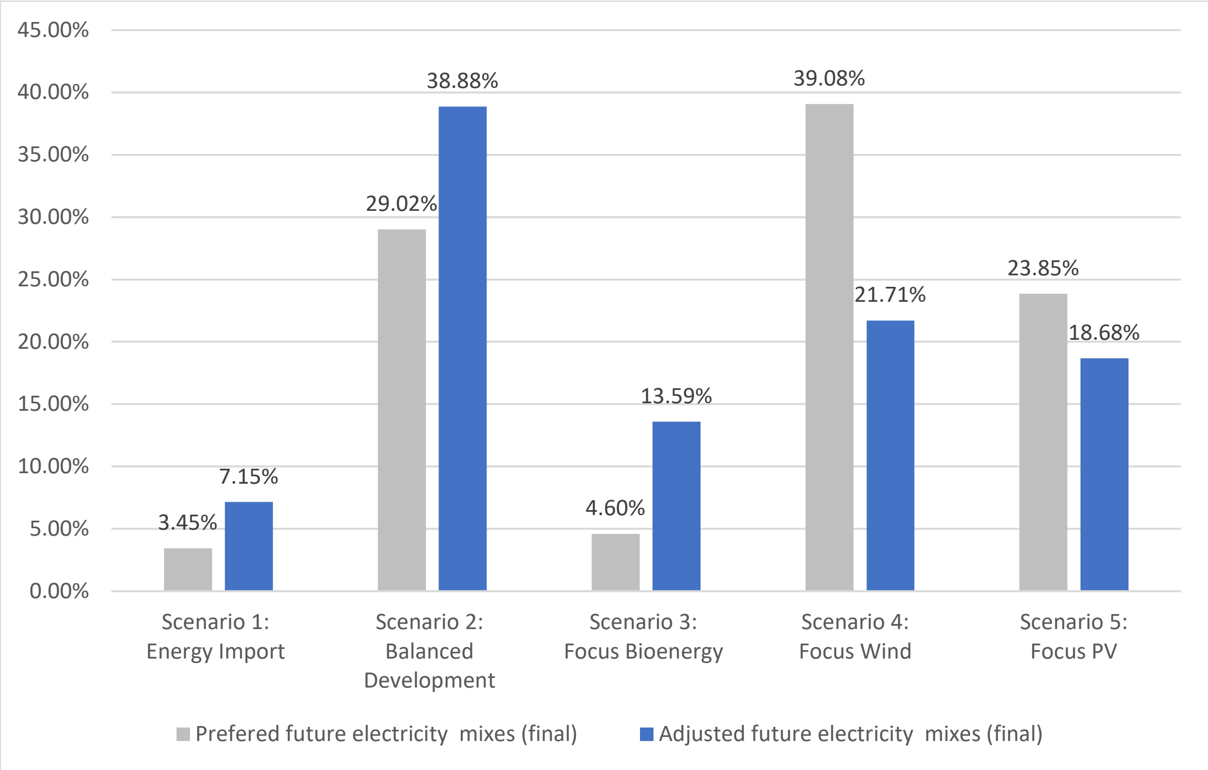

Figure 20: Desired future electricity mixes of the sample after providing additional Information, including preferences weighted by political affiliation

Figure 20 shows the preferred electricity mixes after the reconsideration of scenario choice by some participants as well as the results adjusted depending on political attitudes. When assessing the adjusted data based on political preferences, the scenario *Balanced Development* achieves the highest rating out of all scenarios with 38.9% of Bavarians preferring this scenario. This scenario is highly supported across a wide political spectrum. This approach seems to strike a balance between substantial renewable energy development and minimising local impacts of the energy transition for many. The focus wind scenario did decrease significantly to 21.7%, marking the biggest difference between the primary and adjusted samples. This can be traced back to the bias of the sample towards environmental-orientated parties, which make up a significantly smaller proportion in the Bavarian political landscape. After weighing the results, the Focus wind scenario now aligns closer with the PV scenario, which also decreased, although to a lesser extent. The bioenergy scenario increases substantially to 13.6% due to the substantial number of conservative and right-leaning individuals preferring this option. The energy import scenarios achieve the lowest number of votes even when accounting for political biases. However, it must also be mentioned that the majority of respondents selecting scenario 1 did not indicate their political preferences and could therefore not be taken into account when weighing the results according to political preferences.

Supplementary energy supply

Another important factor to consider when evaluating the acceptance of future energy supply is the need for supplementary energy sources. These additional forms of energy supply will be required even when achieving a scenario with 100% domestic renewable energy generation due to the energy demand from other sectors such as industry (e.g. for synthetic naphtha & methanol) and aviation (i.e. synthetic kerosine). Furthermore, substantial quantities of hydrogen will be required to operate gas power plants in a climate-neutral manner. It can be anticipated that the capacities of electrolysers as well as RE generation will not be sufficient to meet the demand for this application purpose as stated by an industry expert. Therefore, it can be assumed that despite substantial renewable energy development additional forms of energy supply will be required. Those additional means of supply include further electricity imports, imports of synthetic energy carriers, nuclear energy, carbon capture and storage (CCS) or future technologies.

The survey results on preferences for future energy strategies reveal varied levels of support for the different options. Interestingly, the most popular option was the development of future technologies, which gathered 199 votes across different age groups, gender, educational levels and political attitudes. A provided example for future energy systems was fusion energy. The results indicate that the majority of individuals are very optimistic about the development of a new form of electricity generation with fewer perceived impacts. It should also be noted that 62% of participants selected an additional option indicating that they do not see this option as a definitive solution. Nonetheless, the number of individuals, which can be mostly associated with environmental-orientated parties, selecting only this option is surprisingly high. The technology of nuclear fusing also receives growing support from political stakeholders on the federal level which shows through increasing funding of research on this topic. The current Bavarian government has officially launched the "Mission Nuclear Fusion," to position Bavaria as a pioneer in this "energy supply of the future" (StMWK, n.d.). This development is also positively evaluated from the perspective of an association representing multiple economic and industry stakeholders. However, it was also underscored that researching this technology can be regarded as an additional measure towards climate neutrality but should not replace current efforts in renewable energy development.

Secondly, electricity imports have high levels of acceptance, with 149 participants (39.6 %) selecting this option. For the attitude towards this option, there is a notable correlation between political affiliation (p-value = 0.006; Cramer's V: 0.22) and age (p-value = 0.006; Cramer's V: 0.23). Participants identifying with right-wing parties uniformly opposed electricity imports, with conservatives also selecting this option significantly less frequently. In contrast, individuals with environmental inclination view electricity imports as more favourable. Younger participants also showed a significantly higher tendency to see electricity imports as a crucial form of supplementary energy supply. The import of synthetic energy carriers was also a popular choice, receiving a total of 107 votes. Regarding this technological option, a gender disparity was evident, with men showing a tendency to select this option more often (p-value < 0.001; Cramer's V: 0.17).

Nuclear energy receives a moderate level of support, with 62 participants selecting this option. Considering the strong focus on nuclear energy in the past in Bavaria this result can be regarded as relatively low. In contrast, when evaluating political acceptance, the current government of Bavaria repeatedly states that they consider the phase-out of nuclear energy a mistake, which should be reversed. In contrast, more environmentally orientated political actors view this technology as not relevant for the future energy system and support the phase-out. The survey results also indicate that the majority of members of the public support the decision of the federal government of Germany to refrain from using nuclear power. However, in the case of nuclear energy, political affiliation plays a significant role in shaping opinions (p-value < 0.001; Cramer's V: 0.55). Right-wing, conservative, and liberal individuals seem more supportive of nuclear energy, whereas those with environmental views are overwhelmingly against it, with 98% voting against nuclear energy.

