Science and Public Policy, 2021, **00**, 1–27
DOI: https://doi.org/10.1093/scipol/scab076
Article

Capturing the invisible. Sociotechnical imaginaries of energy. The critical overview

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Abstract

While the need and general direction of the energy transition are widely accepted, the implementation has different dynamics throughout the world. Sociotechnical imaginaries concept, bridging the science, policy, and society, seems promising in understanding and explaining the global differences. The present paper analyses 135 abstracts that contain the topic keywords, sociotechnical imaginaries, published in international, peer-reviewed scientific journals during the last 11 years. Further on, the author conducted a qualitative and quantitative analysis of 43 energy-related articles to offer a panoramic overview of sociotechnical imaginaries in energy research out of the more extensive background. The paper aims to present a critical overview of the concept usage in energy studies to identify incoherences and blind spots in concept usage. What is more, this research intents to show the promising direction of using sociotechnical imaginaries. It also proposes new operationalisation and theoretical frame as well as potentially contributes to policymaking.

Key words: sociotechnical imaginaries; energy-SSH; energy transition; future; STS; sociology

1. Introduction

Since the concept appearance, the idea of sociotechnical imaginaries has been gaining attention, and many academics have conducted their research using this idea. In the last 10 years, the importance of this notion has increased, and more and more scientists are using sociotechnical imaginaries in their research (see Appendix A). However, the concept itself remains difficult to capture, and its translation into specific policymaking action is not obvious. At the same time, sociotechnical imaginaries have key importance in creating policies (they affect the allocation of funds, research directions, means of communicating development priorities, etc.). Policymakers are not always aware of this influence. The key point of this article is not only to conceptualise the sociotechnical imaginaries but also to operationalise the concept and start a discussion on how to study and use it. The term is used in different contexts, and this raises distinct methodological challenges. Sergio Sismondo articulated in the editorial to the special issue of Social Studies in Science, devoted to the notion of SI, (Sismondo et al. 2020), the concept to be analytically helpful must be stable. It should be clear and coherent enough to offer the possibility of shaping terrains of choices and thereby of actions (Sismondo 2020). In response to this challenge, the paper contributes to discussions on the sociotechnical imaginaries concept operationalisation with a critical review of the methodologies and theoretical approaches, particularly in energy research. The main object of the paper is to identify potential incoherence and differences between the existing operationalisations, with a focus to propose a new operationalisation approach and possible gaps, considering the sociotechnical imaginaries in the energy research.

The history of ideas and science teaches that many concepts and theories have been redefined and further developed. Therefore, stability does not mean invariability but consistency in understanding the phenomenon itself, methods of its research and the purpose of these studies. This applies to both the concept complexity and the understanding of how imaginations emerge and function.

To illustrate better the phenomenon of sociotechnical imaginaries, the analysis of all the research tools and procedures used for their identification was made. This investigation will guide the readers through the history of the concept from a broader theoretical perspective. Then, the research will look into the foundations and most essential theories related to the research on sociotechnical imaginaries in the energy-SSH field. Moreover, it will try to answer where, when, and how sociotechnical imaginaries can be traced and identified. Finally, the results will show the differences between various understandings of the concept, raising the questions that need further elaboration to make sociotechnical imaginaries a stable and coherent concept. This article will analyse the research on sociotechnical imaginaries from 2009 to the beginning of 2020, focusing on energy research.

2. The concept of sociotechnical imaginaries—origin and development

In recent years, many scholars, politicians, and activists are raising the necessity of the energy transition from fossil fuels

to low carbon sources (Rockström et al. 2017; de Coninck et al. 2018; Rogelj et al. 2018; Sovacool et al. 2018). However, energy transition processes occur differently in different regions, whereas globally slower as was expected during the Paris Climate Summit in 2015. It turns out that the dominant techno-economical perspective is insufficient to break the deadlock. Therefore, there has been a growing interest in holistic and interdisciplinary aspects of the energy transition, its conditions, trajectory, and possible consequences (Foulds and Robison 2018). Furthermore, energy transition connotates the reference to the future, which is always linked to uncertainty and imagination as a horizon of human actions (Luhmann 1976).

