Anticipating emerging issues for resilient energy systems: wider, deeper and further perspectives

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Abstract

Purpose – *The purpose of this study is to explore the long-term, deeper transformations occurring in the wider energy transition to anticipate emerging issues through collective anticipatory intelligence.*

Design/methodology/approach – *Through a co-productive research design, the authors collectively scanned and discussed contemporary developments in the Swedish energy transition. The acquired insight was used in a causal layered analysis over three horizons to separate between views and developments in time and space.*

Findings – *Findings of this study present current, transitionary and emerging issues and how they emerge from deeper levels such as values and worldviews. These issues are discussed around how underlying changes may change to mitigate them, suggesting three strategies.*

Practical implications – *The framed and anticipated issues enable monitoring and proactive response, and the discussion contributes insight to ongoing political debates, as well as implications for managing similar initiatives.*

Social implications – *Insights are provided into the changing cultures and values required in a future energy system, showing, e.g. how demand-side response may either come through relinquishing control over consumption or through increased flexibility and change.*

Originality/value – *Studying issues of growing concern and novel approaches, this paper should be of interest to practitioners in the energy sector and foresight professionals. It provides a critique and framing of issues to be monitored, adding to the growing library of energy futures studies.*

Keywords *Emerging issues, Horizon scanning, Weak signals, Energy resilience, Energy futures, Open foresight*

Paper type *Research paper*

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1. Introduction

Global and national outlooks on the development of energy systems stand at an unprecedented stage in history (see e.g. IEA, 2023; Swedish Energy Agency, 2023). In consequence of the trends of sector-coupling, decentralization and electrification (Bravić *et al.*, 2023), actors in industry, mobility, agriculture and residential sectors are getting an increasingly growing stake in the energy system. This shift invites a wider threat landscape and arena of differentiating values (Johansson, 2013; Jasiūnas, *et al.*, 2021; Doh *et al.*, 2021). Concurrently, a transition is occurring from a system steered by supply-side management, towards one where demand-side management and flexibility is critical (Sousa and Soares, 2023). Such a transition entails shifts in our relationships and values towards energy, which requires a deeper form of transformation to avoid future conflict (Heinonen *et al.*, 2016; Fazey and Leicester, 2022). Transformations of such magnitude take time, and the lead- and lifetimes of energy infrastructure have always demanded long-term horizons in their planning and development. However, such planning is characterized by linear forecasts, historical data and modelling, whereas the level of uncertainty introduced with such horizons requires more qualitative methodological approaches (Laimon *et al.*, 2022; Ansari and Holz, 2019). The decisions taken today will have long-lasting impacts on future energy systems and their supporting society (Basu and Bale, 2023). Building resilience in the context of energy systems requires a degree of foresight to prepare for unexpected developments and to provide an early warning system thereto (Sharifi and Yamagata, 2016; Gilmore *et al.*, 2023).

Previous studies have shown the ability of wider collective intelligence to anticipate emergent risks through surveys (Wood *et al.*, 2021); deeper levels of scenario planning for resilience (Sircar *et al.*, 2013); and the necessities of long-term planning (Bathke *et al.*, 2022). It is the combination of wider communities, with deeper levels of understanding and further out horizons that is required to manage the complexity and uncertainty of transformations in systems such as energy (Ravetz *et al.*, 2021; Laimon *et al.*, 2022). However, prior research has primarily taken a quantitative data-driven approach in combination with expert consultation to such questions (Landry, 2020; Koskinen *et al.*, 2022), or in smaller organizational constellations (see e.g. Wiener *et al.*, 2020). Meeting the sustainability challenges of the energy sector requires long-term and holistic solutions rather than short-term fixes on the component-level (Koskinen *et al.*, 2022; Laimon *et al.*, 2022). Building on domain-specific theories surrounding the futures of energy systems (Piirainen and Gonzalez, 2015), the purpose of this study is to explore the combination of deeper levels of transformation among a wider range of actors, in further away horizons, to contribute to the ongoing development of resilient energy system through deeper insights and reflections. Exploring the research question: *What are the long-term, deeper and wider issues emerging in the continued energy transition?* To do so, we draw upon a widening network of actors to account for the increasing complexity and uncertainty by using and attempting to enhance the collective anticipatory intelligence (CAI) thereof (Ravetz *et al.*, 2021).

2. Background

This chapter first outlines how we conceptualize the overarching concept of CAI and its dimensions of wider ranges of interest; deeper levels of transformation; and further away horizons, including an account of previous contributions to these dimensions.

2.1 Collective anticipatory intelligence – wider, deeper and further

CAI is a response to increasing complexity, growing tensions and series of intertwined and deeply rooted issues (Ravetz *et al.*, 2021). It is a form of governance which mobilizes longer time horizons, wider communities and deeper value systems. As such, collective intelligence has become a trend in and of itself, outlined by the European Commission (2022) and described as the process of gathering diverse individuals to share knowledge, data and insights to address societal issues (see also, Glenn, 2016). It is collective in the sense that it considers a breadth of interests rather than centralized values; it is anticipatory in that the purpose is to direct present action in the face of emerging issues (Poli, 2010); and it is labelled intelligence as it refers to insights and knowledge. While it could be argued that all intelligence is collective (Falandays *et al.*, 2023) and that all things can be anticipatory (Poli, 2010). For the purposes of this study, we view collective intelligence as the shared body of knowledge that is created when experts interact with each other, technology and different form of data or insights to create an emergent body of knowledge (Rashid *et al.*, 2023; Glenn, 2016), to be directed towards wider, deeper and further perspectives (Ravetz, 2020).

2.1.1 Wider range of interests. Anticipatory processes using participatory methods aid the understanding of uncertainty and complexity, and doing so continuously allows for understanding the evolution thereof (Basu and Bale, 2023). Although diversity is beneficial, a degree of similarity between participants is also beneficial to facilitate knowledge exchange (Gattringer *et al.*, 2017). A breadth in participation, be it layman or expert, reveals a breadth of perspectives and visions for what the future holds (Koskinen *et al.*, 2022). This does not only include a need for more perspectives to be included within the contemporary energy system, but a widening of who is considered an actor in the energy system. As elements are becoming more renewable, reliable and affordable, parts and power are becoming more decentralized. More people and organizations are becoming active actors in the energy sector through, e.g. prosumerism and sector-coupling, which diffuse previously existing boundaries, showing, for instance, that future energy scenarios require greater integration of adjacent sectors (see, e.g. the circular scenario by Koskinen *et al.*, 2022). Concurrently, more people and systems are growing their dependence on a secure energy system (Hasselqvist *et al.*, 2022). It is no longer only large stakeholders with a stake and part to play, but a greater share of people, organizations and sectors who play a pivotal role going forward. As such, scoping the system in question becomes a difficult challenge that requires case-by-case framing (Jesse *et al.*, 2019), which becomes a value-laden process subject to boundary critique and ethical dilemmas (Helfgott, 2018). Nonetheless, the process of widening the range of interests seeks to go beyond those otherwise considered primary stakeholders, including those indirectly affected, or as far as societal involvement and addressing the bigger picture (Ravetz, 2020). However, seeing transitions, emerging issues and root causes from a range of perspectives can create equally diverse and competing narratives (Höysniemi, 2022). Taking a meta-perspective onto these perspectives contributes to seeing a whole that is greater than the sum of its parts (Ravetz and Ravetz, 2017).

