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Original research article

Adapting to limited grid capacity: Perceptions of injustice emerging from grid congestion in the Netherlands

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ABSTRACT

As renewable energy and electrification expand rapidly, many electrical distribution grids experience *grid congestion*. This situation leads to long waiting lists for parties seeking a new grid connection or aiming to expand their existing grid connection. In addition to traditional grid enforcements, distribution system operators are developing ways to manage congestion by steering electricity supply and demand. As grid congestion limits the previously abundant resource of grid capacity, the challenge of how to fairly distribute this now-scarce resource raises new questions about nondiscrimination and broader notions of justice. This study, grounded in energy justice, explores the distributive and procedural injustices people experience with increasing grid congestion. Our research focuses on The Netherlands, where more than 10,000 parties await new grid connections. Through 16 semi-structured interviews with people either affected by or involved in mitigating grid congestion, our thematic analysis reveals three key categories: (1) injustices arising from legacy policies, legislation, and social norms; (2) injustices due to unclear regulations, inconsistent policies, and policy gaps; and (3) injustices related to changing relationships between DSOs and affected parties. These findings highlight that grid congestion is fundamentally *sociotechnical*; while congestion is both constrained and addressed by technical factors, institutional and social factors such as legacy policies, social norms and communication, significantly influence perceptions of injustice. Our findings call for a comprehensive integration of justice principles within the institutional (e.g. regulation, policy, markets, social norms), technical (e.g. grid infrastructure, IT systems), and social (e.g. community engagement, communication) components of grid infrastructure.

1. Introduction

The rapid expansion of renewable energy production and the electrification of society challenge the operation of electrical distribution grids. In many countries, increased power consumption and supply is leading to *grid congestion*, which occurs when the required amount of power exceeds the technical limits of cables and equipment [1,2]. Traditionally, distribution system operators (DSOs) have addressed grid congestion by reinforcing their assets. However, the current need for expansion of equipment is substantial in many European countries, such as the Netherlands [3], Germany [4], and the United Kingdom [5].

Combined with the shortage of technicians, lengthy spatial procedures, limited land space, and lack of financial resources, the ability of grid operators to achieve the required expansions in time is seriously compromised [6]. As a result, DSOs postpone the allocation of new grid connections until grid reinforcements are finished, resulting in long waiting lists for new connections and for the expansion of existing connections. For example, in the Netherlands, more than 10,000 parties are on the waiting list for new grid connections, with waiting times ranging from 7 to 10 years [7].

An alternative approach to grid expansion for addressing grid congestion is to use the flexibility of the grid to shift loads away from congested points [8]. Consequently, DSOs are focusing on mitigating power peaks to ensure that the overall load on the grid remains within safe limits. Active participation and flexibility of both electricity consumers and producers are required to smooth these peaks. This approach, facilitated by information technology (IT) systems, is commonly referred to as *congestion management*.

A congestion management mechanism should aim for equal treatment among connected parties [9]. However, given the idiosyncratic nature of congestion in different areas, some level of inherent discrimination is unavoidable, such as in price variations or reliability of the grid. Conventionally, nondiscrimination was considered by DSOs for

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strategic decisions on long-term investment planning and cost reduction. The introduction of congestion management raises new challenges concerning the integration of nondiscrimination and broader concepts of justice in the operation of the grid.

Three key factors contribute to these emerging challenges. First, grid congestion gives rise to limitations of a common resource, namely grid capacity, that used to be abundant. Justice concerns arise due to the lack of established norms for distributing this now-limited resource within society [10]. Second, congestion management requires DSOs to make more operational decisions than before. For example, a curtailment algorithm for maintaining voltage levels of PV panels could disproportionately favor connected parties near the transformer over those farther away [11]. Third, grid congestion is a new phenomenon that requires a different way of thinking and acting from citizens, with a potentially significant impact on their daily lives. These changes could lead to social resistance and injustice claims, similar to the developments in wind energy [12].

According to Sullivan et al. [13] "any life situation that hinders equal access to resources or opportunities or is related to suffering or loss can cause perceptions of injustice". We argue that, although distribution grid congestion is still in its infancy, the rapid implementation of congestion management measures necessitates comprehensive insights into the potential injustices that could arise. Therefore, our study focuses on the currently perceived or anticipated injustices of actors affected by grid congestion or involved in congestion management. These insights may guide the development of technological and institutional measures to mitigate grid congestion.

Our main research question is *what injustices do actors experience or anticipate when addressing grid congestion in electrical distribution grids?* Our contributions are twofold. First, we adopt a comprehensive approach grounded in energy justice to address the societal impacts of grid congestion, moving beyond purely technical solutions. Second, this study is one of the first to empirically investigate actors' experiences with grid congestion, offering valuable insights for policymakers and DSOs. These insights are particularly relevant given the prominence of grid congestion in the public debate in countries like the Netherlands [14] and Sweden [15].

This paper starts with background information on energy justice, serving as both a motivating and conceptual lens for our research problem. We then outline the methodology used in this research, followed by the presentation of the identified perceived injustices, categorized into those stemming from legacy policies and norms, policy ambiguities, and changing relationships. Next, we discuss the relationship between these perceived injustices and energy justice, and present policy recommendations based on our analysis. Finally, we conclude that institutional factors such as regulations, policies, and social norms significantly shape perceptions of injustice in this field. Therefore, grid congestion should be viewed as a sociotechnical problem, encompassing technical, social, and institutional dimensions.

2. Conceptual framework: energy justice

The concept of energy justice has gained significant traction in recent years, as scholars increasingly recognize the complex social implications of the energy transition [16]. This growing body of research highlights that the move towards sustainable energy is not merely a technical challenge but also a deeply social one, with the potential to either mitigate or exacerbate existing inequalities. These disparities often mirror existing socioeconomic inequalities: while some may benefit from new opportunities and cleaner environments, others could face job loss or higher energy costs [16].

The energy justice scholarship aims to explore what is just or unjust in energy systems and to promote just energy transitions [17]. Two main frameworks dominate this research field, namely Sovacool and Dworkin's [18] *eight principles* for energy justice and McCauley et al.'s [19] *triumvirate of tenets*. The first framework encompasses eight principles: availability, affordability, due process, good governance, sustainability, intergenerational equity, and responsibility. Although this framework has proven valuable in the literature, its principles do not align well with the exploratory nature of our research.

The other framework, the triumvirate of tenets, is inspired by environmental justice [20] and based on three key principles: distributive, procedural and recognition justice. Distributive justice focuses on the equitable allocation of burdens and benefits among all members of society. Procedural justice refers to the equitable process of determining these allocations, which involves aspects such as transparency, inclusive dialogue, and empowerment. Recognition justice emphasizes the recognition of actors, such as their abilities, knowledge, and historical or systemic injustices, with a specific focus on the absence of misrecognition [21]. In recent years, this set has been expanded with cosmopolitan and restorative justice [22]. Cosmopolitan justice is based on the belief that we are all global citizens, highlighting the importance of considering cross-border impacts. Restorative justice aims to address and correct past injustices, ensuring that harms are acknowledged and remedied.

We focus in this study exclusively on distributive and procedural justice, leaving recognition, cosmopolitan, and restorative justice for future work. Recognition justice is considered out of scope as it would require the participation of parties that could be misrecognized, who are not yet involved in congestion management. Therefore, it was not feasible to study recognition justice in-depth within the scope of this research. Cosmopolitan justice is excluded due to our focus on developments within the Netherlands, allowing for an in-depth contextual understanding. Restorative justice is also excluded from this study, as the exploratory nature of this research does not allow for an expanded scope to address historical injustices.

According to Sovacool and Dworkin [18], energy justice can serve three functions: 1) it can function as a conceptual framework that describes and combines various justice perceptions; 2) it can act as an analytical instrument that allows researchers to understand how values are woven into energy systems; and 3) it can be a decision-making aid for policymakers to normatively evaluate whether energy policies are just. In this research, we adopt the first function to identify and map perceptions of injustice of a wide range of actors.

Although the triumvirate of tenets approach to energy justice has been shown to be valuable in previous research, it also has several limitations [23,24]. First, it lacks a clear definition of justice and injustice, making it difficult to identify what needs improvement. In this study, we adopt a descriptive approach that considers the definitions of justice and injustice from various actors, rather than striving for a universal definition. Second, it often overlooks community perspectives, favoring a top-down approach that may misrepresent the concerns of ordinary people. Therefore, we incorporate the perspectives and concerns of a wide variety of actors in our analysis, including connected parties, system developers, and policymakers, to avoid a top-down approach. Third, while interactions between different tenets are often overlooked in the literature, we aim to examine the relationship between distributive and procedural justice in our analysis.