Nevertheless, the future is a very complex and challenging issue for sociologists. From the sociological perspective, it has roots in the present time and depends on social practices, patterns of thinking, utopias, cultures, and values. People try to make the future more tangible and understandable to mitigate uncertainties about forthcoming events (Adam 2004). Considering the holistic and complex nature of this phenomenon and the role of technology as a crucial element of social reality, Sheila Jasanoff and Sang-Hyun Kim proposed a new concept called Sociotechnical Imaginaries (SI). The idea introduced in 2009 was designed to understand the role of imagining the technological future as a crucial constructive element in social life (Jasanoff and Kim 2009a). The very first definition introduced in the article 'Containing the atom: sociotechnical imaginaries and nuclear power in the United States and South Korea' was linking the term with the concept of nation and nation-specific technological goals and projects. The research proposed by these authors was firstly limited to cross-national comparison, first between the two states—the USA and South Korea (Jasanoff and Kim 2009), and then to three countries—the USA, South Korea, and Germany (Jasanoff and Kim 2013). After 6 years after the publication of their first article on sociotechnical imaginaries, both authors published the book *Dreamscapes of Modernity*, developed their definition and broadened the term, which made its usage more universal. They define sociotechnical imaginaries as phenomena that could be articulated and propagated by local, regional, and global actors (Jasanoff and Kim 2015). Since then, the number of articles concerning sociotechnical imaginaries has been continuously growing. One of the most important factors relating to the development of sociotechnical imaginaries research was the emergence of the Energy Research & Social Science Journal. Since 2014, when the edited by Benjamin Sovacool journal was created, the number of articles concerning SI has significantly gone up. Since 2014, when the edited by Benjamin Sovacool publication was created, the number of articles has significantly gone up. Until April 2020, it has become the journal with the most frequent articles on sociotechnical imaginaries—the concept proposed by Jasanoff and Kim (22 articles so far). Alongside the growing interest of the researchers on the topic, the citation number of articles concerning sociotechnical imaginaries has also been growing. In 2016, the citation number of articles regarding sociotechnical imaginaries was 99, rising to 302 in 2018. This number increased to 510 citations in 2019. It is reasonable to state that the trend will also continue in the future.

3. Conceptualising the sociotechnical imaginaries: from social imagination to sociotechnical imaginaries

Following the paper's main objectives, this section surmises the theoretical background and conceptual assumptions set initially by the SI designers. It aims at consolidating them and tries to put open questions that emerge from the original definition by Jasanoff and Kim. This is helpful for further analysis and understanding the construction of research designs dealing with sociotechnical imaginaries.

3.1 Theoretical backgrounds set by concept authors

Theoretical backgrounds of the concept introduced by Jasanoff and Kim run deep into the history of sociology and philosophy. Beginning with Weberian *Verstehen* and the assumption that the social actors subjectively understand how things fit together, the concept is embedded into interpretive sociology. As the authors describe, 'Imaginaries are securely established in interpretive social theory as a term of art referring to collective beliefs about how society functions' (Jasanoff and Kim 2015). The foundation for the concept of imaginaries comes from the works of early anthropologists like Evans-Pritchard and Meyer Fortes. Sifgnicifact contribution comes out of the works of Benedict Anderson, and his theory of Imagined Communities as well as Charles Taylor, with his concept of *collective social imaginations* describing overall social existence. Jasanoff and Kim situate sociotechnical imaginaries between the construction of imaginaries in political and cultural theory and sociotechnical systems in STS. Being in-between means that they benefit from both schools and create a bridge to fill the gap between morals, values, power, policies, and technology.