2.1.2 Deeper levels of transformation. Drawing from Inayatullah's (2008) theory of Causal Layered Analysis (CLA), we frame deeper levels of meaning as the underlying structures, values, worldviews and myths from what is observable at the surface. The first level, *litany* is the official description of the problem, measurable and observable facts oftentimes stated in newspaper headlines. Its systemic causes concern the social, economic and political causes of the issue. Followed by culture and worldview that dictate how we think about and perceive the world. Finally, the myths and metaphors that are the underlying stories we tell ourselves (Inayatullah, 2008, 2017). Although myths, metaphors and visions may be propagated equally in popular media, they do not aim to describe the world but rather speak of the world at a deeper level (Alvesson and Sköldberg, 2018). Projections on energy futures assume changes on the functional surface-layer that concerns trends and quantitative changes, whereas long-term changes occur at the deeper levels (Heinonen *et al.*, 2016; World Energy Council, 2024). As we are transitioning from a finite source of energy, to one which is virtually endless, changes in such underlying beliefs and mental models will be necessary (Dasgupta and Sanyal, 2020). Addressing issues at the higher levels provides actionable short-term solutions (Inayatullah, 2008, 2009). Whereas addressing root causes by identifying issues stemming from the deeper levels provides greater leverage as they enable restructuring of how systems and relations function and rewiring of how actors think and act (Inayatullah, 2008). As a research method, CLA provides useful insights for the development of deeper, long-term and inclusive policies and strategies (Inayatullah, 2017).

2.1.3 Further away horizons. Addressing immediate issues through short-term solutions allows for rapid recovery and returning to business as usual (Ravetz, 2020). However, as the context keeps changing, the system and business as usual grow increasingly inept at dealing with disturbances (Sharpe *et al.*, 2016). Thinking further ahead, one might learn from previous failures to bounce forward and meet future disturbances even better (Sircar *et al.*, 2013). Or, like deeper leverage points, CAI in the longer term enables the transformation of how things are done such that recurring issues are resolved indefinitely (Ravetz, 2020). However, far-reaching scopes in time are nothing new to energy system planning. Current projections in future energy scenarios tend to congregate around

2045–2050 (see, e.g. Statnett, 2023; Fingrid, 2023; SVK, 2024). These far scopes in time are partly due to the long lead times of developing energy infrastructure (Bösch and Graf, 2014) and partly due to the long-term roadmaps set out by, e.g. the Paris agreement of net zero by 2050. However, as stated in the introductory chapter, these longer time perspectives connotate greater degrees of uncertainty and possibility, which are inadequately addressed in energy planning (Laimon *et al.*, 2022; Koskinen *et al.*, 2022), which provides a way around this uncertainty by refraining from stipulating time horizons and instead dealing with scenario-solutions that are dependent on different technologies and developments and therefore reside on different temporal horizons. Similarly, Gilmore *et al.* (2023) build on these scenarios by exploring emerging issues as a range of future possibilities stemming from different scenarios rather than providing timely projections. Emerging issues develop over different time frames (Molitor†, 2018). Therefore, a more prudent approach becomes anticipation and monitoring in horizons as far as we can see (Hines *et al.*, 2021; van Rij, 2010; Sharpe *et al.*, 2016), which lays forth the three horizons (3H) framework as a theoretical lens to encourage further and wider considerations of system transformations. The different horizons delineate between different systems in time and their strategic fit to the context. These are described as the current dominant system propagated by dominant social paradigms and ideologies (*H1*); the turbulent yet opportunistic transitioning stage containing challenges and uncertainties (*H2*); and a systems transformation as the third built up by emerging issues or weak signals (*H3*) (Curry and Hodgson, 2008; Curry, 2015; Sardar and Sweeney, 2016). *H1* describes the current system as it loses its prominence as the leading configuration as the contextual environment changes. Innovations at the transitionary phase can either bolster *H1* or provide stabilizing properties during the transition to a more fit for the future system of *H3* (Sharpe *et al.*, 2016).

3. Methodology

This study adheres to a co-productive research design, wherein researchers and participants share equal footing in practice, building relationships among different groups of stakeholders while combining knowledge and viewpoints (Lindhult and Axelsson, 2021). This study reports on a continuous futures inquiry, beginning in early 2023 and spanning one year of data collection and analysis. The purpose thereof was to develop a forum for CAI to discuss signals of change concerning the Swedish energy transition. The forum, in addition to complementary scanning, served to identify issues, wherefrom they were deepened using CLA, exploring them from multiple perspectives and timeframes (Inayatullah, 2008). What distinguishes this forum is that it was run not for any client or specific stakeholder interest but rather around shared interest in exploring the emerging complexity of the transition. Because the future is increasingly electrified, the focus scoped around the power system of Sweden, including the social, technical, political, economic, environmental and cultural domains, whilst also taking considerations of micro-level developments and the macro-level context of the European Union (EU).