A more general concern in energy justice scholarship is that many studies do not explicitly state the ethical basis for their assessments [17,24]. This omission can lead to the perception that energy justice research imposes a supposedly universalistic idea of what is just, without justifying its applicability to specific contexts. To address this concern, our research acknowledges the plurality of justice conceptions and lays the foundation for future studies that could explore the ethical dimensions of the perceived injustices identified in this study.

3. Related work: energy justice in electrical power grids

Research on grid congestion and congestion management has traditionally focused on technical solutions (e.g. [25]), similar to research on smart grids [26]. To the authors' knowledge, there has not been any previous research on the social or ethical aspects of grid congestion. However, as congestion management is performed within the broader context of electrical power grids and is closely related to smart grids, we explore the literature on justice in traditional power grids and smart grids in this section.

3.1. Energy justice in traditional power grids

Electrical power grids are large-scale physical infrastructures, often perceived by scholars as neutral without regard for justice [27]. The literature on energy justice in traditional power grids is relatively limited, with two notable areas of focus. The first area focuses on justice in the expansion of the grid infrastructure, particularly the transmission grid infrastructure [28,29]. For example, Mueller [30] demonstrated that inclusive and transparent processes can improve public perceptions of fairness in a case study on transmission infrastructure expansion in Germany. In another example, in a case study from Colombia, Vega-Araújo and Heffron [31] identified distributive justice issues arising from an excessive focus on economic compensation for communities affected by grid infrastructure expansion.

The second area of focus is the reliability of transmission and distribution grids. For example, Kaufmann et al. [32] examined the impacts of the Texas blackout of 2021 across social groups and found that the reliability of the grid varied depending on whether the power loss was due to storm or load shedding. In a recent paper, Sovacool et al. [27] were among the first to conceptualize potential injustices in the power system in a comprehensive way, with a focus on distributive justice. They showed how the grid can cause and perpetuate four different types of inequity: demographic within social groups and communities, spatial across urban and rural locations, temporal across time, and interspecies in terms of damaging the environment. Our research builds on their work by expanding energy justice scholarship in the context of power grids, with a specific focus on increasing grid congestion.

3.2. Energy justice in smart grids

The umbrella term “smart grid” often refers to the digitalization of the electrical power grid, driven by the use of IT systems and real-time data on household energy generation and consumption [33]. Smart grids are viewed as important for integrating variable and uncertain renewable energy sources and matching electricity demand and supply [34]. Congestion management can be considered a subset of smart grids, where flexibility is specifically used to maintain grid availability and prevent overloads.

Milchram et al. [35] initially conceptualized justice within smart grid systems, focusing on how these technologies could shape distributive, procedural, and recognition justice. In later work, they expanded this analysis, identifying factors contributing to justice in the design of smart grid pilots, such as data governance, participatory design, user autonomy, inclusiveness of technology and scalability [33]. Moreover, they found that transparency and participatory decision-making are linked to positive perceptions of distributive justice [36,37]. However, the design of smart grid pilots differs from the design of congestion management measures, because smart grid pilots often enjoy exemptions from regulations to encourage experimentation, while congestion management has to deal with existing regulation, market mechanisms, and other legacy systems.

Smart grid projects are generally framed around technological and economic objectives, and tend to exclude justice considerations [38,39]. For example, Van der Wel and Akkerboom [16] found that justice considerations are often neglected in smart grid projects, where sustainability, reliability, and cost efficiency are prioritized. This may be due to the fact that smart grid projects are generally designed through the collaboration of technical and IT-based organizations in the energy sector [38,40]. Prioritized objectives in smart grid systems do not always align with public preferences and goals [41]. For example, although the private sector and grid operators may focus on economic incentives for flexibility, studies reveal that motivations for household flexibility extend beyond financial incentives to include broader goals, such as contributing to climate targets or supporting local communities [42]. Libertson [43] revealed five contrasting perspectives on the configuration of smart grid systems, ranging from technical, automation, and market-driven perspectives to more community-centered and equity-focused approaches. Thus, the design and development of smart grids varies depending on whether they are defined as technical, financial, or social systems [44].

3.3. Summary and research gap

Smart grids are often designed with technological and economic objectives, generally neglecting justice considerations. The literature on energy justice in traditional power grids focuses mainly on the need for inclusive processes and the fair distribution of burdens and benefits in the context of grid infrastructure expansion and reliability among groups. There is a notable gap in the literature addressing the distributive and procedural justice impacts of increasing grid congestion and the digitalization of electrical power grids. Therefore, this research aims to study the distributive and procedural injustices that actors experience in this context. The next section outlines the methodological approach we used for this study.

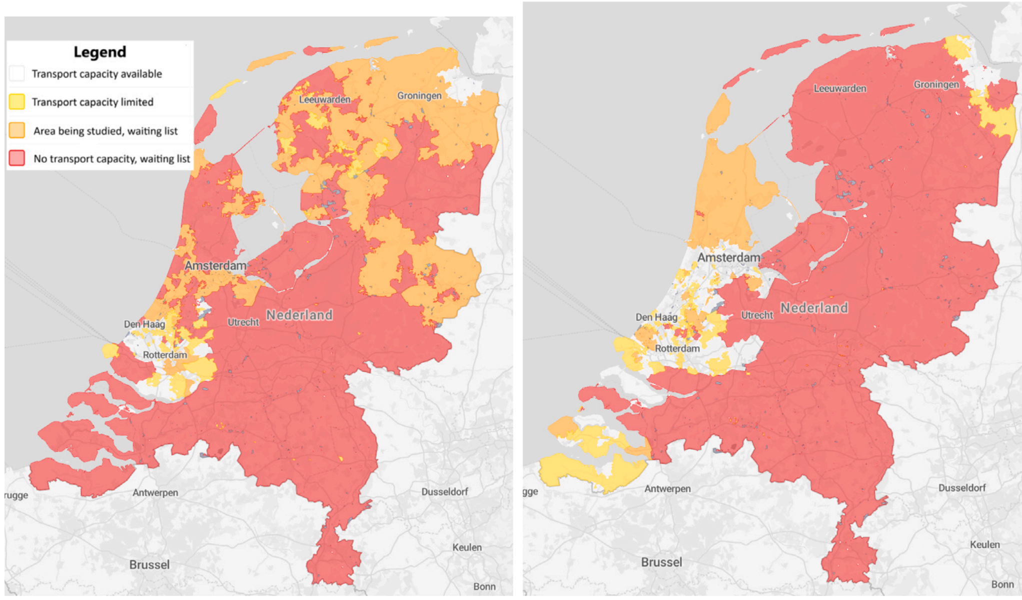
4. Methods

We adopted a qualitative research approach, which aligns with the exploratory nature of our research question. This qualitative approach enables us to understand the “why” and “how” associated with the injustices experienced by actors in congestion management. We decided to conduct semi-structured interviews with people either affected by grid congestion or involved in congestion management due to the inherent versatility and flexibility offered by this method, particularly useful for addressing exploratory research questions [45]. In the following subsections, we further outline the empirical context, sample selection, interview procedures, and data analysis methods.

4.1. Empirical context: grid congestion in the Netherlands

Our study focuses specifically on the Netherlands, which is already facing grid congestion, with more than half of the country experiencing transport limitations (see Fig. 1 for both energy consumption (a) and production (b) [46]). These developments are hampering both the expansion of energy consumption (e.g., necessary for electrification) and of distributed generation (e.g. local wind and solar energy). In the Netherlands, DSO Alliander reported a backlog of 6,000 parties awaiting new grid connections in June 2023, which increased to 9,400 in March 2024 [7]. Some of these parties face waiting times of 7–10 years. Grid operators have been increasing their reinforcement efforts and have informed the public that by 2050, one in three streets will need to be excavated to accommodate grid upgrades [47]. However, these efforts are hindered by three main factors: a shortage of technical personnel, lengthy spatial procedures, and limited availability of public space. As a result, grid congestion is expected to persist for at least another decade.

Currently, grid congestion affects mainly the high- and medium-voltage grid levels, which do not directly impact households [14]. As a consequence, congestion management has until date only been implemented at these higher grid levels. However, Dutch grid operators have warned the parliament about long waiting times for new connections at the low-voltage level as well, with households already experiencing delays of 40 to 70 weeks for new grid connections [14]. As grid congestion is expected to extend to low-voltage grids in the future, residential users will be increasingly affected. Although this study focuses on grid congestion at the medium-voltage level, we recognize



(a) Grid congestion for electricity demand. (b) Grid congestion for electricity supply.

Fig. 1. Grid congestion in the Netherlands (December 2024). Red areas indicate regions with no available transport capacity and existing waiting lists for new grid connections. Orange areas are under study to determine if transport capacity can be made available, and also have waiting lists. Yellow areas have limited grid capacity, while white areas still have available transport capacity. Retrieved from [46]. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the importance of including household perspectives and concerns in future work.

