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# ‘Plausible’ energy scenarios?! How users of scenarios assess uncertain futures

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ABSTRACT

Explorative energy scenarios do not present the most *probable* developments but provide a set of *plausible* pathways in order to highlight the uncertainty and complexity of decision-making contexts. Although plausibility is widely assumed as effectiveness criterion for scenario work, little is known about how the plausibility of a set of scenarios is perceived by users. This paper discusses conceptions from philosophy of sciences, cognitive psychology, narrative theory and linguistics to identify key factors affecting the perceived plausibility of scenarios. A conceptual model is proposed that links users’ perceptions to the narrative storytelling and internal structure of the scenario, the perceived credibility of scenario sources and methods and users’ worldviews and cognitive styles. The model outlines why energy scenarios are discarded or seriously considered by a wider audience that was not involved in the scenario construction process. The paper explains how perceived plausibility constitutes a necessary but not sufficient condition for scenario usage and provides practical implications for scenario producers.

## 1. Introduction

Scenario planning has become an indispensable approach for studying and communicating the uncertainty and complexity of future pathways towards sustainable energy provision, conversion, storage and consumption. For this purpose, scenario planners and researchers continuously develop and apply different methods to construct, assess and compare sets of energy scenarios [1–5]. The scenarios come in different forms and scope – as quantitative model results [6], qualitative storylines [7,8] or combinations of both [9,10] – and cover developments such as the viability of renewable energy technologies in various electricity systems [11], the impact of demographic changes on energy consumption and carbon emissions [12], life-style patterns of energy consumptions on global, regional and local scales [13] or larger-scale social and political context conditions for transformation processes [14,15]. Despite this diversity, the scenarios have in common that they are not limited to the most desirable or probable futures but seek to explore “internally consistent and plausible picture[s]” of what *could* happen in the future [16]. Scenario planning guidelines and methodological reviews name plausibility as a key criterion for the development *and* usage of scenarios [17–20]. The focus on plausibility as a basis for selecting scenarios in the construction process is linked to intended objectives of what scenarios should achieve: The presentation of multiple pathways shall help to push scenario users towards the edge of their own imagination of the future. This way, scenarios challenge their mental maps, confront them with surprises that have not been imaginable prior to considering the scenarios and guide them towards improved decision-making [21,22]. In scenario development processes, plausibility is ‘manufactured’ in different ways: It can be established up-front through *method-driven* processes, for instance when different techniques and development procedures prescribe scenarios as plausible only if input assumptions form mutually enforcing systems maps and are internally consistent [23,24]. Particularly in qualitative scenario construction, plausibility can also be the fruitful result of *actor-driven* processes, meaning that involved actors interactively co-produce a common understanding of a set of scenarios [25,26]. More recent scholarly contributions have added to a better understanding of the overall heuristic value of plausibility in scenario building [20] and have proposed approaches to construct highly plausible scenarios [27].

Yet, beyond these operationalisations, the previous research offers no conceptual or empirical findings on how the plausibility of scenarios is perceived and assessed by users who have not been involved in the development process [28,29]. Ramírez and Selin [26] note that “[i]f the scenarios are not used exclusively by those that produced them, and/or need to be shared or disseminated, altogether different dynamics around plausibility and probability erupt.” This paper, therefore, pursues the

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following research question: *How do scenario users perceive the plausibility of scenarios and what factors influence their plausibility assessments*?

Such inquiry is vital given the circumstances in which many energy scenarios are produced. The current energy scenario practice seems is dominated by a clear gap between producers and users, mostly scientists and policy-makers respectively [6,30,31]. As a result, important scenario user groups are not involved in the actual construction process of the scenarios. This means that a heterogeneous group of potential scenario users is confronted with multiple, sometimes even contradicting scenarios in different forms of presentation, e.g. narrative- or model-based scenarios [32]. Scenario researchers have noted how difficult it is to attend to multiple user groups, particularly to those that use already existing scenario studies and those that may be targeted by specific scenario studies but did not ask for them [33,34]. Dieckhoff [6] argues that when producers and users are separated in energy scenario projects, the underlying inferences and modelling choices made during the construction process often lead to a confusion of users with regards to the way uncertain knowledge about the future is generated. This can make it difficult for users to 'locate' energy scenarios on a spectrum between certain and uncertain knowledge and between political beliefs and scientific assessments. In the scenario planning literature, the plausibility of scenarios is broadly associated with different mechanisms, including the assessment of inferences and causal links between scenario factors [35], the narrative structure of scenarios [36] and the cognitive processing of information by users [37]. This paper, therefore, systematically explores three respective disciplinary strands of theory to conceptualise and better understand plausibility perceptions.

Analysing the factors that determine scenario users' plausibility perceptions bears practical implications for the *construction* of scenarios, their *assessment* and *usage* by different actors – in short: for the 'life path of energy scenarios' [38]. A better understanding of users' assessments is central in order to reflect on and adjust scenario construction methods. Scenario producers often lack a sufficient understanding of "(1) whether what they intend to say with their scenarios is in fact what is being heard and (2) whether these scenarios are what the audience wants and needs to know" [39]. Indeed, previous research indicates that plausibility judgments of scenario users and producers may diverge. When scenarios leave the construction context and 'travel' to other discourses or societal spheres, the plausibility of a scenario is assessed detached from its original context [40]. Different 'cultures of plausibility' may clash, for instance due to discrepancies between scientific and non-scientific interpretations [18]. Furthermore, different scenario formats – narratives, models, systems maps – may trigger different assessments. Analyses have shown how models versus narratives affect the interpretation of information by different stakeholders [41,42] to the extent that scenarios may be more easily conveyed by overarching storylines [43].

As illustrated in Fig. 1, scenario producers construct and disseminate scenarios that they prescribe as 'plausible' and, therefore, may ultimately be considered for direct or indirect strategy- or policy-planning. However, in contexts characterised by a clear gap between scenario producers and users, any decision-maker who chooses to consult energy scenarios faces a critical decision as to what scenarios to consider and how to assess them. Decision-makers must ultimately make an assessment *before* they consider scenarios for their actual decision-making problems [38]. Previous research has already addressed challenges and barriers that can impede the usage of energy and climate change scenarios, including for instance a mismatch between dynamics of scenario production and usage [44], a lack of interaction and communication between scenario producers and users [45] or an incompatible logic and scope of short-term policy-making and long-term scenario perspectives [30]. By building on these findings, this paper argues that little attention has been paid to how plausibility perceptions of scenario users relate to the perceived usefulness of scenarios and thus to the actual usage of scenarios. Scenario reviews posit that the plausibility of scenarios functions as a criterion for effective scenario work [17,20], following the assumption that if users perceive the scenarios to be plausible, they are considered for further use. By dismantling users' plausibility perceptions, the paper problematises this hypothesised relationship. While high perceived plausibility leads to high perceived usefulness, it does not automatically result in the uptake of scenarios by decision-makers. Plausibility, therefore, constitutes a necessary but not sufficient criterion for scenario usage. To make this point, the paper builds on existing research regarding criteria and characteristics that determine the usability of scientific knowledge for decision-making [46,47].

The paper is structured as follows: Section 2 briefly discusses the hypothesised role plausibility plays for the construction of different scenario types and explains how plausibility is expected to relate to three levels of scenario usage. Section 3 takes a systematic literature review as a starting point and explores three disciplinary strands of theory to conceptualise users' perceptions of scenario plausibility. In section 4, findings are synthesised into five key propositions on what determines plausibility perceptions of energy scenarios. Section 5 presents a conceptual model and draws key conclusions for energy scenario construction and usage.