3.1 Data collection and participation

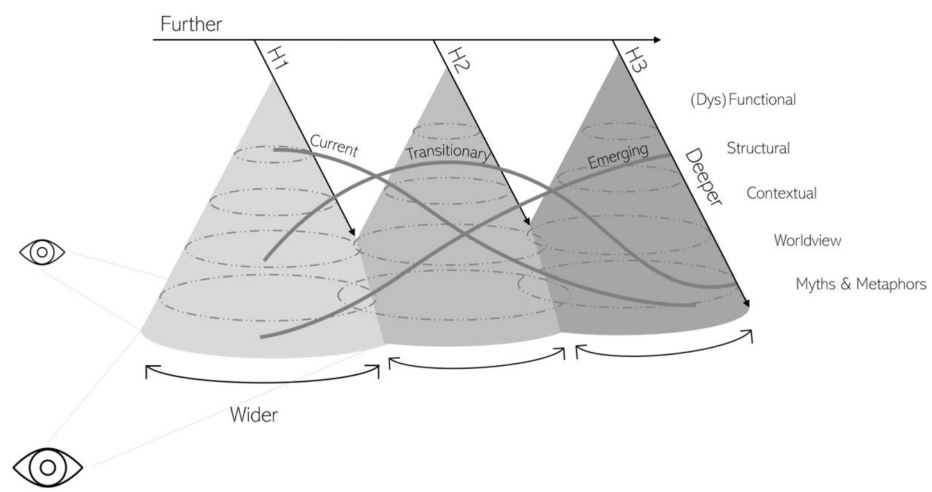
Data were collected through the method of horizon scanning, a systematic process designed to identify issues in their early stages of emergence (van Rij, 2010; Hines *et al.*, 2021). No time horizon was imposed to encourage the identification of weaker signals and emerging issues (van Rij, 2010; Gilmore *et al.*, 2023). Rather, scanning was directed towards sources of more long-term concern, around the idea creation phase, which includes sources such as word-of-mouth, media in niche areas and fringes, social movements and networks, elite awareness found in industry associations, the vast repository of grey literature and other policy documents, whereas surface-level issues may be found in more mainstream media outlets (Hiltunen, 2008; Molitor†, 2018; Hines *et al.*, 2021). This process was carried out in part by the authors of this paper, in conjunction with participants who shared their own knowledge, data and insights towards the shared purpose of anticipating emerging issues and creating a CAI. This process thereby gathered a diverse group of individuals around a shared interest to form a collective and to anticipate emerging issues from different perspectives. Beyond data collection and analysis, this process served as a learning process for participants to understand each other's areas, correct misconceptions and form other exchanges such as networking and sharing tips. This process was organized as monthly workshops where trends, signals and uncertainties could be discussed as they emerged and developed, combining both elements of soft scanning and technical system support (Hines *et al.*, 2021). Recent developments were presented by the lead researchers, including interpretations and questions to which the participants could reflect, interpret and comment directly. After which participants shared their own findings, spurring deep discussions around topical areas. The pool of participants was dynamic, as the forum was designed to be an open environment. Participants represented private-, public- and academic organizations, representing a range of organizations including municipalities, regions, distribution system operators, regional energy offices, the energy agency, a defence agency, private energy companies and industry actors. For a total of 19 distinct participants of varying strategic positions.

3.2 Analysing deeper, wider and further issues

Continuous interpretation of data yielded up-to-date and inclusive perspectives on insights; however, further work is required to see the patterns and anomalies among the data set as they emerge when viewed from the bigger picture (Wildman, 2001). Using a combination of CLA and the 3H framework, we categorized, framed and assessed potential issues from different perspectives. CLA allows for a more nuanced understanding of deeper factors affecting issues, whereas 3H enables the categorization of issues over time, creating an internally consistent scenario for each horizon. Using the method of CLA as developed by Heirani *et al.* (2023) for the context of energy systems, we further delineate the structural level through the internal infrastructure and the external context of the system. The first layer, *functional* concerns the official description often found as mainstream awareness (Hiltunen, 2008; Molitor†, 2018; Hines *et al.*, 2021). The underlying *structural* layer concerns the issues and trends within the energy system, oftentimes mentioned in the background of reports, whereas the *contextual* layer contains external developments such as international developments and changes in other sectors (Heirani *et al.*, 2023). *Worldview* encompasses culture, values and discourses such as religious beliefs and tradition. Finally, the *metaphors* layer, which houses myths and future visions and other underlying assumptions such as power being "too cheap to meter" (Inayatullah, 2017; Heirani *et al.*, 2023). In supporting this analysis, we use the following integrative framework; see Figure 1.

The first step to this method is to assess the current system through a CLA (see, e.g. Inayatullah, 2017). Based on the contemporary issues high on the political agenda identified in the scanning, the underlying levels were drafted using discourse and narrative analysis to deepen the understanding of the current state. Understanding the current issues and planned changes allows for a conceptualization of the transitionary issues and the challenges therein to reach the third horizon (Sharpe *et al.*, 2016). It is therefore necessary to do this in an iterative fashion, exploring *H3* before finishing this step and revisiting horizons to infuse them with new learnings and insights. In addition, it is required to understand what uncertainties exist and why those challenges and uncertainties are by deepening the analysis. The third horizon is based on weak signals of change and visions of the future. Some weak signals may be viewed as emerging issues for some and a growing opportunity for others. As such, they are the same thing viewed from different perspectives (Dator, 2018). Different images of the future can be mapped to coexist as part of the same future system, whereas others may have to be regrouped into an alternative third horizon existing on another timeline, representing a different future. As such, this view

Figure 1 Integrated analytical framework, combining CLA as depth and 3H as time, and a third dimension of breadth as perspectives



Source: Authors' own work based on Heirani *et al*. (2023), Sharpe *et al*. (2016), Ravetz (2020)

only provides a linear representation of the future, whereas the plurality thereof must be acknowledged (Sardar and Sweeney, 2016). In this study, the focus lies on the top-down imposed view on the so-called official future dubbed the high electrification scenario, which means that some issues have been omitted to retain the consistency of the scenarios as the issues appeared to belong to an alternative future.

4. Results

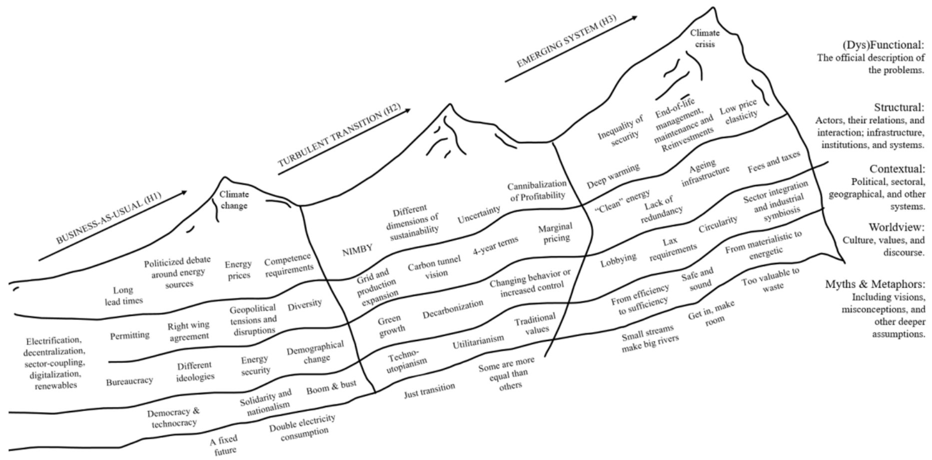
In response to the research question "What are the long-term, deeper and wider issues emerging in the continued energy transition?" this section presents an empirical study rendering a CLA of the current state and contemporary issues; transitionary issues, uncertainties and challenges to the transition; and finally, a more solution-oriented outlook on the emerging issues of the so-called official future. Figure 2 provides an overview of findings showing these scenarios over time. These issues are a synthesis of a wide range of perspectives, which have been probed to uncover the deeper levels. The dimension of further is not only represented by further out horizons in time but also greater transformation.

4.1 Causal layered analysis of current issues

This section outlines immediate issues and their perceived causes in the current state of the system (*H1*) as described by participants, media reporting, leading authorities and government bodies. There are a plethora of contemporary issues, the most prolific of which include climate change, long lead times, competence requirements, high energy prices and the politicization of energy sources:

- Climate change is not only a consequence of energy consumption but also a threat in and of itself since it affects production capabilities and consumption patterns (Yalew *et al.*, 2020). This creates a dual challenge of mitigating further climate change and adapting to the consequences thereof. The structural causes for which are fossil fuel consumption and an ingrained reliance on centralized systems and supply-side demand, which is shifting towards a more weather-dependent and demand-side

Figure 2 CLA of different systems in time based on the combined analysis



Source: Authors own work

managed system. The underlying worldview has been that the resources of nature should be used and catered to our needs.

