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Original research article

Electrifying tensions: Stakeholder narratives to electrification of industry and transport in Sweden

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ABSTRACT

Large-scale electrification of industry and transport is central to the decarbonization of the energy sector. Rapid transformation of the existing electricity system, however, presents significant challenges. Using the Q-methodology, this study examines challenges to the electrification of industry and transport in Sweden from the viewpoints of key stakeholders. We identify three narratives that correspond to *meta-challenges* to electrification: 1) *Procedural deadlocks, hindering the expansion of variable electricity production*, 2) *Competing political preferences, slowing the progress of electrification*, and 3) *Poor governance, hindering an effective electrification process*. From these, we propose corresponding policy elements: 1) Streamlining the permitting process for electricity generation; 2) Fostering a fair but differentiated low-carbon policy mix; and 3) Recognizing multi-partisan benefits in the energy transition. These findings aim to support policymakers in developing effective decarbonization policies.

1. Introduction

Deep decarbonization of the energy system is essential to mitigate climate change. Globally, energy use accounts for 75 % of anthropogenic greenhouse gas (GHG) emissions, with the largest contributors being electricity and heat generation, as well as manufacturing and transport [1]. Advancements in renewable energy technologies and energy storage solutions are making it increasingly feasible to transition away from fossil fuels on a large scale. In regions with a highly decarbonized electricity production, such as the Nordics, aligning electrification efforts with continued power sector decarbonization can help reduce emissions from industry and transport sectors [2]. Large emission reductions can be achieved by replacing fossil-based energy carriers in industry and transport with direct or indirect (e.g., via hydrogen) electrification [3,4]. In Sweden, in focus of this work, electrification is considered the major measure to decarbonize energy-intensive industry, while fuel shift and carbon capture and storage may also contribute to an extent [5].

Despite its potential to reduce GHG emissions, electrification requires substantial and rapid investments in electricity generation technologies and supporting infrastructure, such as transmission grids [3]. However, nationwide electrification strategies often overlook regional variations in grid development and struggle to outline plausible pathways [2,6]. Beyond being a technical shift, electrification necessitates significant adjustments in production and consumption patterns across multiple sectors [7]. This, in turn, demands a radical reconfiguration of existing socio-technical systems and associated value chains [8], introducing numerous new challenges.

For example, industries may move to locations with more advantageous conditions for electricity production, and new value chains may be formed around low-carbon technologies [8,9], affecting regional economic development [10,11] as well as global politics [12]. An expansion of renewable electricity has also been known to create conflicts within local communities and between different interest groups [13]. Unresolved disputes and conflicts may lead to ineffective policymaking [14]. These social and political challenges underline the importance of understanding the diverse perspectives of key stakeholders, including industry stakeholders, policymakers, and civil society organizations, who shape decision-making in the energy sector. As different stakeholders engage in the future of energy systems, how challenges are framed and communicated becomes crucial.

A narrative, which is the basic element of a discourse, consists of ideas and concepts that are strung together into coherent storylines [15,16]. A narrative can be understood as a story that describes an issue

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with an objective and internal logic regarding the problems and solutions. Although not commonly used for analyzing different perspectives on challenges in a transition context, studies on narratives have in recent years gained increasing traction in sustainability transition research [17,18]. In transition studies, a narrative commonly relates the story of the need to move from one state to another, i.e., to a more socially desirable state with specific end-points, such as net-zero carbon emissions, and it also outlines and justifies the interventions required to meet the end-state [16,19].

This study focuses on a specific class of narratives — how stakeholders articulate and value different challenges in the energy transition. At an aggregate level, we refer to these as *Meta-Challenges*. Examining these meta-challenges is crucial as they emerge from key stakeholders' interpretation of individual challenges while providing a nuanced yet high-level perspective on dominant meta-challenges that should be reconciled for electrification to progress. Given the complexity of transitioning from fossil fuel-based energy systems to low-carbon alternatives across multiple sectors, understanding these narratives is essential for identifying both alignments and conflicts in stakeholder perspectives on the direction of the transition.

The purpose of this study is, thus, to identify and analyze the overarching Meta-Challenges that emerge from key stakeholder perspectives on electrification as a central pathway for decarbonization. Beyond offering empirical insights, our theoretical aim is to contribute to transition studies by demonstrating how contested stakeholder interpretations of individual challenges aggregate into structured meta-challenges. These meta-challenges represent aggregated narratives that highlight different problem framings, value priorities, and directionality preferences in the energy transition. We propose that identifying such meta-challenges complements existing approaches, such as Technological Innovation Systems (TIS) and the Multi-Level Perspective (MLP), by illustrating how discursive dynamics shape the prioritization of challenges and policy options.

To identify and analyze the meta-challenges we apply the so-called *Q methodology*. Originally developed by Stephenson [20], the Q methodology is commonly used in psychology and social science research to study subjectivity, and it consists of both qualitative and quantitative elements. The Q methodology is applied to Sweden's electrification case due to its unique position as a highly industrialized country with energy-intensive industries historically benefiting from low electricity prices and domestic resources. Sweden has ambitious plans to replace fossil fuels in industry with electricity and hydrogen, alongside ongoing transport electrification, leading to a sharp rise in electricity demand. Despite favorable conditions for the new generation, this shift has sparked political and public debate over social acceptance, permitting, and technology choices [21]. Understanding the meta-challenges driving these tensions is crucial for navigating conflicts, aligning stakeholder perspectives, and enabling large-scale electrification across sectors in the long run.

The paper is organized as follows. Section 2 (*Challenges to electrification*) provides a literature review on socio-technical challenges to the low-carbon energy transition in the Nordics (Section 2.1), as well as provides the context of Swedish electrification (Section 2.2). Section 3 (*Research design*) describes how the Q methodology is used in the paper. Section 4 (*Results*) examines the identification of meta-challenges to electrification (Sections 4.1–4.3). Section 4 (*Discussion*) presents a cross-comparison of meta-challenges and discusses the policy implications based on the findings. We conclude the paper with ways forward in Section 6 (*Conclusion*).

2. Challenges to electrification

2.1. From challenges to meta-challenges

Different transition approaches, such as multi-level perspectives (MLP) [22,23] and technological innovation systems (TIS) [24,25], are commonly applied to identify socio-technical challenges [26]. The MLP framework, for instance, facilitates the analysis of the dynamics of socio-technical transitions by examining interactions within and between three analytical levels: niches, regime, and landscape. This approach helps to identify challenges and intervention points [27]. In TIS studies, challenges are identified by analyzing the interplay between structure and functions in emerging systems. Sometimes these challenges are referred to as “system weaknesses”, “system problems”, “system failures”, “blocking mechanisms”, or “barriers” [28–30].

The presence of these challenges can be partly explained by path dependencies leading up to the present electricity system concerning technologies, infrastructure, and institutions [31], but also due to adjacent multi-system interactions [32]. These characteristics are typically pronounced in the electricity sector due to capital intensity, often long lead times in developing new infrastructure [33,34], and spatially dispersed physical assets [33]. While path dependencies reinforce the stability of the regime configuration [7], they also contribute to lock-in phenomena, hindering technological developments and societal experimentation [35] supporting the transition [36].

In existing literature, numerous studies identify various socio-technical challenges to the low-carbon energy transition. Table 1 provides a summary of challenges related to decarbonizing the energy system, specifically drawing from research on electrification in the Nordic countries. We have categorized the challenges identified in the different studies into four main types: social, economic, political, and other challenges.

Regarding the social challenges, Andersen [37] zoomed into coordination issues impacting stakeholders in the low-carbon energy transition on a systemic level or with a focus on individual technologies or stakeholder groups. Focusing on new high-voltage transmission (HVDC) in Europe, the author demonstrated how uncertainty and challenges in coordination, investment, and resource mobilization make stakeholders like transmission grid operators and investors hesitate to decide on the development of the HVDC infrastructure. The study concludes that these coordination difficulties risk delaying the integration of renewable energy sources into the electricity infrastructure, ultimately hindering the transition to a low-carbon energy system.

The literature also concentrates on the societal acceptance of low-carbon energy technologies and infrastructure. Aitken [45], for example, emphasized the challenges in achieving consensus regarding the community benefits associated with wind power projects, which arise from the varying perspectives outlined in a five-year longitudinal case study conducted in Scotland. Meanwhile, Wolsink [51] argued that although there has been considerable emphasis on public attitudes and opinions as indicators of the rate of wind power implementation, institutional capital plays a more significant role in wind power deployment. Building on concepts such as “place imaginaries” and “imagined publics” in the social acceptance literature, Peacock and Devine-Wright [49] analyzed and discussed how different stakeholders legitimize their preferences regarding the locations of low-carbon energy projects in Sweden based on their stereotypes of different regions and the people who reside there. It underscores the importance of stakeholder perspectives in fostering the legitimacy of a strategy or policy.

Table 1

A list of 10 challenges to the low-carbon energy transition with a Nordic focus in existing literature.

Type of challenge	Challenges identified	Definition	Selected literature
Social	Poor coordination and collaboration	The degree that disputes or unresolved conflicts slow down or block the transition.	[37–43]
	Social resistance	The degree that public and local opposition arises with the deployment of low-carbon energy infrastructure.	[13,44–51]
	Justice	The degree that transition goals and arrangements perpetuate unjust practices (which ultimately impedes transition speed or extent).	[52–56]
Economic	Financing challenge	The challenges in accessing, mobilizing, or directing finance into low-carbon energy projects.	[10,57,58]
	Lack of effective market instruments	The lack of effective market instruments that hinder the transition.	[59–65]
	Lagging business models	The degree that firms lack the capacity to innovate or reorganize in line with the transition (which ultimately impedes transition speed or extent).	[66–68]
Political	Policy uncertainty	The lack of effective policy design, execution, or aim to enable the transition.	[8,42,48,58,62,67,69–76]
	Lengthy permitting process	The degree that permit-granting procedures hinder or block the development and deployment of low-carbon energy projects.	[77–83]
Other	Cybersecurity concerns	The degree that the increase in digitalization and IT capacity in low-carbon energy infrastructure raise the risks of cyberattacks for consumers and other value chain stakeholders (which ultimately impedes transition speed or extent).	[12,55,84,85]
	Resource constraint	The degree that electrification contributes to an exacerbation of environmental impact (which ultimately impedes transition speed or extent).	[12,72,73,86–90]

Additionally, energy justice has emerged as a critical issue among social challenges, with research highlighting disparities in how different social groups engage with and benefit from low-carbon energy transitions [52]. Procedural concerns, such as the lack of transparency in permitting processes and the dominance of incumbent stakeholders in decision-making, further limit effective stakeholder participation [91,92].

From an economic perspective, by simulating scenarios that align with the European Union (EU)'s Intended *Nationally Determined Contribution* [93], Fragkos et al. [57] outlined the financial challenge related to accelerating the decarbonization of the EU economy. This includes issues related to access to funding, mobilization of resources, and the direction of investments. Similarly, Klaaßen and Steffen [10] through their analysis pointed out a substantial investment requirement for low-carbon infrastructure, especially within the power sector. Furthermore, several studies indicate a lack of market incentives, such as for flexibility measures [61,94,95].

Navigating technology and political shifts presents a challenge for businesses in the context of the low-carbon economy. Research has explored how firms — both new and incumbent — navigate these transitions, as well as how different organizational models influence their ability to compete across industries [66,68]. For example, automotive dealerships might need to adapt their sales strategies, maintenance revenue streams, and refueling structures, considering that electric cars currently take more time and effort to sell compared to vehicles with internal combustion engines [96].

Policy uncertainty presents significant political challenges with wide-ranging implications. Mignon and Rüdinger [42] found that different stakeholders' perspectives could impact systemic factors affecting the deployment of renewable energy cooperative projects, either reinforcing or mitigating barriers related to political stability and grid access. Although the share of low-carbon energy has increased in the Nordic region, indirect support for fossil fuels persists, for example, considering the recent increase in fossil fuel subsidies in several EU Member States [97] and the ongoing work to revise the EU energy taxation [98]. At the same time, the literature also goes into the absence of regulatory frameworks and legislations that support the transition, for example, in enabling the diffusion of new low-carbon energy technologies [69,71,76], increasing flexibility and sector coupling in the energy system [62], or considering systemic impact such as circularity [72,73] in energy policy. It has, therefore, been argued that policymakers continue to fall short in addressing externalities and facilitating the large-scale adoption of clean electrification [99].