The Netherlands has three large DSOs and some smaller ones, each serving different geographical areas [48]. Following the liberalization of energy companies in the 1990s, Dutch DSOs have been incentivized to minimize costs while optimizing reliability, resulting in a highly reliable power system, but leading to underinvestment in new capacity [49]. With increasing grid congestion, the regulator allows since 2022 larger-scale congestion management [50]. For example, the regulator has mandated that Dutch DSOs provide capacity-restricting contracts. These contracts operate in the day-ahead domain, allowing operators to request that connected parties consume or supply less electricity on the following day if a potential overload is predicted. Additionally, DSOs have implemented local markets for re-dispatch within the intra-day domain. Here, operators can request that connected parties adjust their electricity consumption or supply in shorter time frames, such as 15-minute intervals [51]. Similarly, a real-time interface was developed in collaboration with industrial partners to directly control the load of renewable energy sources above 1 megawatt [52].

In addition to these measures, the regulator is considering various other initiatives to further reduce grid congestion. These include introducing new grid tariffs to encourage reduced consumption or supply during peak times [53], flexible grid capacity contracts at reduced rates [54], and group contracts [55]. These group contracts would allow energy communities to autonomously balance their electricity use and supply within the technical limits of the distribution grid. Similarly, the regulator is working on a “social prioritization” framework to distribute new grid connections [56]. This framework prioritizes parties of societal importance, such as schools, healthcare facilities, police and defense applications.

Although our focus on the Netherlands presents a limitation in terms of generalizability, the rapid increase of grid congestion is a new phenomenon of high institutional and technological complexity, requiring an in-depth research approach. As such, our study’s methodology may provide a template for future studies in other countries and its results can help to inform jurisdictions that are at risk of experiencing grid congestion in the future. As other European countries have similar institutional arrangements based on the same legislation and similar grid configurations, it is expected that some of our results could be transferable to other contexts.

4.2. Sample selection

Interviews were conducted with a diverse group of actors affected by grid congestion or involved in congestion management. The first participants were recruited using our existing network. A snowball sampling process was used to identify other actors. We opted for a strategy of maximum variation instead of selecting all actors from the snowball sampling approach [57]. Sixteen participants were selected from the following actor groups: DSOs, research institutes, demand response parties, energy communities, renewable energy developers, non-profit organizations, and the national government. Two participants were women and all the others were men. All participants had at least a bachelor’s degree and had been involved in the electricity sector for at least 3 years already. Table 1 presents an overview of our interviewees, organized in random order. Before approaching prospective participants, we obtained approval from the human research ethics committee on our research design and informed consent form.

4.3. Interview procedures and questions

Interviews were conducted during the summer and fall of 2023, each session lasting between 45–60 min. All participants were interviewed once by the first author and signed the informed consent form before starting the interview. Nine interviews were conducted in person and seven interviews were conducted online, according to participants’ preferences. To guide the interview, we used an interview protocol that can be found in the supplementary material. This protocol was developed by the first author and reviewed by the fourth author. We based the interview protocol on potential distributive and procedural justice aspects known from the literature, such as from Milchram et al. [33]. In the first part of the interview, we introduced the topic and asked about the participant’s involvement in congestion management. We then asked if they felt there were any injustices related to grid congestion or the approaches for mitigating grid congestion. This initial discussion set the stage for a deeper exploration of their perspectives on justice in this context.

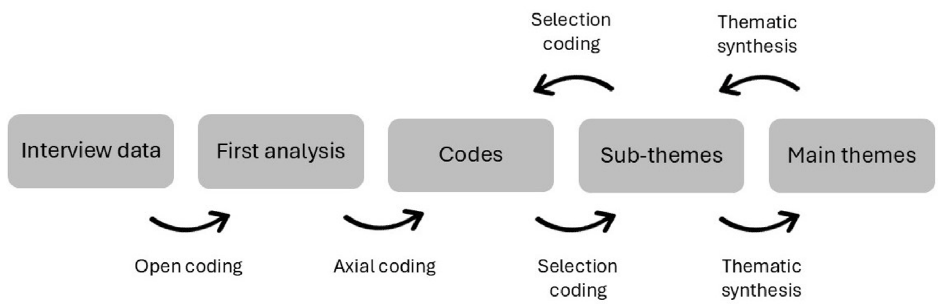


Fig. 2. Four phases of interview data analysis.

Table 1
Overview of interviewees with their ID number, organization and role.

ID	Organization	Role
P01	DSO	Product owner system operation
P02	Research institute	Researcher in congestion management
P03	DSO	Project manager for innovation projects
P04	Property developer	Participant in congestion management
P05	Renewable energy developer	On waiting list for grid capacity
P06	Energy supplier	Participant in congestion management
P07	DSO	Implementing congestion management
P08	Trade associations	Consultant for congestion management
P09	Research institute	Researcher in grid tariffs
P10	Energy community	Director
P11	Grid operator association	Product owner system operation
P12	DSO	Consultant for grid congestion
P13	Renewable energy developer	Consultant for grid integration
P14	Non-profit organization	Researcher on digital technologies
P15	DSO	Product owner system operation
P16	National government	Consultant for congestion management

4.4. Data analysis

Data analysis was performed concurrently with data collection to document the emergence of new themes and to identify data saturation, which occurred when additional interviews did not produce new themes [57]. The interviews were transcribed and anonymized by the first author, allowing an initial familiarization with the data. The combined dataset consists of 8,660 lines and approximately 110,168 words. The transcripts are in Dutch and generally between 400–600 lines. We used Atlas.ti for qualitative data analysis [58]. The unit of analysis was individual paragraphs, typically consisting of 3–4 sentences. The coding was performed in Dutch by the first author and reviewed by the fourth author.

Subsequently, we performed a four-round coding and thematic analysis, as illustrated in Fig. 2 [59]. In the first round of coding, we performed open coding of five transcripts to become familiar with the data. Open coding involves breaking qualitative data into parts, scrutinizing them, and comparing for patterns [60]. In the open coding phase, we specifically searched for quotes referring to a perceived injustice, including, for example, *"what I find unfair…"*, *"what I find strange…"* and *"what I worry about…"*.

In the axial coding phase, we carefully grouped similar codes and used these to analyze all sixteen transcripts [61]. If new transcripts raised additional codes, we would add these for the analysis. During the selection coding phase, we looked at how codes were alike and combined them into broader subthemes. These subthemes were identified by iteratively reviewing and comparing the data and the codes.

In the final stage of our coding process, we engaged in thematic synthesis, where we consolidated the identified subthemes into three overarching main themes. This process involved iteratively reviewing and comparing the subthemes to ensure that the main themes accurately captured the core patterns and insights from the data. The resulting themes, subthemes, codes, number of quotes and illustrative quotes for each subtheme are provided in the supplementary material.

4.5. Limitations

Three main limitations could affect the validity and generalizability of our findings. First, the gender representation among the participants was skewed, with only two female participants and the rest being male. This limited representation of female participants can raise questions about the validity and generalizability of the findings. The themes identified in this study may not fully capture the perspectives and experiences of women in the energy sector. However, due to the complex process of recruiting interview participants and the general overrepresentation of men in the energy sector, we proceeded with this mix of participants.

Second, the mix of in-person and online interviews presents another limitation. Nine interviews were conducted in person, while seven were conducted online. This mix was not intentionally designed to compare the two modes, but was rather a practical decision based on the availability of participants and logistic considerations. Although we did not notice any significant differences in the depth or length of the interviews between the two modes, it is possible that subtle differences in the quality of the interaction could exist.

Finally, interview studies are prone to interviewer bias, and there is a likelihood that participants will give answers that they believe are socially acceptable or what the interviewer wants to hear. Therefore, we do not claim to provide an all-encompassing overview of all perceptions of injustice in this context, but rather offer a nuanced interpretation of the potential injustices that can occur, acknowledging that certain injustice perceptions may have been overlooked.

5. Findings: legacy policy and norms, policy ambiguities, and changing relationships

The injustices raised by the interview participants are structured according to three main themes. The first theme is *legacy policy and norms*, which refers to outdated regulations and established practices that may no longer be effective. Second, *policy ambiguities* involves unclear or inconsistent regulations that create uncertainty and potential inequities. Third, *changing relationships* highlight the evolving dynamics between DSOs and their customers, driven by IT systems and increased citizen participation.

These themes are not isolated; they influence and interact with each other. For example, changing relationships within the energy sector often require new policies. However, these policies can be outdated or nonexistent, potentially leading to injustices related to legacy policies or policy ambiguities. Legacy norms in the energy sector also influence the changing relationships between DSOs and their customers. Fig. 3 provides an overview of the main themes, subthemes, and associated subsections in this article.