- With the projected future demand comes a surge of infrastructure development. From many perspectives, current lead times for permitting are viewed as an issue obstructing the transition towards an electrified system. This has given rise to new ambitions of shortening them, which includes a knowledge platform and forum for competence transfer between stakeholders (Swedish Energy Markets Inspectorate, 2023). Underlying systemic causes for these lead times are the number of permits required for, e.g. crossing existing infrastructure, exemptions from environmental protection acts, water and land use change and the number of expert consultations associated with such surveys (ibid.). These permits aim to mitigate risks and cover all interests of concern, representing both technocratic and democratic worldviews.
- Adding to the challenge of infrastructure development is the intense need for workforce and competence requirements to drive this transition, requiring a fleet of engineers and senior project leaders (Swedenergy, 2022). Structural causes for this issue include low numbers of female workers in the sector, increasing numbers of workers going to retirement and a weaker interest in the sector from new students. Contextually, we see changing demographics, heightened competition for the workforce and a trend towards more students in higher education, whereas the energy sector calls for more hands-on skills.
- The Russian invasion of Ukraine and subsequent energy crisis have caused price shocks with long-lasting ripple effects (World Energy Council, 2024). Creating a cost-of-living crisis through recession, inflation and spiking interest rates, which affect households, economies and infrastructure investments (Konjunkturinstitutet, 2024). Consequently, these challenges have created public dissent towards the integrated energy market of the EU, which itself is there to support energy security by creating interdependence and distributing resources. The prevailing worldview of EU solidarity is increasingly challenged by rising nationalism.
- Politicization of energy sources has been labelled as a prominent issue in politics. Historically debated nuclear power on a path to decommissioning has taken a turn, with

a new roadmap enabling extensions of lifespans and new production (Government Offices of Sweden, 2023; World Energy Council, 2024). However, security of long-term investments requires broad political agreements to create certainty, and with a lack thereof, plans fail to materialize and are subject to the whims of political cycles.

Supporting these layers lie several myths, metaphors and visions. Coining an underlying myth of *a fixed future*, we highlight the discrepancy between the official future and the reality thereof. This myth bears a double connotation. The first is the fact that the future appears as a singular and determined thing over which they have ultimate control; the other is that all problems are seemingly solved and issues are resolved with little consideration for new issues that may arise. In line with this is the myth and vision of *double electricity consumption*, which began as a lobbying narrative and soon made its way into official reports. This myth creates a prescriptive future as a self-fulfilling prophecy.

4.2 Transitionary issues

Surmounting pressure from contextual factors such as the accelerating electrification of industry and transportation and increased demand from emerging industries is driving energy systems into a state of transition (*H2*) (Swedish Energy Agency, 2023). This transition includes a suit of developments occurring across the wider energy sector, such as electrification; sector-coupling; changing energy sources and carriers; changing markets and business models; changing characteristics of system stability due to an increased share of power electronic-interfaced devices rather than synchronous generators; and weather dependence, which is changing the system from one governed by supply-side to demand-side response. However, with change comes conflict, as many of these transitions are characterized by a high degree of uncertainty, conflicts of interests and balancing feedback loops that impede the transition to *H3*. This horizon represents the realm of challenges and uncertainties focusing on the contextual environment. In addition, transitions bring with them transitionary issues such as conflicts of interest working towards different futures, temporary interventions causing issues, or simply volatility and change causing disturbances and inconveniences;

- Uncertainties are oftentimes framed as issues because they impose challenges to long-term planning and reduce the security of investments. The Nordic Grid Development Perspective (SVK *et al.*, 2023) lays out key uncertainties as the future of hydrogen; the role of flexibility; industrial and political development; technological uncertainties; and despite much of the political discourse revolving around the high electrification scenario, the pace and extent of change remain an uncertainty.

The future of bioenergy becomes an uncertainty due to the number of interests calling for its use, such as bioenergy coupled with carbon capture and storage (CCS), use cases in aviation and maritime, district heating and interests stemming from other sectors. As such, the biomass currently allocated towards district heating networks may not be secure from political and economic measures. Concurrently, pushes from the EU towards heat pumps to increase heating efficiency compete with the expansion of district heating networks and come with rebound effects by also enabling cooling (Halvorsen and Larsen, 2021):

- Further turbulence in the social dimension comes from the sudden development of infrastructure (SVK, 2024). Causing tension, such as conflicts of interest and unfairly distributed gains and impacts from developments, until a new steady state of maintenance and small-scale development is reached. Social acceptance is a major enabler of what is considered a just energy transition and what is deemed acceptable changes over time (Swedish Energy Agency, 2023). Going from supply-to-demand-side management is one such development poised to cause tensions either through relinquishing control over consumption or by changing behaviours. As such, it stands to show whether this transition will be seen as a turbulent or just transition, and it may come down to how the deeper levels are transformed because these are heavily tied with traditions, habits and values.

- Beginning to show stronger signals of change are the negative spot prices of electricity, whereby renewables are cannibalizing their own profitability. This is a trend only expected to increase, which is causing concerns for the continued investments in renewables (ACER, 2023). A solution to this could be increased storage, which leverages the volatility of electricity prices to buy low and sell high. However, these face the same problem, as their profitability stems from the volatility, which they themselves reduce. In the longer term, greater market reform is necessary; however, what this should look like is yet another uncertainty and is viewed as a threat to some business models and an opportunity to others.
- Discussions reveal tensions between the different dimensions of environmental sustainability in the prolonging and potential development of nuclear and hydropower and the proliferation of solar and wind power. Although these technologies may suppress carbon emissions, they bring forth their own issues of waste management, biodiversity loss and externalities such as material extraction and end-of-life management, which are likely to give rise to new issues. While focus may lay on decarbonization, only marginal concerns for aspects such as biodiversity, acidification and land use are prevalent, which may grow stronger in the future.