Yet another important political challenge is the lengthy permitting process for low-carbon energy infrastructure. This has received much attention in research. Bergek [77], for example, showed that wind power planning encounters competition with both public and private interests, contributing to the many conflicts of interest that delay the planning and permitting process for wind power. Wretling, Balfors and Mörtberg [83] found significant variations in wind power planning practices across Swedish municipalities, pointing to a general lack of decision-making capacity, including outdated wind power planning frameworks. Nuclear power has witnessed a renewed interest, both related to the conventional and small modular reactors (SMR). Michanek and Söderholm [81] highlighted the political sensitivity of nuclear power and the challenges of translating national targets into local actions. In Sam et al. [82], the limited legal and regulatory experiences with SMRs were seen as a challenge, which could lead to prolonged license-granting time and tension between stakeholders.

Beyond social, economic, political, and other challenges, the transition to a low-carbon energy system intersects with broader concerns such as cybersecurity and environmental impacts. The shift from centralized power plants to distributed energy technologies may increase system vulnerability to cyberattacks, ranging from data breaches and hacking to cyberterrorism, posing risks to both consumers and critical infrastructure [84,85]. Moreover, the resource requirements for low-emission infrastructure raise environmental and social sustainability concerns, including access to critical metals [73,87] and biomass [88,89], supply chain disruptions [88], and geopolitical dependencies [12]. While the discussions on decarbonization often focus on accelerating deployment, less attention is given to long-term sustainability, such as in the decommissioning of power plants and infrastructure at the end of their lifecycles [69,72] and the management of stranded assets [86].

The literature highlights that socio-technical challenges in the transition impact stakeholders, while stakeholder perspectives, in turn, influence how these challenges are addressed. Different stakeholders view challenges differently, focusing on different aspects of what constitutes the challenge, its importance, and the potential solutions. Perspectives on challenges are shaped by how various stakeholders perceive the transition, which is influenced by their visions, values, interests, and knowledge of the subject. These perspectives extend beyond technological preferences and cost considerations, encompassing mental frameworks that define how the future system could, would, and should look, creating a complex and multidimensional landscape for policy and strategic choices [100].

While much research has explored individual challenges and stakeholder roles in the low-carbon transition, there is a lack of studies that systematically examine how key stakeholders perceive different challenges and link them into broader narratives, here called meta-challenges. These meta-challenges emerge at the intersection of consensus and contestation among stakeholders, reflecting different visions of the future energy system. By unpacking these meta-challenges, we provide an integrated perspective on the energy transition discourse, revealing tensions, blind spots, and points of convergence.

2.2. The Swedish electrification challenge

The electricity sector in Sweden shares many similarities with other Nordic countries. All the Nordic countries share a synchronous electrical grid and a common electricity market. Furthermore, the electricity supply in the region is largely low-carbon, and all the countries set strong targets for carbon neutrality with an interest in electrifying the economy [101]. The electricity mix, however, differs between countries. Sweden, like Finland and Norway, has a large share of hydropower and biomass contribution to the power supply, and in the past decade, onshore wind power, as well as other renewables, have significantly increased their contribution to the electricity system [102]. Unlike Norway and Denmark, but similar to Finland, nuclear power plays a key role in the Swedish power sector, amounting to 40 % of the consumed electricity at present [103].

On the demand side, Sweden is characterized by the presence of various energy-intensive industries [104]. To meet the climate targets, the country has a legally binding climate policy framework [105], including national climate goals to reach net-zero emissions by 2045, a Climate Act, and a Climate Policy Council [106]. The emission reduction target is divided into decadal milestone targets in line with the EU's Effort Sharing Regulation [107].

In line with Sweden's high share of energy-intensive industries, several projects are aiming to electrify industrial processes [108,109], to produce fossil-free hydrogen [110], electro-fuels, and to electrify processes in the petrochemical industry [111]. As a result of both policy support and interest in reducing climate impact from industry stakeholders, Sweden has, up to the present, reduced domestic emissions at a faster pace than the average rate in the EU [112].

Despite the progress that is being made, the main part of the transition of the electricity system is yet to come and will pose challenges for various stakeholders [21]. As a result, there is an increased debate on which direction the transition of the electricity system should take, which is associated with a number of potential governance dilemmas [113]. For instance, there is considerable polarization in the political energy debate between those who favor wind power and those who favor nuclear power [21,53,83]. This is largely caused by the national political debate, which appears heated when it comes to which road to follow, a nuclear power-focused one or one continuing the recent years trend with continued expansion in wind power (and some solar power) [21]. It seems, however, that most industry stakeholders and the research community, as well as regional politicians, have more pragmatic views on the way forward, i.e., that the real challenge is not the choice between nuclear and wind power, but rather the urgency in expanding electricity generation at a sufficient pace.

3. Research design

We used the Q methodology to explore how key stakeholders perceive and prioritize the socio-technical challenges to electrification in Sweden. This methodology is relevant in the Swedish context, where the electrification transition involves multiple stakeholders with divergent perspectives on challenges and solutions, making it appropriate to analyze how these viewpoints aggregate into overarching narratives. The methodology minimizes the risk of over-reliance on individual insights by aggregating responses across a diverse stakeholder group and analyzing these responses statistically to identify shared patterns, ensuring a systematic and replicable process.

The Q methodology has five main steps: 1) Identifying the concourse and selecting statements; 2) Selecting participants; 3) Conducting the Q survey and interviews; 4) Performing Q analysis; and 5) Interpreting results from the factor analysis [114]. The steps in the analysis are summarized in Fig. 1 and described below.

For our study, we invited stakeholders from various organizations associated with the energy sector, as well as those affected by the strategy of using electrification as a means of decarbonizing the energy sector, to rank statements about potential challenges in order of their perceived importance.

3.1. Step 1: identification of concourse and selection of statements

The *concourse* comprises relevant discourses related to socio-technical challenges to electrification in Sweden. The concourse was identified by conducting a review of scientific articles and reports of the main socio-technical challenges to electrification in the Nordic countries (Section 2). While we applied the study to the Swedish conditions, we expected that they share many, but not all, of the challenges with other Nordic countries.

After defining the concourse, we developed a collection of 52 statements to express various key challenges associated with achieving significant emission reductions through electrification in Sweden. While the statements are primarily derived from the literature review presented in this paper, they were further refined through discussions and an expanded literature search, including grey literature. Given this iterative and discursive process of constructing the concourse and formulating the statements, we were careful to present the statements as informed by, rather than directly derived from, the challenges identified in Table 1.

The statements, numbered from s1 to s52, addressed a range of issues. Some focused on the electrification of industry and transport in general, while others focused on specific technologies, such as the social acceptance of wind turbines.

Each statement captured a unique key challenge. For example, while social acceptance for low-carbon electricity generation can be seen as a broad challenge, we further refined it into specific issues, such as financial compensation, concerns for nature, and concerns about health and safety. To maintain clarity, we avoided including multiple challenges in a single statement. The complete list of statements (termed a *Q set*) and their associated numbers can be found in Table A.1 in Appendix A.

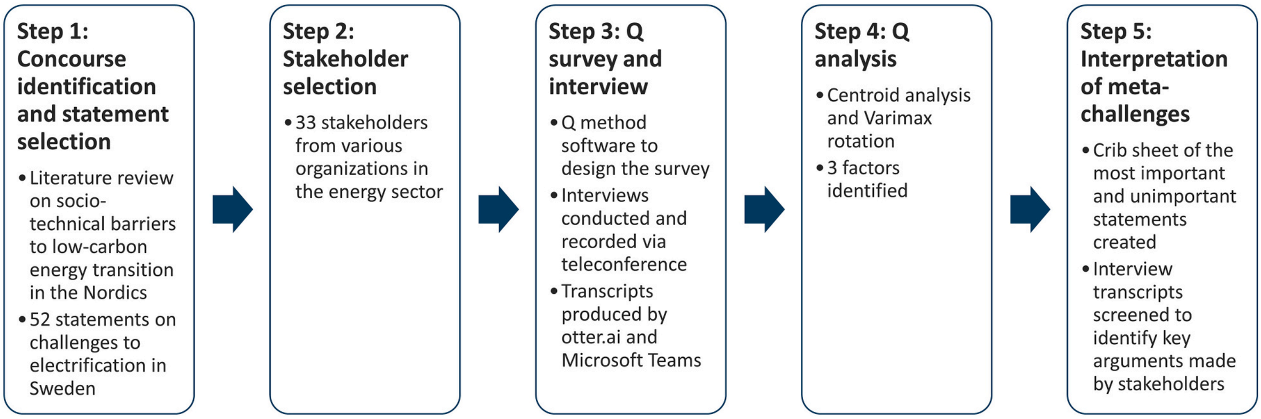

Fig. 1. Application of the Q methodology in the present study.

3.2. Step 2: selection of stakeholders

We identified potential stakeholders based on their roles and affiliations through referrals from our existing contacts and online research. A total of 33 stakeholders participated in the survey, conducted between November 2022 and January 2023, forming our P-sample. Participating stakeholders included researchers, managers, and specialists from both the supply and demand sides, as well as intermediary businesses, employees in state agencies, politicians, and staff in non-governmental organizations.

We ensured a diversity of perspectives by selecting politicians from different areas of the political spectrum, from left to right, as well as stakeholders from various parts of the energy sector, including representatives from civil societies advocating environmental conservation and marginal social groups. All participants were involved in high-level strategy and decision-making related to the energy transition, providing them with a strong awareness of the challenges associated with the energy transition. This is because the statements require some a priori knowledge of issues such as energy targets, details related to ongoing projects, plans for future technological developments, and the current state of the electricity infrastructure.

3.3. Step 3: Q survey and interview

The Q-methodology software (https://qmethodsoftware.com/) was used to design the survey and for the data analysis. The survey was performed online using Zoom and Microsoft Teams, while the transcripts were created with the online tool *otter.ai* and the transcription service of Microsoft Teams.

Before the survey, the stakeholders were given information on the study background and the survey steps. It was specified that their survey responses and expressed opinions should not necessarily represent those of their organizations. The sorting was done in two steps. In the first step, the stakeholders ranked each statement as to whether it was

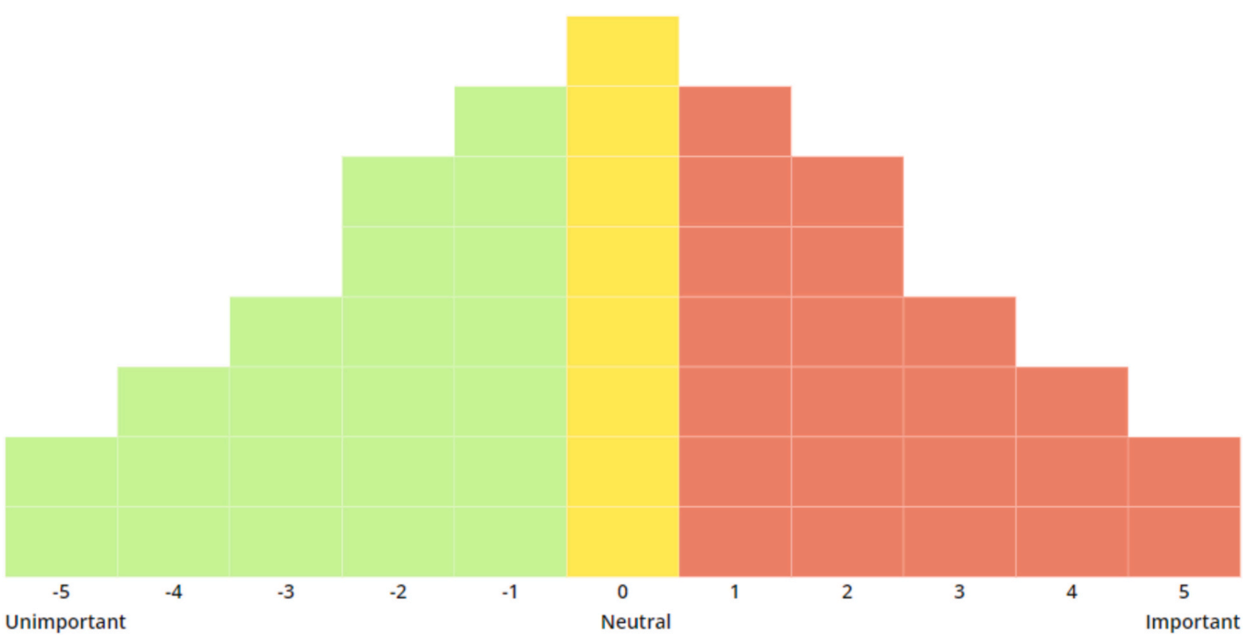

Fig. 2. The quasi-normal distribution, pyramid-shaped grid used for the sorting of the Q survey, divided into 52 boxes representing 52 statements. A horizontal scale (range, −5 to 5), corresponding to the most-unimportant to the most-important statements, is indicated at the bottom of the grid. The degree of importance was measured from the horizontal placement of the statements; the vertical placement of statements in the same column carries no weight. The higher the sorting order (in both the negative and positive sides of the pyramid), the fewer boxes are available. The colors (red for more-important challenges, green for less-important challenges, and yellow for intermediary challenges) are used to enhance visualization. The stakeholders were free to change the positions of their statements on the pyramid until they were satisfied with their sorts. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

important, unimportant, neutral or no comment (and not as to whether they agreed with the statements). From these Q pre-sorts, the stakeholders were asked in the second step to rank the statements onto a normal distribution grid with 11 positions, from the most-important to the most-unimportant challenges to electrification in Sweden (Fig. 2). The statements in position −5 were considered the most-unimportant and those in position 5 were the most-important, indicating the impact of the challenge on the transition. The steep distribution ensures the variability in the placement of statements. This is critical for meaningful factor analysis since it allows for careful deliberation and prioritization of statements for participants.