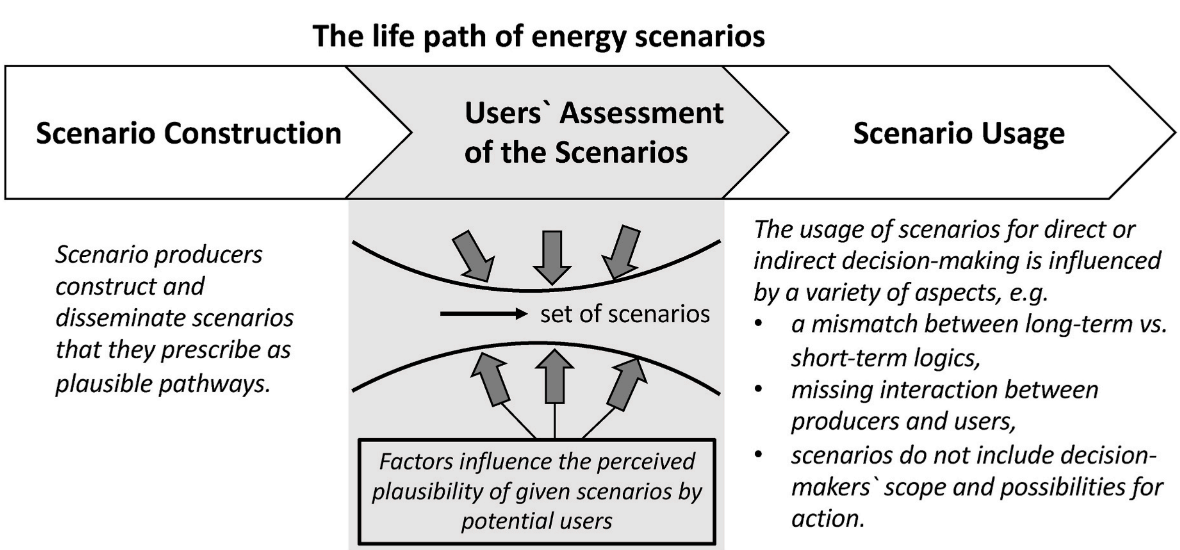


**Fig. 1.** The trajectories of plausibility across the life path of energy scenarios.
Source: Illustration informed by Grunwald [38].

## 2. The assumed role of plausibility across scenario types and uses

### 2.1. Plausibility and scenario construction

Scenarios emphasise the unpredictability and complexity of future events in that they a) depict a set of multiple, alternative pathways of the future, b) illustrate how and why these developments could occur, and c) help actors to assess the performance of policies or strategies across the identified scenarios [48–50]. With the proliferation of scenario planning in multiple fields, including sustainable energy systems and climate change research, the diversity of scenario types and methodological approaches has rapidly grown. This has also led to confusions about what a scenario is and what scenario planning can and ought to achieve [30,51]. Scenario typologies represent archetypes that cannot keep up with the pace in which the research community develops and applies construction methods, but are helpful in discussing those scenario types for which the concept of plausibility is assumed to be relevant.

Scenario exercises can follow predictive, normative or explorative purposes [33,52]. The former often rests on computer-based modelling and sensitivity analyses and is used, for instance, for emission scenarios that extrapolate past and present data to estimate long-term climate developments [30,53]. Normative scenarios, however, strive to identify desired futures. Through processes of visioning or road-mapping, they examine what measures can be taken to achieve these futures [52]. These scenarios are driven by probability and preferability respectively, while explorative scenario approaches explicitly refer to plausibility as a guiding principle to construct scenarios. By focusing on a range of uncertainty factors about the future and their complex relationship with each other, explorative scenarios look at what *could* happen in order to understand and possibly anticipate changes of the future from the present or the status quo [54]. The scenarios focus on the ‘contextual environment’ [22,55] that is beyond the direct realm of influence of scenario users. Several types of energy scenarios follow an explorative purpose. The construction of so-called *context scenarios* in the past years has been populated to appreciate social, environmental and political context conditions in which energy systems are embedded [56]. The systematic but often qualitative processing of the contextual environment can be integrated in the construction of *socio-technical energy scenarios* that seek to better understand energy transition processes that are inherently shaped by the development and use of new technologies as well as their interplay with societal practices, policy measures and institutional changes [57,58]. While these types typically do not comprise specific courses of action of the implicit scenario user, *strategic or policy scenarios* rest on the assumption that ‘policy-free scenarios’ do not account for the agency of relevant actors [59]. Therefore, the scenarios integrate certain policies or strategic decisions and illustrate potential implications of actor choices across several scenarios [60].

For the construction of these types of scenarios, plausibility functions as a ‘methodological-limiting criterion’ [20]. As Trutnevyte et al. [39] point out, the intrinsic uncertainty of long-term energy outcomes leaves scenario producers with an infinite number of possible futures to be presented. However, in order to display a workable and relevant bandwidth, scenarios inevitably need to be a limited representation of all theoretically possible futures. Plausibility is used as a vehicle to select scenarios because it limits the final set to the most ‘justified’ assumptions about the future [35]. Whether a scenario study presents three or three-hundred scenarios, the ultimate number is always a deliberate selection. This has practical consequences: The indicators or procedures used to determine plausibility drive what kind of scenarios are generated and presented in scenario studies. Scenario planners and researchers propose different means to operationalise plausibility. One group introduces a set of clear indicators. Plausibility is not considered a matter of likelihood but is still defined as a measurable, scientific criterion. Wiek et al. [61], for instance, develop a framework for appraising plausibility depending on whether the scenarios are ‘theoretically occurrable’ and whether depicted developments have occurred in different circumstances elsewhere in the present or the past. In a similar manner, a working group of the German Academy of Science and Engineering [62] notes that energy scenarios need to be selected based on whether developments are consistent with the current state of knowledge about the factors influencing the energy system. Particularly for *context scenarios*, plausibility is directly linked to the internal consistency of key assumptions in the scenarios [56,63]. The plausibility of *socio-technical scenarios* is often implicitly or explicitly determined by referring to historical patterns and theoretical insights on dynamics of socio-technical change [57], for instance with references to transition [64,65] or social theory [66]. Taken together, plausibility is about the evidence a scenario holds that relates it to past or present developments, or as Enserink et al. [30] argue, it is “(…) what distinguishes sound analytical scenarios from mere fantasy”. In contrast, a second group of scenario planners maintains that plausibility is not intrinsic to the scenario itself but is linked to the social contexts in which scenarios are constructed, assessed and interpreted by different actors [18,26,43,67]. For them, plausibility rests on “the social process of arguing, convincing and coordinating subjective ideas about the future rather than the objective possibility or probability of specific future states” [68]. Plausibility is established not by methodological assessments criteria but by actor-driven processes, meaning that actors interactively make sense of the future and converge on a set of agreeable scenarios. Taken together, despite these different forms of operationalisations evident in the research literature, plausibility is not explicitly explained or defined in most energy scenario studies. Rather, it is implicitly included in the studies in that certain scenarios are selected and presented (as plausible futures) and others are left out (as implausible) [28].