CCS relying on fossil fuels received a relatively low acceptance with a total of 48 individuals selecting this technological option. The approval of CCS technology is significantly age-related, with younger individuals being more in favour of its adoption (p-value = 0.002; Cramer's V: 0.25). Lastly, a total of 51 participants remained unsure about their preferred energy strategy, indicating some uncertainty within the group. The option to remain unsure was selected slightly more frequently by female participants in the survey (p-value = 0.002; Cramer's V: 0.18)

Origin of energy imports

To further assess how a socially acceptable climate-neutral energy supply system in Bavaria should look, it is essential to consider the origin of energy imports. The majority of participants preferred sourcing the supply within Germany, with 218 votes (40%), closely followed by the option to source electricity through the European grid, summing up to 188 votes (34%). Both options have been regarded as essential by political and economic stakeholders. Based on the currently very strong reliance on electricity imports from German states and through the European grid, these numbers can be regarded as surprisingly low. The third most popular choice with 169 votes involved not relying on imports, indicating a sufficiency approach. This approach aims at a significant reduction in energy demand and a substantial increase in renewable energy development, thereby allowing the abandonment of energy imports. However, most participants who opted for this approach also selected other options, suggesting they view it as a supplementary action. Participants who favoured the sufficiency approach were more likely to associate themselves with an environmentally oriented rather than a right-leaning, conservative, or liberal party (p-value < 0.001; Cramer's V: 0.28). This option was also statistically more likely to be preferred by women (p-value < 0.001; Cramer's V: 0.17). Notably, seventy-three individuals exclusively selected the sufficiency option, indicating their preference for energy autarky as a desirable end goal. Interestingly, the autarky approach showed no statistically significant correlation with either participants' political orientation or gender.

Additionally, 84 participants (15%) indicated support for importing energy from Northern African countries with a tendency of men to support this approach more compared to females (p-value < 0.001; Cramer's V: 0.21). According to an economic stakeholder, these approaches are primarily focused on exporting synthetic energy carriers rather than electricity. Even though this option seems not to have the greatest support from members of the public, this approach could prove to be of deciding importance if Bavaria wants to reach their goal of climate neutrality and even more so, if the aim is to hold energy-intensive industry in Bavaria. The support of economic stakeholders is shown in the first pilot projects with Bavarian companies such as Siemens Energy, which have been initiated recently to develop hydrogen clusters in these regions, where the geographical circumstances for renewable energy generation are more favourable compared to Bavaria. How these projects will evolve in the future and how economically effective synthetic fuels can be produced remains unclear. Lastly, it was also mentioned in an interview that importing energy from the international market (i.e. not Europe or North Africa) will be of critical importance as the aim should be to diversify trade relations to reduce dependencies on trade partners. This could include in the future countries like Australia or Chile. However, looking at the results of the survey this option cannot be associated with high acceptance levels as it only received 42 votes which is equivalent to 8% of participants.

4.2.2 Community acceptance

The following chapter will present the findings regarding social acceptance on the local scale. The section will be structured similarly to the Integrated Acceptance Model developed by Hübner (2023). This section distinguishes between the most prominent acceptance variables attitudes towards the energy transition, impact on residents and ecosystems, planning process, distributional justice and economic aspects and social norms. The technological focus of this section will be primarily on photovoltaic (PV) sites and wind turbines, as these were the main subjects of discussion in the interviews. Moreover, these technologies are the most critical for achieving Bavaria's climate targets. However, some insights related to bioenergy will also be discussed where relevant.

4.2.2.1 Attitude towards the energy transition and renewable energies

Previous research has underscored the importance of attitudes towards renewable energy technologies as a predictor of community acceptance (Ruddat & Sonnenberger, 2017). As previously laid out survey results indicate a high level of acceptance for the energy transition and renewable energies on a general level, which can also be partially used as an indicator for a general supportive attitude by the majority of citizens on the local scale. Supporting this presumption are the findings of an interview partner stating that higher acceptance levels are not only evident regarding general attitude but also translate to a more favourable perspective on renewables in the siting decision process and local project planning. This holds true not only regarding acceptance levels of the public but especially for local political acceptance. One interviewee reported that he observed a notable shift in attitudes towards renewable energy projects especially within municipalities and among decision makers. In previous years municipalities tried to avoid new energy projects in their administrative area to circumvent possible tensions. In contrast, today, many mayors and other political stakeholders actively seek the implementation of new projects, a condition which was described as “previously unthinkable”.

Similar to the broader acceptance of the energy transition, the key driver behind the rising support at the local level has been the energy crisis triggered by the Russian invasion, which has significantly increased acceptance among local political stakeholders. Additionally, as the energy crisis negatively impacted economic stakeholders, the awareness of the importance of the energy transition on a local scale increased. This shift led these economic stakeholders to actively support the development of renewable energy projects in their local areas, aiming for a more reliable and cost-effective energy supply. The influence of larger companies on the regional economy further amplified the growing acceptance among local political stakeholders, reinforcing the ongoing upward trend. This observation clearly shows the interconnectedness of different acceptance dimensions on the local scale.

One crucial aspect influencing acceptance on the local scale is familiarity with the technology. Previous research by Wolinski (2007) reported a u-shaped development of attitudes towards wind energy in different phases of the project planning with high levels of acceptance towards the technology before the project planning, a more negative attitude during the actual project development phase and more positive attitudes once the technology is in operation. During an interview, it was stated that this theory is also evident in the case of RE development in Bavaria especially for wind energy. However, it was also mentioned that attitudes in different stages are strongly dependent on familiarity with the technology. Therefore, it can be stated that the trajectory of this change of attitudes strongly correlates with existing technology development. To give an example, in regions where no wind turbines have been installed yet, there are a lot of fears and perceived risks associated with wind energy, which leads to a strong downward trend of acceptance levels when first project development plans are announced. If, however, there are existing turbines in the vicinity, this decrease in attitudes can be observed less, as many uncertainties such as noise emissions or shadow flicker have already been resolved.

Furthermore, the impact such as on the landscape might be perceived as less striking due to the familiarisation effect. This hypothesis is supported by the assessment of the perceived landscape impact of bioenergy crops such as corn. While several years ago the impacts of this practice have been heavily discussed in public media, the results of this survey indicate that it is only a minor concern regarding this technology. Referring back to the observed U-shape by Wolinski (2007), it appears that the growing confrontation with a specific technology decreases negative attitudes and behaviours, resulting in the acceptance curve becoming more linear without substantial variations in acceptance levels during the different site development processes. In other words, "the first project is always the most complex". However, it is important to consider that this only holds true until a certain threshold is reached, and the acceptance level decreases again. It was mentioned by the interviewed municipality, that they actively participate in wind energy planning to keep it within reasonable limits and to avoid being encircled.

For the context of Bavaria, the familiarisation effect can have both positive and negative implications regarding wind energy. A positive aspect is that regions with higher wind speeds are already more familiar with wind turbines, making further developments in areas, where they are the most economically effective, and easier to implement. On the other side, substantial areas which have not been exposed to wind turbines yet will need to be developed, and these regions are likely to face more resistance and negative attitudes. The interviews did not provide further insights into how this effect might influence the development of ground-mounted PV systems and bioenergy plants

While the energy crisis offers a broad explanation for the overall trend in increasing local acceptance of renewable energy projects, it is crucial to consider local circumstances that can significantly influence the attitude towards the energy transition. In some regions, there are higher proportions of individuals who hold contrarian views on political topics and hold deep scepticism toward initiatives from the federal or state governments. In these areas, any project development is substantially more likely to face fierce resistance. Additionally, local media coverage plays a pivotal role in shaping public opinion. While on a general scale, only minor influence is attributed to media coverage, on a local scale it can exceed stronger influence as stated in one of the interviews. Depending on the journalist, newspaper, and specific circumstances, media coverage can either positively or negatively impact local acceptance. One interviewee specifically criticized the superficial media reporting in certain cases and the occasional lack of thorough fact-checking by journalists. For instance, in one case, it was inaccurately reported that wind turbines are a major factor contributing to the decline of insects, which is not an argument supported by scientific evidence. Such misinformation can quickly be picked up and reproduced online by citizen initiatives opposing renewable energy projects.

It is also crucial to note that regardless of general acceptance some technologies are still substantially more likely to face opposition than others. While the survey has shown higher support levels for wind energy than for bioenergy and ground-mounted PV systems, this is oftentimes not observable in practice. Despite the favourable trend for wind energy in the last years, local acceptance presents a considerable issue for this technology. In an interview, a project developer noted currently "every project [that he is involved in] has a citizens initiative". Here, it must be mentioned that the sample size for wind energy in the past years is very small, with only a small number of projects being realised. Therefore, it is hard to define a notable trend. In contrast, while the survey results show a generally more critical perspective towards ground-mounted PV systems, local opposition appears to be of smaller concern for the project development perspective.