All interview participants expressed concerns about the risks of injustice related to increased grid congestion and the widespread adoption of congestion management measures. They noted that these developments could potentially exacerbate inequities within the energy transition. The following subsections elaborate on the injustices that our interview participants raised.

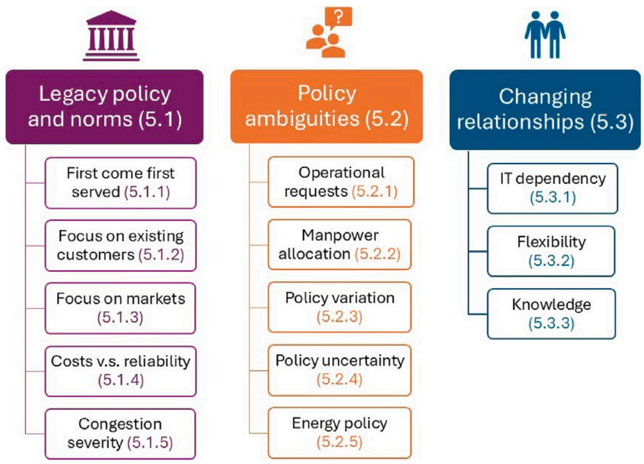


Fig. 3. Overview of main themes and subthemes (with related subsections).

5.1. Main theme: legacy policy and norms

The first theme highlights injustices stemming from legacy policies and social norms within DSOs and the broader energy system. Participants questioned the compatibility of these legacy influences with emerging grid congestion. The following sections elaborate on the five perceived injustices that relate to this theme.

5.1.1. Adhering to the "first come, first served" policy for distributing new grid capacity

All participants believed that the "first come, first served" policy for the distribution of new grid capacity was unjust with the growing scarcity of grid capacity. Most of the participants referred to social prioritization policies in the making, where parties with activities of social value, such as schools, police, dykes, and renewable energy generation, gain priority on waiting lists for grid capacity. However, in these draft policies, social prioritization only comes into play when there is congestion on the grid, and some participants found it more just to allow for social prioritization when grid congestion is foreseen shortly. Participants also found it more fair to prioritize storage systems, such as batteries, for new grid connections, given their ability to partially alleviate congestion and provide space for other parties. There was consensus among participants that those given priority for grid capacity should provide flexibility for congestion management and some participants even believed that all connected parties gaining new grid connections should provide these services.

In addition, some participants suggested that it would be fair to discriminate in favor of nonprofit organizations for new grid connections, as commercial organizations typically have more resources and knowledge. However, some participants criticized instances in which DSOs favored energy cooperatives over commercial renewable energy developers without a clear justification. Furthermore, participants felt it unjust that companies strategically request substantial grid capacity merely to secure a position on the waiting list, specifically disadvantaging parties with less financial capacity. However, the "first come, first served" policy rewards companies for these practices, even within social prioritization policies.

5.1.2. Prioritizing existing connected parties over parties on the waiting list

The majority of participants found it unjust that DSOs strictly adhere to high reliability standards that prioritize the distribution of electricity to existing connected parties over providing electricity to parties on the waiting list for grid capacity. They also questioned whether this is a conscious decision by policymakers and DSOs or whether this focus has inadvertently evolved, originating in a historical focus on increasing the reliability of distribution grids. Many participants expressed concerns about the extensive measures imposed by DSOs to uphold reliability standards, suggesting that lowering reliability standards could provide more space on the distribution grid for new parties. As a participant (P04) stated, "We have a very reliable grid, but only for the happy few that already have a grid connection".

5.1.3. Focusing on markets and profits

Several participants emphasized that policymakers and DSOs prioritize remunerations for congestion management over other methods that do not require financial compensation. Some argued that the focus should shift from remunerations to a broader societal discussion on how grid infrastructure costs should be distributed. Some participants suggested using cost reflectivity as a starting point for determining cost distribution. However, there was no consensus on which factors should be excluded from cost reflectivity calculations, specifically concerning the influence parties have on these aspects, such as their location, congestion in the area, investing plans, future neighbors, ability to reduce peak load or demand, and ability to pay.

Others advocated that grid operators should compensate for lost revenue and emphasized that it would be unjust if congestion management became a profit model. The first reason for this is that paying customers for providing flexibility tends to benefit parties with larger grid connections and initially more electricity usage in contrast to smaller parties with less electricity usage. Secondly, some participants mentioned that it would be unjust if connected parties that could easily change their electricity use without any significant losses would profit from that at the expense of others.

In addition, several participants highlighted that grid congestion is location dependent, meaning that often only a few parties can help alleviate it at specific locations and times. Market mechanisms for congestion management assume sufficient supply to determine a fair price. However, there are often only a few parties capable of assisting with congestion management. If these parties recognize that they are the only option for a DSO, they might exploit the situation. Similar concerns were raised about individual negotiations between grid operators and connected parties for congestion management remunerations, with potential advantages for skilled negotiators.

5.1.4. Overlooking the trade-off between increasing grid costs and reliability

Many interviewees were concerned about the rapidly increasing grid tariffs. They specifically mentioned that regulatory incentives prioritize grid reliability, leading DSOs to focus on reliability over other objectives such as minimizing cost or providing new grid connections. Several participants felt that it was unjust that DSOs and policymakers were not consulting the general public about fundamental trade-offs regarding these increasing costs. A participant (P07), working in a DSO, stated, "You can also ask clients if they are willing to receive a 20 percent discount on your grid connection if you experience more disruptions. But we never ask that question. We always choose to maintain supply reliability and let prices rise". They felt that these policies should be revised with public input, as they were established when grid congestion was not yet an issue.

5.1.5. Lacking justification of the severity of local-level grid congestion

Many participants raised concerns about the severity of grid congestion as reported by DSOs. They doubted whether there is actual congestion in the distribution grid or if it is mainly "contractual congestion". The term "contractual congestion" indicates that DSOs use high safety margins in their estimates for grid congestion to ensure reliability. These estimates are based on forecasting algorithms, internal policies and contractual agreements, which may not always reflect real-time loads. Consequently, participants questioned whether grid congestion is as severe as communicated by DSOs. These doubts stem from a reliability-oriented culture and a lack of high-quality measurement data, particularly in low-voltage distribution grids.

5.2. Main theme: policy ambiguities

The second theme addresses the injustices participants experienced due to unclear, inconsistent, and incomplete policies on grid congestion. Participants felt that the new types of decisions made by DSOs often lacked justification and were not always well represented in policy and legislation. This has led to uncertainty and inconsistent decision-making. The following sections detail the five injustices we identified related to this theme.

5.2.1. Lacking justification of operational congestion management requests

Multiple participants felt that there was a lack of justification for operational requests to reduce electricity consumption or production as part of congestion management. An interviewee (P01) from a DSO provided an example, "At one substation, [a DSO] has a solar park and a wind park. Now, the question is, when do you call each of them?" Participants stressed that there should be clear policies for distributing grid capacity in the operational domain, which are currently lacking. This is even more pressing with the introduction of non-firm transport capacity, where DSOs increasingly allocate grid capacity to connected parties within the operational domain.

Participants emphasized many potential selection criteria for this allocation, such as weather forecasts, the alternation between connected parties, the carbon footprint of electricity generation, the reliability of weather or load predictions, or the reliability of parties in executing requests. Despite the lack of consensus on which factors should be considered for distributing grid capacity, participants stressed the importance of transparency and consistency in these decisions.

5.2.2. Lacking justification of the allocation of manpower for pilot projects

Participants, including both connected parties and DSO employees, expressed concerns about the lack of justification for the allocation of manpower to pilot projects that aim to reduce grid congestion. These projects often explore activities that fall outside the legal responsibilities of a DSO, thus being classified as "pilot projects". Due to their experimental nature, these projects require customized approaches. The limited manpower available within DSOs for these types of projects often becomes a bottleneck.

Several participants expressed concerns that those who are the most vocal or well-connected are the ones who secure pilot projects with DSOs. It remains unclear whether this is due to a lack of policy criteria for selecting and prioritizing these projects, or if the participants were simply unaware of such criteria. Additionally, while most participants acknowledged the challenges DSOs face due to a shortage of skilled workers, those on the waiting list for new grid connections found it troubling that they could not help alleviate grid congestion by forming energy communities because of this manpower shortage.

5.2.3. Lacking justification of policy variation among DSOs

Some participants mentioned that various DSOs within the country seem to interpret or deal with regulations differently, often without a clear justification. For example, while some DSOs allow batteries to be connected to the distribution grid, others have stated they will not do so for at least another year. Similar inconsistencies were reported for new initiatives with non-firm grid contracts. These inconsistencies arise in part because some DSOs are more willing to explore beyond established regulations than others. This leads to confusion among parties requesting new grid connections, particularly those operating in multiple locations across the country.