### 2.2. Plausibility and scenario usage

The scenario planning literature is rich in expectations about how scenarios should be interpreted and used. Three levels of intended scenario usages can be distinguished that are linked to the concept of plausibility. First, in circumstances of deep uncertainty – when it is impossible to determine clear uncertainty factors and their potential interrelations – plausible scenarios can provide “a semantic and hermeneutic structuring” of the future space [69,70]. According to Urueña [20], plausibility helps scenario users to imagine alternative developments and reflect upon their previously held assumptions and perceptions about the future. In this sense, plausibility is expected to induce learning and conceptual change [55]. This is done, for instance, by reducing cognitive heuristics and by clarifying uncertainties and complexities of systems factors [71–74]. On a second level, plausibility shall foster an improved understanding and cooperation between diverse actors. Scenarios are often discussed as ‘boundary objects’ and several studies name scenarios as being able to act as a bridge between different worlds or communities in the energy and environmental policy domain [6,44,45]. It implies that actors with diverging interests and values can agree on a common reference that makes mutual understanding and cooperation possible [75]. Here, plausibility is expected to be the result of social interaction processes and deliberations between actors and promotes the convergence of perceptions about the future. On a third level, plausible scenarios are expected to help users in systematically exploring the consequences of alternative future developments and in testing policies and strategies [33]. Such a use of explorative scenarios is often associated with concepts of ‘wind tunnelling’ [76] and robust decision-making [77]. Both procedures rest on the assumption that scenarios need to be tentatively accepted as given realities so that they can be used as different ‘lenses’ [55] through which the viability of strategies can be assessed. Only by accepting the scenarios as plausible, those strategic planning exercises can lead to the development of transition pathways and increase the commitment of actors towards certain decisions.

In contrast to the diverse expectations towards scenario usage, scholars have pointed to the gap in research that empirically evaluates the effects of scenario studies on the behaviours and decisions of scenario users [34,78,79]. Several studies emphasise challenges and barriers in the 'usage' of scenarios: Grunwald [32] maintains that energy scenario users are confronted with an enormous number of scenarios that seem to have followed almost similar development processes, and yet often produce very different results. This gives rise to arbitrariness from the viewpoint of users. In the same vein, Dieckhoff [6] notes that for users, energy scenarios combine apparently opposing elements: The precision of scenario models and their alleged clarity stand in contradiction to the ambiguity, or even arbitrariness of only a few depicted scenarios and pose the question of who choose them and why. Empirical analyses have shown that scenarios are often judged as to whether they come true – with important repercussions: 'False predictions' contribute to the decreasing credibility of both the scientists and the scenarios, which in turn causes decision-makers to call for 'better' methods [30,80]. When users are confronted with the selective uncertainties as presented in the scenarios, they often look for certainty rather than embracing the uncertainty. According to Bryant and Lempert [34], this is aggravated when scenarios are used "in broad public debates among participants with diverse interests and values." Hulme and Dessai [44] point to the imbalance of supply and demand for energy scenarios; they criticise the disproportional supply of scenarios that is paired with a lack of clarity about the effects scenarios can have on the 'implicit user'. Pulver and VanDeveer [45] take issue with the fact that fundamental matters on scenario use and scenario users remain unanswered, even though renowned scenario studies, e.g. from the IPCC, seem to be either not used or used for purposes they were not designed for. As a result, although plausibility is assumed to be critical for scenario usage, the previous findings do not specifically address how users' plausibility perceptions support or impede the usage of scenarios.

## 3. Plausibility across three disciplinary strands of theory

The previous section has demonstrated that the scenario literature proposes different ways in which plausibility is established during scenario construction. However, there is a need to better understand how scenario users assess the plausibility of scenarios and to analyse whether their assessments differ from how scenario producers operationalise plausibility in their studies. The research literature on scenario planning does not provide theoretical frameworks or distinct directions for investigating plausibility assessments. However, a review of the extant scenario plausibility debate provides some helpful starting points [28]: It shows that plausibility is associated with informal logic and inferences, with storytelling, with the grounding of scenarios in cultural narratives as well as with individuals' cognitive information processing. Scenario research is continuously enriched through other academic disciplines and theory-building [81]. Therefore, to initiate conceptual and empirical research on scenario plausibility, theoretical concepts from the corresponding disciplines are explored (for an overview, see Table 1). The contexts of the consulted disciplinary conceptions are analysed and the applicability for energy scenario planning processes are discussed. Section 4 then highlights the most relevant findings in the form of five propositions.

### 3.1. Plausibility assessments in the philosophy of sciences

Regularly, we are confronted with pieces of information from which we must draw conclusions on how to think or act about a matter. Often, this information lacks details that we need for our conclusion, or else, the information given is inconsistent. Following the philosophical studies of *informal logics*, i.e. the analysis of practical arguments [82], these mundane assessments happen based on plausibility [83,84]. Next to deductive and inductive thinking, plausible reasoning presents a third, distinct mode of logic that is more tentative and defeasible [85]. It is clearly distinct from probabilistic inferences in that plausibility assessments rely on qualitative, comparative judgments of the credibility and reliability of given statements. The purpose of Rescher's [86] well-known *theory of plausible reasoning* is to substitute the often intuitive and ad-hoc human judgment with formal but simple rules. Two key premises underlie these formal rules: First, assessments of the plausibility of a statement are based on the credibility of its source. Rescher labels this an "authority-oriented approach to plausibilistic inference". Second, plausibility assessments are typically made for sets of propositions. For all propositions, the individual sources are to be ranked in relation to one another. It follows that the higher the credibility of the source is determined, the higher the plausibility of the corresponding statement. This approach has also been applied to the assessment of complex policy arguments, which are often entanglements of different forms of data, information, expert opinion, value judgments and mathematical arguments. The methodology of Majone [87] seeks to understand how policy arguments appear plausible or implausible to policy actors. While this approach acknowledges that data credibility and its scientific quality (validity, reliability) plays a significant role for assessing the overall plausibility of an argument, the extent to which the argument is persuasively presented and communicated to the audience is highlighted. Majone argues that if information is placed "at a wrong point in the argument or choosing a style of presentation that is not suitable for the intended audience, it can destroy effectiveness of information used as evidence […]." Central parallels to energy scenario planning are evident. For energy scenario users to arrive at any conclusive judgments and to ultimately make critical strategy choices, assessments first need to be made on the complex mixture of different and often contradicting pieces of information and evidence provided in the scenarios.

### 3.2. Plausibility assessments in linguistics and narrative theory

A scenario's plausibility is often linked to its narrative form: Scenario producers assemble their ideas and diverse knowledge components into plausible and coherent contexts [22,88] so that the temporal ordering of

**Table 1**
Overview of analysed theoretical concepts of plausibility.

| **In scenario planning, plausibility is associated with…** | | |
|---|---|---|
| *Informal logic and inference* [50] | *Narrative storytelling* [51–53] | *Cognitive capabilities* [56] |
| **The corresponding disciplines are consulted:** | | |
| Philosophy of sciences,<br>informal reasoning [57–60],<br>argumentation theory in policy studies [60] | Narrative theory [62–64],<br>including notions from linguistics, structural and cultural narrative theory | Cognitive and educational psychology [65–70] |
| **Key notions on how plausibility assessments are made:** | | |
| • A statement's plausibility can be explicitly assessed by evaluating the credibility and reliability of the source of the statement.<br>• The plausibility of an argument depends on the persuasiveness of the data and the evidence. | • The plausibility of a narrative is dependent on whether the narrative adheres to generalized internal structures, or 'story grammars'.<br>• A narrative's plausibility is dependent on the story's resonance with cultural identities and well-established rules of social interaction. | • Processes and resources involved in individuals' plausibility judgments include: the relation between plausibility and congruence of information with individuals' own beliefs, their cognitive and emotional involvement in the topic, their personality traits and styles. |

events and its cause-and-effect linkages (the key characteristics of a good story) render the scenario accessible and imaginable. Particularly for qualitative *context scenarios*, the benefits of narrative scenarios in conveying plausibility are emphasised [89], yet mostly without an explicit recourse to narrative theory. The interdisciplinary field of narrative research inquires how plausibility resides in narrative forms and is perceived by readers. Two perspectives are relevant for the study of scenario plausibility: First, linguistic approaches maintain that the internal structure of narratives conveys plausibility. It emphasises the canonical sequence of events as the ‘story grammar’ that organises time in narratives [90,91]. Canter et al. [92] demonstrate that the implementation of these structures directly leads to improved understandability and recall by readers. Here, plausibility is also explicitly linked to persuasion, which is often implicitly evident in arguments about scenario planning, for instance when scholarly contributions offer guidance towards the construction of scenarios through “compelling storytelling” [93].