4.3 Emerging issues

Weak signals of change belong to a wide range of futures. This section is a critical investigation of the official future to uncover what issues may emerge in this future system. Issues are contingent on certain developments or lack thereof; as such, some of these may mature, whereas others may die in their infancy reflecting the uncertainty of *H2* (Dator, 2018). Regardless of uncertainties of the transition, lies an official future that is set to be electrified, progressively more efficient and highly integrated between systems. Building a system in which electricity becomes a single point of potential failure. This energy system goes from having trading zones between other systems to complex areas of interchange of resources and forces. This system is built to solve current problems but is not without its own issues:

- Currently extending lifetimes of, e.g. nuclear power plants is pushing an imminent problem forward (Negáwatt Association, 2017), whereas at the same time, fewer nuclear power plants may entail increased costs and emissions and weakened electricity security (IEA, 2019; World Nuclear Association, 2024). Beyond the horizon of 2045, the pressure of ageing infrastructure will continue to accumulate. Offsetting their power whilst simultaneously meeting an increased demand will require a transition at double the pace, which would introduce many more challenges. Concurrently, grid infrastructure requires extensive reinvestments in parallel to new developments (SVK, 2023).
- Due to increased weather dependence, lower system inertia and an ensuing climate crisis, longer periods of cold, dark and calm winds will pose significantly greater issues. Household resilience remains low due to a systemic lack of emergency inverters and approximately only a third of single-family housing having alternative heating solutions (Lindén and Tsegai, 2023; Paulson, 2024). This creates a general unpreparedness for a prolonged energy crisis.
- A third issue is that of inequality of security between those able to afford it and those reliant on centralized support. Those who can afford an electric vehicle or other battery backup system or even a secondary home with a wood stove have much stronger

resilience against a potential disturbance. A long-standing history of being safe and sound has nurtured a systemic lack of household resilience.

- As society becomes more dependent on constant access to electricity and further fees and taxes are needed to support a growing system, price elasticity is reduced. This future will require more demand-side management (Sousa and Soares, 2023) and this entails changes in underlying values (Önnered and Bravić, 2024). As opposed to supply-side management, demand-side entails tuning demand in response to availability rather than simply generating more. As price elasticity is decreasing due to increased fees and taxes and dependence on constant electricity increases, such management will become more difficult without further interventions. Such interventions can either be technological, where control is taken by, e.g. utility companies who can regulate customers' heating and appliances, or through active user flexibility and participation.
- A deeper issue brewing from the laws of thermodynamics is that of waste heat warming (Buchanan, 2023). Although greenhouse gases make up the vast majority of global warming, a small yet significant share emanates from the release of waste heat as inherent to any energy conversion (Zevenhoven and Beyene, 2011). Clean energy alternatives, such as nuclear power and fossil fuels with CCS, suffer from this effect whereas renewables do not. This heat can be repurposed, however, reducing the need for virgin energy for heating purposes by coupling sources of excess heat with demand for heat in, e.g. food production and space heating. This entails an underlying shift towards viewing waste heat as waste and considering circularity beyond the materialistic focus of today (Önnered, 2023).
- Continuous efficiency improvements are not a long-term sustainable strategy as there are theoretical limits to energy conversion, and they by themselves are not enough to reach climate goals (Paoli and Cullen, 2020). Nor is continued growth of the power sector sustainable due to the reasons outlined above and increasing resource scarcity. This requires the idea of degrowth and a level of energy sufficiency. That rather than scaling the system to make more room, we make room by reducing and reallocating resources. Complementing continued efficiency policies with incentives for total demand reduction. Sufficiency policies act to question mental structures, social norms and economic systems (Zell-Ziegler *et al.*, 2021). However, today's notion of sufficiency is mostly seen as an individual level, which needs to transcend to create macro-level policies (Lindgren *et al.*, 2023).

In the greater context of the EU, a lot of known unknowns are expected to emerge. Similar issues, such as those outlined above and variations thereof, are bound to manifest elsewhere, and more worryingly are the potentially aggregate effects of such developments. Potentially causing cascading systemic threats as new issues can propagate throughout the system (Körner *et al.*, 2022). In addition to the degree of uncertainty posed by global and European developments, which can create a different playing field for national systems to operate within and with, see, e.g. the scenarios by the World Energy Council (2019).

5. Discussion and concluding remarks

The purpose of this study was to explore the combination of deeper levels of change with wider interests and further out horizons to contribute to the resilience of emerging energy systems through deeper insights and reflections. For this purpose, we use the CAI of a widening stakeholder network to provide domain-specific insights on energy systems, as presented in the prior chapter (Piirainen and Gonzalez, 2015). By using the CLA framework by Heirani *et al.* (2023) and the 3H framework, this study has presented current, transitionary and emerging issues, which shed light on the brewing complexities, uncertainties and challenges of the future.

The functional issues of today have emerged from the structures, contextual environment and underlying worldviews and myths over time; hence, they are not necessarily propagated by the currently dominant worldviews but rather a result of historical values and systems. As such, the currently dominating deeper layers give rise to novel issues in the emerging system. This reveals how there may be a fundamental gap between planned developments affecting the functional and structural levels and the deeper contextual worldviews and visions of the future. It is therefore necessary to apply a deeper assessment in long-term planning to account for these emerging issues and underlying changes (Heinonen *et al.*, 2016). Our results suggest that such an approach, combining the dimensions of wider, deeper and further away horizons, contributes to understanding the plurality of perspectives and thus reveals underlying mental models and values those perspectives are based on (see also, Heinonen *et al.*, 2016). Understanding the complexities and uncertainties of transitions highlights the plurality of the future and the breadth of issues that may arise, especially considering the multi-level uncertainties and considerations. Based on our collective scanning and analysis, we provide a comprehensive outlook on such emerging issues. Addressing these issues, we suggest, can be done through changes in the underlying levels, such as switching focus from efficiency to sufficiency, viewing waste heat as waste and shifting from supply-side to demand-side management.

The theory of foresight tells us that the future is plural and that any notion of an official future should be contested (Inayatullah, 2013). Faced with both uncertainty and urgency, the dominant narrative around a highly electrified future may give rise to unanticipated consequences or unfulfilled expectations. Therefore, this is a critical time to apply foresight for the continued energy transition, updating scenarios as we go along by incorporating deeper and wider insights for the long-term sustainable development of the system and creating agency in transforming it. By anticipating emerging issues and deepening the analysis to consider underlying myths and metaphors, we steward change towards a more desired state (Inayatullah, 2008; Fazey and Leicester, 2022). Going from a stage of managing existing infrastructure to developing new provides an exemplary leverage point for such change. Due to growing complexity and uncertainty, scanning and analysing data in siloed environments is no longer enough. For which CAI steps in to support by aggregating the process of scanning and analysis. Yielding greater coverage of perspectives, finding common ground and grievances and uncovering deeper conflicts as issues are identified in the intersection of perspectives rather than from distinct ones. Doing so continuously provides more timely knowledge for improved decision making (Diggle, 2013). Furthermore, acknowledging the plurality of the future, such issues must be anticipated across scenarios beyond the tunnel vision of the official future to ensure resilience against the breadth of emerging issues.