In their works Anderson and Taylor define social imaginaries as a phenomenon that preerected societies, nations, or even such a broad issue as the concept of modernity. Benedict Anderson's notion of *imagined communities* provides us with an explanation of how a specific group of people, through language, artefacts, and standard practices, creates an imagined community (Anderson 2016). Charles Taylor, whose concept of social imaginaries grows out of Anderson's notion, uses the idea to name conventional narratives embedded in practices, stories, and ordinary people's sense of legitimacy. Taylor's understanding of social imaginaries is based on shared insights on what is right or wrong, mutual recognition, and representations (Taylor 2003). Arjun Appadurai uses the notion of imagination to switch its meaning from mere fantasy into organised work and practice that holds the concept of modernity (Appadurai 2002: Disjuncture and Difference in the Global Cultural Econo). On the other hand, Cornelius Castoriadis stresses that imagination helps produce systems of meanings, which is an essential factor in collective interpretations of social reality. What is more, the Greek philosopher has created the notion of *social imaginary significations*, which is a central reference point to all values, norms, and practices developed by society. This core imaginary cannot be rationally supported or rejected. As an example of *significations imaginaries*, Castoriadis provides a concept of God, the Holy Trinity, or a constant growth paradigm in the capitalistic system (Castoriadis 1997).

Social imaginaries by Benedict Anderson, Charles Taylor, Arjun Appadurai, and Cornelius Castoriadis are all rooted in understanding the imagination as a crucial element that constitutes society. Sociotechnical imaginaries introduced by Sheila Jasanoff and Sang-Hyun Kim draw from all the concepts mentioned above on the assumption that societies share a common narrative of their roots and present and future course. Nevertheless, Jasanoff's and Kim's concept is strictly connected to technological development. It is more focused on the active exercise of state power, funds allocation, and the development of priorities.

One of the essential starting points for the concept was the notion of *technoscientific imaginaries* proposed by George Marcus and his colleagues (Marcus 1994). This concept, introduced by the representatives of the anthropology of science and technology, is focused only on the imaginaries of scientists, their practices, and current positionings. The results from the study of this concept were limited to highly individual (scientists) accounts on the future. Sociotechnical imaginaries instead go far beyond this notion, focusing on society as a whole than particular groups of people.

As Jasanoff and Kim mention in their book *Dreamscapes of Modernity—Sociotechnical Imaginaries and the Fabrication of Power*:

> *Our ambition in this book is spatially and temporally larger and more symmetrical. It is to investigate how, through the imaginative work of varied social actors, science and technology become enmeshed in performing and producing diverse visions of the collective good, at expanding scales of governance from communities to nation-states to the planet. This is why we choose the term 'sociotechnical' (not technoscientific) to characterise our elaboration of imaginaries* (Jasanoff and Kim 2015).

Another necessary theoretical background for the sociotechnical imaginaries concept comes from Yaron Ezrahi's *Descent of Icarus* and *Imagined Democracies*, where an Israeli political theorist and philosopher stresses that democracies need *necessary fictions* and those fictions are strictly connected with technologies. Democracies continually need to prove themselves to their citizens, leading to the non-stop development of technology. The state has to prove its efficiency and power. Ezrahi also describes the role of necessary fictions in a democratic country. Those *fictions*, defined as the elements of a democratic system, are performed by every member of the society despite all the hidden machinery and vain illusion. The imaginary, in which one man, by voting, influences the whole state-power, could serve as an example. The same comes with the technology, which society performs (citizens and their taxes, state and research funding, researchers, and business) to achieve constant social development.

> *Technologies seen in this light operate as performative scripts that combine values and interests, materialising and making tangible the invisible components of social imaginaries. Such performances, in turn, embed technological systems into the 'masonry of political world-making'* (Ezrahi 2012)

Another vital factor in Jasanoff's and Kim's consideration is understanding the role of order and disorder in contemporary societies. Finally, the concept of co-production is crucial, being the theoretical framework that binds science and culture. Co-production describes how scientific ideas evolve simultaneously with discourses, representation, practices, and institutions (Jasanoff 2004).