4.2.2.2 Impact on residents and local ecosystems

The impact of renewable energy on nature and residents is significantly influencing local acceptance. Concerns regarding the impacts on residents in the vicinity of ground-mounted PV systems are mainly about land use. Particularly in predominantly agricultural areas, new developments spark debates among local stakeholders and the public over using land for food production versus energy production. Another concern residents express when they are informed about a new project development is the potential glare from PV panels influencing the safety of car traffic on roads nearby and the disturbance of the landscape. For wind energy, the main concerns by residents are noise emissions and shadow flicker as well as visual impacts on the surroundings. Furthermore, concerns related to construction processes, especially regarding heavy transport and the crane area, are regularly formulated. These issues are predominantly mentioned by individuals before project implementation, rather than presenting a complaint after the project has been developed, highlighting the influence of the previously mentioned familiarization effect.

Regarding the impact of RE on local ecosystems, the effect of wind turbines on birds of prey was frequently mentioned in past years as a concern for further wind turbine development. More recently, however, it can be observed that this particular nature conservation concern is reported less frequently in opposition to such projects. Interestingly, this shift coincides with changes to spatial planning regulations and the clarification of legal uncertainties of wind energy development across various governance levels. For example, earlier regulations required extensive overflight analyses of predatory birds particularly red kites to avoid bird strikes. The substantial overall increase in population numbers in Bavaria over the last years resulted in a situation where large areas were evaluated to be unsuitable for wind turbines. The updated regulatory framework now prescribes a 500-meter exclusion zone around the nests of protected birds of prey, providing a much clearer guideline compared to relying on overflight analysis. The observation of a bypassing protected bird can therefore not be implemented in the planning process as an exclusion criterion. Following these regulatory changes, the concerns about red kites from members of the public seem to decrease significantly. Although it can be argued that the decrease in concerns can be traced back to the increasing population numbers, these observations indicate that wind energy opponents may have exploited the uncertainties in the previous regulatory framework to their advantage, effectively instrumentalizing nature conservation for their interests. This presumption was also shared by a nature conservation stakeholder.

Although these elaborations suggest the instrumentalization of ecological issues in some cases, the impact on wildlife should still be considered a crucial aspect of community acceptance. These concerns depend on the particularities of different technologies as well as the specifics of local ecosystems. From an environmental stakeholder perspective, the installation of PV systems can generally have a positive impact on biodiversity, for example through the conversion of rapeseed monocultures to grazing areas or the implementation of wildflower strips as compensation areas. Communicating these positive impacts of PV installations can foster more positive attitudes in the general public. Nonetheless, this process also requires careful site selection to avoid disrupting valuable biotopes, making broad generalisations difficult. In Bavaria, there are numerous areas next to roads and highways allocated as compensation areas for previous infrastructure projects which have formed ecologically valuable biotopes. Concentrating further developments of ground-mounted PV on available spaces next to (rail-)roads, which is the current practice due to public funding regulations and to minimise landscape impacts, can in certain cases threaten the integrity of those valuable ecosystems. Here an appropriate spatial planning procedure can help avoid such ecological issues for further developments

The incorporation of these aspects is substantially more complicated for wind energy, as planning processes take place on the regional instead of local level. Therefore, negative implications for small-scale ecosystems such as ponds or old-grown trees are more complicated to circumvent. To avoid impacting local biotopes, from an environmental perspective, it would be advisable to have more flexibility in the concrete siting decisions. However, it must also be noted that spatial planning authorities and project developers need to find a balance between a wide range of interests, such as economic aspects i.e. high enough wind speeds, road access, ownership rights and compliance with the Bundesemissionsschutzgesetz (federal emission control act) making it difficult to consider the interests of all stakeholders. In contrast, technical solutions to minimise ecological impacts are easier to implement. In particular, collision-avoiding systems help to reduce the impact on avian wildlife. For the protection of bats, it is also advisable to install preventative measures which shut down turbine activity in case of low wind speeds during night times as these are periods when these animals are the most active. Since these shutdowns are only necessary at certain times of the day and during low wind speeds, the economic consequences can be regarded as relatively small.

An important factor influencing the acceptance of wind turbines is their perceived impact on forest ecosystems. In Bavaria, spatial planning regulations and required distances from settlements often lead to wind turbines being developed in forested areas. The website of a citizens' initiative against wind energy in Altötting (XX) highlights clearcutting as a major concern, with particularly negative effects on local ecosystems. However, this perspective overlooks two key points. First of all, what is considered natural and ecologically viable forest areas in Bavaria oftentimes consist of monocultures aimed at maximising timber production. According to an interview partner, the concept of a natural, untouched forest is something most people cannot fully grasp, primarily because examples of such ecosystems are scarce in Bavaria today. If ecological impacts are of significant concern, the discussion should focus on the widespread forestry practices including clearcutting, rather than the impact of wind turbines. For context, around 300 hectares are deforested annually in Bavaria due to forestry activities, whereas a wind turbine requires only 0.3 hectares. Secondly, climate change presents a threat to forests in Bavaria which is arguably more significant than local clearcutting. Increasing temperature levels and changing participation patterns cause high levels of stress for trees which makes them vulnerable to bark beetle infestations leading to substantial forest areas dying off. As mentioned by an interview partner, the current forest composition consisting mainly of spruce trees cannot be sustained given the changing climate conditions resulting in a timber boom in the coming years. The scale of these issues is likely to be much greater than the impact of wind turbine development.

4.2.2.3 Procedural aspects

The procedural aspects are of deciding importance for the community acceptance of RE development in Bavaria. This aspect includes trust in involved stakeholders, procedural justice as well siting decisions.

Trust

To assess the importance of trust, the questionnaire asked participants how important it is for them that local actors, such as municipalities or public utility companies, are involved in renewable energy projects in their area. The responses indicated a strong preference for local involvement in renewable energy projects. 73.9% (277 respondents) considered it “very important,” and 18.1% (68 respondents) selected the option “important.” A significantly smaller proportion of participants rated it as “neutral” (3.2%), “rather unimportant” (2.7%), or “not important” (1.6%). Further statistical analysis revealed that participants with an educational background in craftwork qualifications placed more emphasis on the involvement of local actors than those with other educational backgrounds (p-value < 0.001; Cramer’s V: 0.20). Furthermore, the political attitude also has a significant influence with individuals identifying with right-wing parties having a higher tendency to have a neutral stance (p-value < 0.001; Cramer’s V: 0.23). Conservatives predominantly rated it as “very important” or “important.” Participants preferring environmentally orientated parties demonstrated a clear tendency to rate local involvement as very important, with 85.1% selecting this option.

The importance of trust as a factor for acceptance was also discussed with several interview partners using the example of the wind park in Altötting. This wind energy project stands out as one of the few cases receiving attention beyond the local level and is an example of strong resistance from the public regarding the development of the technology. One possible explanation for the opposition is mistrust in the project developer, Qair, a company based in France, which is developing renewable energies across Europe. One possible concern could be that the foreign investor might prioritize maximising profits over local environmental impacts. Furthermore, it could be interpreted as local economic value leaving the region rather than benefiting the communities, which are affected. However, despite the project being developed by an external investor, several key regional political and economic stakeholders advocate for the project and are involved in the development process. This suggests that support and involvement from local actors alone is not sufficient to ensure community acceptance. Another aspect to consider, which was mentioned in several interviews is, that investors originating outside of the region of the specific development will be of deciding importance to realise large-scale RE projects due to the substantial investment costs.