Semi-structured interviews were carried out post-sorting, wherein the stakeholders were given the opportunity to explain how they ranked different statements. The stakeholders were asked to reflect on how they had reasoned when conducting the exercise, and then explain the statements they had ranked as most-important and most-unimportant before commenting on the remainder of the statements. Finally, the stakeholders were asked if they would like to add any statements and if they considered there to be discrepancies between their rankings and the standpoints of their workplace, e.g., they were allowed to assess if, and to what extent, their viewpoints differed from what their organizations represent. This was an individual comparison between the viewpoints of the stakeholders and those held by their organization, and the research team did not assume any preconceived position of the organization. Each of the 33 survey sessions lasted for approximately 1 h. The interview questions can be found in Appendix C.

3.4. Step 4: Q analysis

Using the Q-methodology software, we conducted a factor analysis using the rankings obtained from the surveys and interviews to identify common variance. This variance was then clustered into factors based on the intercorrelations between the 33 individual Q sorts. The factor analysis consisted of factor extraction and factor rotation, the detailed procedure for which can be found in Appendix B. The main goal of this analysis is to maximize the shared variance in the dataset. Nevertheless, while choosing more factors confers a higher explanatory power on the dataset, at some point, the increase in explained variance derived from adding another factor would be too small to be valuable for data interpretation [115].

To determine the shared variance, the factor loading of each statement in each factor was computed. This represents how strongly correlated each statement is to the factor. From these loadings, eigenvalues were calculated by summing the squared loading of each sort for that factor. Eigenvalues were used as the basis for choosing the number of factors to retain, since they represent the common variance in the dataset explained by each factor. They thus quantify the strength or importance of a factor depending on the differences or similarities among Q sorts [116].

Three factors were derived from the analysis, for which the main statistical results are presented in Table 3. We selected the three factors following the Kaiser-Guttman criterion and Humphrey's rule as common statistical criteria for the Q methodology [115,117].

The Kaiser-Guttman criterion and Humphrey's rule are common statistical criteria for the Q methodology [115,117]. Kaiser-Guttman criterion considers retaining extracted factors that have eigenvalues greater than one. Meanwhile, Humphrey's rules state that extracted factors should be retained if the standard error, i.e., standard deviation of the sampling distribution, is smaller than the cross-product of the two highest factor loadings [115]. In our study, three factors (Factors 1–3) were finally retained as shown in the next chapter. Appendix B provides details of the statistical analysis, including the rank values and the Z scores corresponding to each statement derived from our analysis in Table B.2, while the correlations between the factors and the sorts are shown in Table B.3.

From the factor loadings, we derived weighted sorting scores for each statement in each factor. We then compiled a list of the statements that received the highest positive and negative ranks for each factor, as well as the statements with unique scores in one factor, e.g., positively ranked for one factor while negatively ranked for others. This list is called a *crib sheet*, which essentially represents the bridge between the quantitative and qualitative sides of the methodology.

3.5. Step 5: interpretation of meta-challenges

In this study, the factors in combination with the post-sorting interview analysis were considered the three *meta-challenges*, which represent shared ways of thinking about challenges to electrification among the participant set. The statements that received the highest positive and negative scores are essential to the makeup of a meta-challenge, as they point to the most-important and most-unimportant issues. Moreover, statements that significantly differ in rankings in one meta-challenge over the other two meta-challenges were also considered in the interpretation process.

In parallel to the crib sheet, we screened the interview transcripts for the main arguments that the stakeholders used to motivate their rankings. Finally, a cross-meta-challenge comparison was conducted qualitatively by mapping out the common and unique features among the three factors, resulting in a Venn diagram (Fig. 3).

4. Results - meta-challenges to electrification

The result of the factor analysis using the rankings obtained from the surveys is given in Table 3 for the three factors with the highest eigenvalue. Factor 1 has the highest eigenvalue (10.32), indicating the greatest area of commonalities between the sorts, while Factors 2 and 3 both have eigenvalues just above one. All three of the factors that satisfied the Kaiser-Guttman criterion also met Humphrey's rule. Cumulatively, these three factors explain 41 % of the rankings in the dataset, almost one-third of which was attributed to Factor 1. The number of defining Q sorts for Factors 1, 2, and 3 was 8, 4, and 8 sorts, respectively, with the correlations between the three factors and the Q sorts ranging from 0.51 to 0.68. This reflects moderately strong associations between the factors and the Q sorts. Furthermore, since the majority of the defining Q sort share this loading among the three factors, this indicates cross-loading, i.e., that stakeholders share similar rather than distinctive perspectives across factors.

The factor analysis indicates that there are three main meta-challenges to electrification:

1. **Procedural Deadlock**. This refers to the procedural deadlock associated with expanding variable electricity generation and is concerned with the scaling up of the demand for new electricity generation on time (Section 4.1)
2. **Competing Political Preferences**, which highlights carbon prices, flexibility instruments, and political disputes as the main issues hampering the transition (Section 4.2)
3. **Poor Governance**, which focuses on multi-stakeholder coordination, especially concerning an increased grid capacity, hinders an effective electrification process (Section 4.3).

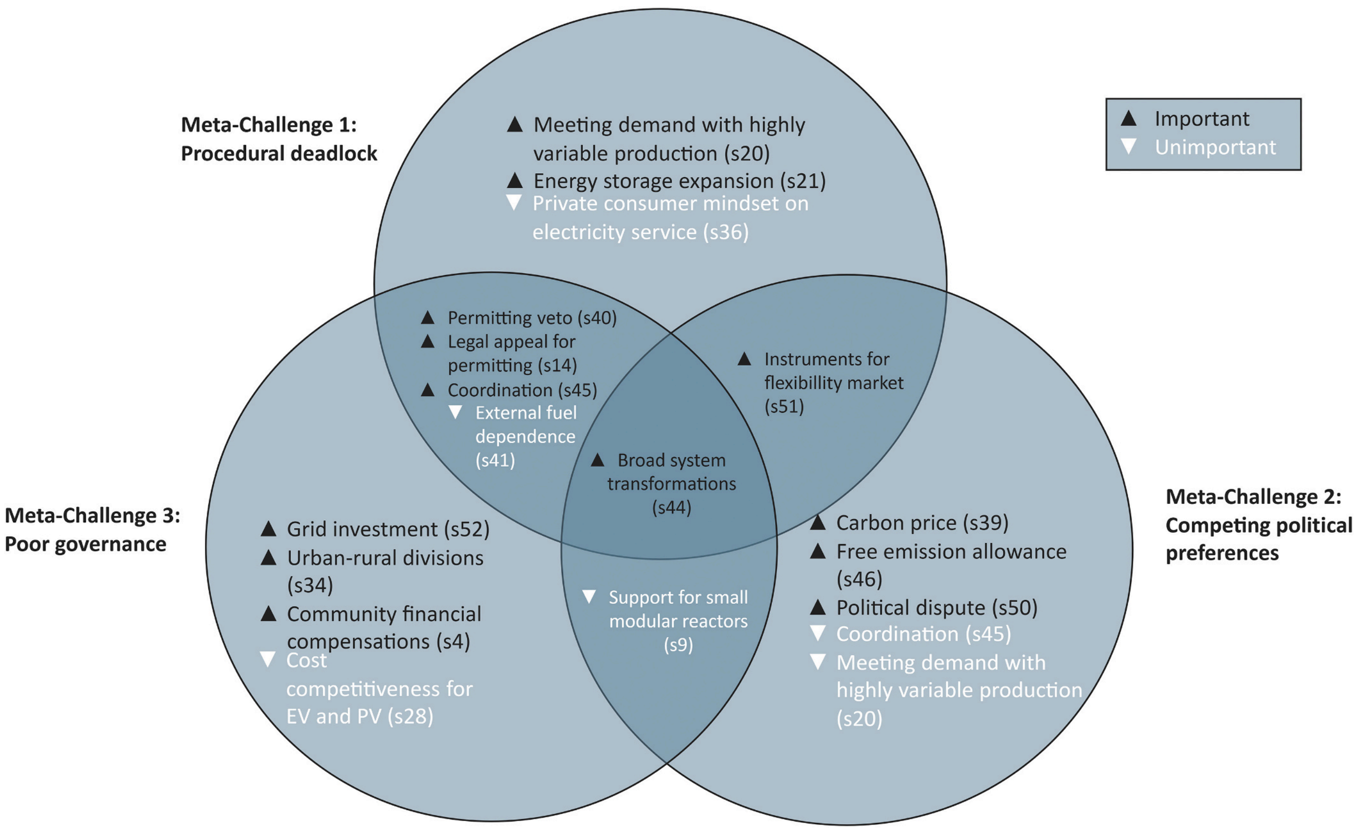

Fig. 3. Issues that are common and unique in the rank-order of the three identified meta-challenges, each linked to its original statement in brackets. Texts are colored according to their ranks, from the most important to the most unimportant. Black text with upward arrows: issues ranked as important; white text with downward arrows: issues ranked as unimportant.

In the following sections, the challenges with high low and unique ranking for each of the three factors are explored to define the meta-challenges it represents.

4.1. Meta-challenge 1: procedural deadlock

Procedural deadlocks hinder the expansion of variable electricity production

Table 4 shows the statements that had the highest positive and negative ranks, as well as the statements with unique scores for the meta-challenge of "Procedural Deadlock" (Meta-challenge 1). The statements with the highest ranking by the stakeholders associated with this meta-challenge concern the resistance to the construction of a new low-carbon electricity infrastructure. This is characterized by prolonged permit application processes and appeal processes, and concerns regarding the diffusion rates of flexibility measures. These issues appear to stem from a lack of coordination at the institutional level, rather than a reluctance to change from large state-owned firms or private consumers.

The meta-challenge of "Procedural Deadlock" has been highly ranked in terms of **permitting issues**. This includes the repeated **use of veto power** in the permit application and appeal processes, which is applicable to wind power within the territorial border (s40, Table 4). Furthermore, **lengthy legal appeals in the permitting processes** (s14, Table 4) were ranked as the most-important issue for this meta challenge.

This meta challenge stands out from the other meta-challenges in that while broad system transformations are seen as important, it emphasizes **technological concerns regarding the electricity supply side**, including how the instantaneous demand can be met with a high share of renewables (s20, Table 4), and the extent to which there can be sufficient development of energy storage (s21, Table 4).

On the other hand, the Procedural Deadlock challenge considers **resistance to change** as the most-unimportant issue, irrespective of whether this reluctance to change is from firms (s35, Table 4) or private consumers (s36, Table 4).

4.2. Meta-challenge 2: competing political preferences

Competing political preferences slow the progress of electrification

Table 5 shows the statements that have the highest positive and negative ranks, as well as the statements that received unique scores for the challenge of "Competing Political Preference" (Meta-challenge 2). This meta-challenge identifies a weak policy for carbon pricing as a key challenge to electrification. Furthermore, this meta-challenge shows that electrification projects are hindered by contestation at the political level, involving both national and international climate discourses.