5.2.4. Policy uncertainty leading to strategic and conservative behavior

Many participants expressed a lack of predictability with the rapid emergence of grid congestion and its related policies. Two demand response parties specifically mentioned that many parties were surprised by grid congestion a few years ago. Some of these parties had already invested in land, buildings, or electrification equipment to find that they could not get a grid connection. They felt that the grid operators had taken away their perceived right to a grid connection.

Most of the participants mentioned concerns about "taking away" grid capacity from existing customers. While some participants, working at a DSO or the ministry, believed that people would be more willing to share grid capacity within an energy community, those involved in such communities reported that members were also hesitant to give up their grid capacity rights. Similarly, parties were cautious about adopting flexible grid capacity contracts, which would require them to give up some of their fixed rights to grid capacity in exchange for a flexible right and lower grid tariffs. A participant highlighted the concern that giving up grid capacity that they do not currently need could prevent them from obtaining additional capacity in the future for needs such as heat pumps or electric cars. This uncertainty about the availability of grid capacity in the future is leading to conservative and strategic behavior among connected parties, which disadvantages those currently on the waiting list for grid capacity.

5.2.5. Lacking recognition of grid congestion in energy transition policies

Many interviewees also highlighted that grid congestion hinders electrification goals to support the energy transition, such as using electricity for heating in industry and adopting electric trucks for industrial transportation. They noted that grid congestion and rising grid tariffs are a key challenge for these efforts. From a procedural standpoint, the conflict between policy demands and public encouragement to electrify, combined with practical grid limitations, creates a sense of contradiction and discouragement. Therefore, the lack of coherence between national and local policies for electrification, combined with the reality of grid congestion, may lead to perceptions of injustice.

5.3. Main theme: Changing relationships

Our final theme is related to the changing relationships between DSOs and affected parties, including both consumers and producers of electricity. These changing relationships require new approaches to collaboration, communication, and interaction. Participants expressed concerns about the growing influence of IT systems, and the lacking recognition of the flexibility constraints and knowledge levels of connected parties. The following sections elaborate on the perceived injustices related to this theme.

5.3.1. Dependency on private IT companies

Multiple interviewees, most of whom did not work for a DSO, expressed concerns about possible injustices related to the risks of lock-in with IT companies developing new solutions for managing grid congestion. They noted that many pilot projects are not developed in an open-source manner, limiting access to data and algorithms for actors not participating in these projects. This situation has led to public funds benefiting private entities that can establish market positions without sharing their innovations. Moreover, a dependency on proprietary systems could restrict DSOs' abilities to influence and legitimize design choices for IT systems, limiting their capacity to anticipate or address potential injustices both before and after these systems are deployed.

5.3.2. Overlooking connected parties' flexibility constraints

Participants stressed the importance of recognizing the degree to which parties can be flexible in their electricity use. This concern is also reflected in the literature on *flexibility capital* (e.g., [62,63]). For example, a participant noted that suggestions to shift factory production to the night are impractical, as this would require workers to also work during the night. Interviewees also raised concerns about the varying levels of resources available to different groups for mitigating grid congestion. For example, forming an energy community requires significant investments that not everyone can afford.

Table 2
Distributive and procedural injustices that underlie perceived injustices as raised by our participants.

Perceived injustice	Distributive injustice	Procedural injustice
1. First come first served	Unfair distribution of grid capacity	
2. Existing customers	Unfair distribution of reliable electricity access	Lack of justification and public input
3. Market focus	Unfair distribution of costs	
4. Cost vs. reliability	Unfair distribution of costs and reliable electricity access	Lack of public input
5. Congestion severity		Lack of justification
6. Operational requests	Unfair distribution of grid capacity	Lack of justification
7. Manpower allocation	Unfair distribution of manpower	Lack of justification
8. Policy variation	Unfair distribution of innovation opportunities	Lack of justification
9. Policy uncertainty		Lack of perspective
10. Energy policy		Lack of coherence
11. IT dependency		Lack of transparency and control
12. Flexibility constraints		Lack of acknowledgment
13. Knowledge		Lack of acknowledgment

In addition, participants emphasized that they often have limited capacity to shift to other physical locations. One participant mentioned that flexible contracts, especially those with market-based tariffs for grid capacity, could disadvantage connected parties in congested areas. Generally, participants agreed that different parties have varying capacities to be flexible. According to them, this should be recognized by staying away as much as possible from incentives based on capacities that cannot be easily accessed.

5.3.3. *Overlooking connected parties' knowledge levels*

Participants also mentioned a lack of recognition by DSOs of the knowledge connected parties have about electricity grids. For example, a participant noted that small energy cooperatives might feel overwhelmed by grid operators. Another participant highlighted that the technical challenges that cause grid congestion could be exacerbated by a lack of knowledge among connected parties. Participants suggested that DSOs and policymakers could implement initiatives to better understand and acknowledge the expertise of connected parties.

6. Discussion: energy justice and policy recommendations

This discussion contextualizes our findings within the energy justice literature, focusing on distributive and procedural justice. The first subsection categorizes the perceived injustices by these tenets to highlight their multifaceted nature. The second subsection offers policy recommendations to address these perceived injustices.

6.1. *Relation between perceived injustices and energy justice*

We initially categorized each perceived injustice into a single tenet but soon found that some injustices could not be classified into a single category. For example, the perceived injustice related to the prioritization of existing connected parties over new applicants appeared to primarily concern distributive justice, as it affects the equitable distribution of grid capacity. However, it also has significant procedural justice implications, as participants noted that the decision-making process may lack inclusivity. Some participants focused more on the distributive aspects of this perceived injustice, while others emphasized procedural elements. Consequently, it was unclear whether a perceived injustice stemmed from the distributive or procedural justice tenet.

To address these complexities, we adopted a more nuanced approach. We carefully examined each perceived injustice to identify the relevant tenet of justice that it touched on, which is shown in Table 2. Distributive injustices primarily involve an unfair distribution of grid capacity, reliable energy access, or costs. Procedural injustices mainly concern the lack of justification and public input in decision-making processes. Some perceived injustices relate to both distributive and procedural justice, such as prioritizing existing customers over new customers and overlooking the trade-off between costs and reliability.

Fig. 4 provides an overview of how the main themes are positioned with respect to distributive and procedural justice. Perceived injustices

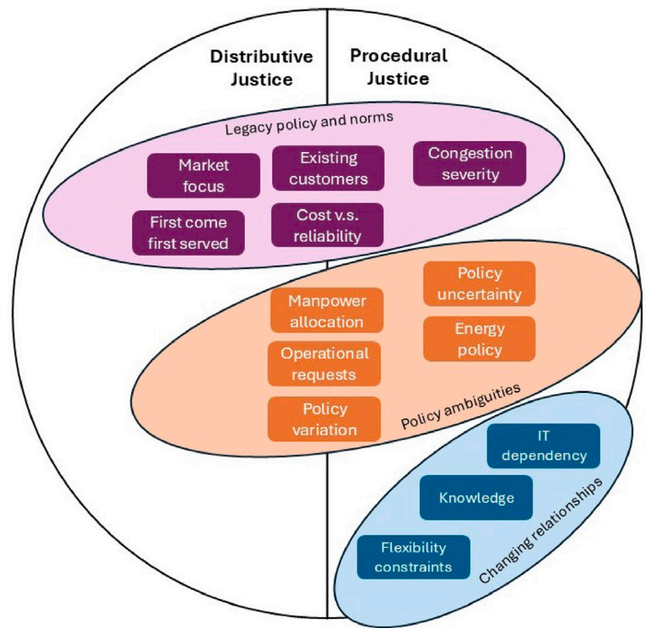


Fig. 4. Relationship between the main themes and distributive and procedural justice.

placed on the central axis relate to both distributive and procedural justice. This figure shows that injustices stemming from legacy policies and norms are varied, some relating to distributive justice, others to procedural justice, and some encompassing both. In contrast, injustices stemming from policy ambiguities and changing relationships are more closely related to procedural justice.

Identifying the tenet of justice behind each perceived injustice is valuable for two reasons. First, it allows for a deeper analysis of a perceived injustice, distinguishing whether concerns arise from the allocation of burdens and benefits or from the decision-making processes. These insights could enable targeted policy recommendations: depending on whether an injustice is distributive or procedural, specific policy interventions can be designed. Second, this framework shows that injustices are multifaceted, offering a nuanced view that enhances our understanding of energy justice.