Procedural justice

Clear and transparent communication regarding renewable energy projects was described as one of the key aspects to ensure local acceptance in interviews. The questionnaire explored how important participants found being informed and involved in the planning process of renewable energy projects and came to similar results. The survey data showed that 41.3% (155 respondents) considered it "very important", 37.1% (139 respondents) found it "important", while 11.2% (42 respondents) had a "neutral" stance. In contrast, 7.2% (27 respondents) rated it as "rather unimportant," and 2.9% (11 respondents) selected "not important." Interestingly, younger individuals tend to adopt a more neutral stance on this issue, while older individuals place greater importance on being informed and involved (p-value = 0.022; Cramer's V:0.17). Although no statistical correlation was found regarding political affiliation evaluating the cross-tables showed a slight tendency of right-leaning and conservative individuals to select "important" or "very important" compared to the environmentally conscious group, as evidenced by the expected values in the cross-table analysis.

While transparent communication should always be employed, the possibilities to involve local stakeholders and citizens in the planning process come with certain complexities and vary also depending on the technology. Using participatory approaches for wind energy planning can be regarded as challenging to implement. However, when municipalities have expertise in developing wind turbines, their contributions can help find suitable outcomes. For example, for the municipality of Speichersdorf, it was clear that additional priority areas for wind energy would be designated in the new regional plan on their administrative area. The municipality proactively evaluated possible locations which were provided by the regional planning authority and made several proposals laying out their preferences. This course of action allows better integration of the priorities of local political stakeholders and indirectly also the public as local stakeholders. This also brings benefits for the planning authority as they oftentimes have a better overview of the special characteristics of proposed sites. This proactive approach can help to prevent the encirclement of a municipality with wind turbines or increase public value by using communal land. However, it must be mentioned that this requires expertise and also the proposals of the municipalities must not be adhered to. In the case of PV systems, it is much more common that the municipality is actively involved in planning processes as the planning autonomy is at the municipality and not the regional level. Therefore, the municipality can directly propose suitable areas to project developer according to their preferences. This also allows participatory mapping approaches of local political stakeholders in cooperation with other stakeholders as well as residents.

Siting decisions

The acceptance of renewable energy can also be influenced by the preferred allocation and siting of renewable energy installations. To assess the generally preferred distribution approach the survey results asked participants about the optimal distribution of renewable energy projects across Bavaria. A substantial number of individuals (37.3%) believe that renewable energy sites should be concentrated in regions with high potential, such as placing wind turbines in areas with particularly high wind speeds. Meanwhile, 23.7% favour an even distribution of renewable energy projects across all districts of Bavaria, as far as possible. In addition, 17.9% of respondents suggest prioritizing the development of renewable energy in locations with high energy consumption, such as urban areas, their surrounding regions, or near industrial zones. A smaller group, making up 9.6% of the sample, supports focusing on structurally weak or environmentally burdened areas, such as those along highways. Additionally, 8.0% of participants selected "other option", which means in most cases that they indicated through the text entry that they would prefer a combination of several approaches.

In the exchange with economic stakeholders, it was made clear that the development of renewable energies in all regions of Bavaria is necessary to achieve the goals of the energy transition and solely relying on wind energy in the Northern Regions of Bavaria will not be sufficient. As specific regions of Bavaria are not suitable for wind energy development, these areas should prioritise the development of ground-mounted PV systems and bioenergy.

4.2.2.4 Distributional justice and economic aspects

Distributional justice refers to the perceived fairness of the outcomes of the RE project and how costs and benefits are shared. The previous paragraphs have made it clear that all Bavarians will inevitably encounter some form of renewable energy generation, which may bring certain negative impacts at the local level. Therefore, it is essential to ensure that the benefits of these projects are also shared with the affected citizens. Numerous interviews have confirmed that financial participation is a crucial tool for increasing acceptance at the local level. On the federal level, the EEG (§6) recommends that operators of wind energy and ground-mounted PV installations provide financial compensation to the affected municipalities based on the electricity generated. Recently, at the state level, it was announced that a new law would be introduced to mandate the financial participation of citizens to further enhance acceptance. This development underscores the growing emphasis from political stakeholders on ensuring that local communities benefit from renewable energy projects. Some municipalities already make citizen participation a requirement for their approval of the project.

The survey data mostly supports the impression of the interview partners regarding the importance of personal benefits. When participants were asked if personal benefits of any kind would influence their acceptance levels, only a small proportion of participants (6.7%) stated that their acceptance would be influenced by personal benefits and that they are not interested in renewable energy projects in their vicinity. In contrast, 22.7% confirmed that a corresponding personal advantage would positively influence their acceptance, while 17.3% of respondents indicated that their acceptance would depend on the specific technology and personal benefit involved. The majority, constituting 52.5% of the sample, expressed that they would accept renewable energy projects regardless of any personal benefits. Further analysis shows a comparatively strong correlation between political parties and the perceived importance of personal benefits (p-value < 0.001; Cramer's V: 0.34). Individuals leaning towards environmental-focused parties have a higher tendency to accept renewable energies regardless of personal benefits. In contrast, participants identifying with conservative parties are significantly more likely to either state that financial compensation would influence their attitude towards renewable energies or is dependent on the specific technology or compensation. The majority (57.4%) of those leaning towards right-wing parties state that their acceptance would not be influenced by personal benefits followed by 28.6% stating that the implication of such measures would depend on the technology or benefit. Furthermore, education levels showed significant correlations for this question (p-value = 0.016; Cramer's V:0.16). Individuals with higher education levels (such as those with a university degree or higher technical qualifications) are more likely to state that their acceptance would be influenced by personal benefits. In contrast, individuals with lower education levels display a more balanced distribution of answers.

There are several ways citizens can economically benefit from renewable energy projects, each with their respective advantages and drawbacks. The primary method of citizen participation currently employed involves direct investment in RE projects. These investments generate a return on investment through the sales of electricity. In some cases, additional investments from citizens can also help the municipality to fully own a RE project, thereby fostering a regional value chain and ensuring that economic benefits remain in the community. While the concept of having local co-ownership can be very beneficial for local acceptance levels, there is an important factor to consider. These models of co-ownership often require minimum investment sums, which can exclude vulnerable groups from participating. This method is most attractive for individuals who have "several thousand euros" at their disposal for investing in these RE infrastructures, which excludes a large proportion of citizens. In addition, it should be considered that larger RE infrastructure projects, such as wind farms, require very high initial funding which cannot be covered solely by the municipality and its citizens. Therefore, completely rejecting external investors is oftentimes not a realistic approach for the successful implementation of RE projects. However, even when an external investor is involved, they should always provide opportunities for citizens' investment to improve the acceptance levels. As stated by a project developer, this practice slightly increases the complexity of project planning but is "not rocket science" and is becoming increasingly common practice.

Another form of economic benefit aims to directly reduce electricity costs for all households in the municipality, potentially offering equitable benefits for all citizens. However, current regulatory frameworks pose significant challenges to effectively implementing this approach. One proposed solution aims at deducting network charges, which currently constitute over 20% of the electricity price (Bundesnetzagentur, n.d.), from the electricity bills of residents if the municipality supplies more electricity to the grid throughout the year than they consume. This approach constituted the opposite of the current system, where network charges are influenced by regional RE development. As a result, areas that generate significantly more electricity than they use face higher electricity costs due to the need for more extensive grid reinforcements. Consequently, residents near RE sites experience two negative impacts: higher costs and local impacts of renewable energy sites. Implementing this innovative approach could enhance acceptance of existing RE sites by reducing costs for residents, while also improving acceptance for implementing more renewables in regions with low RE capacity due to the prospect of reduced electricity bills.

Other economic benefits of renewable energies which should not be overlooked are indirect forms of income for the municipality including tax revenues and lease agreements for projects developed on municipal land. These additional means of income can be used to reinvest in public infrastructure. Mentioned examples of investments in local infrastructure are new sports halls for schools, reduced fees for kindergarten or the development of new walking trails with benches making the area more attractive. Similar to the second described method, this form of economic benefit is advantageous for all citizens in the municipality.

