Sustainability expectations towards Artificial Intelligence in the energy and mobility sector

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Abstract. The rise of artificial intelligence (AI) is associated with narratives and visions of the future that claim to reduce complexity through predictability. Especially when it comes to the energy and mobility sector, the increased possibilities to analyse huge amounts of Data are said to enhance "objectivity, precision, predictability, and consistency in decision-making" (Vandycke & Irungu 2021). Futures studies have shown how visions, expectations or imaginaries are shaping scientific and technological developments (van Lente and Rip 1998) and seek to manage complexity and uncertainty (Beckert 2016). The multiple and contested future visions around AI (Barais & Katzenbach 2022) provide rich insights into the role of distinct orientations towards the future (Beck et. al) and how they are shaping what developments are considered relevant and urgent, possible, or inevitable. Our contribution is centered around two research questions: First, which expectations towards the future are voiced by which actors concerning the use of AI in the energy and mobility sector? And second, how do respective narratives of AI futures envision solutions for sector-specific sustainability challenges? Our contribution is based on two case studies containing document analyses and interviews. For the energy sector we investigated which promises are associated with the use of AI in the smart grid, with the focus on the integration of renewable energies. For the mobility sector, we investigated the role attributed to AI-based autonomous and connected driving in the context of the mobility transition, using the example of autonomous minibuses in rural areas. We find that AI futures envisioned for the energy sector have a clear orientation towards climate protection goals while those for (rural) mobility sector lack a clear orientation in this regard.

1 Introduction

Futures studies have shown how visions, expectations or imaginaries are shaping scientific and technological developments (van Lente and Rip 1998) and seek to manage complexity and uncertainty (Beckert 2016). The multiple and contested future visions around artificial intelligence (AI) (Barais & Katzenbach 2022) provide rich insights into the role of distinct orientations towards the future (Beck et. Al 2021).

We show the narratively produced expectations of AI futures in the energy and mobility sector in Germany – two sectors that are associated with high expectations towards achieving climate protection goals (Federal Government of Germany 2022; Gossen, Rohde, und Santarius 2021; Yigitcanlar und Cugurullo 2020). AI futures in both sectors are still uncertain but voiced expectations around AI function as orientation towards the future and eventually determine what developments are considered relevant, urgent, possible or inevitable. Against this backdrop, our contribution is centred around two overarching research questions:

1. Which expectations towards the future are voiced by which actors concerning the use of AI in the energy and mobility sector?
2. How do respective narratives of AI futures envision solutions for sector-specific sustainability challenges?

The goal of the energy transition, i.e. the transformation of the energy system from fossil fuels and nuclear power to an energy system that is neutral in terms of greenhouse gas emissions, is for renewable energies to cover 80% of the gross electricity demand in Germany by 2030. A particular challenge in implementing the energy transition is that grid stability must be always ensured in the electricity system in order to avoid power outages. However, electricity from renewable sources fluctuates in generation depending on the weather (e.g. generation by wind or photovoltaic plants). At the same time, renewable energy plants are significantly smaller and spatially distributed in a much more decentralised manner compared to conventional power plants. An essential condition for the success of the energy transition and very high shares of renewable energies in the electricity mix is therefore to control the electricity grid more flexibly and intelligently (so-called 'smart grids'). Due to advances in the field of big data analysis through machine learning, many use cases in the energy sector have become possible or have expanded. AI applications are said to be useful for forecasting, demand-side management, maintenance, grid condition analysis, automated electricity trading or decentralised system services and thereby address challenges such as fluctuation and distribution of renewable energy (Ali & Choi 2020, Omitaomu & Niu 2021, Kumar et al. 2020, Zhang et al. 2018, Massaoudi et al. 2021, Hossain et al. 2019). It is argued that such smart grid technologies are solving some of the main challenges of integrating renewable energies into the electricity system (Appelrath 2013). For the investigation of AI futures in the energy sector, we therefore asked:

Which promises are raised by which actors with regard to the use of AI for the integration of renewable energies?