6.1.1. *Relation between perceived injustices and distributive justice*

In terms of distributive justice, participants mainly expressed concerns about the unfair distribution of available grid capacity, the reliability of electricity access, and the associated costs. In addition, they questioned the distribution of manpower and opportunities for innovation. Legacy policies and norms significantly impacted perceptions of distributive injustice, such as the "first come, first served" principle and the use of high safety margins to determine grid congestion. Social norms that prioritize reliability over costs, favor existing connected parties, and focus on markets and profits (also discussed in [16,31,42]) further exacerbate these issues. Our analysis further revealed that, compared to the literature on pilot projects, the injustices experienced by actors in real-world applications changed significantly. Specifically, injustices related to legacy policies, social norms, and policy ambiguities – frequently identified in our study – were less prevalent in the literature on pilot projects due to their experimental nature.

6.1.2. Relation between perceived injustices and procedural justice

This study has found many perceived injustices related to procedural justice. However, it is too straightforward to say that procedural justice is more important than distributive justice in this context, as we did not study in detail which perceived injustices were found to be more important than others. For example, concerns about markets and profits, which relate to distributive justice, have been highlighted more often by participants than many other perceived injustices. In addition, a large part of the perceived injustices were found to have both a distributive and procedural basis.

In terms of procedural justice, five key elements emerged from our analysis. First, a lack of justification for decisions often resulted in perceived injustices among our participants. This created a sense of arbitrariness as participants could not understand the reasoning behind certain actions or policies. For example, when the manpower for pilot projects was allocated without detailed justifications, participants questioned whether this was based on a certain logic. However, it remains uncertain whether providing justifications would suffice to address these perceptions or if participants would still find these developments unjust on, for example, distributive grounds. As perceptions of injustice are location- and time-specific, changing conditions could potentially lead to new injustices or different bases for injustices [64].

Second, decision-making processes that did not consider public input were sometimes perceived as unjust. For example, participants felt that DSOs and policymakers overlooked fundamental trade-offs, such as balancing reliability with costs and accommodating new grid connections. Ensuring that these processes are inclusive and transparent could help address these concerns. Third, participants raised the issue of a lack of understanding and acknowledgment of the diverse needs of affected parties, highlighting an increased social responsibility for DSOs [65]. Fourth, participants were concerned about a lack of transparency and control in the development and operation of IT systems, which increasingly shape the relationship between DSOs and connected parties. Finally, a lack of coherence between policies at various decision-making levels has been raised as a perceived injustice.

6.2. Policy recommendations

Our study is descriptive in nature and we do not claim that all these perceived injustices are normatively unjust. However, we identify four key policy recommendations for policymakers or DSOs who wish to address these perceptions.

6.3. Revising legacy law and policies

The impact of legacy law and policies on decision-making in the context of increasing grid congestion emerged as a significant topic in our interviews. This shows how regulations and policies established in the past continue to influence decision-making processes, even as new challenges like grid congestion arise. Our interviews showed that many actors acknowledge the importance of reviewing and updating these old rules. They understand that sticking to outdated policies could impede effective solutions to congestion and might not fully meet the changing needs of modern distribution grids. To address these issues, policymakers could consider revising the legislation and incentives for DSOs after reevaluating their responsibilities. For example, while economic stagnation caused by grid congestion is not directly the responsibility of DSOs under the current institutional structures, it negatively impacts society, and DSOs are uniquely positioned to address it.

6.4. Reconsidering fundamental trade-offs

Policymakers and DSOs could work together to clearly outline the fundamental trade-offs related to the mitigation of grid congestion. These may include balancing reliability with costs or accommodating new connections while maintaining reliability standards. In order to outline these trade-offs, DSOs could make the technical constraints surrounding these trade-offs explicit, and policymakers could consider alternatives to existing incentive structures and policies. In addition, national policymakers could factor these fundamental trade-offs into political decision-making processes. They could also explore the participation of society in decision-making concerning these fundamental trade-offs, as they are increasingly doing through participatory value evaluation approaches for policymaking on the energy transition [66].

6.5. Improving transparency and information provision

National policymakers and DSOs could also prioritize justifying new decisions and policies to society. Participants noted that, although they understand the necessity of certain trade-offs, the reasoning behind some decisions appears to be lacking. A starting point could be to provide citizens with information on where they are connected in the grid and the level of congestion in their area. Similar to how navigation apps provide insight into traffic jams or train delays, this approach aims to offer visibility into the severity of local-level grid congestion. Achieving this requires open and concrete communication from DSOs to affected parties.

Additionally, DSOs could create a "Frequently Asked Questions" webpage that not only provides information about their ongoing projects and general activities but also addresses specific questions, such as "Why is grid operator A allowing the connection of batteries while grid operator B is not?" This would help clarify ambiguities regarding current legislation and policy and explain how these issues are being managed during this period of policy development. Such a platform could also enable people to raise questions and engage in constructive dialogues about these issues.

6.6. Considering justice in IT development

Our interviews revealed concerns about the design and governance of IT systems used for managing grid congestion. For example, participants highlighted the absence of clear policies that guide the allocation of grid capacity within these systems. Concerns were also raised about the dependency on private IT companies, which may limit access and control over critical IT systems. This dependency could hinder actors' ability to influence and validate design choices, potentially leading to injustices. Addressing these challenges requires proactive steps to integrate justice principles into the design and governance of IT systems for managing grid congestion.

To address these issues, grid operators could establish clear criteria for the allocation of grid capacity in the operational domain and integrate these criteria into IT systems. Regular audits and reporting on the performance of IT systems will improve transparency and accountability. Furthermore, setting up continuous monitoring and evaluation frameworks to assess the impact of IT systems on different actor groups can help to understand the distributive effects of operational decisions made by these systems. Finally, promoting the use of open-source software could reduce the risk of lock-in with private parties and ensure better transparency and control over IT systems.

7. Conclusion: the importance of institutional factors

Although grid congestion is increasingly recognized as an important issue, its societal implications remain underexplored. Our study highlights a critical gap in the scientific understanding of these implications.

The research question that informed this study was *what injustices do actors experience or anticipate when addressing grid congestion in electrical distribution grids?* Our analysis revealed 13 perceived injustices in this context, categorized into three main themes: (1) injustices arising from legacy policies, legislation, and social norms; (2) injustices due to unclear regulations, inconsistent policies, and policy gaps; and (3) injustices related to changing relationships between DSOs and affected parties. We found that participants accepted that grid congestion is inevitable in the current situation. Therefore, the identified perceived injustices were mainly related to how DSOs and policymakers manage grid congestion than to the rise of grid congestion itself.

These perceived injustices were underpinned by both distributive and procedural issues, with several relating to both justice dimensions. We also highlighted the interactions between distributive and procedural justice in this study. By making these underlying aspects explicit, we offered insights for policymakers to develop targeted policy solutions. However, we did not study causal interactions between the different justice dimensions, which could be of interest to fully capture real-world complexity [24].

Recognizing the *sociotechnical* nature of power grids, our analysis emphasizes that grid congestion cannot be fully addressed by technical solutions alone. A sociotechnical perspective emphasizes that grid congestion is shaped by the complex interplay of technical, social, and institutional factors [67]. Our analysis showed that institutional factors, such as regulations, policies, and social norms, significantly influence perceptions of injustice among participants. Consequently, we support the call by Sovacool et al. [27] to comprehensively integrate justice principles within the institutional (e.g. regulation, policy, markets, social norms), technical (e.g. physical grid infrastructure, IT systems) and social (e.g. community engagement, communication) components of grid infrastructure.

Although our analysis reveals nuanced insights into the justice aspects of grid congestion, our study has three main limitations that should be addressed in future work. First, this study examined interviews collected from 16 participants and is inherently exploratory in its approach. In addition, the findings of this study are influenced and limited by the Dutch context in which the data were gathered. Interviews with different types of participants, such as residential customers with other educational backgrounds or actors in other countries, especially non-Western countries where there may be different conceptions of justice, would enhance our dataset and have the potential to make a valuable contribution to a broader and more nuanced exploration of perceptions of injustice in congestion management.

Second, this study focused only on the distributive and procedural aspects of justice. Future studies could more explicitly incorporate recognition, restorative, and cosmopolitan justice. Third, our study captured perceptions of injustice at a specific point in time. However, normative interpretations of justice are not static and evolve in response to sociocultural and sociotechnical transitions [64]. Given that grid congestion is an emerging problem, it is not surprising that we found many injustices related to decision-making procedures. Research on (energy) systems in transition could provide more detailed insight into how justice perceptions might change over time as systems mature.

Our study shows the need for future research to deepen our understanding of the societal implications of congestion management. We identify two directions for future research. First, future research could draw comparisons between grid congestion and other historical infrastructure changes, such as the transition to renewable energy or the transition from coal to natural gas. By examining these historical precedents, researchers can gain insight into perceptions of justice, regulatory responses, and societal impacts, which could help develop more effective strategies to manage grid congestion. Second, future research could encompass comprehensive studies in other countries, each with its own regulatory environments, technology, and societal contexts.