The meta-challenge of "Competing Political Preference" has **broad system transformation** (s44, Table 5) as the most-important issue. Furthermore, the current setups of **carbon instruments** are regarded as important challenges to electrification, in that the **level of carbon pricing is too low** (s39, Table 5) and that the **free emissions allowances for industry disincentivize heavy-industry from implementing electrification** (s46, Table 5). **Political dispute** is also highlighted as an important issue in meta-challenge 2 (s50, Table 5). On the other hand, statements regarding the technological issues related to electrification were ranked very low for this meta-challenge. In addition, two statements on nuclear power, **the stigma of nuclear power safety** (s17, Table 5) and **the lack of support for small modular reactors (SMR)** (s9, Table 5), were ranked as relatively unimportant compared to the other statements.

4.3. Meta-challenge 3: poor governance

Poor governance hinders an effective electrification process

"Poor governance", Meta-challenge 3, focuses on governance in relation to the transition. While the permitting issues and the need for broad system transformation are shared with the other meta-challenges, the challenge of "Poor governance" focuses on multi-stakeholder coordination and especially in relation to increasing grid capacity, but also how the benefits of a transition should be distributed between different groups in society. Table 6 shows the statements that have the highest positive and negative ranks, as well as the statements with unique scores for this challenge.

The challenge of "Poor governance" highlights **permitting** issues for new electricity infrastructure and considers them to be the most-important issue (s40, Table 6). The second most-important issue identified for this meta-challenge is **coordination** (s45, Table 6). The difficulty associated with achieving a **broad system transformation** (s44, Table 6) was also highly ranked. On the other hand, concerns **regarding investments in grid capacity** (s52, Table 6) were uniquely ranked as the most-important aspects for this meta-challenge. The Poor-governance challenge also emphasizes the importance of a **just transition**, to the divisions existing between different regions or between city and countryside (s34, Table 6). On the other hand, the statements related to **cost and market**, including the integrated market (s42, Table 6) and the necessity for reductions in the prices of end-use technologies (s28, Table 6), were ranked as the most-unimportant for this meta-challenge. It also regards the **lack of investment in SMR** as an unimportant matter.

5. Discussion

5.1. Cross-comparison of meta-challenges

To compare the abovementioned meta-challenges, Fig. 3 displays in a Venn diagram the concerns that are common and unique for each meta-challenge. The overlapping areas highlight issues that are viewed similarly. All three meta-challenges share as the highest (most-important) ranking item the need for **broad system transformation** (s44). **Permitting** (s40 and s14) and **coordination** issues (s45) are considered important by Meta-challenges 1 and 3, while **market instruments for flexibility** (s51) are regarded as critical for Meta-challenges 1 and 2. In contrast, **fuel dependence** on other countries (s41) is seen as unimportant for Meta-challenges 1 and 3, similar **to support for small modular reactors** (s9) for Meta-challenges 2 and 3.

The remaining circles in the Venn diagram constitute what is unique for each meta-challenge. These include concerns regarding **increasingly variable electricity production** (s20 and s21) for the meta-challenge 1 on Procedural Deadlock, **carbon instruments** (s39 and s46) and **political disputes** (s50) for the Meta-challenge 2 on Competing Political Preferences, and issues related to **grid capacity** (s52) and a just transition, including the **urban-rural division in the transition and community compensation** (s34 and s4) for the Meta-challenge 3 on Poor Governance. Regarding issues considered unimportant, Meta-challenge 1 consists of **the mindset of private consumers on electricity service** (s36), while Meta-challenge 2 devalues **coordination** (s45) and **meeting electricity demand with a high level of variability** (s20) in the electricity system. Meta-challenge 3 instead regards **cost competitiveness for EV and PV** (s28) as unimportant.

The challenges (s1–52, Table A.1, Appendix A) identified through the concourse vary in importance across the meta-challenges (Tables 3–5). Since the Meta-challenge 1 on Procedural Deadlock has the highest eigenvalue (Table 2), with a value far higher than those for the two other meta-challenges, this meta-challenge has the highest explanatory power. This means that the issues rated as most important and most unimportant for this challenge share the ranking with a high number of stakeholders in the sample. In contrast, the Meta-challenge 2 on Competing Political Preference has the lowest correlation and has less in common with the other two meta-challenges. This indicates that the viewpoints that constitute the content of this challenge differ from the viewpoints clustered in the other two meta-challenges and are mainly shared by those stakeholders who associate with this meta-challenge rather than the other meta-challenges.

While the factor loadings are of similar levels across the factors, the issues that have common sort values may be interpreted differently for each meta-challenge. For instance, the statement regarding **the lack of broad system transformation** (s44) is unanimously ranked as the most important in all three meta-challenges. The stakeholders associated with each meta-challenge offered various interpretations as to why they considered this aspect to be most important. For the meta-challenge 1 on Procedural Deadlock, the statement explored different solutions beyond the electricity infrastructure, such as paying greater attention to non-electricity infrastructure or the distribution side of the value chain. Strengthening the market-based approach for wind power, e.g., in the permitting process, was suggested as an explanation concerning Meta-challenge 2 of Competing Political Preferences. For Meta-challenge 3 of Poor Governance, stakeholders remarked on the need for a more techno-neutral approach to electricity generation, as well as the need for a cross-party energy agreement to enable stable investment conditions for electrification.

Table 2
List of stakeholders in the Q study, the P-sample.

ID	Position	Organization type
P1	Executive	Utility
P2	Advisor	Utility
P3	Project Manager	Power Generation
P4	Manager	Grid
P5	Manager	Grid
P6	Manager	Grid
P7	Project Manager	Grid
P8	Advisor	Utility
P9	Executive	Intermediary
P10	Executive	Intermediary
P11	Specialist	Intermediary
P12	Manager	Industry
P13	Specialist	Industry
P14	Executive	Industry
P15	Executive	Industry
P16	Specialist	Industry
P17	Manager	Transport
P18	Researcher	Technical University
P19	Advisor	Research body
P20	Researcher	Research body
P21	Researcher	Research body
P22	Specialist	Research body
P23	Manager	Governmental Agency
P24	Manager	Governmental Agency
P25	Specialist	Governmental Agency
P26	Specialist	Governmental Agency
P27	Investigator	Governmental Agency
P28	Civil Servant	Regional Council
P29	Politician	Political Party
P30	Politician	Political Party
P31	Politician	Political Party
P32	Project manager	NGO
P33	Executive	NGO

Table 3
Quantitative results of the factor analysis.

	Factor 1	Factor 2	Factor 3
Eigenvalues	10.32	1.92	1.42
% Explained Variance	31	6	4
% Cumulative Explained Variable	31	37	41
Humphrey's Rule	0.51	0.25	0.14
Standard Error	0.05	0.05	0.05

Table 4

Statements (with associated numbers and sorting scores) that received the highest positive and negative scores and statements that received unique scores for the Procedural Deadlock Meta-challenge (Meta-challenge 1).

Statement number	Statement	Sorting score
Most important for the Procedural deadlock challenge (Meta-challenge 1)		
s40	The prominent number of stakeholders that have a veto on new developments hinders the deployment of new low-carbon electricity infrastructure.	5
s14	Lengthy legal appeals prolong the processing time for permits to develop new electricity infrastructure.	5
s51	Market instruments for flexibility to adapt to a higher level of renewable penetration are insufficient.	4
s44	Broad system transformations, and not just technological substitutions, are needed for electrification.	4
s45	The lack of coordination between authorities involved in the permitting processes hinders the deployment of new electricity infrastructure.	4
Most unimportant for the Procedural deadlock challenge (Meta-challenge 1)		
s18	There is too little faith in emissions reductions by means of electrification.	−5
s35	State-owned firms such as Svenska Kraftnät and Vattenfall are not leading the transition.	−5
s36	The mindset of private consumers in relation to electricity services hinders an increase in the share of renewables in the energy mix.	−4
s41	Electrification will ultimately create more fuel dependence on geopolitically sensitive areas.	−4
s2	Concerns regarding the health and safety of local people hinder the deployment of new low-carbon electricity infrastructure.	−4
More important than those in Meta-challenges 2 and 3		
s20	A high share of renewables in the power mix will fail to meet "just-in-time" demand from consumers.	1
s21	The expansion of energy storage capacity will be inadequate to accommodate a high renewable share in the electricity system.	2
s24	The installation of fast charging stations is occurring too slowly for the electrification of road transport.	1
More unimportant than those in Meta-challenges 2 and 3		
s32	A large fraction of the population is poorly informed on electrification and energy transition.	−1

Relevant quotes from interviews

"*Different kinds of energy storage will be so much more important, and that needs to be increased. And you have to look into the whole picture in order to, I mean, to stabilize and get a fully functioning energy system at the end of the day.*" (*P7*)

"*It's so important to have a very narrow, close and early dialogue with different stakeholders on the local regional level… to explain that there are benefits coming with this transformation.*" (*P7*)

"*This is the tension that everyone thinks electrification is great, but no one wants it to happen where they live to disturb their particular thing.*" (*P18*)

"*Path dependencies are always one of the biggest problems in all technological change.*" (*P18*)

"*I think the solution lies in involving them, so it's the solution lies in making them want to have wind power in this case, and maybe being owners as well of it. So maybe they will invest in it and you know be part of it and have a building community around it.*" (*P32*)

"*If inclusion includes sharing the money, I think it may be sufficient.*" (*P32*)

"*It* (*The energy transition*) *is not only about information or knowledge, it is also about a polarized and populist debate… Perhaps it's not a matter of knowledge, it is about positions.*" (*P33*)

"*I think that still people think that well, this thing with biodiversity, it's less important than the one with climate. And I mean… it is not correct… we need to consider coexistence much more.*" (*P33*)

Table 5

Statements (with associated numbers and sorting scores) that received the highest positive and negative scores and statements that received unique scores for the Competing Political Preference Meta-challenge (Meta-challenge 2).

Statement number	Statement	Sorting score
Most important for the Competing political preference challenge (Meta-challenge 2)		
s44	Broad system transformations, and not just technological substitutions, are needed for electrification.	5
s39	Current carbon pricing levels are too low for electrification to be implemented in industries.	5
s46	Free emissions allowances disincentivize heavy industry from implementing electrification.	4
s50	Political disputes, such as those related to nuclear power vs wind power, become a barrier to electrification.	4
s51	Market instruments for flexibility to adapt to a higher level of renewable penetration are insufficient.	4
Most unimportant for the Competing political preference challenge (Meta-challenge 2)		
s20	A high share of renewables in the power mix will fail to meet "just-in-time" demand from consumers.	−5
s9	There is too little support for the development of new nuclear technologies, such as small modular reactors (SMRs).	−5
s7	There is too much investment in demonstration projects for new technologies, and not enough in market implementation.	−4
s17	The stigma around nuclear power safety hinders its continued deployment.	−4
s22	It is overly optimistic to expect people to consume electricity in a more flexible manner at home.	−4
More important than those in Meta-challenges 1 and 3		
s12	Large companies are locked into outdated technologies.	2
s41	Electrification will ultimately create more fuel dependence on geopolitically sensitive areas.	2
s43	Polarized mindsets on climate actions at the international level limit the progress of electrification in Sweden.	3
s37	The mindset of industrial stakeholders in relation to electricity provision hinders electrification in end-use sectors.	1
More unimportant than those in Meta-challenges 1 and 3		
s3	Security risks linked to the supply chain for critical materials will limit the scale-up of low-carbon electricity infrastructure.	−3
s5	Concerns regarding reduced local property values hinder the deployment of new low-carbon electricity infrastructure.	−2
s45	The lack of coordination between authorities involved in the permitting processes hinders the deployment of new electricity infrastructure.	0
s16	Poor communication between new consumers, producers, and grid operators hinders effective grid expansion planning.	−1

Relevant quotes from interviews

"*The environmental legislation in Sweden is, and I think it is probably the same in most countries, that it's very, very focused on the local environmental impact. Whereas I work with these projects that will have a huge global impact, like positive climate effect, but the Swedish legislation doesn't take that into consideration at the moment at all.*" (*P5*)

"*What I see from the industries that I speak to, which is in this case LKAB and H2 Green steel mostly, they do this* (*electrification*) *anyway because they see a market value. And also, LKAB and SSAB being sort of state-owned can also play sort of the longer game. But perhaps for smaller players, carbon pricing levels is more important then.*" (*P5*)

"*It is easier to destroy the electricity supply rather than the diesel storage… In an emergency, the country is run on diesel. This part is often overlooked in the clean energy discussions.*" (*P23*)

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Table 5 (*continued*)

Statement number	Statement	Sorting score
"I think the whole system should change… We have a market-based system in Sweden, I don't think it's enough. And if you have that kind of auction system, it is easier to solve the issue of conflict of interest. Because it gives a certain certainty, because the market system is really uncertain all the way. Even if there are permits given to someone to build an offshore wind park, they might not do it. Then, of course, it is difficult for the rest to adjust to that future establishment if they don't know if it is even going to be built." (P20)		

The weight assigned to the three meta-challenges is influenced by how stakeholders envision the future energy system and the pathways required to meet climate and energy targets. This reflects a core theme from the literature on socio-technical transitions, where the visions, values, and interest of different stakeholders shape their interpretation of transition challenges [22,7]. Similar to the highlights of other studies on transition narratives [19], our findings challenge the notion of a single, uniform objective for the energy transition. Instead, the meta-challenges identified here emphasize the plurality of perspectives and the normative debates on the direction of the transition.