The mobility sector is responsible for about one fifth of greenhouse gas emissions in Germany (UBA 2022). To make its contribution to climate protection it is important to increase the share of climate-friendly modes of transport like public transport, bicycle and walking in the modal split. However, the provision of public transport services in rural areas in particular poses a major challenge, especially financially, due to sparse population, low usage and extensive service areas (Kling 2021). Digitally connected services make it easier for users to access sharing services and public transport and are seen as a driver of the mobility transition (Hofmann et al. 2020, Hennicke et al. 2021). While mobility offers within the concept of 'Mobility as a Service' represent a lucrative business field for the mobility industry in densely populated urban areas, rural regions remain economically unattractive. AI-supported mobility is seen as a way out. Autonomously driving and networked minibuses are expected to save labour costs and can be used flexibly to supplement mobility services in rural areas (Mörner & Boltze 2018, Sinner et al. 2017). The efficient and cost-effective provision of public transport services in sparsely populated areas should make it possible for more people to abandon their own cars (Hennicke et al. 2021). For the investigation of AI futures in the mobility sector, we therefore asked:

What expectations are associated with the use of AI with regard to sustainable mobility? How can autonomous minibuses in particular contribute to sustainable mobility in rural areas? With what objectives are autonomous minibuses being developed and which priority is given to the sustainable design of AI-supported mobility in rural areas?

2 Theoretical Framework

Envisioned or imagined futures can be understood as visions of a pretended future that are forcefully driving innovative activity (Beckert 2016). The prospective structures that those visions, expectations or imaginaries entail, are shaping scientific and technological developments (van Lente and Rip 1998; Konrad and Böhle 2019). Those envisioned futures open up space for action and seek to manage complexity and uncertainty (Beckert 2016; Engels and Münch 2015), set agendas, create relationships, define roles and influence the allocation of resources (Beckert 2016). Since these future visions are collectively shared, the explicit claims and implied framings they entail are shaping what developments are considered relevant and urgent, possible, or inevitable (Konrad and Böhle 2019). Imagined futures do not only mobilize diverse actors from different political and cultural backgrounds to move and invest in emerging technology fields (Borup et al. 2006) but may also "stir public debate on the desirability of what particular technologies might entail for society" (Konrad and Böhle 2019, p. 102). We understand visions of the future as a society's, or social group's, distinctive orientation toward the future and "representations of how collectives want that world to be." (Beck et al. 2021, p. 147). The various concepts such as sociotechnical imaginaries (Jassanof & Kim 2015), visions (Dierkes et al. 1996; Wiek and Ivaniec 2014) or expectations (Borup et al. 2006) can be subsumed under the term socio-technical futures (Lösch et al. 2019).

We are interested in narratively produced expectations and how they are able to shape issue-based fields (Hoffman 1999). Van Lente and Rip, for example, explain the constitution of technological fields in terms of narratively produced attributions of expectations and the gradual formation of a shared agenda (van Lente & Rip 1998).

"Voicing expectations has been part and parcel of doing science and mobilizing resources through the ages. In fact, knowledge claims (generalizations of findings, up to the speculations found in the final sections of research papers) already voice expectations, in this case about the validity of the wider claims. And they are put forward to mobilize interest and, hopefully, reputation. Promises and expectations, including broad and interesting claims, are a way to get your audience to listen." (van Lente & Rip 1998, p. 223)

We refer to this approach and seek to identify which expectations can be observed and which promises are associated with the use of AI in the smart grid and the mobility sector. Instead of referring to technological fields, we refer to the concept of issue-based fields (Hoffmann 1999) i.e., fields that form around a central issue rather than a technology or market. We argue that this conceptualization is distinct from van Lente and Rips (1998) notion technological fields because it allows to capture the heterogeneity of actors, the competing interests and the divergent expectations voiced by different actor groups when it comes to AI. Consequently, we look at the voiced expectations that are raised by diverse actors within issue-based fields and how socio-technical futures on AI are articulated and negotiated within those fields. Furthermore, this framework is aimed to explain how the attribution of expectations and the mobilisation of resources are able to exert influence and thus have performative effects (Horst 2007) on such fields. With the increasing use of AI technologies in the energy and mobility sectors, new complexities are emerging, and new narratives are being developed. With our case studies, we want to elaborate these narratives and critically examine which expectations, aspirations and fears are articulated by different actors. Furthermore, we want to investigate which social, ecological and economic impacts are voiced by the actors in the AI-supported smart grid and mobility fields.