Viewing weak signals from a range of perspectives renders virtually any observation into a potential threat; they can, however, be reframed into opportunities depending on the perspectives (see also, Dator, 2018; Hines *et al.*, 2021). For example, one participant considered the European push towards heat pumps as a threat towards the future of district heating in Sweden, wherefrom another participant posited that perhaps they can have synergetic effects by shifting loads and creating redundancy, thereby contributing to resilience. On the contrary, deepening discussion towards the nuclear question reveals aligned but differentiating perspectives in terms of what is deemed sustainable, that which is better than the current state or that which is sustainable in the longer term. This might delineate differences between resilient and sustainable energy systems, whereby the former are more concerned with decarbonization and security in the face of imminent crises, while the latter is more oriented towards the breadth of sustainability dimensions. In addition, in acting within a professional capacity, two challenges arise concerned with information transference: Weak signals fail to reflect the organization's official stance and are therefore reluctantly shared, and elements of secrecy hinder the sharing of strategic or sensitive information. As the spheres of participation are expanded, these obstacles are exacerbated. To then effectively foster a CAI requires, in our view, active scanning and assessment directed towards sources of weaker signals, which is benefitted by a throughput of perspectives to disrupt groupthink and requires an open and safe environment to elicit insights. Furthermore, consensus does not have to be formed around what is and is not a problem, but all concerns are valid even if they might not require immediate attention.

6.1 Practical implications

This paper contributes to the current energy debate and development of Sweden by delving deeper into the underlying shifts occurring in a widening power system and the emerging issues thereof. Anticipation and continuous monitoring of these potential issues supports the proactive response thereto and can thereby contribute to a more resilient energy system (Hines *et al.*, 2021; Sharifi and Yamagata, 2016). Furthermore, understanding the tensions between different perspectives and how different metaphors can be changed provides a strategic leverage point to support continued energy transitions. However, the energy system need not develop to support economic goals but rather co-evolve with other sectors to achieve a more sustainable state. Determining what this sustainable state is is a question for the collective intelligence of the expanding system's actors. Organizing this collective intelligence, we find, is best achieved by broadening participation without fully opening it to create a secure environment; creating buy-in from participants to secure participation; and pushing discussions and thinking towards questions of more long-term and big picture concern to capture agency and create proactiveness (Ravetz and Miles, 2016).

6.1 Limitations and future(s) research

Despite the broad inclusion of perspectives in this study, this study is limited by contextual influences and biases. Therefore, we encourage similar investigations to challenge, complement or build upon our approach and insights. Similarly, though some of these insights are relevant to energy systems of other countries, understanding the underlying discourse and worldviews requires case-by-case analysis. Therefore, future research should explore the potentially changing relationships between consumers and energy in different contexts. Future research should uncover emerging issues of alternative scenarios to ensure resilience against the breadth of possibilities of the future and to create new alternative futures to overcome this widening threat landscape.

References

ACER (2023), "Demand response and other distributed energy resources: what barriers are holding them back?", available at: www.acer.europa.eu/sites/default/files/documents/Publications/ACER_MMR_2023_Barriers_to_demand_response.pdf (accessed 14 May 2024).

Alvesson, M. and Sköldberg, K. (2018), *Reflexive Methodology: New Vistas for Qualitative Research*, 3rd ed., Sage, Los Angeles.

Ansari, D. and Holz, F. (2019), "Anticipating global energy, climate and policy in 2055: constructing qualitative and quantitative narratives", *Energy Research & Social Science*, Vol. 58, p. 101250, doi: 10.1016/j.erss.2019.101250.

Basu, S. and Bale, C.S.E. (2023), "A framework for exploring futures of complex urban energy systems", *Frontiers in Climate*, Vol. 5, p. 1145277, doi: 10.3389/fclim.2023.1145277.

Bathke, H., Munch, C., von der Gracht, H.A. and Hartmann, E. (2022), "Building resilience through foresight: the case of maritime container shipping firms", *IEEE Transactions on Engineering Management*, Vol. 71, pp. 1-23, doi: 10.1109/TEM.2021.3137009.

Bösch, F. and Graf, R. (2014), "Reacting to anticipations: energy crises and energy policy in the 1970s an introduction", *Historical Social Research*, Vol. 39 No. 4, pp. 7-21, doi: 10.12759/hsr.39.2014.4.7-21.

Bravić, I., Önnered, S. and Neubauer, M. (2023), "Systems innovation energy hub: the permeating system of systems", available at: https://media2-production.mightynetworks.com/asset/2a01d696-29f5-4cda-bdce-dd8fb218ff0f/Energy_Hub_Position_Paper.pdf (accessed 21 August 2023).

Buchanan, M. (2023), "Deep warming", available at: https://aeon.co/essays/theres-a-deeper-problem-hiding-beneath-global-warming (accessed 22 August 2024).

Curry, A. (2015), "Searching for systems: understanding three horizons", *APF Compass*, No. January, pp. 11-13.

Curry, A. and Hodgson, A. (2008), "Seeing in multiple horizons: connecting futures to strategy", *Journal of Futures Studies*, Vol. 13 No. 1, pp. 1-20.

Dasgupta, S. and Sanyal, D. (2020), "The march towards infinity – the impending era of deep thinking", *foresight*, Vol. 22 No. 2, pp. 129-143, doi: 10.1108/FS-04-2019-0029.

Dator, J. (2018), "Emerging issues analysis: because of Graham Molitor", *World Futures Review*, Vol. 10 No. 1, pp. 5-10, doi: 10.1177/1946756718754895.

Diggle, T. (2013), "Water: how collective intelligence initiatives can address this challenge", *Foresight*, Vol. 15 No. 5, pp. 342-353, doi: 10.1108/FS-05-2012-0032.

Doh, J., Budhwar, P. and Wood, G. (2021), "Long-term energy transitions and international business: concepts, theory, methods, and a research agenda", *Journal of International Business Studies*, Vol. 52 No. 5, pp. 951-970, doi: 10.1057/s41267-021-00405-6.

European Commission (2022), "Collective intelligence", available at: https://knowledge4policy.ec.europa.eu/foresight/collective-intelligence_en (accessed 7 September 2023).

Falandays, J.B., *et al.* (2023), "All intelligence is collective intelligence", *Journal of Multiscale Neuroscience*, Vol. 2 No. 1, pp. 169-191, doi: 10.56280/1564736810.

Fazey, I. and Leicester, G. (2022), "Archetypes of system transition and transformation: six lessons for stewarding change", *Energy Research and Social Science*, Vol. 91 (June), p. 102646, doi: 10.1016/j.erss.2022.102646.

Fingrid (2023), "Prospects for future electricity production and consumption", available at: www.fingrid.fi/globalassets/dokumentit/fi/kantaverkko/kantaverkon-kehittaminen/prospects-for-future-electricity-production-and-consumption-q1-2024-fingrid.pdf (accessed 27 February 2024).

Gattringer, R., Wiener, M. and Strehl, F. (2017), "The challenge of partner selection in collaborative foresight projects", *Technological Forecasting and Social Change*, Vol. 120, pp. 298-310, doi: 10.1016/j.techfore.2017.01.018.

Gilmore, N., *et al.* (2023), "Identifying weak signals to prepare for uncertainty in the energy sector", *Heliyon*, Vol. 9 No. 11, p. e21295, doi: 10.1016/j.heliyon.2023.e21295.