Accordingly, stakeholders aligned with different meta-challenges prioritize different issues. For example, those associated with the meta-challenge of **Procedural Deadlock** emphasized the need to overcome permitting and infrastructure delays in expanding the electricity supply mix, while those associated with **Competing Political Preferences** focus on policy disputes, particularly around carbon pricing and technology-neutral incentives. Stakeholders associated with **Poor Governance**, on the other hand, place emphasis on future grid planning and just transitions.

This demonstrates that different stakeholders perceive policy success through various lenses, such as emission reduction, cost efficiency, or fairness. Furthermore, how stakeholders prioritize challenges may also be influenced by their desire for policy instruments that would benefit them. Our findings suggest that the transition is a complex, context-dependent process where these normative values drive the preferences and goals of stakeholders, subsequently shaping their viewpoints on potential challenges. This aligns with arguments in transition literature regarding the importance of considering diverse perspectives as a complement to frameworks for diagnosing system failures [30,32], as well as for problem prioritization and solution directions [118,119]. Rather than a purely rational, top-down policy design process, the results indicate a need to better account for power struggles [120,121] and political bargaining [122,123] that influence policy outcomes.

The findings suggest that for a policy to be successful, it should be developed considering the context of the socio-technical system in which it is embedded. The characteristics of a policy should not only be seen as design objectives [124,125] but also a perceived attribute from the eyes of stakeholders and the context it engenders. Such a context-sensitive approach in policymaking ensures that policymakers can adapt the framework to uncover meta-challenges relevant to their specific energy systems. As the transition unfolds, it will be crucial to re-evaluate how stakeholders' views shift on key challenges and corresponding solutions. The ranking of statements should thus not be seen as fixed but might shift with time as social, political, and technological landscapes change during the transition. Recognizing the contested and negotiated nature of the meta-challenges found in this work raises the need to explore and reify the often-ambiguous and fragmented decision space where policy development takes place.

In contrast to previous Q methodology studies, focusing on single technologies or specific stakeholder groups, such as bioenergy [115,126], hydrogen [127], or public acceptance of wind power [15], the present research broadens the focus to system-wide meta-challenges as a basis for policy strategies that integrate cross-technology perspectives. By analyzing the interconnectedness of challenges across sectors,

Table 6
Statements (with associated numbers and sorting scores) that received the highest positive and negative scores and statements that received unique scores for Poor Governance Meta-challenge (Meta-challenge 3).

Statement number	Statement	Sorting score
Most important for the Poor-governance challenge (Meta-challenge 3)		
s40	The prominent number of stakeholders that have a veto on new developments hinders the deployment of new low-carbon electricity infrastructure.	5
s45	The lack of coordination between authorities involved in the permitting processes hinders the deployment of new electricity infrastructure.	5
s44	Broad system transformations, and not just technological substitutions, are needed for electrification.	4
s14	Lengthy legal appeals prolong the processing time for permits to develop new electricity infrastructure.	4
s52	There is not enough investment in measures that alleviate grid capacity constraints needed for electrification.	4
Most unimportant for the Poor-governance challenge (Meta-challenge 3)		
s41	Electrification will ultimately create more fuel dependence on geopolitically sensitive areas.	−5
s42	The integrated EU electricity market and the impact that it has on Swedish electricity prices represent a barrier to electrification.	−5
s28	The pace at which the prices of end-use technologies, such as solar photovoltaics and electric vehicles, are decreasing is too slow for most people to afford.	−4
s9	There is too little support for the development of new nuclear technologies, such as small modular reactors (SMRs).	−4
s37	The mindset of industrial stakeholders in relation to electricity provision hinders electrification in end-use sectors.	−4
More important than those in Meta-challenges 1 and 2		
s34	Electrification will likely deepen or perpetuate regional and urban-rural divisions.	1
s35	State-owned firms such as Svenska Kraftnät and Vattenfall are not leading the transition.	0
s4	The idea that financial compensations to local communities with new wind power developments are considered bribery will hinder the deployment of new low-carbon electricity infrastructure.	0
More unimportant than those in Meta-challenges 1 and 2		
s39	Current carbon pricing levels are too low for electrification to be implemented in industries.	−3
Relevant quotes from interviews		
"We should have a legal discussion, and it should be democratic, but I think one thing that we have discussed is to actually have a combined environmental permit for the grid, demand, production, and storage at the same time. Because if you remove one of those (environmental permits), then why should you do the other? So now we see permits for each and everything that we want to do separately, but we need to make a story… Otherwise, we just do a lot of things that harm the environment, but we gain nothing." (P2)		
"We have a history of handling Saami people badly. The historical mistreatments must be overcome by reaching a common understanding. I don't see it has been done yet." (P2)		
"The industry is taking the lead here, and politicians and the different parts of government - what we say is we are taking on the bet they haven't realized it… The thing that stops this (electrification) or slows it down is the permits." (P14)		
"There is no barrier for nuclear as I see it right now… And if you have techno-neutral, so to speak, politics, this means that nuclear also has to compete in a neutral way with renewable electricity." (P14)		
"That is a barrier that you don't have a broad energy strategy that all the political parties can agree on that could continue for more than four years. That has been we have had it before, but not in the last years… And if the relations change every fourth year, that is not good – we need to have stability in energy politics." (P14)		
"There is a democratic balancing that would need to happen, otherwise it will not go fast enough. We cannot have spent 15 years discussing whether we should establish a wind farm or not in a certain place. Maybe we can spend three years doing that or so. Then we		

(continued on next page)

Table 6 (*continued*)

Statement number	Statement	Sorting score
	have to start building, or we have to move to the next project and leave that project behind, in that case." (*P17*)	
	"*Transport will be more expensive, but if they are too expensive, I don't think so. I think transport today is too cheap.*" (*P17*)	
	"*It is the biggest obstacle for wind energy right now that the local protests are so loud right at the moment, and the local politicians do not have the strength or will to decide on any wind when their voters in their society are worried…*" (*P28*)	
	"*People find it to be more provocative, like the companies in China are making money on our land… Well, we have a bigger polarization in society… There is so much hate, hate toward politicians in general, and some of it is also followed by a skepticism on climate change.*" (*P28*)	

this work portrays the multi-level, multi-stakeholder complexities of the transition. Furthermore, the shared importance of deep system transformations across the meta-challenges identified indicates a consensus that structural change is necessary to achieve electrification, echoing findings from transition literature that stress the need for alignment between technical systems and institutional reforms [118,128].

The analysis can also be compared to existing transition frameworks, such as Technological Innovation Systems (TIS) analyses, which focus on identifying system weaknesses based on pre-defined key functions [24,25], or Multi-Level Perspectives (MLP), where challenges are identified through three levels: landscape, niche, and regime [23,31]. While frameworks such as TIS and MLP are robust for identifying structural conditions and functional failures in transitions, they often treat challenges as objective and analytically separable [129]. In contrast, our approach foregrounds the subjective and contested nature of the challenges, as understood by different actors with diverging normative views [16,130]. The Q methodology enables the identification of competing aggregated narratives—what we here term meta-challenges—which cluster perceived barriers into high-level interpretations that influence strategic decisions and political conflicts. The analysis, therefore, maps out socio-technical challenges through a discourse-based lens, capturing how cultural, political, and environmental factors shape stakeholder views. Since the narrative aggregation and discourse analysis using the Q methodology can accommodate a high level of interpretative activities, e.g., with discursive framings of challenges, we argue that Q studies could provide empirical insights that complement existing theoretical models for understanding key challenges in socio-technical transitions. As such, we position the Q methodology as particularly useful for understanding how directionality conflicts and value-laden trade-offs manifest in transition governance.

While this study provides valuable insights, it is important to acknowledge certain limitations. The Q methodology offers unique advantages for exploring complex socio-technical transitions, combining qualitative and quantitative elements to provide a nuanced understanding of stakeholder perspectives while systematically identifying overarching narratives. However, the findings are inherently dependent on the perspectives of the selected stakeholders and the statements used in the study. This study predominantly sampled established experts and stakeholders at the center of the energy transition, focusing on more tangible issues within the current electrification discourse, as reflected in scientific literature. Moreover, the focus on areas of consensus and commonality across meta-challenges may underrepresent more radical or contested viewpoints, including those from marginalized groups or grassroots initiatives, which often hold transformative potential for energy transitions. Despite these limitations, meta-challenges offer valuable insights for policymaking, particularly by highlighting systemic challenges and points of alignment across diverse stakeholders. These findings, while reflective of the Swedish context, contribute to a broader understanding of how stakeholder perspectives shape transitions in socio-technical systems.

5.2. Policy implications

Considering that it is possible that policies that address different meta-challenges can coexist [124] and to effectively mitigate the meta-challenges identified in this study, we suggest that policymakers should incorporate the following three elements:

1. **Streamlining permitting processes for electricity generation.** Meta-challenge 1, ***Procedural Deadlock***, emphasizes delays in the permitting process for the new electricity generation infrastructure. Streamlining these processes is critical to expanding variable electricity production, such as wind and solar power. Measures to fast-track permitting, while maintaining compliance with environmental regulations and local interests, could help address these delays. For instance, it is suggested that reducing procedural bottlenecks, such as by supporting municipalities in decision making, would be instrumental in facilitating the deployment of infrastructure essential for achieving net-zero carbon emissions [84]. Early introduction of vetoes, bundling permits, and making the economic benefits of low-carbon technologies more visible to local communities could serve as effective strategies.
2. **Forming a fair but differentiated low-carbon policy mix.** Meta-challenge 2, **Competing Political Preferences**, might suggest the importance of ensuring a level playing field for various technology options, enabling multiple solutions to develop and diffuse in parallel [131,132]. This can be achieved through cross-technology policies such as carbon pricing or taxation in combination with other and more tailored incentives. While broad support across technologies could ensure implementation across different policy cycles, policymakers must consider the impact of the overall low-carbon policy mix [131]. For example, emerging low-carbon technologies would benefit from additional technology-specific market-oriented instruments, while large-scale infrastructure projects may necessitate state loan guarantees to reduce uncertainty for private investors [131]. Thus, besides carbon efficiency and cost, the conditions enabling cost-efficient investment and deployment of different technologies and infrastructure components should be looked into.
3. **Recognizing the benefits of multi-partisan efforts in the energy transition.** Meta-challenge 3, ***Poor governance***, focuses on sectoral inter-linkages by highlighting the need for better coordination of permitting processes, as well as the need for investment conditions that enable effective expansion of the grid infrastructure. These issues call for measures that secure the directionality of the energy transition in the Swedish energy policy by bridging the partisan divide [23]. This could be done by legislating long-term policy targets that can be sustained through political shifts while anchoring those to measures that address near-term concerns. While governance arrangements like cross-party energy agreements have emerged in the country previously, policymakers could further learn from the success stories of how shared visions are fostered in politically diverse areas in other fields [133] or countries [134].

While these policy recommendations offer potential solutions to the identified meta-challenges, it is also essential to establish a process for balancing competing priorities, such as the need to increase electricity demand through electrification versus the urgency of streamlining permitting processes for new power generation plants. As highlighted in Sonnsjö [113], some of these trade-offs are already prominent in Swedish political debates, where concerns about energy security, price volatility, and technology choice frequently collide. Our findings complement this picture by showing how such tensions are reflected in stakeholder perceptions and may hinder the formulation of coherent transition strategies. Mapping out interconnected meta-challenges thus opens the possibility for a more comprehensive transition policy mix and policy process coherent to the context it is applied to, as well as being responsive to stakeholder perspectives.