But what makes societies choose their path of development, and why some choices gain stability while others do not? Jasanoff and Kim provide us with another theory here. According to Actor–Network Theory by Michel Callon and Bruno Latour, humans are not the only elements of social relations. Other organisms (viruses, microbes, and animals), as well as concepts, technologies, and many other ideas that surround us, are part of our societies. Moreover, all *agents* (all members of social reality) are hybrid (composed of cultural, natural, and nonhuman entities; Latour 1993). That is why Jasanoff and Kim proposed the concept of sociotechnical imaginaries to consider all human and nonhuman factors. This theory also explains the structure and distribution of power. As an example, Jasanoff and Kim mention the history of the French mission to Sakhalin island and the savage description of the island topography by an old Chinese man contrasted with a much more 'civilised' way of drawing a map by French sailors. That illustrates how nonhuman objects, technology, items, education, etc., also have the mission of civilising 'others'. But according to Jasanoff and Kim, reducing analysis only to this 'raw power' is too simple. Sociotechnical imaginaries are going one step ahead and reveal the topographies of power. Jasanoff and Kim define their concept:

> *Our definition pulls together the normativity of the imagination with the materiality of networks: sociotechnical imaginaries thus are "collectively held and performed visions of desirable futures" (or of resistance against the undesirable), and they are also "animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology." Unlike mere ideas and fashions, sociotechnical imaginaries are collective, durable, capable of being performed; yet they are also temporally situated and culturally particular. Moreover, as captured by the adjective "sociotechnical," these imaginaries are at once products of and instruments of the co-production of science, technology, and society in modernity* (Jasanoff and Kim 2015)

3.2 Open questions arising from the original definition of sociotechnical imaginaries

This SI definition, however, is very comprehensive. It does not explain why and how particular sociotechnical imaginaries become collectively held. This section allowed to pose a set of questions. What are the mechanisms of sociotechnical imaginaries emergence and performativity? What are the processes and relations between dominant and alternative imaginaries? How can the performativity of imaginaries be explained and measured? Is the role of specific actors in creating a desirable future crucial? Those questions were a starting point for posing a research question on the other researchers' concept evolution and proposed theoretical and operationalisation background.

Furthermore, Jasanoff and Kim used the term *desirable futures*, which places the whole concept as a normative dimension of the future that should or should not be attained. To

fully understand the intentions of Jasanoff and Kim, there is a need to put the concept in the context of *public reason*. Jasanoff referred to it (Jasanoff 2012), describing the role of power and authority and how the state is justifying the execution of its control over society. The *public reason* consists of three essential sections: *civic epistemologies* (understood as institutionalised practices by which members of society choose the 'right knowledge' to make their collective choices; Jasanoff 2011), *sociotechnical imaginaries* (the collective visions of the future and progress), and *bioconstitutionalism* (which describes the styles of reasoning present in relations between human lives and law regulations and practices; Jasanoff 2011). Using the notion of the public reason, it is justified to state that sociotechnical imaginaries are inextricably linked with regulations, knowledge-making processes, and practices. Therefore, they can be an element of control over society. But how does this relate to alternative imaginaries? Sheila Jasanoff and Sang Hyun Kim state that sociotechnical imaginaries are dominant and collectively held. At the same time, both authors did not deny the existence of other alternative imaginaries. Still, the question about the emergence of imaginaries, their diversity, how some become dominant or alternative, and their relations between each other remains in Jasanoff's and Kim's works without an answer. Based on those reflections, Sections 9 and 10 *try* to propose a way forward and develop an integrated methodological and operationalisation approach for sociotechnical imaginaries.

4. Research method

This research aims at summarising the theoretical, conceptual, and operationalisation backgrounds that were a base for the scientific reflection on the sociotechnical imaginaries and propose a new operationalisation and possible future directions of concept development. The study was conducted following the mixed sequential exploratory study procedure (Creswell et al. 2007), focusing primarily on collecting and analysing quantitative data, followed by collecting and studying qualitative data. This method was implemented to deepen the reflection based on qualitative research with a more detailed qualitative exploration. The author has decided to use this perspective to reflect on the methods, approaches, and incoherencies in energy-related articles, having a broader analytical background. The results were based on 135 English-language articles or book abstracts published in leading scientific journals between 2009 and January 2020 downloaded from the Scopus database and Web of Science. The studies were limited to the research that refers to the definition of sociotechnical imaginaries proposed by Sheila Jasanoff and Sang-Hyun Kim in 2009 and developed in 2015.