In conclusion, grid congestion is creating a new divide in the energy transition, leading to groups of "haves and have-nots". Given the severity and expected persistence of grid congestion in countries such as the Netherlands, studying perceptions of injustice in affected areas can help ensure that congestion management promotes justice and supports an equitable energy transition for everyone.

CRediT authorship contribution statement

Eva de Winkel: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Zofia Lukszo:** Writing – review & editing, Validation, Supervision. **Mark Neerincx:** Validation, Supervision. **Roel Dobbe:** Writing – review & editing, Validation, Methodology, Funding acquisition.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the first author used ChatGPT to improve English grammar. After using this tool, the authors reviewed and edited the content as needed, and, as such, they take full responsibility for the content of the publication.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.erss.2025.103962.

Data availability

The authors do not have permission to share data.

References

[1] S. Nandini, P. Suganya, K. Lakshmi, Congestion management in transmission lines considering demand response and facts devices, Intern. J. Innov. Res. Sci. Eng. Technol. 3 (1) (2014) 682–688.

[2] K.L. Anaya, M.G. Pollitt, Options for allocating and releasing distribution system capacity: Deciding between interruptible connections and firm DG connections, Appl. Energy 144 (2015) 96–105, http://dx.doi.org/10.1016/j.apenergy.2015.01.043.

[3] Netbeheer Nederland, Integrale Infrastructuurverkenning 2030–2050 – Hoofdrapport, Tech. Rep., Netbeheer Nederland, 2023, https://tennet-drupal.s3.eu-central-1.amazonaws.com/default/2023-10/II3050_Eindrapport.pdf. (Accessed 4 December 2024).

[4] Bundesnetzagentur, Netzentwicklungsplan Strom 2035, Tech. Rep., Bundesnetzagentur, 2021, https://www.netzentwicklungsplan.de/archiv/netzentwicklungsplan-2035-2021. (Accessed 4 December 2024).

[5] ESO, Beyond 2030: A national blueprint for a decarbonised electricity system in Great Britain, Tech. Rep., ESO, 2024, https://www.neso.energy/publications/beyond-2030. (Accessed 4 December 2024).
[6] G. Verhoeven, B. van der Holst, S. Sharma, K. Kok, A co-simulation framework design to assess the effectiveness of flexibility activation mechanisms on congestion in dutch distribution networks, in: 2022 Open Source Model. and Simul. of Energy Syst., OSMSES, 2022, pp. 1–6, http://dx.doi.org/10.1109/OSMSES54027.2022.9769151.
[7] D. Telegraaf, Alliander: Nog zeker tien jaar file op stroomnet, duizenden technici uit buitenland nodig, 2024, https://www.telegraaf.nl/financieel/939560999/alliander-nog-zeker-tien-jaar-file-op-stroomnet-duizenden-technici-uit-buitenland-nodig?utm_source=(direct)&utm_medium=webpus. (Accessed 2 December 2024).
[8] K. Spiliotis, A.I. Ramos Gutierrez, R. Belmans, Demand flexibility versus physical network expansions in distribution grids, Appl. Energy 182 (2016) 613–624, http://dx.doi.org/10.1016/j.apenergy.2016.08.145.
[9] R.J. Hennig, L.J. de Vries, S.H. Tindemans, Congestion management in electricity distribution networks: Smart tariffs, local markets and direct control, Util. Policy 85 (2023) 101660, http://dx.doi.org/10.1016/j.jup.2023.101660.
[10] D. Miller, Stanford encyclopedia of philosophy. Justice, 2021, https://plato.stanford.edu/entries/justice/. (Accessed 4 December 2024).
[11] M. Noorman, B. Espinosa, S. Lavrijssen, AI and energy justice, Energies 16 (2023) http://dx.doi.org/10.3390/en16052110.
[12] M. Sonnberger, M. Ruddat, Local and socio-political acceptance of wind farms in Germany, Technol. Soc. 51 (2017) 56–65, http://dx.doi.org/10.1016/j.techsoc.2017.07.005.
[13] M.J. Sullivan, E. Yakobov, W. Scott, R. Tait, Perceived injustice and adverse recovery outcomes, Psychol. Inj. Law 7 (2014) 325–334, http://dx.doi.org/10.1007/s12207-014-9209-8.
[14] Tweede Kamer der Staten-Generaal, Hoorzitting met de ceo's van de netbeheerders over de aanpak netcongestie, 2024, https://debatdirect.tweedekamer.nl/2024-11-13/klimaat/groen-van-prinstererzaal/hoorzitting-met-de-ceos-van-de-netbeheerders-over-de-aanpak-netcongestie-17-00/onderwerp. (Accessed 4 December 2024).
[15] F. Libertson, Competing socio-technical narratives in times of grid capacity challenges: the representative case of Sweden, Energy, Sustain. Soc. 11 (4) (2021) http://dx.doi.org/10.1186/s13705-021-00279-4.
[16] K. van der Wel, S. Akerboom, Overlooked, misunderstood, or sidelined?: Explaining why energy justice is not safeguarded in smart local energy systems, Energy Res. Soc. Sci. 118 (2024) 103785, http://dx.doi.org/10.1016/j.erss.2024.103785.
[17] N. Van Uffelen, B. Taebi, U. Pesch, Revisiting the energy justice framework: Doing justice to normative uncertainties, Renew. Sustain. Energy Rev. 189 (2024) 113974, http://dx.doi.org/10.1016/j.rser.2023.113974.
[18] B.K. Sovacool, M.H. Dworkin, Energy justice: Conceptual insights and practical applications, Appl. Energy 142 (2015) 435–444, http://dx.doi.org/10.1016/j.apenergy.2015.01.002.
[19] D.A. McCauley, R.J. Heffron, H. Stephan, K. Jenkins, Advancing energy justice: the triumvirate of tenets, Intern. Energy Law Rev. 32 (3) (2013) 107–110.
[20] D. Schlosberg, Defining Environmental Justice: Theories, Movements, and Nature, Oxford University Press, 2007.
[21] N. Van Uffelen, Revisiting recognition in energy justice, Energy Res. Soc. Sci. 92 (2022) 102764, http://dx.doi.org/10.1016/j.erss.2022.102764.
[22] D.A. McCauley, V. Ramasar, R.J. Heffron, B.K. Sovacool, D. Mebratu, L. Mundaca, Energy justice in the transition to low carbon energy systems: Exploring key themes in interdisciplinary research, Appl. Energy 233 (2019) 916–921, http://dx.doi.org/10.1016/j.apenergy.2018.10.005.
[23] N. Wood, K. Roelich, Substantiating energy justice: Creating a space to understand energy dilemmas, Sustain. 12 (5) (2020) 1917, http://dx.doi.org/10.3390/su12051917.
[24] N. Wood, Problematising energy justice: Towards conceptual and normative alignment, Energy Res. Soc. Sci. 97 (2023) 102993, http://dx.doi.org/10.1016/j.erss.2023.102993.
[25] A.R. Vadavathi, G. Hoogsteen, J. Hurink, Fair and efficient congestion management for low voltage distribution networks, in: 2024 IEEE 8th Energy Conference, ENERGYCON, IEEE, 2024, pp. 1–6.
[26] A. Kumar, Beyond technical smartness: Rethinking the development and implementation of sociotechnical smart grids in India, Energy Res. Soc. Sci. 49 (2019) 158–168, http://dx.doi.org/10.1016/j.erss.2018.10.026.
[27] B.K. Sovacool, S. Carley, L. Kiesling, Energy justice beyond the wire: Exploring the multidimensional inequities of the electrical power grid in the United States, Energy Res. Soc. Sci. 111 (2024) 103474, http://dx.doi.org/10.1016/j.erss.2024.103474.
[28] N. Komendantova, A. Battaglini, Beyond decide-announce-defend (DAD) and not-in-my-backyard (NIMBY) models? Addressing the social and public acceptance of electric transmission lines in Germany, Energy Res. Soc. Sci. 22 (2016) 224–231, http://dx.doi.org/10.1016/j.erss.2016.10.001.
[29] J.K. Knudsen, L.C. Wold, Ø. Aas, J.J. Kielland Haug, S. Batel, P. Devine-Wright, M. Qvenild, G.B. Jacobsen, Local perceptions of opportunities for engagement and procedural justice in electricity transmission grid projects in Norway and the UK, Land Use Policy 48 (2015) 299–308, http://dx.doi.org/10.1016/j.landusepol.2015.04.031.
[30] C.E. Mueller, Examining the inter-relationships between procedural fairness, trust in actors, risk expectations, perceived benefits, and attitudes towards power grid expansion projects, Energy Policy 141 (2020) 111465, http://dx.doi.org/10.1016/j.enpol.2020.111465.
[31] J. Vega-Araújo, R.J. Heffron, Assessing elements of energy justice in Colombia: A case study on transmission infrastructure in La Guajira, Energy Res. Soc. Sci. 91 (2022) 102688, http://dx.doi.org/10.1016/j.erss.2022.102688.
[32] R.K. Kaufmann, M. Kelly-Fair, C. Schroer, Distributive energy justice: Who lost power in Texas during the 2021 winter storm? Energy Res. Soc. Sci. 109 (2024) 103416, http://dx.doi.org/10.1016/j.erss.2024.103416.
[33] C. Milchram, R. Künneke, N. Doorn, G. van de Kaa, R. Hillerbrand, Designing for justice in electricity systems: A comparison of smart grid experiments in the Netherlands, Energy Policy 147 (2020) 111720, http://dx.doi.org/10.1016/j.enpol.2020.111720.
[34] M. Wolsink, Conceptualizations of smart grids –anomalous and contradictory expert paradigms in transitions of the electricity system, Energy Res. Soc. Sci. 109 (2024) 103392, http://dx.doi.org/10.1016/j.erss.2023.103392.
[35] C. Milchram, R. Hillerbrand, G. van de Kaa, N. Doorn, R. Künneke, Energy justice and smart grid systems: Evidence from the Netherlands and the United Kingdom, Appl. Energy 229 (2018) 1244–1259, http://dx.doi.org/10.1016/j.apenergy.2018.08.053.
[36] R. Folger, Distributive and procedural justice in the workplace, Soc. Justice Res. 1 (1987) 143–159.
[37] A. Lind, T. Tyler, The Social Psychology of Procedural Justice, Springer Sci. & Bus. Media, 1988.
[38] N. Verkade, J. Höffken, The design and development of domestic smart grid interventions: Insights from the Netherlands, J. Clean. Prod. 202 (2018) 799–805, http://dx.doi.org/10.1016/j.jclepro.2018.08.185.
[39] N. Hargreaves, T. Hargreaves, J. Chilvers, Socially smart grids? A multi-criteria mapping of diverse stakeholder perspectives on smart energy futures in the United Kingdom, Energy Res. Soc. Sci. 90 (2022) 102610, http://dx.doi.org/10.1016/j.erss.2022.102610.
[40] L. Schick, C. Gad, Flexible and inflexible energy engagements—A study of the Danish smart grid strategy, Energy Res. Soc. Sci. 9 (2015) 51–59, http://dx.doi.org/10.1016/j.erss.2015.08.013, special issue on Smart Grids and the Social Sciences.
[41] P. Calver, N. Simcock, Demand response and energy justice: A critical overview of ethical risks and opportunities within digital, decentralised, and decarbonised futures, Energy Policy 151 (2021) 112198, http://dx.doi.org/10.1016/j.enpol.2021.112198.
[42] O. Pitkänen, T.M. Skjølsvold, Shifting patterns – The patterned enactments of flexible electricity consumption by Norwegian households, Energy Res. Soc. Sci. 115 (2024) 103639, http://dx.doi.org/10.1016/j.erss.2024.103639.
[43] F. Libertson, Misalignments of theory and practice: Exploring Swedish energy utilities' understandings of energy justice, flexibility capital, and just energy transitions, Energy Res. Soc. Sci. 111 (2024) 103471, http://dx.doi.org/10.1016/j.erss.2024.103471.
[44] J.A. Beaulieu, What are smart grids? Epistemology, interdisciplinarity and getting things done, in: A. Beaulieu, J. de Wilde, J.M. Scherpen (Eds.), Smart Grids from a Global Perspective: Bridging Old and New Energy Systems, Springer International Publishing, 2016, pp. 63–73, http://dx.doi.org/10.1007/978-3-319-28077-6_5.
[45] H. Kallio, A.-M. Pietilä, M. Johnson, M. Kangasniemi, Systematic methodological review: developing a framework for a qualitative semi-structured interview guide, J. Adv. Nurs. 72 (12) (2016) 2954–2965, http://dx.doi.org/10.1111/jan.13031.
[46] Netbeheer Nederland, Map of electricity grid capacity in the netherlands, 2024, https://capaciteitskaart.netbeheernederland.nl/ (accessed 2 Dec. 2024).
[47] Alliander, Alliander investeert record in energienetten, toch blijven er nog zeker 10 jaar files op elektriciteitsnet, 2024, https://www.alliander.com/nl/financieel-nieuws/alliander-investeert-record-in-energienetten-toch-blijven-er-nog-zeker-10-jaar-files-op-elektriciteitsnet/. (Accessed 27 January 2025).
[48] Netbeheer Nederland, Onze leden, 2024, https://www.netbeheernederland.nl/onze-leden. (Accessed 2 December 2024).
[49] F. Kern, M. Howlett, Implementing transition management as policy reforms: a case study of the Dutch energy sector, Policy Sci. 42 (4) (2009) 391–408, http://dx.doi.org/10.1007/s11077-009-9099-x.
[50] Autoriteit Consument & Markt, Codebesluit congestiemanagement, 2024, https://www.acm.nl/nl/publicaties/codebesluit-congestiemanagement. (Accessed 2 December 2024).
[51] GOPACS, Hoe werkt gopacs?, 2024, https://www.gopacs.eu/hoe-werkt-gopacs/. (Accessed 2 December 2024).
[52] Netbeheer Nederland, Realtime interface, 2024, https://www.netbeheernederland.nl/netcapaciteit-en-flexibiliteit/realtime-interface. (Accessed 2 December 2024).
[53] Autoriteit Consument & Markt, Onderzoek naar de flexibilisering van nettarieven, 2019, https://www.acm.nl/nl/publicaties/onderzoek-naar-de-flexibilisering-van-nettarieven. (Accessed 2 December 2024).
[54] Autoriteit Consument & Markt, Ontwerp codebesluit alternatieve transportrechten, 2024, https://www.acm.nl/nl/publicaties/ontwerp-codebesluit-alternatieve-transportrechten. (Accessed 2 December 2024).