Second, sociological and cultural theory approaches are concerned with how the content of narratives determines plausibility assessments. All narratives, so the argument, underlie a “cultural-historical fabric” [94]: The way an individual tells a story is not only dependent on own emotions and experiences but also resembles some ‘cultural conventions’. Narratives, therefore, are more than descriptions of individuals’ perceived realities; rather, they constitute instructions and implicit orders for humans to make meaning of their environment. These instructions incorporate what is plausible within a cultural context. Narrative theory also emphasises that whether a narrative is perceived as plausible depends on the author-reader relationship. This is particularly applicable to the contexts of energy scenario practices. Often, the only medium through which producers, i.e. the scenario team and modellers, and the scenario users interact are the scenarios themselves. Following narrative theorists, both actor groups, therefore, construct their own images of one another in order to make sense of and interpret the narrative/the scenario. The ‘implied author’ [95] thereby presents a powerful concept to assume that scenario users inevitably create their own picture of scenario authors and seek to identify the authors’ intentions behind the scenarios.

### *3.3. Plausibility assessments in cognitive and educational psychology*

The scenario literature is rich in statements about the assumed cognitive benefits of scenarios, for instance, because of their potential to limit the power of common cognitive heuristics in decision-making (e.g. availability heuristics) or by enhancing people’s preparedness to consider more than one future [52,71,72]. The concept of plausibility has long been anchored in cognitive psychology. It pertains to how individuals construct their own mental representations about given information, how they subsequently evaluate new incoming data, and how and when information processing leads to a change in previously held conceptions [96]. Cognitive researchers, albeit in different ways, assume that individuals construct mental representations of incoming data and integrate the data with some theoretical explanation [97,98]. Chinn [99] argues that whether individuals ignore, reject, reinterpret or reconstruct data depends on the “availability of a plausible alternative theory”. This means that the plausibility of an individual’s existing model or predisposition competes with the plausibility of the data presented. The model of Lombardi et al. [100] builds on these assumptions and investigates how the cognitive and emotional involvement in the subject matter influences plausibility perceptions on climate change narratives. It distinguishes between plausibility judgments that happen more quickly and impromptu, and those that are made as more explicit and conscious assessments, also known as ‘system 1’ and ‘system 2’ modes [101]. The models of plausibility assessments present an enhancement for the study of energy scenario planning. Particularly, the role of plausibility as a precondition for learning and conceptual change reveals parallels to the expected objectives of scenarios. In this context, the models also account for the epistemic nature of scenarios. Following Chinn and Brewer [96], individuals do not see presented data as ‘facts’ but rather as ‘complex evidence structures’. When energy scenario users engage with (scientific) scenario reports, they face multiple positions from different sources that are often contradictory. This requires a careful evaluation of the methodology and source structures of the reports.

## 4. Propositions on scenario users’ plausibility assessments

The afore-described disciplinary conceptions have demonstrated that plausibility assessments are related to the *content* of scenarios but also to the *context* of scenario production and dissemination. Section 3 has also illuminated how the circumstances of energy scenario usage and construction are resembled in the conditions under which the theories view plausibility: That is, in the assessment of given statements following rules of informal logic (philosophy of science), in the construction and reception of narratives (linguistic and narrative theory), in the reception and interpretation of verbal and non-verbal messages (cognitive psychology) and in conditions for individuals’ learning and conceptual change (educational psychology). From these insights, five propositions are derived that i) are supported by conceptual and empirical findings of the disciplinary perspectives, and ii) concern the contexts and circumstances of energy scenario construction and usage as described in this paper. Because the energy scenario literature does not provide empirical findings or clear hypotheses on the dynamics of plausibility, propositions are used as a means to articulate reasoned assumptions that have potential implications for the phases of energy scenario planning.

### *4.1. Proposition 1: A user’s plausibility assessment of a scenario is linked to the format in which a scenario is presented (narrative vs. model-based)*

Findings from narrative research, argumentative discourse analysis and cognitive psychology stress the merits of narrative formats when it comes to assessing the plausibility of a scenario. In the former, scholars highlight the persuasiveness messages convey when presented as stories [102]. Also, approaches from policy argumentation [87] to view any verbal or written interaction between policy analysts and their audiences as argumentation emphasises how overall plausibility assessments rest on sharing, criticising and engaging with specific formulations in a scenario. The assumed link between narratives and plausibility, however, is not without reservations. Narrative theories argue, for instance, that how exactly storylines can be interpreted by readers cannot be unequivocally predicted, because every aspect of it – be it individual components, the protagonists, or the overall dramaturgy – may be extremely vulnerable to plausibility judgments [95]. At the same time, complex models and presentation styles can seriously bolster the overall plausibility assessments of model-based scenarios because models are often perceived as an ‘ultimate authority’ and give the impression of high credibility [87]. In the scenario literature, different scenario methods are controversially discussed for their accessibility by scenario users; their qualities are attributed to their qualitative storyline-character [36,55] or formal analyses and traceability in the scenario model [23]. Following the theoretical concepts, it is hypothesised that, while the plausibility of narrative-based and model-based scenarios follows fundamentally different mechanisms, the former is perceived more plausible given the power of narrative structures in conveying plausibility.

### *4.2. Proposition 2: A user’s plausibility assessment of a scenario is linked to the perceived credibility of the scenario source and to the trust in the scenario itself*

All disciplinary perspectives present credibility as a key factor in plausibility assessments. Credibility features in normative theories of plausibility, e.g. in guidelines on how plausibility assessments *should* be performed [86], but also in elaborations on how individuals *actually make* assessments [100]. Two different notions of credibility are used and need to be clarified. On the one hand, the *credibility of the source* of the narrative/the scenario is emphasised by several scholars across disciplines. In the philosophy of sciences, the plausibility of a proposition is based on the credibility of its source while 'source' may mean the author of a specific statement or the type of knowledge used in a scenario. The credibility or 'trustworthiness' of the source is also stressed within educational and cognitive psychology, e.g. when individuals assess scientific versus media-based statements about climate change [103] or in argumentative discourse analysis with regards to policy analysts' perceived authority in a field [87]. On the other hand, in conceptual discussions of plausibility, the *credibility or trustworthiness of the scenario itself* is assumed to play a major role. The models-of-data theory demonstrates that individuals assess presented data as well as the connection between the data [96]. With both forms of credibility, the latter may play a more significant role in scenario planning since the source of a scenario is often not exactly known to its users. However, also the credibility of the source is considered for two reasons: First, discussions in narrative research maintain that even if the author is unknown, readers still posit an 'implied author' to make assessments [95]. Second, in scenario literature, the relevance of trust and credibility has been conceptually discussed and differences between trust in scenario sources, in scenario methods, the content and the narrative are highlighted [104].