Glenn, C.J. (2016), "Collective intelligence systems for science and technological convergences to benefit society", *Handbook of Science and Technology Convergence*, Springer Cham, doi: 10.1007/978-3-319-07052-0.

Government Offices of Sweden (2023), "Färdplan för ny kärnkraft i sverige", available at: www.regeringen.se/globalassets/regeringen/dokument/klimat–och-naringslivsdepartementet/ppt/231116-presentationsbilder-fardplan-for-ny-karnkraft-i-sverige.pdf (accessed 2 May 2024).

Halvorsen, B. and Larsen, B.M. (2021), "Identifying drivers for the direct rebound when energy efficiency is unknown. The importance of substitution and scale effects", *Energy*, Vol. 222, p. 119879, doi: 10.1016/j.energy.2021.119879

Hasselqvist, H., Renström, S., Håkansson, M. and Strömberg, H. (2022), "Exploring renewable energy futures through household energy resilience", *Conference on Human Factors in Computing Systems – Proceedings*, doi: 10.1145/3491102.3517597

Heinonen, S., Minkkinen, M., Karjalainen, J. and Inayatullah, S. (2016), "Testing transformative energy scenarios through causal layered analysis gaming", *Technological Forecasting and Social Change*, Vol. 124, pp. 101-113, doi: 10.1016/j.techfore.2016.10.011

Heirani, H., Bagheri Moghaddam, N. and Fazli, M.H. (2023), “Development of a novel framework for the analysis of technological innovation systems by causal layered analysis (CLA) in energy systems”, *Technology Analysis & Strategic Management*, pp. 1-14, doi: 10.1080/09537325.2023.2214639

Helfgott, A. (2018), “Operationalising systemic resilience”, *European Journal of Operational Research*, Vol. 268 No. 3, pp. 852-864, doi: 10.1016/j.ejor.2017.11.056.

Hiltunen, E. (2008), “Good sources of weak signals: a global study of where futurists look for weak signals”, *Journal of Futures Studies*, Vol. 12 No. 4, pp. 21-44.

Hines, A., *et al.* (2021), “Monitoring emerging issues: a proposed approach and initial test”, *World Futures Review*, Vol. 13 Nos 3/4, pp. 195-213.

Höysniemi, S. (2022), “Reimagining energy futures: global energy transition and dependence on Russian energy as issues in the sociotechnical imaginaries of energy security in Finland”, *Energy Research & Social Science*, Vol. 93 No. October, doi: 10.1016/j.erss.2022.102840.

IEA (2019), “Nuclear power in a clean energy system”, available at: www.iea.org/reports/nuclear-power-in-a-clean-energy-system (accessed 29 August 2024).

IEA (2023), “World Energy Outlook 2023”, available at: www.iea.org/reports/world-energy-outlook-2023 (accessed 26 March 2024).

Inayatullah, S. (2008), “Six pillars: futures thinking for transforming”, *Foresight*, Vol. 10 No. 1, pp. 4-21, doi: 10.1108/14636680810855991.

Inayatullah, S. (2009), “Causal layered analysis: an integrative and transformative theory and method”, *Futures Research Methodology*.

Inayatullah, S. (2013), “Futures studies. Theories and methods”, *There’s a Future. Visions for a Better World*, pp. 36-66.

Inayatullah, S. (2017), “Causal layered analysis: a four-level approach to alternative futures”, *The Prospective and Strategic Foresight Toolbox*, pp. 1-21.

Jasiūnas, J., Lund, P.D. and Mikkola, J. (2021), ” “Energy system resilience – a review”, *Renewable and Sustainable Energy Reviews*, Vol. 150, doi: 10.1016/j.rser.2021.111476.

Jesse, B.J., Heinrichs, H.U. and Kuckshinrichs, W. (2019), “Adapting the theory of resilience to energy systems: a review and outlook”, *Energy, Sustainability and Society*, Vol. 9 No. 1.

Johansson, B. (2013), “Security aspects of future renewable energy systems-A short overview”, *Energy*, Vol. 61, pp. 598-605.

Konjunkturinstitutet (2024), “Konjukturläget Mars 2024”, available at: www.konj.se/download/18.265f19318e5606b9db67270/1711534803096/Konjunkturlaget-Mars-2024.pdf (accessed 2 May 2024).

Körner, M.F., Sedlmeir, J., Weibelzahl, M., Fridgen, G., Heine, M. and Neumann, C. (2022), “Systemic risks in electricity systems: a perspective on the potential of digital technologies”, *Energy Policy*, Vol. 164 No. June 2021, doi: 10.1016/j.enpol.2022.112901.

Koskinen, I., Gilmore, N. and Gui, E.M. (2022), “Designing energy futures: a participatory foresight study in Australia”, *Foresight*, Vol. 25 No. 4, doi: 10.1108/fs-09-2021-0186.

Laimon, M., Yusaf, T., Mai, T., Goh, S. and Alrefae, W. (2022), “A systems thinking approach to address sustainability challenges to the energy sector”, *International Journal of Thermofluids*, Vol. 15, p. 100161, doi: 10.1016/j.ijft.2022.100161.

Landry, P. (2020), “The EU strategy for gas security: threats, vulnerabilities and processes”, *Energy Policy*, Vol. 144, p. 111507, doi: 10.1016/j.enpol.2020.111507.

Lindén, M. and Tsegai, B. (2023), “Solar energy resilience: emergency power from solar panels during blackouts”, available at: www.sweco.se/wp-content/uploads/sites/3/2023/06/Report_Solar-energy-resilience_Urban-Insight-by-Sweco.pdf (accessed 16 August 2024).

Lindgren, O., *et al.* (2023), “Exploring sufficiency in energy policy: insights from Sweden”, *Sustainability: Science, Practice, and Policy*, Vol. 19 No. 1, doi: 10.1080/15487733.2023.2212501.

Lindhult, E. and Axelsson, K. (2021), “The logic and integration of coproductive research approaches”, *International Journal of Managing Projects in Business*, Vol. 14 No. 1, pp. 13-35, doi: 10.1108/IJMPB-07-2020-0215.

Molitor†, G.T.T. (2018), “The Molitor model of change”, *World Futures Review*, Vol. 10 No. 1, pp. 13-21, doi: 10.1177/1946756717747636.

Negáwatt Association (2017), “Nega Watt scenario 2017-2050”, available at: https://negawatt.org/IMG/pdf/181128_negawatt-scenario_eng_12p.pdf

Önnered, S. (2023), “Current and future systems of circularity in the energy system: closing the energy loop”, *Proceedings of XXXIV ISPIM Innovation Conference*, available at: https://urn.kb.se/resolve?urn=urn:nbn:se:mdh:diva-63292

Önnered, S. and Bravić, I. (2024), “Systemic innovation in the European energy sector: a collective outlook”, *Journal of Innovation Management*, Vol. 12 No. 2, pp. 50-73, doi: 10.24840/2183-0606_012.002_0003.

Paoli, L. and Cullen, J. (2020), “Technical limits for energy conversion efficiency”, *Energy*, Vol. 192, doi: 10.1016/j.energy.2019.116228.