[55] Autoriteit Consument & Markt, Voorstel codewijziging groepstransportovereenkomst, 2024, https://www.acm.nl/nl/publicaties/voorstel-codewijziging-groepstransportovereenkomst. (Accessed 2 December 2024).
[56] Autoriteit Consument & Markt, Codebesluit prioriteringsruimte bij transportverzoeken, 2024, https://www.acm.nl/nl/publicaties/codebesluit-prioriteringsruimte-bij-transportverzoeken. (Accessed 2 December 2024).
[57] A. Moser, I. Korstjens, Series: Practical guidance to qualitative research. Part 3: Sampling, data collection and analysis, Eur. J. Gen. Pr. 24 (1) (2018) 9–18, http://dx.doi.org/10.1080/13814788.2017.1375091.
[58] ATLAS.ti Scientific Software Development GmbH, ATLAS.ti web [software], 2024, https://atlasti.com (Accessed 4 December 2024).
[59] V. Braun, V. Clarke, Thematic Analysis, Am. Psychol. Assoc., 2012.
[60] A. Strauss, J. Corbin, Basics of Qualitative Research Techniques, Citeseer, 1998.
[61] J. Saldaña, The Coding Manual for Qualitative Researchers, Sage Publications, 2009.
[62] F. Libertson, (No) room for time-shifting energy use: Reviewing and reconceptualizing flexibility capital, Energy Res. Soc. Sci. 94 (2022) 102886, http://dx.doi.org/10.1016/J.ERSS.2022.102886.
[63] G. Powells, M.J. Fell, Flexibility capital and flexibility justice in smart energy systems, Energy Res. Soc. Sci. 54 (2019) 56–59, http://dx.doi.org/10.1016/j.erss.2019.03.015.
[64] A. de Looze, S. ten Caat, A. Maiello, S. Jhagroe, E. Cuppen, Temporalities of energy justice: Changing justice conceptions in Dutch energy policy between 1974 and 2022, Energy Policy 191 (2024) 114174, http://dx.doi.org/10.1016/j.enpol.2024.114174.
[65] J. Rossi, A. Srivastava, T.T. Hoang, Q.T. Tran, M. Warneryd, Pathways for the development of future intelligent distribution grids, Energy Policy 169 (2022) 113140, http://dx.doi.org/10.1016/j.enpol.2022.113140.
[66] N. Mouter, R.M. Shortall, S.L. Spruit, A.V. Itten, Including young people, cutting time and producing useful outcomes: Participatory value evaluation as a new practice of public participation in the Dutch energy transition, Energy Res. Soc. Sci. 75 (2021) 101965, http://dx.doi.org/10.1016/j.erss.2021.101965.
[67] P. Kroes, M. Franssen, I.v.d. Poel, M. Ottens, Treating socio-technical systems as engineering systems: some conceptual problems, Syst. Res. Behav. Sci. 23 (6) (2006) 803–814, http://dx.doi.org/10.1002/sres.703.