6. Conclusion

This study employs the Q methodology to analyze stakeholder perspectives on electrification in Sweden, identifying three interrelated meta-challenges: Procedural Deadlock, Competing Political Preferences, and Poor Governance. Procedural Deadlock underscores delays and inefficiencies in scaling up variable electricity production, hindering the deployment of technologies critical for achieving net-zero carbon emissions. Competing Political Preferences highlights how divergent political priorities, particularly regarding carbon policies and flexibility incentives, slow progress toward electrification. Poor Governance emphasizes grid capacity constraints and equity challenges, particularly in ensuring fair access to electrification across diverse stakeholder groups. The Q methodology facilitates a comprehensive understanding of how challenges, through stakeholder interviews and surveys, form overarching narratives, or meta-challenges, revealing areas of alignment and tension that shape Sweden's energy transition. These findings underscore the need for integrated, adaptive policy frameworks that move beyond polarizing debates, such as the conflict between proponents of wind power and nuclear energy, toward solutions that address systemic challenges. By systematically aggregating diverse stakeholder perspectives, the Q methodology provides valuable insights for both policy development and broader socio-technical analysis.

Theoretically, this study contributes to sustainability transitions research by introducing and operationalizing the concept of meta-challenges—aggregated narratives that reflect how different actors frame, interpret, and prioritize challenges to electrification. These meta-challenges highlight not only functional or structural deficits but also contestations over values, directionality, and governance logics. In doing so, we add a narrative-sensitive perspective to existing frameworks, such as Technological Innovation Systems (TIS) and the Multi-Level Perspective (MLP), by capturing the dynamic interplay of socio-political and cultural factors that influence transitions. For instance, integrating Q studies with TIS can address the oversimplification of stakeholder interactions, while combining meta-challenge analysis with MLP can reveal how landscape pressures like climate change are translated into regime-specific challenges. Finally, the study highlights the potential for longitudinal Q studies to track changes in stakeholder perspectives over time, offering a deeper understanding of the evolving dynamics of energy transitions. As noted by ten Berge [135], combining discourse analysis with Q methodology can also help trace the historical and theoretical roots of transition debates, further enriching insights into the social and political configurations underpinning regime change. Together, these approaches provide a robust framework for exploring and addressing the challenges of decarbonization.

CRediT authorship contribution statement

Nhu Anh Phan: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Hans Hellsmark:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Lisa Göransson:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Filip Johnsson:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Nhu Anh Phan reports financial support was provided by Swedish Foundation for Strategic Environmental Research. Filip Johnsson reports financial support was provided by Swedish Foundation for Strategic Environmental Research. Lisa Goransson reports financial support was provided by Swedish Foundation for Strategic Environmental Research. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2025.104142.

Data availability

Data will be made available on request.

References

[1] ClimateWatch, Historical GHG Emissions. https://www.climatewatchdata.org/ghg-emissions?breakBy=sector&chartType=percentage, 2023. (Accessed 23 March 2023).
[2] Z. Yin, X. Lu, S. Chen, J. Wang, J. Wang, J. Urpelainen, R.M. Fleming, Y. Wu, K. He, Implication of electrification and power decarbonization in low-carbon transition pathways for China, the U.S. and the EU, Renew. Sustain. Energy Rev. 183 (2023) 113493, https://doi.org/10.1016/j.rser.2023.113493.
[3] IEA, Electrification - Energy System, IEA, 2023. https://www.iea.org/energy-system/electricity/electrification. (Accessed 14 August 2023).
[4] IPCC, Summary for Policymakers, IPCC, Geneva, Switzerland, 2023, https://doi.org/10.59327/IPCC/AR6-9789291691647.001.
[5] Swedish Energy Agency, Resan till ett mer elektrifierat samhälle [The journey to a more electrified society]. https://www.energimyndigheten.se/klimat/sveriges-elektrifiering/, 2025. (Accessed 17 July 2023).
[6] Y. Zhong, R. Li, W. Cai, Coordinating building electrification with regional grid decarbonization: comparison of carbon emissions of different scheduling strategies, Energy 303 (2024) 131942, https://doi.org/10.1016/j.energy.2024.131942.
[7] G.P.J. Verbong, F.W. Geels, Exploring sustainability transitions in the electricity sector with socio-technical pathways, Technological Forecasting and Social Change 77 (2010) 1214–1221, https://doi.org/10.1016/j.techfore.2010.04.008.
[8] F. Bauer, T. Hansen, L.J. Nilsson, Assessing the feasibility of archetypal transition pathways towards carbon neutrality – a comparative analysis of European industries, Resour. Conserv. Recycl. 177 (2022) 106015, https://doi.org/10.1016/j.resconrec.2021.106015.
[9] G. Lopez, T. Galimova, M. Fasihi, D. Bogdanov, C. Breyer, Towards defossilised steel: supply chain options for a green European steel industry, Energy 273 (2023) 127236, https://doi.org/10.1016/j.energy.2023.127236.
[10] L. Klaaßen, B. Steffen, Meta-analysis on necessary investment shifts to reach net zero pathways in Europe, Nat. Clim. Chang. 13 (2023) 58–66, https://doi.org/10.1038/s41558-022-01549-5.
[11] L. Montrone, J.C. Steckel, M. Kalkuhl, The type of power capacity matters for economic development – evidence from a global panel, Resour. Energy Econ. 69 (2022) 101313, https://doi.org/10.1016/j.reseneeco.2022.101313.
[12] R. Vakulchuk, I. Overland, D. Scholten, Renewable energy and geopolitics: a review, Renew. Sustain. Energy Rev. 122 (2020) 109547, https://doi.org/10.1016/j.rser.2019.109547.
[13] P. Devine-Wright, F. Sherry-Brennan, Where do you draw the line? Legitimacy and fairness in constructing community benefit fund boundaries for energy infrastructure projects, Energy Res. Soc. Sci. 54 (2019) 166–175, https://doi.org/10.1016/j.erss.2019.04.002.
[14] M.J. Janssen, J. Torrens, J.H. Wesseling, I. Wanzenböck, The promises and premises of mission-oriented innovation policy—a reflection and ways forward, Science and Public Policy 48 (2021) 438–444, https://doi.org/10.1093/scipol/scaa072.
[15] Z. Dubský, L. Tichý, The role of narratives in the discourse on energy security of the European Commission: the EU's transition in energy relations with Russia, The Extractive Industries and Society 17 (2024) 101392, https://doi.org/10.1016/j.exis.2023.101392.
[16] L. Hermwille, The role of narratives in socio-technical transitions—Fukushima and the energy regimes of Japan, Germany, and the United Kingdom, Energy Research & Social Science 11 (2016) 237–246, https://doi.org/10.1016/j.erss.2015.11.001.
[17] K.B. Janda, M. Topouzi, Telling tales: using stories to remake energy policy, Building Research & Information 43 (2015) 516–533, https://doi.org/10.1080/09613218.2015.1020217.
[18] M.D. Jones, M.K. McBeth, A narrative policy framework: clear enough to be wrong? Policy Stud. J. 38 (2010) 329–353, https://doi.org/10.1111/j.1541-0072.2010.00364.x.
[19] C. Luederitz, D.J. Abson, R. Audet, D.J. Lang, Many pathways toward sustainability: not conflict but co-learning between transition narratives, Sustain Sci 12 (2017) 393–407, https://doi.org/10.1007/s11625-016-0414-0.
[20] W. Stephenson, The Study of Behavior; Q-technique and Its Methodology, University of Chicago Press, 1953.
[21] D. Lindvall, P. Sörqvist, S. Lindeberg, S. Barthel, The polarization of energy preferences – a study on social acceptance of wind and nuclear power in Sweden, Energy Policy 198 (2025) 114492, https://doi.org/10.1016/j.enpol.2024.114492.