However, these economic benefits also have their limitations. An interesting dynamic between stakeholder acceptance and public acceptance can be observed in some regions with energy-intensive industries. As previously noted, industrial stakeholders generally show high levels of acceptance of renewable energy (RE) development, as it can contribute to lower energy costs and reduce their dependence on external energy supplies. Consequently, these stakeholders often advocate for further RE expansion, which can also lead to increased political support. These companies also positively impact regional value chains and significantly strengthen the local economy. As a result, the economic situation in these regions is generally strong, making incentives such as lower electricity costs or increased municipal revenue less compelling. Therefore, while local stakeholders and politicians are supportive of RE development, public acceptance can remain low, as residents do not feel the necessity to accept changes to their environment. As one interviewee put it, “They can afford such a position”. In addition, legal objections against renewable energy development are also tied to significant costs which make them more accessible to individuals with a stronger economic standing. A similar situation occurs in regions with high income from tourism, although stakeholder acceptance and political acceptance tend to be lower under those circumstances as well.

Another crucial aspect of increasing acceptance of renewable energy projects locally is ensuring that the generated electricity benefits residents. For instance, powering a district heating network using locally sourced electricity constitutes an example of this “perceptible use”, making the positive impacts of renewable energy more tangible resulting in higher support levels. Other approaches might include charging stations for electric vehicles with discounted rates for residents or the installation of electrolysers which can provide hydrogen for public transport or other local uses. This sector coupling strategy adds complexity to the project development but can also prove the economic viability and usefulness of renewable energy development. This method of providing benefits to locals near RE projects can be described as innovative, and further approaches should be developed to further assess the potential of this concept.

4.2.2.5 Social norms

The interview with the municipality of Speichersdorf indicates the strong influence social norms can have on the local acceptance of renewable energies. In this specific case, the public appears to have high levels of confidence in the local political leadership, which is advocating for the further development of renewable energies. This is evident from the fact that the current mayor prioritized the energy transition in his election campaign and was voted for by an absolute majority in the first round of elections. Furthermore, very high acceptance levels were observed in the development of renewable energy projects, with no objections regarding the installation of new wind turbines and a large-scale ground-mounted PV system. For the inauguration of the PV site, even a small festivity was organized with numerous individuals from the municipality attending. The decision to further develop wind energy in the municipality area was not met with resistance as reported for most other cases in Bavaria. This indicates that the energy transition has become identity-forming for the municipality creating a social norm to support renewable energy development. It can be assumed that this trend is further reinforced through the positive media reporting and awards such as the best-practice example for citizen engagement through the association C.A.R.M.E.N. e.V., which constitutes a central network for advancing the energy transition in Bavaria.

4.2.3 Market acceptance

This chapter will explore the market acceptance of renewable energy implementation and future electricity mixes in Bavaria. It is important to note that there is a significant overlap between market acceptance and stakeholder/political acceptance at a general level. To avoid redundancy, aspects already covered in Chapter 4.2.1 will not be repeated here.

4.2.3.1 Energy transition and renewable energy development

As a general assessment, the energy transition and implementation of renewable energies in Bavaria receive high market acceptance from households to organisations and investors implementing the technologies. Especially for insurance and investment companies, developing renewable energies and other aspects of the energy transition such as developing new grid connections is an increasingly important division of their business. Furthermore, renewable energy development can be described as the only viable solution for Bavaria's current energy supply system, which is in a precarious state due to its heavy dependence on imported electricity and energy carriers for its industry as well as high electricity costs. While this holds for most states in Germany, this is a particular issue in Bavaria as it was the federal state with the strongest focus on nuclear energy. Following the phase-out of nuclear power plants, the resulting gap in energy supply could not be compensated by increasing the generation of electricity from renewable sources. Furthermore, the political decision to increase regulatory hurdles for wind energy a decade ago, which effectively stopped further advancements, also presents a significant issue for the electricity market of Germany. The consequence of this one-sided development could be the separation of the German electricity market resulting in further increasing electricity costs for Bavaria. In a situation where the affordability of electricity is already described as "very poor", this could prove to be detrimental for large economic stakeholders relying on energy-intensive processes and overall, the attractiveness of the business location of Bavaria.

Given this circumstance, it is strongly advisable from industry and economic perspective to aim for an accelerated energy transition and swift development of renewable energies. From a technical perspective, switching towards using a climate-neutral energy supply is technically achievable for the vast majority of cases. Furthermore, using carbon certificates for emission-producing processes is common practice, but increasing costs for certificates are putting growing pressure on industrial and other economic stakeholders. However, it is also less appealing to reduce reliance on fossil fuels as long as it is unclear how electricity prices and the cost of climate-neutral energy carriers will develop in the future. This leads to the current situation where an increasing number of stakeholders actively advocate for more local renewable energy development. If left unaddressed, it can be anticipated that existing industries may not immediately shut down their operations in Bavaria, but it reduces the willingness of companies to reinvest in their sites, which creates a long-term issue. Furthermore, it is less attractive for companies to settle in Bavaria, which hampers economic development in the shorter term. Therefore, if the aim is to maintain a robust industrial sector in Bavaria, an accelerated energy transition and a rapid increase in RE development are essential. Achieving this goal will likely necessitate significant government subsidies and support during the transitional phase, to alleviate some of the financial burden on affected companies. On the other hand, history has shown that industry clusters tend to develop where energy is abundantly available at a low cost. The primary reason for the establishment of industry stakeholders in Bavaria was the high potential of hydropower and extensive timber resources. Given the dependency on external supply through imports of climate-neutral energy carriers to achieve the climate goals in the future and the anticipated costs of those, the question arises as to whether energy will come to the industry or if the industry will relocate to where those energy carriers will be produced. A key advantage for Bavaria in countering this potential industrial migration is the existing expertise and infrastructure.

While the market acceptance for renewable energies in Bavaria is at a very high level, two main aspects are hampering the economic effectiveness which is the lack of storage systems as well as grid reinforcements. To address the former issue, it is crucial to install battery systems to manage daily fluctuations, especially given the current reliance on PV systems. Several interview partners mentioned that they view current outlooks on the battery market as a positive indicator that will help achieve the necessary advancements. Furthermore, electrolysers are essential for longer storage periods and to supply the demand of the industry sector for this energy carrier. One benefit of the development of electrolysers is the presence of electrical engineering companies with substantial expertise in this area. One example is Siemens Energy, which has its headquarters in Munich and already has experience in industrial-scale applications of the technology. Secondly, the lack of grid development seems to be a more challenging issue for further implementation of RE, as it requires substantial time for the project planning and permission as well as significant monetary means. While network operators are obligated to provide renewable energy developers with a grid connection point, they have the authority to choose their location. In some cases where congestion of the local grid is already an issue, this assigned connection point can be 40 kilometres or more away making any project development economically unviable.

Next to stakeholder acceptance, end-user acceptance is also essential to allow further market penetration of RE technologies. Here the acceptance category of "support" indicates whether people would actively participate in the technology's development including the utilisation of the generated electricity. The survey results indicate a very high market acceptance for roof-mounted PV systems at the end-user level and considering this technology is applicable in most contexts, this option shows great potential for decarbonization efforts. For other technologies, it is necessary to make the technology accessible to the end-user. This can for example be the development of district heating networks which are powered by wind turbines in combination with large-scale heat pumps.

An interesting aspect of market acceptance is the willingness to incur higher costs, which the survey investigated for electricity, heat and synthetic fuels. The distribution of responses is shown in Table 6.

Table 5: Willingness to endure higher costs for various applications of renewable electricity

	Category 1: Not willing to pay more	**Category 2: up to 10% more**	**Category 3: 10% to 30% more**	**Category 4: more than 30%**
Electricity	99 (26.4%)	123 (32.8%)	121 (32.3%)	30 (8,0%)
Heat	86 (22.9%)	133 (35.5%)	119 (31.7%)	32 (8.5%)
Synthetic fuels	106 (28.3%)	135 (36.0%)	95 (25.3%)	33 (8.8%)

In general, it can be stated that the majority of participants are willing to endure higher costs for a climate-neutral energy supply meaning up to 10% or between 10% and 30%. The inclination for higher prices is the most present for climate-neutral heat supply, although there are only slight differences between the three categories. Given that electricity is a fundamental necessity for everyone, and the high costs associated with producing synthetic fuels, it's somewhat surprising that there is not a more significant difference in people's willingness to pay more for synthetic fuels. Using these findings to assess how to optimally make renewable energy accessible for end users using sector coupling, an approach aiming at providing climate-neutral heat supply through power to heat can be anticipated to be a reasonable solution while using it to produce synthetic fuels for individual use appears to be a less viable solution.