Paulson, P. (2024), “Energy statistics for one- and two dwelling buildings 2023”, available at: www.energimyndigheten.se/49d2bb/globalassets/statistik/officiell-statistik/statistikprodukter/energistatistik-i-smahus/tabeller/smh_2023_tabellverk_slut.xlsx (accessed 16 August 2024).

Piirainen, K.A. and Gonzalez, R.A. (2015), “Theory of and within foresight – ‘what does a theory of foresight even mean?’”, *Technological Forecasting and Social Change*, Vol. 96, pp. 191-201, doi: 10.1016/j.techfore.2015.03.003.

Poli, R. (2010), “The many aspects of anticipation”, *Foresight*, Vol. 12 No. 3, pp. 7-17, doi: 10.1108/14636681011049839.

Rashid, M.T., Wei, N. and Wang, D. (2023), “A survey on social-physical sensing: an emerging sensing paradigm that explores the collective intelligence of humans and machines, collective intelligence”, Vol. 2, doi: 10.1177/26339137231170825.

Ravetz, J. (2020), *Deeper City: Collective Intelligence and the Pathways from Smart to Wise*, Routledge, New York, NY.

Ravetz, J. and Miles, I.D. (2016), “Foresight in cities: on the possibility of a ‘strategic urban intelligence”, *foresight*, Vol. 18 No. 5, pp. 469-490, doi: 10.1108/FS-06-2015-0037.

Ravetz, J. and Ravetz, A. (2017), “Seeing the wood for the trees: social science 3.0 and the role of visual thinking”, *Innovation: The European Journal of Social Science Research*, Vol. 30 No. 1, pp. 104-120, doi: 10.1080/13511610.2016.1224155.

Ravetz, J., Neuvonen, A. and Mäntysalo, R. (2021), “The new normative: synergistic scenario planning for carbon-neutral cities and regions”, *Regional Studies*, Vol. 55 No. 1, pp. 150-163, doi: 10.1080/00343404.2020.1813881.

Sardar, Z. and Sweeney, J.A. (2016), “The three tomorrows of postnormal times”, *Futures*, Vol. 75, pp. 1-13, doi: 10.1016/j.futures.2015.10.004.

Sharifi, A. and Yamagata, Y. (2016), “Principles and criteria for assessing urban energy resilience: a literature review”, *Renewable and Sustainable Energy Reviews*, Vol. 60, pp. 1654-1677, doi: 10.1016/j.rser.2016.03.028.

Sharpe, B., Hodgson, A., Leicester, G., Lyon, A. and Fazey, I. (2016), “Three horizons: a pathways practice for transformation”, *Ecology and Society*, Vol. 21 No. 2, doi: 10.5751/ES-08388-210247.

Sircar, I., Sage, D., Goodier, C., Fussey, P. and Dainty, A. (2013), “Constructing resilient futures: integrating UK multi-stakeholder transport and energy resilience for 2050”, *Futures*, Vol. 49, pp. 49-63, doi: 10.1016/j.futures.2013.04.003.

Sousa, J. and Soares, I. (2023), “Benefits and barriers concerning demand response stakeholder value chain: a systematic literature review”, *Energy*, Vol. 280, p. 128065, doi: 10.1016/j.energy.2023.128065.

Statnett (2023), “System development plan 2023”, available at: www.statnett.no/en/for-stakeholders-in-the-power-industry/our-analyses-and-assessments/system-development-plan/ (accessed 27 February 2024).

SVK (2024), “Långsiktig marknadsanalys: scenarier för kraftsystemets utveckling fram till 2050”, available at: www.svk.se/siteassets/om-oss/rapporter/2024/lma_2024.pdf (accessed 27 February 2024).

Swedenergy (2022), “Undersökning om kompetensbehov bland energiföretagens medlemmar och branschens attraktivitet på arbetsmarknaden”, available at: www.energiforetagen.se/4964ca/globalassets/dokument/kompetensforsorjning/rapport-for-hemsidan-kompetensenkat_.pdf (accessed 2 May 2024).

Swedish Energy Agency (2023), “Utvecklingsvägar för elproduktion möjligheter och utmaningar för att möta ett växande elbehov”, available at: https://energimyndigheten.a-w2m.se/FolderContents.mvc/Download?ResourceId=214523 (accessed 2 May 2024).

Swedish Energy Markets Inspectorate (2023), “Kortare tider för elnätsutbyggnad: utveckla arbetssätt och paralella processer”, available at: https://ei.se/download/18.43e19b9d18779705cf7b0b2/1682595042339/Kortare-ledtider-f%C3%B6r-eln%C3%A4tsutbyggnad-Ei-R2023-09.pdf (accessed 2 May 2024).

van Rij, V. (2010), “Joint horizon scanning: identifying common strategic choices and questions for knowledge”, *Science and Public Policy*, Vol. 37 No. 1, pp. 7-18, doi: 10.3152/030234210X484801.

Wiener, M., Gattringer, R. and Strehl, F. (2020), “Collaborative open foresight – A new approach for inspiring discontinuous and sustainability-oriented innovations”, *Technological Forecasting and Social Change*, Vol. 155, p. 119370, doi: 10.1016/j.techfore.2018.07.008.

Wildman, P. (2001), “Anticipating emerging issues: reflections from a futurist”, *Journal of Futures Studies.*

Wood, S.L.R., Luers, A., Garard, J., Gambhir, A., Chaudhari, K., Ivanova, M. and Cronin, C. (2021), “Collective foresight and intelligence for sustainability”, *Global Sustainability*, Vol. 4, doi: 10.1017/sus.2021.3.

World Energy Council (2019), “World energy scenarios: European regional perspective”, available at: www.worldenergy.org/publications/entry/world-energy-scenarios-2019-european-regional-perspectives (accessed 10 September 2024).

World Energy Council (2024), “World energy trilemma 2024: evolving with resilience and justice”, available at: www.worldenergy.org/transitiontoolkit/world-energy-trilemma-framework (accessed 20 February 2024).

World Nuclear Association (2024), “Nuclear power and energy security”, available at: https://world-nuclear.org/information-library/economic-aspects/nuclear-power-and-energy-security#measuring-energy-security (accessed 29 August 2024).

Yalew, S.G., *et al.* (2020), “Impacts of climate change on energy systems in global and regional scenarios”, *Nature Energy*, Vol. 5 No. 10, pp. 794-802, doi: 10.1038/s41560-020-0664-z.

Zell-Ziegler, C., *et al.* (2021), “Enough? The role of sufficiency in European energy and climate plans”, *Energy Policy*, Vol. 157, p. 112483, doi: 10.1016/j.enpol.2021.112483.

Zevenhoven, R. and Beyene, A. (2011), “The relative contribution of waste heat from power plants to global warming”, *Energy*, Vol. 36 No. 6, pp. 3754-3762, doi: 10.1016/j.energy.2010.10.010.

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