[22] F.W. Geels, B.K. Sovacool, T. Schwanen, S. Sorrell, The socio-technical dynamics of low-carbon transitions, Joule 1 (2017) 463–479, https://doi.org/10.1016/j.joule.2017.09.018.
[23] F.W. Geels, J. Schot, Typology of sociotechnical transition pathways, Research Policy 36 (2007) 399–417, https://doi.org/10.1016/j.respol.2007.01.003.
[24] A. Bergek, S. Jacobsson, B. Carlsson, S. Lindmark, A. Rickne, Analyzing the functional dynamics of technological innovation systems: a scheme of analysis, Research Policy 37 (2008) 407–429, https://doi.org/10.1016/j.respol.2007.12.003.
[25] M.P. Hekkert, R.A.A. Suurs, S.O. Negro, S. Kuhlmann, R.E.H.M. Smits, Functions of innovation systems: a new approach for analysing technological change, Technol. Forecast. Soc. Chang. 74 (2007) 413–432, https://doi.org/10.1016/j.techfore.2006.03.002.
[26] J. Köhler, F.W. Geels, F. Kern, J. Markard, E. Onsongo, A. Wieczorek, F. Alkemade, F. Avelino, A. Bergek, F. Boons, L. Fünfschilling, D. Hess, G. Holtz, S. Hyysalo, K. Jenkins, P. Kivimaa, M. Martiskainen, A. McMeekin, M. S. Mühlemeier, B. Nykvist, B. Pel, R. Raven, H. Rohracher, B. Sandén, J. Schot, B. Sovacool, B. Turnheim, D. Welch, P. Wells, An agenda for sustainability transitions research: state of the art and future directions, Environ. Innov. Soc. Trans. 31 (2019) 1–32, https://doi.org/10.1016/j.eist.2019.01.004.
[27] L. Kanger, B.K. Sovacool, M. Noorkõiv, Six policy intervention points for sustainability transitions: a conceptual framework and a systematic literature review, Res. Policy 49 (2020) 104072, https://doi.org/10.1016/j.respol.2020.104072.
[28] R. Klein Woolthuis, M. Lankhuizen, V. Gilsing, A system failure framework for innovation policy design, Technovation 25 (2005) 609–619, https://doi.org/10.1016/j.technovation.2003.11.002.
[29] K.M. Weber, H. Rohracher, Legitimizing research, technology and innovation policies for transformative change: combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework, Research Policy 41 (2012) 1037–1047, https://doi.org/10.1016/j.respol.2011.10.015.
[30] A.J. Wieczorek, M.P. Hekkert, Systemic instruments for systemic innovation problems: a framework for policy makers and innovation scholars, Sci. Public Policy 39 (2012) 74–87, https://doi.org/10.1093/scipol/scr008.
[31] F.W. Geels, Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study, Research Policy 31 (2002) 1257–1274, https://doi.org/10.1016/S0048-7333(02)00062-8.
[32] A.D. Andersen, F.W. Geels, Multi-system dynamics and the speed of net-zero transitions: identifying causal processes related to technologies, actors, and institutions, Energy Res. Soc. Sci. 102 (2023) 103178, https://doi.org/10.1016/j.erss.2023.103178.
[33] H.L. Sataøen, O.A. Brekke, S. Batel, M. Albrecht, Towards a sustainable grid development regime? A comparison of British, Norwegian, and Swedish grid development, Energy Res. Soc. Sci. 9 (2015) 178–187, https://doi.org/10.1016/j.erss.2015.08.011.
[34] G. Verbong, F. Geels, The ongoing energy transition: lessons from a socio-technical, multi-level analysis of the Dutch electricity system (1960–2004), Energy Policy 35 (2007) 1025–1037, https://doi.org/10.1016/j.enpol.2006.02.010.
[35] K.S. Rogge, B. Pfluger, F.W. Geels, Transformative policy mixes in socio-technical scenarios: the case of the low-carbon transition of the German electricity system (2010–2050), Technological Forecasting and Social Change 151 (2020) 119259, https://doi.org/10.1016/j.techfore.2018.04.002.
[36] F.W. Geels, The dynamics of transitions in socio-technical systems: a multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930), Tech. Anal. Strat. Manag. 17 (2005) 445–476, https://doi.org/10.1080/09537320500357319.
[37] A.D. Andersen, No transition without transmission: HVDC electricity infrastructure as an enabler for renewable energy? Environ. Innov. Soc. Trans. 13 (2014) 75–95, https://doi.org/10.1016/j.eist.2014.09.004.
[38] A. Berntsen, S. Sæther, J. Røyrvik, M.E. Biresselioglu, M.H. Demir, The significance of enabling human consideration in policymaking: how to get the E-ferry that you want, Front. Psychol. 12 (2021) 1851, https://doi.org/10.3389/fpsyg.2021.635722.
[39] B. Glaa, I. Mignon, Identifying gaps and overlaps of intermediary support during the adoption of renewable energy technology in Sweden – a conceptual framework, J. Clean. Prod. 261 (2020) 121178, https://doi.org/10.1016/j.jclepro.2020.121178.
[40] L. Göransson, M. Lehtveer, E. Nyholm, M. Taljegard, V. Walter, The benefit of collaboration in the North European electricity system transition—system and sector perspectives, Energies 12 (2019) 4648, https://doi.org/10.3390/en12244648.
[41] J.S. Gregg, S. Nyborg, M. Hansen, V.J. Schwanitz, A. Wierling, J.P. Zeiss, S. Delvaux, V. Saenz, L. Polo-Alvarez, C. Candelise, W. Gilcrease, O. Arrobbio, A. Sciullo, D. Padovan, Collective action and social innovation in the energy sector: a mobilization model perspective, Energies 13 (2020) 651, https://doi.org/10.3390/en13030651.
[42] I. Mignon, A. Rüdinger, The impact of systemic factors on the deployment of cooperative projects within renewable electricity production – an international comparison, Renew. Sustain. Energy Rev. 65 (2016) 478–488, https://doi.org/10.1016/j.rser.2016.07.026.
[43] G. Zarazua de Rubens, L. Noel, The non-technical barriers to large scale electricity networks: Analysing the case for the US and EU supergrids, Energy Policy 135 (2019) 111018, https://doi.org/10.1016/j.enpol.2019.111018.
[44] G. Ellis, J. Barry, C. Robinson, Many ways to say 'no', different ways to say 'yes': applying Q-methodology to understand public acceptance of wind farm proposals, Journal of Environmental Planning and Management 50 (2007) 517–551, https://doi.org/10.1080/09640560701402075.
[45] M. Aitken, Wind power and community benefits: challenges and opportunities, Energy Policy 38 (2010) 6066–6075, https://doi.org/10.1016/j.enpol.2010.05.062.
[46] D. Bell, T. Gray, C. Haggett, The 'social gap' in wind farm siting decisions: explanations and policy responses, Environmental Politics 14 (2005) 460–477, https://doi.org/10.1080/09644010500175833.
[47] K. Ek, Public and private attitudes towards "green" electricity: the case of Swedish wind power, Energy Policy 33 (2005) 1677–1689, https://doi.org/10.1016/j.enpol.2004.02.005.
[48] J. Kester, B.K. Sovacool, L. Noel, G. Zarazua de Rubens, Rethinking the spatiality of Nordic electric vehicles and their popularity in urban environments: moving beyond the city? J. Transp. Geogr. 82 (2020) 102557 https://doi.org/10.1016/j.jtrangeo.2019.102557.
[49] A. Peacock, P. Devine-Wright, How stakeholders legitimate 'acceptable' national energy transitions through spatial imaginaries and imagined publics: a Swedish case study, Energy Res. Soc. Sci. 120 (2025) 103854, https://doi.org/10.1016/j.erss.2024.103854.
[50] M.T. Koecklin, G. Longoria, D.Z. Fitiwi, J.F. DeCarolis, J. Curtis, Public acceptance of renewable electricity generation and transmission network developments: insights from Ireland, Energy Policy 151 (2021) 112185, https://doi.org/10.1016/j.enpol.2021.112185.
[51] M. Wolsink, Wind power implementation: the nature of public attitudes: equity and fairness instead of 'backyard motives', Renew. Sustain. Energy Rev. 11 (2007) 1188–1207, https://doi.org/10.1016/j.rser.2005.10.005.
[52] J. Liljenfeldt, Ö. Pettersson, Distributional justice in Swedish wind power development – an odds ratio analysis of windmill localization and local residents' socio-economic characteristics, Energy Policy 105 (2017) 648–657, https://doi.org/10.1016/j.enpol.2017.03.007.
[53] V. Ramasar, H. Busch, E. Brandstedt, K. Rudus, When energy justice is contested: a systematic review of a decade of research on Sweden's conflicted energy landscape, Energy Res. Soc. Sci. 94 (2022) 102862, https://doi.org/10.1016/j.erss.2022.102862.
[54] M. Ring, E. Wilson, K.N. Ruwanpura, M. Gay-Antaki, Just energy transitions? Energy policy and the adoption of clean energy technology by households in Sweden, Energy Res. Soc. Sci. 91 (2022) 102727, https://doi.org/10.1016/j.erss.2022.102727.
[55] B.K. Sovacool, J. Kester, L. Noel, G.Z. de Rubens, Energy injustice and Nordic electric mobility: inequality, elitism, and externalities in the electrification of vehicle-to-grid (V2G) transport, Ecol. Econ. 157 (2019) 205–217, https://doi.org/10.1016/j.ecolecon.2018.11.013.
[56] J. von Platten, M. Mangold, K. Mjörnell, A matter of metrics? How analysing per capita energy use changes the face of energy efficient housing in Sweden and reveals injustices in the energy transition, Energy Res. Soc. Sci. 70 (2020) 101807, https://doi.org/10.1016/j.erss.2020.101807.
[57] P. Fragkos, N. Tasios, L. Paroussos, P. Capros, S. Tsani, Energy system impacts and policy implications of the European intended nationally determined contribution and low-carbon pathway to 2050, Energy Policy 100 (2017) 216–226, https://doi.org/10.1016/j.enpol.2016.10.023.
[58] K. Linnerud, M. Simonsen, Swedish-Norwegian tradable green certificates: scheme design flaws and perceived investment barriers, Energy Policy (2017) 560–578, https://doi.org/10.1016/j.enpol.2017.04.012.
[59] A. Battaglini, N. Komendantova, P. Brtnik, A. Patt, Perception of barriers for expansion of electricity grids in the European Union, Energy Policy 47 (2012) 254–259, https://doi.org/10.1016/j.enpol.2012.04.065.
[60] Y.-K. Chen, H. Koduvere, P.A. Gunkel, J.G. Kirkerud, K. Skytte, H. Ravn, T. F. Bolkesjø, The role of cross-border power transmission in a renewable-rich power system – a model analysis for Northwestern Europe, J. Environ. Manage. 261 (2020) 110194, https://doi.org/10.1016/j.jenvman.2020.110194.
[61] A. Gadea, M. Marinelli, A. Zecchino, A market framework for enabling electric vehicles flexibility procurement at the distribution level considering grid constraints, in: 2018 Power Systems Computation Conference (PSCC), 2018, pp. 1–7, https://doi.org/10.23919/PSCC.2018.8443012.
[62] K. Skytte, O.J. Olsen, Regulatory barriers for flexible coupling of the Nordic power and district heating markets, in: 2016 13th International Conference on the European Energy Market (EEM), 2016, pp. 1–5, https://doi.org/10.1109/EEM.2016.7521319.
[63] A. Temmes, E. Heiskanen, K. Matschoss, R. Lovio, Mobilising mainstream finance for a future clean energy transition: the case of Finland, J. Clean. Prod. 319 (2021) 128797, https://doi.org/10.1016/j.jclepro.2021.128797.
[64] M. Welisch, Multi-unit renewables auctions for small markets - designing the Danish multi-technology auction scheme, Renew. Energy 131 (2019) 372–380, https://doi.org/10.1016/j.renene.2018.07.044.
[65] B. Zakeri, V. Virasjoki, S. Syri, D. Connolly, B.V. Mathiesen, M. Welsch, Impact of Germany's energy transition on the Nordic power market – a market-based multi-region energy system model, Energy 115 (2016) 1640–1662, https://doi.org/10.1016/j.energy.2016.07.083.
[66] E. Karakaya, C. Nuur, A. Hidalgo, Business model challenge: lessons from a local solar company, Renew. Energy 85 (2016) 1026–1035, https://doi.org/10.1016/j.renene.2015.07.069.
[67] I. Karlsson, J. Rootzén, F. Johnsson, Reaching net-zero carbon emissions in construction supply chains – analysis of a Swedish road construction project, Renew. Sustain. Energy Rev. 120 (2020) 109651, https://doi.org/10.1016/j.rser.2019.109651.