Further statistical analysis reveals significant differences in attitudes towards higher costs based on gender and political preferences. Specifically, men were slightly less likely to express a willingness to pay higher prices for renewable electricity (p-value = 0.015; Cramer's V: 0.18), heat (p-value = 0.033; Cramer's V: 0.17) and fuel (p-value = 0.002; Cramer's V: 0.17) supply compared to female participants. While gender differences were also present for other forms of energy supply, they were slightly higher than the set confidence interval. Evaluating the differences based on political preferences reveals a clear trend as individuals identifying with right-leaning, liberal and conservative parties are generally rejecting higher prices for renewable electricity (p-value < 0.001; Cramer's V 0.249), heat (p-value < 0.001; Cramer's V: 0.27) and fuels (p-value = 0.002; Cramer's V: 0.17). However, it must be noted, that there is still a substantial proportion of conservatives willing to accept an increase of up to 10% in contrast to members of the other two political categories. For participants preferring parties in the social-left category the most selected option is paying up to 10% more. Individuals who associated themselves with environmental-focused parties show the highest willingness to endure higher prices with the majority being open to paying 10-30% more and only 11.8% not accepting higher prices.

4.2.3.2 Future electricity mixes

Looking in the future it will be necessary to further develop PV systems especially wind energy while using bioenergy and hydropower more efficiently to stabilise the electricity supply. Further putting a strong focus on electricity generation from PV systems would entail very substantial demand for energy storage systems. As this would entail negative consequences for economic effectiveness, the scenario Focus PV is not recommendable from a market acceptance perspective. Regarding wind energy it has to be considered, that the spatial planning regulations in Bavaria can still be regarded as the strictest within Germany, making further adaptations of the regulatory framework a necessity to enable the economic potential of the technology. Furthermore, the duration of new planning processes, the lack of experience with permitting wind energy in Bavaria, the congestion of local grids and to some extent, the acceptance of the technology will most likely constitute considerable hurdles for further adoption of the technology. Although large areas are economically viable for the development of wind energy, the effects of the politically induced wind energy prevention through the 10H regulation in the last 10 years, will continue to affect the development of the technology for years to come. Therefore, it cannot be anticipated that the adoption of wind energy can reach the level proposed in the Focus wind scenario. Regarding bioenergy, the market acceptance is more multifaceted. From a plant management perspective, the acceptance can be regarded as very high as farmers are now seeing it as an additional form of income, which they rely on. From an energy supply perspective, bioenergy is also highly useful as it can be used under many circumstances and for sector coupling. However, from an electricity generation perspective, it is imperative to convert existing biogas power plants and build new power plants aiming at meeting peak time demand rather than constant electricity generation. Considering the increasing supply of wind energy and solar PV this will otherwise result in negative electricity prices, which should be avoided for ensuring economic effectiveness, occurring more often. Considering the growing emphasis on supplying peak demand as well as using biomass of other sectors, the focus biomass scenario should not be aimed at from a market acceptance perspective.

Next to these three renewable energies, the fourth central building block for a climate-neutral electricity supply will be imports of electricity and energy carriers. Regarding electricity imports, it has been stated by several interview partners, that even when assuming high RE development, Bavaria should rely on the German and European electricity markets to address the volatility of intermittent renewables and to improve economic efficiency. Although some of the imports of electricity will be balanced out by exports during high production, it can be anticipated that the sum of imports will exceed the exports. For the imports of energy carriers, hydrogen will be required for industry processes as well as gas power plants to supplement renewable energy generation. As producing hydrogen is an energy-intensive process it can be assumed that two-thirds of the demand must be supplied through imports. Further reliance on imports should be avoided as they cause dependencies on external decision-makers and result in higher costs. Considering these reasons, it can be stated that the energy import scenario should be avoided. Considering these factors, scenario 2 emerges as the preferred choice for industry and economic stakeholders as well as project developers, as it achieves the highest level of market acceptance.

5 Discussion

Whereas the preceding part was focused on reporting the results of the survey, the following section aims to interpret the findings regarding the social acceptance of the energy transition, renewable energy development and future electricity mixes in Bavaria while contextualising and comparing them with existing studies. Furthermore, the limitations of this research will be laid out.

5.1 Interpretation of research findings and comparison with existing literature

The observed trend of increasing acceptance levels resulting from the energy crisis is in line with quantitative findings from Wolf et al. (2022) investigating acceptance levels in Germany. The results of this study indicate that reducing dependencies on energy imports and increasing self-sufficiency are the primary reasons Bavarian citizens support the energy transition after accounting for the political preferences of the sample. These results are substantially different compared to the results of the AEE (2018) study, where fighting climate change was mentioned by 81% of participants as a crucial advantage of RE development compared to 68% stating that increasing independence of energy imports is an inherent benefit of renewable energy development. As this research has shown, this is highly dependent on the political views of an individual with conservatives prioritising energy independence while those associating themselves with an environmental-orientated party name fighting climate change as a primary reason. Unfortunately, the more recent AEE (2023) study did not include this question when assessing current acceptance levels of the energy transition as this would have allowed further investigation of whether there are differences in trends on the federal and the state level. The exact reason for the shift in focus is challenging to pinpoint, but it can be assumed that while climate change presents a more abstract and gradual threat, the energy crisis had immediate and tangible effects on daily life, particularly through significantly rising electricity and natural gas costs, as well as overall price inflation.

When considering the results for all evaluated technologies, roof-mounted solar PV is the most accepted form of RE, followed by hydropower, wind energy and biomass and lastly, ground-mounted PV systems. The AEE (2023) study comes to different conclusions for the case of Germany as their assessment names ground-mounted solar PV as the second most accepted form of PV after roof-mounted systems. The substantial difference in acceptance in both studies for ground-mounted PV systems cannot only be attributed to statistical variances but must be rooted to a certain degree in local specifics. One plausible explanation might be the substantial increase of (large-scale) PV systems over the past years has led to a situation where the scale of development leads to a reduction in acceptance as the environmental impacts are evident in most regions. As research by Cousse (2021) has shown, the acceptance of solar PV is linked to the size of installations and the initial high acceptance levels decrease to a level similar to those of wind energy when exceeding a certain size for a project. However, the findings of Ruddat & Sonnberger (2019) suggest even lower levels of acceptance for solar PV in Germany as depicted in Figure 21. While the number of individuals fitting in the protest category is slightly higher in the sample of this study, the proportion of individuals rejecting the technology is substantially lower. Furthermore, the willingness to actively support the development of ground-mounted PV systems is also more present in the sample of this study. It must be noted that their study aimed at investigating local acceptance of solar PV, which limits the comparability between the two studies. However, the telephone survey data Ruddat & Sonnberger (2019) relied on did not take into account whether residents are confronted with these technologies, equivalent to the approach of this study. Considering the findings of both the AEE and Ruddat & Sonnberger (2019) studies, the assessment of ground-mounted solar PV in this research reflects a moderate position, suggesting that the results are grounded in a realistic interpretation of the data.

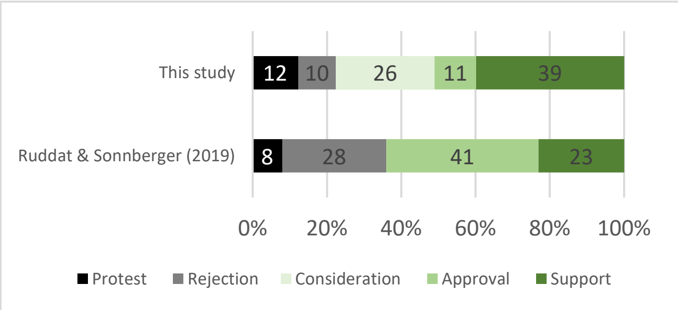

Figure 21: Comparison of acceptance levels of solar PV with results from previous studies conducted in Germany

Regarding wind energy, the study of Ruddat & Sonnberger (2019) assesses the acceptance levels in Germany to be significantly lower compared to the results of this study for Bavaria (Figure 22). This can partly be attributed to the fact that their data sample is from 2015, meaning that a large proportion of the population has not been subject to wind turbines in their vicinity, resulting in high levels of uncertainty and concerns. In addition, the sample dates back to before the energy crisis which has significantly increased acceptance levels. When comparing the findings to the more recent study by the Fachagentur Windkraft (FA) (2024) the results are considerably closer aligned with this study. One clear difference is that the consideration category was not present in their assessment. Comparing the results it can be anticipated that a considerable proportion of the approval category in the FA (2024) study would fit into this category. In addition, the support category is substantially larger compared to the FA (2023) study, which most likely stems from the method used as outreach for this study leading to a sample which is more involved in the development of renewable energies compared to the overall population in Bavaria. This aspect will be further discussed in the limitation section.