### *4.3. Proposition 3: A user's plausibility assessment of a scenario is linked to whether the scenario corresponds with the user's own beliefs*

Models from cognitive and educational psychology see great relevance in 'concept-coherence' for plausibility judgments. Connell and Keane [84] maintain that "some concept, scenario, or discourse is plausible if it is conceptually consistent with what is known to have occurred in the past". Plausibility is operationalised as degrees of complexity, corroboration and conjecture between a statement and what an individual knows. This is also evident in Chinn and Brewer [96] who demonstrate that individuals contrast given statements with different forms of 'knowledge', ranging from individuals' fact-based background knowledge to underlying theories or intuitive gut-feelings about how the world works. Researchers from narrative research distinguish between what we know about the world and what corresponds best with accepted guidelines and norms in our society [94]. In this respect, the unruliness of individuals' own worldviews in contrast to given plausibilities becomes evident. Majone [87] notes that arguments must be very convincing for people to reassess previously formed plausibility assessments and to seriously consider other explanations and actions. Educational psychologists [100,103] also maintain that conceptual change may only happen if a given statement's plausibility is assessed to be significantly higher than previously held understandings. For this reason, the hypothesis is put forward that a scenario is judged plausible if a scenario features many corroborations and only few conjectures with individuals' own worldviews and expectations about the future.

### *4.4. Proposition 4: A user's plausibility assessment of a scenario is linked to cognitive styles of information processing*

Models on plausibility by cognitive psychologists hold that when confronted with decision tasks, individuals' cognitive styles, i.e. the way they approach data and process it, play an important role. Lombardi and Sinatra [105] found that decisiveness or the need for cognitive closure, which means an urgent need for a person to reach closure on an open matter, is significantly related to plausibility judgments. This notion is particularly relevant with respect to the distinction between plausibility assessments made implicitly and quick ('mode 1') versus more consciously and explicitly ('mode 2') and hence between the cognitive efforts individuals put into assessing a scenario [100]. In this respect, several cognitive heuristics, e.g. the availability heuristic is assumed to play a role in plausibility judgments. It implies that what is most readily available in individuals' minds will drive assessments. While the effect of cognitive styles is, indeed, specific to cognitive psychology and narrative theory and only plays a marginal role in argumentation theory, it is relevant for two reasons: First, longstanding, empirical research on human judgments of probability has demonstrated the prevalence of some rather robust cognitive patterns [106]. Second, scenario researchers have been discussing cognitive styles of scenario actors for some years now. They assume, for instance, that competence and expertise of participants are key conditions for the quality of scenarios [107] and propose to select scenario teams based on their information processing and problem-solving styles [108]. In assuming that also scenario users' cognitive styles make a difference in scenario plausibility, the hypothesis constitutes a furthering of the energy scenario research.

### *4.5. Proposition 5: A user's plausibility assessment of a scenario is linked to the internal structure of the scenario, the argumentation strength and persuasiveness*

Besides the assumed effects of context-factors and psychometric factors, the relevance of a scenario's internal data structure presents a common thread in the explored theoretical concepts of plausibility. Linguistic approaches to narratives maintain that the sequence in which sentence components are structured, directly influences plausibility judgments [109]: Typical structures such as "Abstract – Orientation – Complicating Action – Evaluation – Resolution" thereby positively affect plausibility. Next to narrative approaches, also cognitive psychology holds that the internal structure of a scenario matters for plausibility judgments. Chinn and Brewer [96] argue that the linkages between arguments (causally, attributional, temporal) are carefully reconstructed and assessed by individuals. Following Connell and Keane [84], if this structure is too complicated for individuals to deconstruct and understand, plausibility decreases. Also, Majone's [87] approach to argumentation assumes that people assess data and information, methods and tools used in an argument to decide whether the argument holds admissible evidence. This is also evident in more formal notions of plausibility assessments. Rescher [86] notes that as a preparatory step, an individual looks out for logical inconsistencies between two or more statements. Therefore, the hypothesis is put forward that formal consistencies and logical connections between scenario components as perceived by the scenario user are positively linked to plausibility assessments.

## 5. A conceptual model on users' plausibility perceptions of scenarios

The five propositions discussed above are synthesised in a conceptual model featuring key factors that explain how users may assess the plausibility of given energy scenarios. The purpose of the model is to support a 'theory-research circle' [110] in which the analysed theoretical concepts provide a better understanding of the complex interfaces between producers and users that are at play when users assess scenarios. For further research endeavours, the model can inspire and structure empirical studies. The contexts and boundaries of the model, i.e. the specific contextual conditions under which plausibility is viewed, are represented as units of analysis in Fig. 2: Scenario construction processes, including the producers of the scenarios and the methods applied (unit 1) create a set of scenarios, often in form of a scenario report in distinct forms of presentation (unit 2) that are received by the potential scenario user (unit 3). The model connects the units with categoric laws of interaction, implying that a change in one unit potentially triggers a change in the overall plausibility assessment.

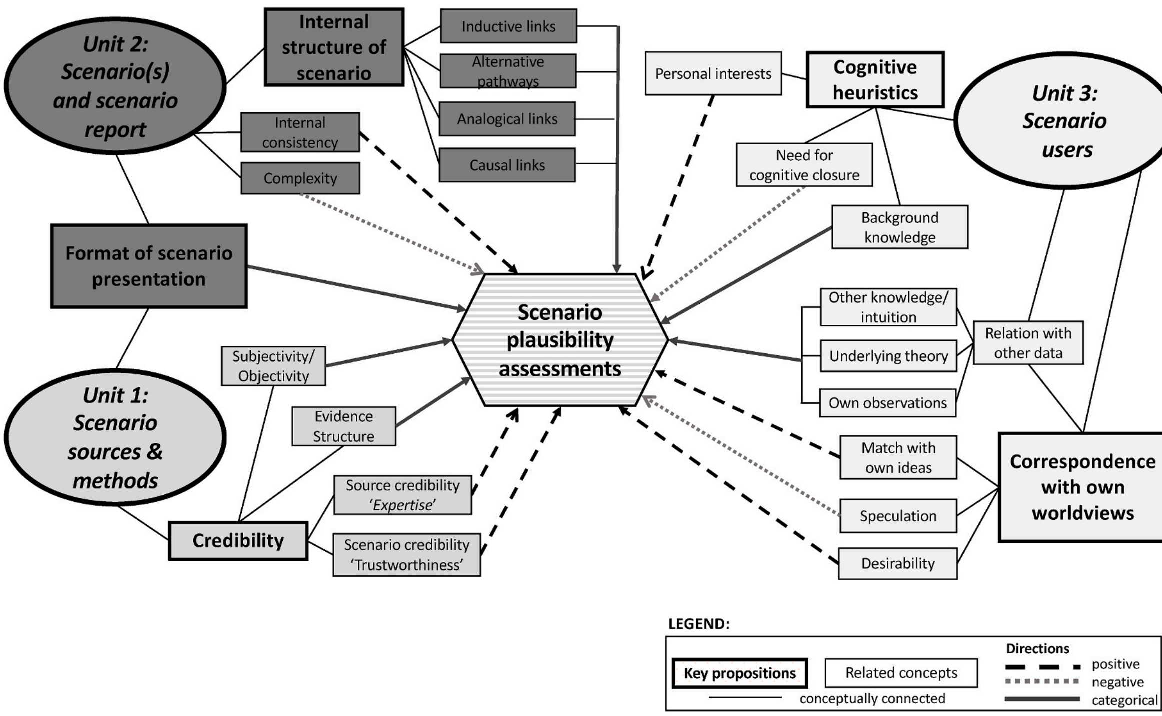


**Fig. 2.** Overview of key factors explaining scenario plausibility assessments of scenario users.
Source: Adjusted from Schmidt-Scheele [28].