Research questions (Graph 1):

To summarise theoretical, conceptual, and operationalisation approaches:

1. In which context was the concept of sociotechnical imaginaries studied?
2. What are the most commonly used theoretical concepts while analysing sociotechnical imaginaries? What are the main ontological paradigms?
3. What kind of social reality has been studied using the concept of sociotechnical imaginaries?
4. What are the underlying methodological assumptions, and what research methods and techniques were used?

To propose a new integrated methodological and operationalisation approach for sociotechnical imaginaries, possible paths of concept development:

1. What are the research gaps and differences in understanding between different authors?
2. What are the mechanisms of sociotechnical imaginaries, emergence, and performativity?
3. What are the relations between alternative and dominant sociotechnical imaginaries?

The study was divided into two steps to answer research questions and follow the mixed sequential exploratory study procedure: step 1—quantitative and step 2—quantitative and qualitative.

Step 1

The Scopus and Web of Science databases of scientific publications were systematically searched based on the topic keyword *sociotechnical imaginaries*. The selected research sample is limited. It was narrowed to the most influential (according to the citation number) English language research. One hundred thirty-five abstracts (see Appendix A) of the downloaded articles were analysed, focusing on the elements of research on energy and the energy futures and capturing the most important clusters, topics, and bibliometric information. For this purpose, the method of the Scope Review, according to a five-step protocol, was implemented (Arksey and O'Malley 2005). The procedure identified clusters, and topics collocations and retrieved 43 abstracts of articles connecting the sociotechnical imaginaries concept with energy research studies (see Appendix B). The first quantitative part of the analysis was done in the QDA Miner program.

Step 2

Based on the abstract analysis in Step 1, 43 articles concerning sociotechnical imaginaries in the energy sector were selected for the second part of this analysis. Later, in the same way, as in Step 1, the quantitative analysis was used, and the word clusters, topics, coexistence between concepts, and bibliographical information were identified. Next, as the mixed sequential exploratory study method suggests, the quantitative approach was used, and 43 articles were coded in the following categories: *research methodology*, *theoretical background*, *research context*, and *research material*.

5. Sociotechnical imaginaries in the context

During the analysis of all 135 abstracts, according to frequencies, the most repeated words (for the number of cases) appearing in the abstracts were as follows: *technology* (in 99 abstracts), *policy* (in 76 abstracts), and *future* (in 64 abstracts). Considering those statistics, not surprisingly, it is justified to state that the scientific interest of authors dealing with sociotechnical imaginaries is concentrated on the influence of science and technology on society. They examine how governments, international organisations, and

OBJECTIVE 1

To summarize theoretical, conceptual and operationalisation approaches

Research questions:

1. In which context was the concept of sociotechnical imaginaries studied?
2. What are the most commonly used theoretical concepts while analysing sociotechnical imaginaries? What are the main ontological paradigms?
3. What kind of social reality has been studied using the concept of sociotechnical imaginaries?
4. What are the underlying methodological assumptions, what research methods and techniques were used?

OBJECTIVE 2

To propose a new integrated methodological and operationalisation approach for sociotechnical imaginaries and possible paths of concept development

Research questions:

1. What are the research gaps and differences in understanding of the concept?
2. What are the mechanisms of sociotechnical imaginaries, emergence, performativity?
3. What are the relations between alternative and dominant sociotechnical imaginaries?

Graph 1. Research objectives and research questions. Author's own elaboration.