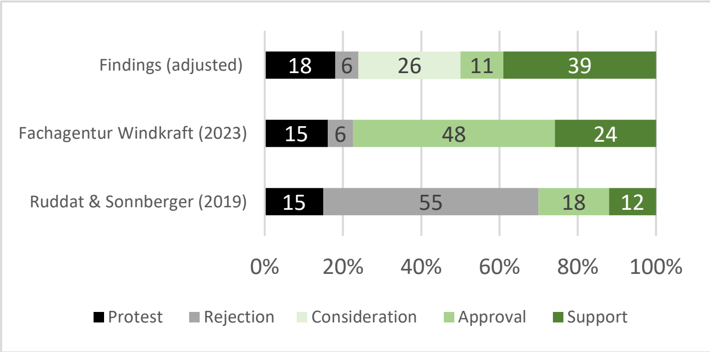

Figure 22: Comparison of acceptance levels of wind energy with results from previous studies conducted in Germany

Previous research primarily investigating the impact of socio-demographic criteria on the acceptance of RE technologies has drawn attention to the importance of age and education in Germany (Bertsch et al., 2016: Scheer et al. 2013). Statistical analysis of the present data sample shows correlations regarding age only for ground-mounted PV systems and for the evaluation of certain issues of a technology such as the landscape impact of bioenergy or the ecological impact of wind turbines. Similarly, the assessment of education as a factor influencing acceptance reveals that it generally has only a minor impact on acceptance levels. However, there is one exception in the case of wind energy, where the effect is more pronounced regarding the overall acceptance of the technology as well as the perception of noise emissions, shadow flicker and deconstruction constituting concerning issues.

In contrast to the socio-demographic factors of age and education, the political orientation of an individual had the most significant impact on acceptance levels and perceptions of challenges associated with a technology, which previous acceptance studies in Germany did not investigate (Ruddat & Sonnberger, 2019; Zoellner et al., 2008; Bertsch et al. (2016). In fact, previous research emphasising the political influence on support for decarbonisation of the energy system in the United States found bipartisan support for decarbonised energy systems and favourable responses across the political spectrum (Horne & Kennedy, 2018; Miniard et al., 2020). This does, to a certain degree, contradict the results found in this study. While the data from this research does suggest that the further development of renewable energies is generally supported across the political spectrum, this support is heterogeneously distributed across individual technologies. While right-wing and conservative-leaning individuals are more supportive of bioenergy and hydropower, participants favouring environmentally orientated parties are significantly more likely to have a positive attitude and behaviour towards wind energy and PV systems. Similar statistical correlations can be found regarding the perceived challenges of each technology as well as the attitude towards mechanisms aiming at increasing acceptance such as financial participation or participation of local actors.

Furthermore, the results of this study suggest various factors influencing the acceptance of each technology and associated concerns. This contradicts the findings of Bertch et al. (2016), who make the generalised statement that landscape modification is the single most important factor influencing acceptance for all assessed technologies, including solar PV and wind energy. While landscape impact does present a substantial issue for wind energy as it ranks second among all perceived challenges, it is one of the least frequently selected options for ground-mounted PV systems. Interestingly, Zoellner et al. (2008) note that economic considerations are more relevant and while this seems to be a considerable concern for the development of wind energy especially for right-leaning individuals, the findings of this study show that economic concerns are the least out of all concerns regarding solar PV. The most likely explanation for this difference in results is that the cost of solar PV systems has dropped dramatically over the past decades making it the cheapest form of electricity generation in Germany (Kost et al., 2021). This trend also underscores the impact technological advancements can have on acceptance levels. Therefore, it is highly advisable to further enhance electricity storage capacities, as strain on the electricity grid remains the most notable concern for solar PV at present. One notable aspect regarding the perceived challenges of wind energy is the high number of participants being concerned about the dismantling of existing turbines. While this aspect was the most selected issue regarding wind turbines, a previous study investigating acceptance levels of wind energy in Bavaria conducted by Langer et al. (2016) did not even mention it as a perceived issue.

The integrated acceptance model (IAM) of Hübner et al. (2023) describing five main drivers of local acceptance for wind turbines provided a suitable framework for structuring and describing community acceptance of different renewable energy systems. However, one aspect which this framework does not include is the importance of familiarity with technology to ensure local acceptance. As the results indicate, this aspect is crucial for the continued development of renewable energies, particularly in the context of wind energy. Prior exposure to a technology can significantly help eliminate some of the stigmas associated with it. This is especially effective in alleviating concerns about feared impacts which are strictly regulated, such as noise emissions or shadow flicker from wind turbines, as individuals come to realise that these effects are less significant than initially expected.

Previous research has provided crucial insight into the significant role that trust in local actors (Hübner, 2020) and distributive justice (Langer et al., 2016; Sagreto et al., 2020) play in the local acceptance of RE technologies. While the survey data from this study support these earlier findings and underscore the importance of these factors, it is essential to consider the specific circumstances under which they influence acceptance levels. In this context, it is important to once again highlight the impact of political attitudes on these factors. As previously elaborated, conservative and especially right-leaning individuals tend to view the involvement of local actors as less important compared to the rest of the sample. In addition, the recent FA (2023) study has shown that individuals willing to protest against RE development are significantly less likely to trust the information provided by local actors including scientific, administrative or environmental stakeholders compared to information provided by a citizen's initiative. Furthermore, while the majority of environmental-oriented participants state that they would support RE development regardless of personal benefits, a significant proportion of right-leaning individuals reported that personal benefits would not affect their acceptance levels. Given these findings, it is clear that these factors may not be as effective in increasing acceptance levels among individuals who are generally disinclined towards renewable energy initiatives.

5.2 Limitations

There are several key limitations which must be discussed to critically reflect on the findings of this study. Firstly, regarding the development of the scenarios, the aim was to determine realistic values for the potentials and the energy density of each technology. However, these assumptions are strongly dependent on further technical improvement and innovation of existing technologies. As noted in the methods section, the assumed spatial requirements for roof-mounted solar PV are relatively conservative, reflecting the current standard for newly installed systems. In contrast, for ground-mounted solar systems, slight technical improvements were assumed, though these are still lower than the efficiency gains estimated by the authors of the FfE (2023) study. To further exemplify this, the reference used for further developments of wind energy was a 5 MW turbine. However, recent projects are now planning to implement 7 MW turbine types, which would significantly lower the number of turbines needed to reach the target value of each scenario, thereby also alternating their acceptance levels.

One central aim of this study was to achieve a representative sample of Bavarian citizens, and while this was successful for the demographic criteria of age and, to a certain degree, also, gender, the opposite is the case for political attitudes and educational level. The sample for this study had a significant bias towards environmental-orientated individuals, while the proportion of right-leaning individuals was substantially lower compared to the political landscape. This issue is particularly significant given that the findings of this study indicate that political affiliation is the most crucial determinant of social acceptance. To improve the significance of the findings, several key results, such as the acceptance levels of different renewable energy sources and future electricity mixes, have been weighted to reflect the Bavarian population more closely. However, the accuracy of this approach is also constrained by the fact that it relies on the responses of a small number of right-leaning participants as a proxy for the attitudes of around 15% of the Bavarian population. Given the underrepresentation of individuals identifying as right-leaning, it may be considered a suboptimal decision to make political affiliation a voluntary specification. The intent behind this approach was to avoid deterring participants, as political preferences can be considered sensitive personal information, which individuals might be reluctant to share despite the survey being anonymised. However, responses lacking information on political affiliation had to be excluded from the weighting of the survey sample. Although some participants might have decided to stop filling out the survey had they been required to disclose their political views, those who did not indicate a preference likely included some right-leaning individuals, as their response patterns closely resemble those of participants who did identify as right-leaning. Including more individuals who identified as right-leaning could have helped to improve the robustness of the weighting methodology.