[68] A.B. Svendsen, T. Tollefsen, T. Gjengedal, M. Goodwin, S. Antonsen, Digitalization of the power business: How to make this work?, in: Safety and Reliability – Safe Societies in a Changing World CRC Press, 2018.
[69] S. Anwar, M.Y.I. Zia, M. Rashid, G.Z. de Rubens, P. Enevoldsen, Towards ferry electrification in the maritime sector, Energies 13 (2020) 6506, https://doi.org/10.3390/en13246506.
[70] M.M. Bugge, A.D. Andersen, M. Steen, The role of regional innovation systems in mission-oriented innovation policy: exploring the problem-solution space in electrification of maritime transport, Eur. Plan. Stud. 30 (2021) 1–22, https://doi.org/10.1080/09654313.2021.1988907.
[71] O.Y. Edelenbosch, A.F. Hof, B. Nykvist, B. Girod, D.P. van Vuuren, Transport electrification: the effect of recent battery cost reduction on future emission scenarios, Clim. Change 151 (2018) 95–108, https://doi.org/10.1007/s10584-018-2250-y.
[72] B. Faessler, Stationary, second use battery energy storage systems and their applications: a research review, Energies 14 (2021) 2335, https://doi.org/10.3390/en14082335.
[73] P. Greim, A.A. Solomon, C. Breyer, Assessment of lithium criticality in the global energy transition and addressing policy gaps in transportation, Nat. Commun. 11 (2020) 4570, https://doi.org/10.1038/s41467-020-18402-y.
[74] A. Månsson, Energy security in a decarbonised transport sector: a scenario based analysis of Sweden's transport strategies, Energ. Strat. Rev. 13–14 (2016) 236–247, https://doi.org/10.1016/j.esr.2016.06.004.
[75] I. Mignon, A. Bergek, System- and actor-level challenges for diffusion of renewable electricity technologies: an international comparison, J. Clean. Prod. 128 (2016) 105–115, https://doi.org/10.1016/j.jclepro.2015.09.048.
[76] H. Pihkola, E. Tsupari, M. Kojo, L. Kujanpää, M. Nissilä, L. Sokka, K. Behm, Integrated sustainability assessment of CCS – identifying non-technical barriers and drivers for CCS implementation in Finland, Energy Procedia 114 (2017) 7625–7637, https://doi.org/10.1016/j.egypro.2017.03.1895.
[77] A. Bergek, Levelling the playing field? The influence of national wind power planning instruments on conflicts of interests in a Swedish county, Energy Policy 38 (2010) 2357–2369, https://doi.org/10.1016/j.enpol.2009.12.023.
[78] T. Ejdemo, P. Söderholm, Wind power, regional development and benefit-sharing: the case of Northern Sweden, Renew. Sustain. Energy Rev. 47 (2015) 476–485, https://doi.org/10.1016/j.rser.2015.03.082.
[79] K. Ek, L. Persson, M. Johansson, Å. Waldo, Location of Swedish wind power—random or not? A quantitative analysis of differences in installed wind power capacity across Swedish municipalities, Energy Policy 58 (2013) 135–141, https://doi.org/10.1016/j.enpol.2013.02.044.
[80] J. Khan, Wind power planning in three Swedish municipalities, J. Environ. Plan. Manag. 46 (2003) 563–581, https://doi.org/10.1080/0964056032000133161.
[81] G. Michanek, P. Söderholm, Licensing of nuclear power plants: the case of Sweden in an international comparison, Energy Policy 37 (2009) 4086–4097, https://doi.org/10.1016/j.enpol.2009.04.051.
[82] R. Sam, T. Sainati, B. Hanson, R. Kay, Licensing small modular reactors: a state-of-the-art review of the challenges and barriers, Prog. Nucl. Energy 164 (2023) 104859, https://doi.org/10.1016/j.pnucene.2023.104859.
[83] V. Wretling, B. Balfors, U. Mörtberg, Balancing wind power deployment and sustainability objectives in Swedish planning and permitting, Energy Sustain. Soc. 12 (2022) 48, https://doi.org/10.1186/s13705-022-00376-y.
[84] T.B. Rasmussen, G. Yang, A.H. Nielsen, Z. Dong, A review of cyber-physical energy system security assessment, in: 2017 IEEE Manchester PowerTech, 2017, pp. 1–6, https://doi.org/10.1109/PTC.2017.7980942.
[85] E. Skjong, R. Volden, E. Rødskar, M. Molinas, T.A. Johansen, J. Cunningham, Past, present, and future challenges of the marine vessel's electrical power system, IEEE Transactions on Transportation Electrification 2 (2016) 522–537, https://doi.org/10.1109/TTE.2016.2552720.
[86] J. Farfan, C. Breyer, Aging of European power plant infrastructure as an opportunity to evolve towards sustainability, Int. J. Hydrogen Energy 42 (2017) 18081–18091, https://doi.org/10.1016/j.ijhydene.2016.12.138.
[87] K. Habib, S.T. Hansdóttir, H. Habib, Critical metals for electromobility: global demand scenarios for passenger vehicles, 2015–2050, Resources, Conservation and Recycling 154 (2020) 104603, https://doi.org/10.1016/j.resconrec.2019.104603.
[88] P. Karka, F. Johnsson, S. Papadokonstantakis, Perspectives for greening European fossil-fuel infrastructures through use of biomass: the case of liquid biofuels based on lignocellulosic resources, Frontiers in Energy Research 9 (2021) 112, https://doi.org/10.3389/fenrg.2021.636782.
[89] A.W. Mortensen, B.V. Mathiesen, A.B. Hansen, S.L. Pedersen, R.D. Grandal, H. Wenzel, The role of electrification and hydrogen in breaking the biomass bottleneck of the renewable energy system – a study on the Danish energy system, Appl. Energy 275 (2020) 115331, https://doi.org/10.1016/j.apenergy.2020.115331.
[90] J. Schulte, H. Ny, Electric road systems: strategic stepping stone on the way towards sustainable freight transport? Sustainability 10 (2018) 1148, https://doi.org/10.3390/su10041148.
[91] A. Millot, A. Krook-Riekkola, N. Maïzi, Guiding the future energy transition to net-zero emissions: lessons from exploring the differences between France and Sweden, Energy Policy 139 (2020) 111358, https://doi.org/10.1016/j.enpol.2020.111358.
[92] E. Rodriguez, A. Lefvert, M. Fridahl, S. Grönkvist, S. Haikola, A. Hansson, Tensions in the energy transition: Swedish and Finnish company perspectives on bioenergy with carbon capture and storage, J. Clean. Prod. 280 (2021) 124527, https://doi.org/10.1016/j.jclepro.2020.124527.
[93] UNFCCC, Nationally Determined Contributions (NDCs), (n.d.). https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs (accessed February 24, 2025).
[94] Y. Chen, I.G. Jensen, J.G. Kirkerud, T.F. Bolkesjø, Impact of fossil-free decentralized heating on northern European renewable energy deployment and the power system, Energy 219 (2021) 119576, https://doi.org/10.1016/j.energy.2020.119576.
[95] R. Egging, A. Tomasgard, Norway's role in the European energy transition, Energ. Strat. Rev. (2018) 99–101, https://doi.org/10.1016/j.esr.2018.02.004.
[96] G. Zarazua de Rubens, L. Noel, B.K. Sovacool, Dismissive and deceptive car dealerships create barriers to electric vehicle adoption at the point of sale, Nat. Energy 3 (2018) 501–507, https://doi.org/10.1038/s41560-018-0152-x.
[97] European Environment Agency, Fossil fuel subsidies in Europe, 2023. https://www.eea.europa.eu/en/analysis/indicators/fossil-fuel-subsidies, 2025 (accessed February 24, 2025).
[98] European Commission, Revision of the Energy Taxation Directive (ETD), European Commission - European Commission, 2021. https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3662 (accessed February 24, 2025).
[99] B.K. Sovacool, Contestation, contingency, and justice in the Nordic low-carbon energy transition, Energy Policy 102 (2017) 569–582, https://doi.org/10.1016/j.enpol.2016.12.045.
[100] T.J. Foxon, P.J.G. Pearson, S. Arapostathis, A. Carlsson-Hyslop, J. Thornton, Branching points for transition pathways: assessing responses of actors to challenges on pathways to a low carbon future, Energy Policy 52 (2013) 146–158, https://doi.org/10.1016/j.enpol.2012.04.030.
[101] Energinet, Fingrid, Statnett, Svenska Kraftnät, Nordic Grid Development Perspectives 2023. https://www.svk.se/siteassets/om-oss/rapporter/2023/svk_ngpd2023.pdf, 2023. (Accessed 26 January 2024).
[102] Swedish Energy Agency, Sveriges energisystem [Sweden's energy system]. https://www.energimyndigheten.se/energisystemet/sveriges-energisystem/, 2022 (accessed May 29, 2024).
[103] World Nuclear Association, Nuclear Power in Sweden, World Nuclear Association, 2024. https://world-nuclear.org/information-library/country-profiles/countries-o-s/sweden. (Accessed 30 May 2024).
[104] J. Weibull, L.T. Norman, Sweden - Economy, Trade, Manufacturing, Britannica, 2024. https://www.britannica.com/place/Sweden/Economy (accessed July 25, 2024).
[105] Swedish Government Office, Sweden's climate policy framework. https://www.government.se/articles/2021/03/swedens-climate-policy-framework/, 2021. (Accessed 5 April 2023).
[106] Ministry of the Environment, Sweden's Long-term Strategy for Reducing Greenhouse Gas Emissions, 2020.
[107] Swedish Environmental Protection Agency, Sweden's Climate Act and Climate Policy Framework. https://www.naturvardsverket.se/en/topics/climate-transition/sveriges-klimatarbete/swedens-climate-act-and-climate-policy-framework/, 2017. (Accessed 6 February 2024).
[108] Heidelberg Materials, CemZero. https://www.cement.heidelbergmaterials.se/sv/cemzero, 2018. (Accessed 10 June 2024).
[109] Vattenfall, HYBRIT: The World's First Fossil-free Steel Ready for Delivery, Press Release - Technology and Development, 2021. https://group.vattenfall.com/press-and-media/pressreleases/2021/hybrit-the-worlds-first-fossil-free-steel-ready-for-delivery. (Accessed 10 June 2024).
[110] Vattenfall, HYBRIT: SSAB, LKAB and Vattenfall First in the World With Hydrogen-reduced Sponge Iron, Vattenfall, 2021. https://group.vattenfall.com/press-and-media/pressreleases/2021/hybrit-ssab-lkab-and-vattenfall-first-in-the-world-with-hydrogen-reduced-sponge-iron. (Accessed 17 February 2025).
[111] Vattenfall, Vattenfall and Preem Continue Their Collaboration on Fossil-free Hydrogen Gas for Biofuels, Vattenfall, 2021. https://group.vattenfall.com/press-and-media/newsroom/2021/vattenfall-and-preem-continue-their-collaboration-on-fossil-free-hydrogen-gas-for-biofuels. (Accessed 17 February 2025).
[112] European Parliament, in: European Parliamentary Research Service (Ed.), Climate Action in Sweden, 2021.
[113] H. Sonnsjö, What we talk about when we talk about electricity: a thematic analysis of recent political debates on Swedish electricity supply, Energy Policy 187 (2024) 114053, https://doi.org/10.1016/j.enpol.2024.114053.
[114] E. Cuppen, S. Breukers, M. Hisschemöller, E. Bergsma, Q methodology to select participants for a stakeholder dialogue on energy options from biomass in the Netherlands, Ecol. Econ. 69 (2010) 579–591, https://doi.org/10.1016/j.ecolecon.2009.09.005.
[115] S. Watts, P. Stenner, Doing Q Methodological Research: Theory, Method and Interpretation, SAGE Publications Ltd, 2012, https://doi.org/10.4135/9781446251911.
[116] S.R. Brown, A primer on Q methodology, Osub 16 (1993), https://doi.org/10.22488/okstate.93.100504.
[117] Q Method Software n.d. Study Analysis, Study Analysis https://app.qmethodsoftware.com/docs/articles/study-analysis/analysis.html.
[118] I. Wanzenböck, J.H. Wesseling, K. Frenken, M.P. Hekkert, K.M. Weber, A framework for mission-oriented innovation policy: alternative pathways through the problem–solution space, Science and Public Policy 47 (2020) 474–489, https://doi.org/10.1093/scipol/scaa027.
[119] M.P. Hekkert, M.J. Janssen, J.H. Wesseling, S.O. Negro, Mission-oriented innovation systems, Environ. Innov. Soc. Trans. 34 (2020) 76–79, https://doi.org/10.1016/j.eist.2019.11.011.
[120] B. Arts, J.V. Tatenhove, Policy and power: a conceptual framework between the 'old' and 'new' policy idioms, Policy Sci 37 (2004) 339–356, https://doi.org/10.1007/s11077-005-0156-9.

[121] F. Avelino, Empowerment and the challenge of applying transition management to ongoing projects, Policy. Sci. 42 (2009) 369–390, https://doi.org/10.1007/s11077-009-9102-6.
[122] F.W. Geels, Regime resistance against low-carbon transitions: introducing politics and power into the multi-level perspective, Theory, Culture & Society 31 (2014) 21–40, https://doi.org/10.1177/0263276414531627.
[123] F.W. Geels, B. Verhees, Cultural legitimacy and framing struggles in innovation journeys: a cultural-performative perspective and a case study of Dutch nuclear energy (1945–1986), Technological Forecasting and Social Change 78 (2011) 910–930, https://doi.org/10.1016/j.techfore.2010.12.004.
[124] K.S. Rogge, K. Reichardt, Policy mixes for sustainability transitions: an extended concept and framework for analysis, Research Policy 45 (2016) 1620–1635, https://doi.org/10.1016/j.respol.2016.04.004.
[125] M. Howlett, J. Rayner, Design principles for policy mixes: cohesion and coherence in 'new governance arrangements', Polic. Soc. 26 (2007) 1–18, https://doi.org/10.1016/S1449-4035(07)70118-2.
[126] F. Bauer, Narratives of biorefinery innovation for the bioeconomy: conflict, consensus or confusion? Environ. Innov. Soc. Trans. 28 (2018) 96–107, https://doi.org/10.1016/j.eist.2018.01.005.
[127] J. Baxter, N. Hacking, Expert hydrogen perspectives for technological innovation: a q-method study, Int. J. Hydrogen Energy 40 (2015) 3111–3121, https://doi.org/10.1016/j.ijhydene.2014.06.171.
[128] F.W. Geels, F. Kern, G. Fuchs, N. Hinderer, G. Kungl, J. Mylan, M. Neukirch, S. Wassermann, The enactment of socio-technical transition pathways: a reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990–2014), Research Policy 45 (2016) 896–913, https://doi.org/10.1016/j.respol.2016.01.015.
[129] A. Stirling, Pluralising progress: from integrative transitions to transformative diversity, Environ. Innov. Soc. Trans. 1 (2011) 82–88, https://doi.org/10.1016/j.eist.2011.03.005.
[130] R. Cairns, A. Stirling, Maintaining planetary systems' or 'concentrating global power?' High stakes in contending framings of climate geoengineering, Glob. Environ. Chang. 28 (2014) 25–38, https://doi.org/10.1016/j.gloenvcha.2014.04.005.
[131] C. Azar, B.A. Sandén, The elusive quest for technology-neutral policies, Environ. Innov. Soc. Trans. 1 (2011) 135–139, https://doi.org/10.1016/j.eist.2011.03.003.
[132] B.A. Greenberg, Rethinking technology neutrality, Minn. Law Rev. 100 (2016) 1495.
[133] A. Goldthau, Rethinking the governance of energy infrastructure: scale, decentralization and polycentrism, Energy Res. Soc. Sci. 1 (2014) 134–140, https://doi.org/10.1016/j.erss.2014.02.009.
[134] J. Monstadt, S. Scheiner, Allocating greenhouse gas emissions in the German federal system: regional interests and federal climate governance, Energy Policy 74 (2014) 383–394, https://doi.org/10.1016/j.enpol.2014.09.001.
[135] G. ten Berge, Memory in energy transitions: individual agency through historical narratives in the energy transition to gas and electricity in the Dutch household, Sustain. Sci. 19 (3) (2023) 763–775, https://doi.org/10.1007/s11625-023-01412-2.