Categoric laws do not assume causal relationships between the units. At this stage of the model, not enough is known about the dynamics of plausibility so that relationships are not specified as determinant.

The model suggests that high credibility of a scenario in the sense of its trustworthiness likely leads to high plausibility perceptions (see unit 1, Fig. 2). The credibility of the scenario thereby refers to what is often termed 'information credibility' [111]. This notion of credibility is highly pertinent to the practice of energy scenarios, because the epistemic nature of scenarios makes conventional criteria for information validation, e.g. truthfulness, inapplicable [29]. Hence, when users assess a scenario, contextual interpretations play a particularly important role. This means that scenario assessments are associated not only with the content and the scope of scenarios but with the source of the material used. It presents a fundamental counterargument to assumptions in the scenario literature, holding that scenario plausibility is ensured mainly through the internal consistency of the uncertainty parameters of scenarios [23]. Following the conceptual model, if scenario users perceive the scientific adequacy of the provided evidence and argumentation in the scenario to be strong, this will likely increase the plausibility. In this context, also the perceived subjectivity or objectivity of the scenarios' data determines plausibility perceptions. From a philosophy of science perspective, statements about the future elude from such validation criteria, because scenarios *per se* do not constitute 'truths' that can be independently established from individual perceptions. However, as the theory on argumentative discourse analysis suggests, the style and form of presentation of scenarios as a scientific product may be judged as objective or subjective [87]. Unit 3 of the conceptual model suggests that plausibility judgments of scenario users are related to whether a presented scenario corresponds with their pre-existing knowledge and beliefs. The relevance of this conceptual coherence as factor for scenario plausibility can be supported by findings from longstanding research on cognitive psychology, most notably dissonance theory. Its key argument is that individuals' assessment of given information is never fully detached from own beliefs. Specifically, the 'confirmatory bias' denotes that individuals tend to believe and favour information that corresponds with their own view while they tend to discredit or ignore statements contradictory to their own [112]. Studies have shown that pre-existing beliefs also guide individuals' assessments of the credibility or trustworthiness of given data. Koehler [113] found that people's perceptions of their peers' credibility are influenced by whether their peers' findings correspond with their own conceptions. In a similar vein, Pitz [114] found that pre-existing beliefs and confirmatory processes were the main reason for why individuals tend to stick with their initial judgments and refuse to reconsider even when contradictory information is presented. Such dynamics also relate to unit 2 of the conceptual map - the internal structure of scenarios. (Dis) agreements with scenarios' causal links are brought forward as reasons for (im)plausibility. While causality is named as key driver of plausibility in theoretical conceptions, it is particularly the sense of causality, i.e. 'implicit causalities' [115], that seem to be exploited in scenario contexts. It suggests that the way scenarios are presented tempts users to judge certain arrangements of subjects and objects in a sentence (for narrative scenarios) or interrelations between uncertainty factors (for model-based, non-narrative scenarios) to result from causality. According to the model, causal, analogical or inductive links – implicitly assumed or explicitly stated in the scenario – offer room for attack from the perspective of scenario users. Taken together, the model presents scenarios to be rather vulnerable to users' assessments. At the same time, the explored theories do not present plausibility judgments as arbitrary or random. On the contrary, they point to distinct patterns that cannot simply be represented by other concepts such as credibility or believability. Scholarly-derived plausibility factors, e.g. internal consistency or narrative richness play a role in users' judgments (see Fig. 2) but seem to fail in accounting for the different mechanisms scenario users apply when they have not been involved in the scenario construction processes. What is more, all theoretical concepts view those who make plausibility judgments – the scenario users – as active collaborators in the scenario practice. Independently of whether they apply rules for their judgments or are driven by cognitive heuristics, it is them who decide what meaning, and ultimately what value will derive from the scenarios. In this context, a narrative theorist [95] aptly notes that even "minor details, parts that are quite unnecessarily to the story – like supplementary events and the setting – can exert considerable rhetorical leverage on the way we read".

As has been discussed at the outset of this paper, the construction and usage of energy scenarios resemble a 'life path' [38] in which scenario producers put forth scenarios that they prescribe as plausible. Before the scenarios may actually be used for indirect or direct decision-making, they are subject to a plausibility assessment by scenario users. Here, the presented model makes two contributions: It helps to explicitly discuss and re-visit the often implicitly assumed causal relationship between scenario plausibility and scenario usage, and demonstrates that plausibility constitutes a necessary but not sufficient criterion for scenario usage (5.1). Based on this, the model highlights practical implications for scenario planners and their methodological choices in energy scenario construction processes (5.2).

### 5.1. Implications for energy scenario usage

Explorative scenario planning activities strive for the production of plausible scenarios [27]. Plausibility is presented as a condition for 'good' scenario work [17,116] because the idea of expanding plausibility perceptions of scenario users is assumed to facilitate effective scenario usage [117]. Boenink [57], for instance, notes that plausible scenarios "enhance the reflexivity of users": scenarios help users to better understand how their agency may impact the future as well as how future developments may determine their own future actions. A causal relation between plausibility and scenario usage is often implied; yet, so far there has been relatively little effort to explicitly analyse how plausibility perceptions can shape the usage of scenarios.

Following from the conceptual model, plausibility perceptions can affect the actual usage of energy scenarios in a non-linear way. To understand this non-linearity, the paper distinguishes between 'perceived plausibility', 'perceived usefulness' and 'actual usage' of scenarios. High plausibility perceptions of scenarios also likely lead to an increased perception of the usefulness of the scenarios. To recap, the model illustrates that for energy scenarios, plausibility assessments are linked to three core dimensions: 1) context-related assessments of the credibility and trustworthiness of the underlying methods and sources as well as the format of presentation; 2) content-related assessments, including the internal structure of the scenario and the way uncertainty factors are linked causally; and 3) personality-related assessments involving the congruence of scenarios with individuals' beliefs and background knowledge. Consequently, a scenario that is perceived as very implausible, for instance because of a perceived lack of trustworthiness and credibility of the sources (see Fig. 2), is not likely to be seriously considered by decision-makers. Following the research presented in this paper, in the presence of multiple and diverse scenarios on the future of energy systems, potential users need to at least tentatively accept the premises underlying the scenario. Hence, the model provides indications for why energy scenarios are accepted or rejected as useful at the very end of the scenario 'life path'. More specifically, it sheds light on why often resource-intensive and publicly funded energy scenarios are simply discarded or seriously considered by a wider audience that was not involved in the scenario construction process. This direct relationship between plausibility judgments and perceived usefulness is supported by previous approaches that have sought to explain the persistent gap between the production and usage of scientific knowledge. Cash et al. [47] have famously argued that perceptions of scientific data's credibility, salience and legitimacy influence how decision-makers interpret and ultimately use scientific research results.