3 Methods

To capture expectations towards the use of AI systems in energy and mobility systems, we conducted embedded case studies (Yin 2009) for each sector. Due to differences between the two objects of research – e.g., considered AI systems, involved actors, and relevant policies – individual research designs were slightly geared towards each case. Both involve conceptual considerations as well as empirical research, tapping different sources of information and studying different units of analysis. For both the energy and mobility sector concrete cases of applying AI were explored as embedded in broader contexts, such as the broader European energy sector or the mobility sector in Germany. Both case studies were conducted throughout 2022. Our results and conclusions are mainly based on qualitative analyses.

For the **case study on the energy sector**, our analyses concern both the specific case of ‘energy optimisation in a neighbourhood’ itself as well as its context as units of analysis. The specific case is the attempt to realise ‘intelligent’ optimisation of energy supply in a delimited district, whereby the respective context consists in the use of AI technologies for the integration of renewable energies in general. The context consideration is important because we did not only want to survey concrete potentials and impacts in the neighbourhood, but also the promises, expectations and justification narratives formulated by different actors in the energy sector. The study design thereby aims to relate the transformational potential of AI-based renewable energy integration practices at neighbourhood level to an overall transformative goal in the energy sector.

The aim is to look at the promises, motives and goals associated with the use of AI for the integration of renewable energies as well as anticipated risks and dynamics in the actor constellation of the energy system. The analysis was carried out as from the perspectives of different actors in the field of smart grids (Rohde & Hielscher 2021). The overarching vision of smart grids is seen as an important path to enable demand side management and the de-peaking of energy demands through an enhanced electricity infrastructure equipped with information and communication technologies (Marris 2008). The use of AI for integrating renewable energies is conceptualised as an issue-based field (Hoffman 1999). This means that the issue-based field consists on the one hand of actors who look at the smart grid as outsiders or influence it through their own ideas (motives, goals, promises) and measures derived from them (politics, science, civil society). On the other hand, it consists of actors acting within the smart grid (e.g. energy suppliers, grid operators, ICT service providers, etc.).

Based on desktop and literature research reports, position papers and strategy papers as well as studies by various actor groups were collected that make statements on the role of AI for the energy transition. The actor groups were identified on the basis of preliminary work on smart grids (Rohde & Hielscher 2021). Selected documents should address the use of AI in the energy transition and not have been published before 2017. The aim was not to include all existing publications in the sample, but to achieve a reasonable balance between the groups of actors. Nevertheless, civil society is underrepresented in the sample. This may be related to the search strategy, but also to the fact that civil society has a different, less technology-oriented focus when it comes to the energy transition. The sample consisted of 31 documents from the German, European and international context, distributed among the following actor groups:

- Science and research
- Energy industry (associations, energy company)
- Network operators
- Politics
- Civil society

Based on the documents, the promises and expectation narratives were identified as well as the addressed risks of the use of AI. The documents are regarded as communication material to intendedly communicate actions. By means of a structuring content analysis, the documents were coded with the evaluation software MaxQDA. Essential statements were filtered out of the documents and clustered using a predefined analysis grid, that was derived from the research questions and the theoretical frame and that was inductively refined throughout the coding and clustering process At the centre of the evaluation process was the systematic structuring of text material. The focus was on the qualitative interpretation of the data and quantifying evaluation procedures (e.g., frequencies of coded segments) were used as a support. After the document analysis, a total of five guided expert interviews lasting between 30 and 50 minutes were conducted in March and April 2022. The interviews were conducted with actors who are connected to the specific case of energy optimisation in an existing energy neighbourhood project. Additionally, actors who can be assigned to the larger context were interviewed. They were identified on the basis of the document analysis and a further internet search.