Another aspect to consider regarding political attitudes is that the perspectives within a party also cover a significant range of acceptance levels. Considering the method used to distribute the survey it can be anticipated that the survey reached individuals who are generally more supportive of renewable energies. The majority of survey participants are either employed in the climate protection department of an administrative district, involved in a citizens' energy cooperative, or residents of a municipality recognized for its best-practice approach regarding renewable energy development.

The interviews aimed to provide empirical insights into social acceptance dimensions, particularly those not covered by the survey, such as stakeholder and political acceptance across all three levels. A total of five interviews were conducted for this purpose. While these interviews yielded valuable information, they did not fully encompass the entire spectrum of perspectives. Conducting additional interviews could have enhanced the robustness of the findings and offered further insights that may not be represented in this research. Interviewing a spokesman of an economic umbrella organization did provide valuable insights into the perspectives of numerous economic and industrial stakeholders. However, capturing political acceptance at both the general and local levels would require engaging a broader range of interview partners. At the general level, the research design initially included a second interview, but it could not be conducted as no representative from a conservative party agreed to participate in the study. Similarly, at the local level, several potential interview partners were approached, but these interviews ultimately did not take place due to various reasons.

6 Conclusion

This study aimed to generate knowledge on the social acceptance of the energy transition, relevant renewable energy technologies, and plausible future electricity mixes required for decarbonising the electricity sector in Bavaria from a general acceptance, community acceptance, and market acceptance perspective. The following chapter will conclude the key findings and, in doing so, answer the research questions of this study. Based on the desk research method, this study identified five distinct pathways for Bavaria to achieve a climate-neutral electricity system. Each scenario involves varying levels of development in renewable energy sources and the necessary infrastructure for energy imports. The scenarios demonstrate the feasibility of a decarbonised electricity supply from a land use perspective, relying primarily on imports, solar PV, wind energy, bioenergy, or a mix of all four.

While previous research has already indicated high levels of acceptance towards the energy transition and RE development, the findings of this research demonstrated that the recent energy crisis not only further reinforced acceptance levels across all dimensions but has, more importantly, shifted the primary motivation for the energy transition in Bavaria from climate protection (37%) to energy independence (39%). This trend is evident especially among individuals with conservative views while reducing greenhouse gas emissions to fight climate change remains the primary aim for politically and environmentally orientated individuals. The assessment of individual technologies has shown that roof-mounted PV systems are the most accepted form of renewable energy technology with an acceptance score of 4.56, followed by hydropower (4.14), wind energy (3.48), bioenergy (3.45), and lastly ground-mounted solar PV (3.4) when weighing the sample according to political preferences to resemble the Bavarian population. While previous studies have highlighted statistical correlations between socio-demographic factors such as age or education and technology acceptance, this research found only limited statistical links between these personal characteristics and acceptance levels. In contrast, political attitudes can be identified as the most significant factor influencing the acceptance levels of renewable energy technologies. Individuals with right-wing views display a strong tendency to oppose ground-mounted solar PV (2.29) and wind energy (1.71), while generally being more supportive of hydropower (4.14) and bioenergy (3.71). The most significant concerns for this socio-political group are land use requirements (85.7%) and strain on the electricity grid (85.7%) for solar PV, and economic effectiveness (100%) for wind energy. Those with conservative views exhibit more nuanced and partly critical perspectives, with consideration being the most selected acceptance type for ground-mounted solar, wind energy and biomass. However, this group also show significant numbers in the support category for wind energy (32.3%) and ground-mounted solar PV (33.9%). For the conservative-leaning participants, the largest concern towards wind energy is the visual alteration of the landscape, while for ground-mounted PV, land use requirements (58.1%) and strain on the electricity grid (58.1%) present significant concerns. Individuals with environmentally oriented views are highly likely to support the development of ground-mounted solar PV (4.11) and wind energy (4.62), while primary issues regarding wind are the deconstruction of wind turbines (23.6%) and strain on the electricity grid (54.4%) for solar PV. However, their support for bioenergy (3.28) and hydroelectric power (3.78) is more conditional, especially due to concerns regarding the ecological impacts of hydro (76.4%) and bioenergy (73.3%).

Furthermore, political preferences also had significant influences on the preferred future electricity mixes. The survey sample showed a strong preference for the Focus wind, with 39.1% selecting this scenario. However, when accounting for the political bias of the sample, the scenario *Balanced Development,* consisting of a dispersed mix of available renewable energies as well as significant electricity/energy imports, became the top choice for 38.9% of participants. Providing participants with additional information regarding the spatial requirements of RE in each scenario using the scenario maps had only minimal influence on the preferences of participants as only 17.3% reconsidered their scenario choice due to the scenario maps. A significant number of participants (52.8%) generally felt that spatial requirements to reach climate-neutral electricity systems aligned with their expectations. The remaining proportion of participants was divided, with 15.7% expecting more extensive spatial requirements and 13.6% anticipating a larger spatial extent. A substantial number of participants remained undecided. Regarding supplementary energy sources, future technologies (53.1%) and electricity imports (39.7%) received the highest levels of support.

Regarding the level of community acceptance, the interviews could demonstrate that the recent energy crisis has significantly boosted acceptance levels not only of the general public but also of stakeholders and political acceptance of renewable energy developments. Through the assessment of various factors, this research could mostly confirm existing theory on community acceptance of RE development while also providing empirical data for the importance of each factor exceeding influence in Bavaria. The central factors influencing acceptance levels which were assessed are general attitudes towards energy transition, impacts on residents and ecosystems, procedural aspects, economic considerations and social norms with all of them exceeding influence on the acceptance of renewable energies on the local scale. A crucial finding for this dimension was the importance of familiarity with technology in reducing stigmata and improving acceptance. Furthermore, findings from the survey indicated the impact of political affiliation on the effectiveness of strategies to increase acceptance, such as local involvement and financial participation. While the majority of right-leaning individuals (57.1%) stated that personal benefits such as financial participation would not affect their acceptance levels, conservatives were most likely to state that it either would have an effect on their attitude (32.3%) or that it would depend on or the technology and benefit (32.3%). In contrast, those identifying with environmental-orientated parties accept renewables regardless of individual profits. Right-leaning participants and conservatives evaluate procedural justice in the planning process as crucial. In contrast, trust in local actors is more crucial for individuals with an environmental or left-leaning political orientation.

Lastly, the energy transition in Bavaria is characterised by high market acceptance among households, organisations, and investors, largely driven by the critical state of the current electricity supply system. Following the phase-out of nuclear power, Bavaria now heavily relies on electricity imports and faces high electricity costs. This presents a problematic status quo for consumers with a substantial energy demand, such as the industry and manufacturing sector, which is crucial to Bavaria's economy. Current developments show the increasing demand for locally produced renewable electricity from small-scale manufacturing to large-scale industrial actors. Furthermore, a major concern is the potential fragmentation of the German electricity market due to a lack of renewable electricity generation. This fragmentation would likely lead to further increasing electricity prices, drastically reducing the region's attractiveness as a business location. To allow for increasing implementation of renewable energies, the most pressing challenge is the need to reinforce the grid infrastructure, as its current limitations are already hindering further development. From a market acceptance perspective, the future electricity supply should prioritise a balanced development of photovoltaic (PV) systems, wind energy, and bioenergy, complemented by necessary but limited electricity imports to maintain economic efficiency. Overreliance on imports should be avoided due to associated costs and dependency risks. Consequently, the *Balanced Development* scenario emerges as the most favourable option, offering a well-rounded approach that aligns with market needs while ensuring a sustainable and economically viable electricity supply.

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Appendix (1)

Scenario maps

Appendix (2)

Transcripts

Appendix (3)

Data Set