However, while it follows that usefulness is only attained when scenarios are considered plausible, this does not mean that high plausibility perceptions of a scenario directly influence scenario usage. As longstanding research suggests, a variety of aspects impact the usage of scientific knowledge, including scenarios. To name only a few, Hulme and Dessai [44] have argued that the mismatch between the dynamics of scenario production and usage impedes the usability of climate scenarios in the UK. Pulver and Van Deveer [45] maintain that the (lack of) interaction and communication between scenario producers and users determines the uptake of scenarios. Enserink et al. [30] have shown how the political contexts in which users operate follow short-term logics that are often incompatible with the long-term perspectives of scenarios. Furthermore, scenarios often picture futures that are detached from the issues and contexts of policy-making [15] and do not incorporate policy-makers' scope and possibilities for action [60]. In sum, other contextual factors may be as important as plausibility perceptions for the usage of scenarios. If a scenario's scope does not fit the policy issue or debate at hand, it may not be adopted or used, even if highly plausible. What plausibility perceptions can do is that they solely lay the foundation for scenario usage. In this context, Lemos et al. [46] have illustrated how difficult it is for scientific information on climate change to move from being merely useful to being actually useable. The authors argue that while scientists often put forth climate projections that they hope are *useful*, it is decision-makers' perceptions of the scientific information that affects the usability as *one* interconnected factor. As such, plausibility perceptions of scenarios constitute a necessary, but not sufficient criterion for energy scenario usage. This realisation urges to revisit the originally hypothesised roles of plausibility for the three levels of scenario usage as mapped out in section 2 of this paper.

The first level of usage assumes that scenarios induce learning, conceptual change or at least the exposure to new and challenging assumptions. The conceptual model questions this potential of scenarios for those users that were not involved in the construction process. For all that can be derived from this research, 'learning' in the form of stretching individuals' mental models beyond what they believe about the world is very difficult: The plausibility of challenging scenarios tends to be downgraded and the scenarios only seem to have a chance for consideration if the scenario source and method are considered highly credible. Theorists across the explored disciplines argue for the 'stickiness' of individuals' own plausibility and maintain that learning can only happen if a new storyline/a new scenario is significantly more plausible than individuals' existing conceptions [100].

The second level of scenario usage maintains that scenarios have the potential to bridge the gap and foster mutual understanding and cooperation between diverse actors. Here, the model suggests that the 'multi-interpretability' of plausibility [95] can make this difficult to achieve. The fact that no clear definitions or guidelines exists for both users and producers of scenarios on how to approach plausibility can give way to different 'cultures' of plausibility assessments. A multiplicity of reasonable standards exists to assess an argument and different actors may apply criteria for assessment specific for their organisational or institutional background. In this context, also Wilkinson and Ramirez [18] have raised the concern that "[t]he plausible/implausible outputs from science become implausible/plausible inputs for policy-making". In this sense, the discrepancy between producers' and users' plausibility perceptions may be representative of the different values and expectations that often contribute to a 'usability gap' of scientific projections [46].

For the third level of intended usage – that is, energy scenarios being directly used as 'lenses' to assess strategies or policies – high levels of credibility and thus plausibility can increase the chances that the scenarios become useable. In cases where the scenarios match users' own expectations and worldviews about the future, the perceived legitimacy of the scenario also increases since it gives users the impression that the scientific knowledge directly integrates their own values and beliefs [47]. Yet, at the same time plausibility becomes a double-edged assessment: While high plausibility perceptions likely lead to an increased sense of usefulness of the scenarios, the underlying mechanisms also suggest that scenarios may be selectively used, depending on the users' own interests. Indeed, studies have shown and constantly warn that scenarios can be strategically exploited by scenario users to enforce or justify political or economic interests as scenarios are particularly vulnerable to ideologies [118,119]. This may be aggravated by the fact that perceived credibility can exert an unduly impact on the plausibility of scenarios. Beck and Mahony [120] warn that energy and climate scenarios of renown institutions – most notably the IPCC – exercise a power on scenario users that does not stem from the scenarios' feasibility but simply from the perceived authority of such credible institutions. In a similar manner, Shapin [121] has famously argued that when assessing and adopting scientific knowledge, it ultimately does not come down to *what data to trust* but *whom to trust*. It follows that the usability of energy scenarios may be determined by whose plausibility scenario users rely on. This supports the earlier assumption that plausibility perceptions of scenario users and thus their willingness to adopt the scenarios can also be distorted by external, contextual factors. In this context, scholars have criticised that foresight products, including scenarios, are 'sold' to its consumers which causes an increasing estrangement between 'sellers' and 'consumers' [122]: The power to claim and populate plausible futures then often resides with those actors who develop the scenarios, typically scenario experts or researchers.

### 5.2. Implications for energy scenario construction

The conceptual model suggests that plausibility assessments of scenario users are far from being predictable. The explored theoretical concepts emphasise the multi-interpretability of the concept and maintain that "every single thing signifies" [95] to mean that not only the content of the scenarios but also the contexts in which the scenario was produced, disseminated and received, contributes to users' assessments. This realisation suggests that plausibility is not a *set screw* that can simply be steered into desired directions. Different academic perspectives, most strongly narrative research, suggest that how exactly a potential user interprets a scenario is not always in the power of the producers. Still, these findings hold critical considerations for how scenario processes are currently conducted and offers some practical implications for scenario researchers and planners.

#### 5.2.1. .Understanding users' plausibility assessments requires a better appreciation of who the scenario users are

The findings of this paper depict scenarios not as an unequivocal, 'sure-fire success' planning tool. There is a lot going on at the later stages of the 'life path' that determines the effectiveness of scenario exercises and that has not been systematically explored. While thorough and scientifically sound development processes rightfully present the backbone of many scenario studies, they do not *per se* guarantee an uptake of the scenarios. As has been demonstrated at the outset of this paper, scenario users are mostly unexplored territory in many energy scenario planning projects since only those users who are directly involved in this process are considered. The paper makes clear that more systematic inquiries need to be directed towards scenario users that are not directly involved but still targeted by the scenarios. Investigating their expectations, beliefs and cognitive assessment styles is worthwhile for any successful scenario activity. Critics who may consider this an impossible task are reminded of the small but growing number of studies that have investigated the same for scenario developers [108,123]. While commissioners of energy scenario studies but also the scientific community as potential users of scenarios are rather well-known and defined [124], a very heterogeneous user group, including stakeholders in the wider, democratic public, NGOs, mass media or interested citizens need to be considered as rightful addressees of scenario studies [62,125]. Scenarios are often made possible through public funds; once published, they enter public debates through medial reception and dissemination. Kunkel et al. [126] call for a more nuanced distinction between intermediate users, i.e. scholars, and this group of end-users. Research has shown that even in projects that attempt to integrate scenario users in the construction process, scenario developers tend to construct their own images of the scenario users, their needs and perceptions. In other words, they construct their own "mini-mes" [127]. Often, such constructions correspond to what scientists believe to be credible, useable and relevant. In line with this research, the conceptual model suggests that for scenario construction and assessment processes, conceptions of users cannot stay one-dimensional but need to anticipate users' possible backgrounds and perceptions of what is credibility and thus plausible [128]. This constitutes a key requirement for the following points below.

#### 5.2.2. Attend to different 'cultures' of plausibility assessments

Current discussions regarding the construction and presentation of energy scenario studies often revolve around strengthening the substance of energy scenarios by covering more energy sectors and life cycle assessments [129] or by integrating political and social dynamics [14]. While these present valuable aspects of the energy scenario practice, energy scenario planners are advised to keep in mind the relevance of *how* scenarios are presented, by *whom* and with reference to *what* presently available discourses about the subject matter. As Grunwald [38] notes, a major condition for energy scenario usage is for scenario producers to know the contexts of scenario usage in order to adjust their methodological procedures. This also includes to appreciate the challenges users face before the actual usage of scenarios. Rössler et al. [128] argue that the efforts to provide users of climate data more transparently with larger amounts of information about applied models is commendable. However, this does not solve the most practical question from a user's perspective which is "no longer the lack of downscaled projections; it is how to choose an appropriate data set, assess its credibility". Also, Porter and Dessai [127] maintain that the producers of scenarios approach credibility through emphasising model uncertainties and thus achieve an improved scientific contextualisation of results; however, it does not necessarily speak to users' needs and perceptions of credible scenarios. Producers of energy scenarios are, therefore, advised to attend to the different credibility perceptions of energy scenario users. A starting point can be to look at typologies of scenario users, as suggested by Skelton et al. [130]. The authors distinguish between groups of 'observers' (interested in the scenarios *per se* but not looking to adopt in their work), 'sailors' (interested in key findings of the scenarios as part of their work) and 'divers' (looking for key understandings of the scenarios itself). While for the latter, scientific background information on the scenarios' model assumptions and methodologies can bolster credibility and thus, plausibility, the former two will most likely do not respond to this in the way envisioned by scenario producers.