For the **case study on the mobility sector**, our analyses concerned the application of AI in autonomous vehicles, more specific the use of autonomous public transport minibuses in rural areas, as well as the context of transforming the mobility sector towards sustainability. Our research design related promises, expectations and justification narratives stated by economic, policy, and research actors to the context of transforming rural mobility towards sustainability, which is deemed to require attractive and inclusive supply of mobility options in public transport, cycling and walking. We aimed to identify promises, motives and goals associated with the use of autonomous vehicles for sustainable mobility as well as for minibuses in rural areas in particular. By examining different development and pilot projects in German rural areas, we looked at the priority of sustainability design requirements in existing projects and the AI systems used in each case.

Expectations and promises were extracted from six different strategy papers from various federal states and supplementary desktop research. The analysed set of documents comprises all publicly available political strategies from federal states in Germany addressing digital technologies and/or transitions in the mobility sector. Our document analysis includes:

- Public Transport Strategy Baden-Wuerttemberg 2030 (VM BW, 2022)
- Digitalisation Strategy Baden-Wuerttemberg (IM BW, 2022)
- Digital Programme Brandenburg 2025 (Landesregierung Brandenburg, 2017)
- Hesse Strategy Mobility 2035 (HMWEVW, 2018)
- State Transport Plan Mecklenburg-Western Pomerania (EM MV, 2018)
- State Transport Plan Saxony 2030 (SMWA, 2019)

In addition to the political strategy papers, we evaluated self-descriptions and publicly available information about projects dealing with autonomous buses in rural areas. The projects were derived from an online overview of autonomous buses in Germany, that is compiled by the Association of German Transport Companies (VDV). It lists 61 projects in which autonomous buses are used or tested in public transport. We spoke to staff members of four of those projects in different German regions, that aim at implementing autonomous buses in rural areas. Five interviews were conducted in October, November and December 2022 and lasted between 45 and 55 minutes, each involving between one and three interviewees. Three of them involved several persons. We used a semi-structured interview guideline to capture information for a qualitative analysis.

In a **cross-case analysis** (Babbie 2016:383) we explored common patterns of narratively justifying the use of AI in both case studies. Taking a case-oriented approach, we looked first at respective frequencies of mentioned expectations, limitations, visions, goals and uses for sustainability in both the energy and the mobility setting. Subsequently, we derived thematic clusters for both case studies and compared them across both case studies with a similar technique. However, in this second step, our analytical focus was more on the deduction of possible mechanisms and underlying logics behind the identified narratives. As described above, document analyses, interviews studies and analyses of publicly available information on real-world AI-involving projects served as data sources for the cross-case analysis. This heterogeneously composited data base can, on the one hand, delimit comparability. On the other hand, it enriches the diversity of perspectives captured on each embedded case. Another limitation of our method is set in the relatively low number of investigated instances. Recorded data is not exhaustive nor generalisable, however, it can serve for insightful explorative qualitative analysis to deduct general patterns in emerging sociotechnical imaginaries transported in the field of AI.

4 Findings

Energy

We identified three dominant narratives that relate to the promises and justifications of the use of AI in the smart grid:

1. AI advances the energy transition by enabling the integration of renewable energies, for it deals or will deal with complexity, improve the security of supply and system stability and enhances acceptance and participation in the energy transition.
2. AI increases efficiency and enables process optimisation and cost reduction.
3. The use of AI in the energy sector will lead to economic advantages by lowering costs and increasing revenues.

The main actors pushing these narratives are politics, science and the energy industry. In the first narrative, politics is the dominant actor, while the industry promotes the second and third narratives the most.

While these narratives frame the future of AI in the energy sectors as chances and opportunities, risks play a subordinate role. For example, the expected AI enabled efficiency and process optimisation in the energy system are mentioned in a total of 86 occasions in our empirical material, risks are only mentioned in a total of 20 occasions. The risks most frequently mentioned in the documents and the interviews are cybersecurity and the energy and resource consumption of the infrastructure.

Additional aspects that have been raised in the interviews were, *first*, the ambivalence of using AI in the energy sector. One interviewee pointed out that while AI is supposed to deal with the complexity of the energy system it also adds another layer that enhances the complexity of the system and makes it harder to control its safety. *Second*, in another interview the lack of data as a barrier to the actual implementation of AI, especially for small players in the energy sector was addressed. According to the interviewee it can already be observed that actors move at different paces concerning the implementation of AI. Actors who have been digitalizing their processes in the past are the ones profiting the most from AI now. Others who did not have the capacity, capital or know how to do so, might get lost on the way. In the long run, this might be a hinderance for the energy transition as a whole, as multiple actor groups are needed for it. *Third*, asked for the biggest barriers to overcome for the energy transitions, some interviewees referred to problems that cannot or are currently not addressed by the implementation of AI. These are the need for built infrastructure (e.g. renewable energy plants and storages) as well as issues with legislation and the licensing of renewable energy plants such as solar panels or wind turbines.

Mobility

Our document analysis showed that AI futures in the mobility sector are, if at all, only loosely and vaguely connected to visions for sustainable mobility in rural areas. In some cases, high expectations are expressed for autonomous driving technology. As an example, the digitalisation strategy of the state government of Baden-Wuerttemberg emphasises "numerous opportunities to make the mobility of tomorrow comfortable and sustainable. (IM BW, 2022: 46). In some places, autonomous local transport is seen as a "booster of the transport transition." (DB Regio, 2022: 5); one transport association even expects the "roboshuttle revolution" (VDV, 2022, p. 34). However, it is striking that more detailed descriptions and the concrete benefits, especially for sustainable transport, very often remain blurred.

Moreover, the analysed strategy papers reveal argumentative and strategic incoherencies, when it comes to relating the development of autonomous driving to rural challenges. Saxony's State Transport Plan, for example, emphasises that automated driving functions offer "starting points for providing appropriate mobility services, particularly against the background of demographic change and the development requirements of rural areas". (SMWA, 2019: 72). Sparsely populated regions are thus considered to be particularly suitable locations for AI-supported mobility applications. At the same time, the preparatory testing of such systems in Saxony has paradoxically so far been "concentrated in particular on test fields in urban areas" (ibid.).

More tangible than the expected contributions of AI to sustainable urban mobility is the (national and) federal intention to increase the attractiveness of industrial locations in German regions by implementing autonomous driving test fields or required infrastructures. The Lower Saxony Ministry of Economics, Labour, Transport and Digitalisation, for example, has reached various "agreements" with the automotive industry and two other sectors in the strategic development process for a "gigabit infrastructure" (internet connections with very high transmission rates). (MW NI, 2018: 36). One result is the conviction: "We need intelligent traffic control and autonomous driving" (ibid.).

However, as part of the strategy process, autonomous driving can in this case hardly function as a means, but rather as a legitimisation of the already set goal of a gigabit infrastructure.

The expectations voiced by staff members of projects implementing autonomous buses in rural areas are:

- More efficient clocking and coverage
- More efficient vehicle utilisation and operating and therefore cost reduction
- Increase Safety and comfort

The analysis of the information and self-descriptions of the 61 projects in which autonomous buses are used in local public transport somehow mirrors the findings of the document analysis. Only 16 of these projects are located in rural areas. Of the 16 projects in rural areas, nine deal specifically with typical rural challenges of the mobility transition. The accessibility of mobility offers due to the low-cost provision of automated passenger transport is emphasised several times. But: only 3 of the projects explicitly examine the economic efficiency of operating autonomous buses. Only one project focuses on the greatest leverage for the reduction of greenhouse gases in the transport sector by investigating the potential of autonomous minibuses to reduce private motorised transport. The focus of the analysed projects is on acceptance among the population and further technical development.