#### 5.2.3. Clarify the purpose of scenario projects in order to address plausibility appropriately

When talking about 'effectiveness', scenario studies and research analyses are often rather vague regarding the ultimate purpose of the scenario activity. As has been mapped out, at the individual scenario user's level, objectives are most often associated with learning, conceptual change, or at least with the exposure to new and challenging assumptions. Certainly, there exist the potential for scenario producers and scholars to exploit the plausibility factors as illustrated in the conceptual model. They could actively work towards high plausibility judgments, for instance, by promoting scenarios from very trustworthy sources and methods, by integrating certain cognitive 'hooks', or by carefully combining narrative storylines with some credible numerical evidence. Inspiration from cognitive psychology is here abundantly available; the stimulation of 'peripheral cues' such as message credibility and persuasiveness by the Elaboration Likelihood Model of Persuasion (ELM) [131] presents just one example. Energy scenario modelers, for instance, can build on the method's perceived credibility to push towards high plausibility judgments. At the same time, they need to clarify what it is that their scenarios should achieve: Is it convincing users with the appearance of scenarios or to seriously question users' conceptions of the future? Scholars have also made clear that contextual trust in scenarios is not only difficult to obtain or maintain [104] but raises questions about the power structures among those who tell the scenarios and with what methods [132]. In this context, also the role of *implausibility* – as opposed to plausibility – should be more thoroughly considered by scenario planners. During scenario construction processes, a clear distinction is made between plausible (those scenarios that end up in the final set) and implausible scenarios (those that do not). From a human judgment perspective, however, plausibility presents a continuum. Scenario research should further explore how moving between nuances of plausibility may be a fruitful way of engaging with scenarios. Indeed, the theoretical concepts suggest that less plausible scenarios are not necessarily disregarded *per se* but can be considered as 'food for thought' to develop alternative pathways of the future. Ramirez and Selin [26], for instance, have argued that implausible scenarios should not be the end but the start of a strategic conversation about the future. For this reason, scenario studies could also provide potential users with those scenarios that were discarded during the development process and explain the reasons for this exclusion.

#### *5.2.4. Reconsider plausibility as 'effectiveness' criterion for energy scenario projects*

The presented research finally begs the question whether plausibility constitutes an appropriate assessment criterion for scenarios. The conceptual model implies that a differentiation is needed between plausibility as 'effectiveness criterion' – as has been commended by many scenario reviews – and plausibility as a construct to better understand scenario users' reactions to given sets of scenarios. The findings of the paper question the appropriateness of plausibility as a function of scenario effectiveness given that a scenario is plausible if high credibility perceptions of the scenario itself and/or its methods exists, the scenario matches with users' own ideas about the subject matter and furthermore activates several commonly known cognitive heuristics. To consider these mechanisms as condition for a scenario study's success could run counter to the enormous efforts put into the development of energy scenarios. At the same time, such an amalgamation of plausibility indicators also stems from the fact that the scenario planning literature has provided little guidance on how to interpret scenarios. One consequence from this paper can be to differentiate and flesh out quality criteria for scenarios that build on the findings of this paper and other studies that are more user-oriented [126,133]. Selin [40] has aptly argued that instead of dealing with plausibility as a fixed quality criterion, it can function as "a worthwhile sparring partner that brings up interesting (…) questions around evidence, trust, science and culture and decision-making". Hence, much can be learnt from further conceptual and empirical evaluations of scenario user judgments, but also from other systematic bodies of research into human judgment mechanisms. The scenario community can learn from the elaborate research designs to analyse human judgments e.g. from the research on risk perception and probability assessment [106]. The findings of this paper point to interesting parallels in probability and plausibility judgments that have to date been neglected. For instance, the model points towards the fact that scenarios are judged implausible and too far-fetched when being too far from users' own beliefs and experiences but are also judged implausible when perceived as too simplistic or deterministic. This allows for the hypothesis that plausibility judgments may be represented by the medium density function of probability. Scenario research and practice should more openly look towards other disciplinary perspectives when engaging in micro-perspective analyses of the later phases of scenario planning processes.

## 6. Conclusions

In the face of increased efforts towards the transformation of energy systems, the construction of energy scenarios is expected to help decision-makers in analyssing and evaluating plausible pathways of the future. Despite the omnipresence of the concept of plausibility in energy scenario research and practice, there is little conceptual and empirical clarity on how the plausibility of scenarios is perceived by users. This paper seeks to address this gap and systematically explores plausibility from three disciplinary strands of theory, more specifically from the philosophy of sciences, linguistics and narrative theory as well as cognitive and educational psychology. A conceptual model is introduced that synthesises five key propositions from the theory that help to better understand the factors influencing users' plausibility assessments. The findings suggest that scenario users deploy different mechanisms when assessing the plausibility of narrative scenarios or model-based scenarios. While for the latter, plausibility assessments can be positively influenced by the perceived 'authority' of the model, scenarios in the form of storylines are driven by the persuasiveness of stories' cause-and-effect dynamics. For both types of scenarios, high perceived credibility of a scenario in the sense of its trustworthiness is linked to high plausibility assessments. Furthermore, the credibility of scenario sources is determined as important factor – an interesting finding given that scenarios are not regularly related to specific sources or authors. A critical indicator for scenario plausibility is whether a scenario corresponds with users' own beliefs and expectations. Scenarios that are perceived as too far-fetched in the sense of their likelihood are unsurprisingly judged less plausible. Such dynamics also relate to the internal structure of scenarios. (Dis)agreements with scenarios' causal links are interpreted as reasons for their general (im)plausibility. The findings bear direct implications for the phases of energy scenario construction and usage. For energy scenario usage, the conceptual model illustrates why and how energy scenarios are accepted or rejected at the end of their 'life path' by prospective users. This sheds light on whether often very resource-intensive and publicly funded energy scenarios are simply discarded or seriously considered by its target audience. Here, plausibility assessments can be interpreted as a necessary but not sufficient criterion for scenario usage. At the same time, the model also points out that high plausibility perceptions by users may lead to the adoption of the scenario but may not necessarily result in learning and conceptual change – a key intended objective of many energy scenario projects. For the phase of construction, the paper argues that producers of energy scenarios need to attend to the different perceptions of credibility when it comes to assessing energy scenarios. While for some user groups, particularly those interested in the background of construction, scientific information on the scenarios' model assumptions and methodologies can bolster plausibility assessments, other scenario users may rather respond to aspects that pertain to the legitimacy and salience of the presented scenarios. It follows that scholarly-derived plausibility factors, e.g. internal consistency of input assumptions, play a role in users' judgments but fail to account for the different mechanisms scenario users apply when they have not been involved in the scenario construction process. Lastly, the paper argues to reconsider plausibility as effectiveness criterion for energy scenario planning; instead, plausibility could be used as a means to better understand individuals' perceptions and attitudes towards diverse sets of scenarios.


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## Declaration of competing interest

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