In summary, the greatest hopes for AI-supported rural public transport lie in new transport and business models that integrate (small) automated buses into existing services and thus create additional options for public transport. Autonomous vehicles are not intended to replace conventional public transport systems, but to complement them. There are no strong indications that public autonomous vehicles are supposed to replace private motorised transport. Inherent in the concept is the elimination of the need for drivers for the new vehicles. Transport companies hope to minimise a significant cost factor for the operation of their fleets. It is not yet possible to quantify the corresponding savings, as there is no experience with which to estimate the additional costs for the required control centres.

5 Conclusions and discussion

In conclusion we find that envisioned AI futures for both sectors differ with regard to how they envision solutions for sector-specific sustainability challenges. In the energy sector AI is expected to enable renewable energy integration by dealing with complexity, improving the security of supply and system stability and enhancing acceptance and participation in the energy transition. Therefore, AI futures envisioned for the energy sector have a clear orientation towards sustainability**.** In the mobility sector, by contrast, AI's expected contribution to climate protection remain vague, the rural area is addressed as area of action, but it is rarely expected that AI enabled autonomous driving will help to shift the modal split. Therefore, AI futures envisioned for the mobility sector lack a clear orientation towards sustainability.

Furthermore, envisioned AI futures for the energy sector reveal a strong focus on chances, while potential (sustainability) risks are underrepresented. Also, ambivalent developments are tuned out for the sake of strong narratives: e.g. the quest to reduce complexity versus increasing system complexity by integrating AI in energy system or the vision of a democratic and decentralized energy transition versus Big Data as basis for AI-enabled renewable energy integration that brings advantage only for players with access to Big Data. With their narratives actors promote AI as a solution to urgent societal challenges, e.g. climate change and these voiced expectations promote a convergence of AI and sustainability visions. As such climate protection also functions as a legitimization for AI implementation in the energy sector, which has also been found in other areas of 'smart energy' developments (Rohde & Santarius 2023). In contrast, the consideration of opportunities and risks of AI in the mobility sector regarding sustainability does not play a role. One possible explanation is that the application in the mobility sector takes place without a clear reference to sustainability anyway. Thus, no reflections of opportunities and risks for sustainability take place.

The envisioned AI futures for the mobility sector reveal that the implementation of AI enabled autonomous driving technologies currently only aim at incremental change instead of the mobility transition. The focus is rather put on strengthening automotive industry. This corresponds with research findings on user preferences over different urban transport options (Acheampong et al. 2021), that showed that there will probably be no reduction of private motorized vehicles with autonomous driving technologies in place. The focus on incremental change in the mobility sector may be specifically German because "*incumbent companies such as the German car manufacturers Daimler and Volkswagen are usually not interested in radical change due to sunk investments*" (Graf & Sonnberger 2020). Finally, our findings invoke the question of whether the lack of vision for enabling a modal shift with the use of AI stems from the fact that there might be no technical fix for the mobility transitions. Consequently, it must be asked: If AI does not contribute to this sustainability challenge, is the use of AI in the mobility sector appropriate at all?

When it comes to futures studies our case studies reveal, that analyzing voiced expectations about AI in the energy and mobility sector enable us to reveal how certain actors are pursuing their own agendas while concealing problematic developments or driving incomplete solutions (Sovacool et al., 2020). One of our key insights illustrates that autonomous driving solutions, are rarely addressing the most pressing challenges of a transition of the mobility sector towards sustainability but are heralded as a techno-reductionist solution that is being put into practice not only in Germany but also in projects across the world (Latz et al. 2022). As such, the voiced expectations that emerge around AI are performative (Rudek 2022), because they might be foreclosing alternative pathways, for transforming rural mobility systems. Thereby these expectations can also serve as instruments of legitimation and mask political interests and power constellations that are forcefully driving innovative activities. The question arises of where the societal negotiation should take place to weigh up advantages and risks of AI centered solutions and critically interrogate the somewhat fuzzy, implicit, broadly accepted and culturally embedded understandings of the 'good life' or the 'good future' (Jasanoff an Kim 2015) that those AI futures entail.

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