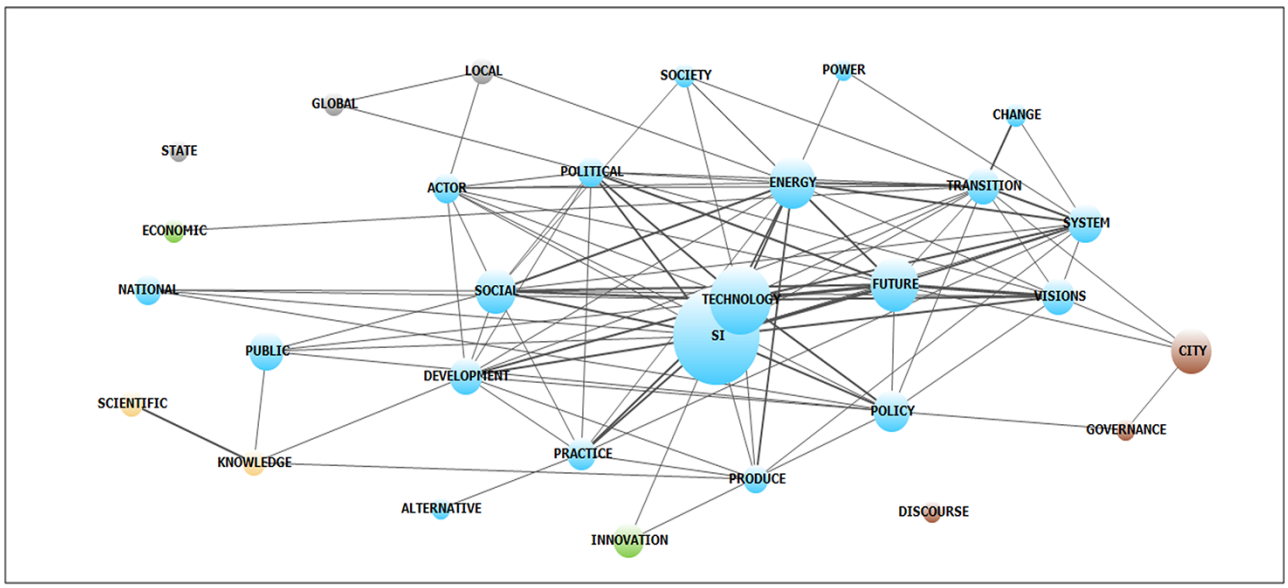


Figure 1. Jaccard's coefficient map of main keywords in all 135 abstracts. Language of the articles: English, published between 2009 and January 2020. Source: own elaboration. The results on the figure were based on the case occurrence in one paragraph higher or equal than 17.

local, regional bodies govern future technological development. The concept of governance is analysed more in the context of policies than politics. The impact of sociotechnical imaginaries on specific policies is one of the main concerns. The authors treat sociotechnical imaginaries consistently as future-oriented co-products of science, technology, and society. Other critical topics mentioned in selected abstracts were future-oriented concepts like energy transition, big data, smart cities, and health. What is worth noticing is that sociotechnical imaginaries are present in a normative context. Dominating or alternative visions of the future present in a public sphere in narratives, documents, policies, and strategies have significant normative and descriptive dimensions. They are leaning towards the future, presenting a desirable or rejected outlook. But far more significant for the overall image of sociotechnical imaginaries and their research is understanding how and which main concepts are close and relate to each other in specific abstracts. The colocations map based on Jaccard's co-occurrence index (Fig. 1) helped gain insight and understand how keywords relate to each other.

The results of the analysis (Fig. 1) led to surprising conclusions. The strong position of the system and its relation to transition and change and the fact that the keyword *actor* is not related to vision, transition, and change are confusing. What is more important, the *actor* is less related to sociotechnical imaginaries than the system. System perspective rather than pressure on actions and perceptions of individual actors is surprising in the context of the dominant interpretive paradigm in which the sociotechnical imaginaries are embedded. An in-depth analysis of the keyword *actor* led to the conclusion related to the keywords *political, global*, *local*, and *energy*. This suggests that researchers'

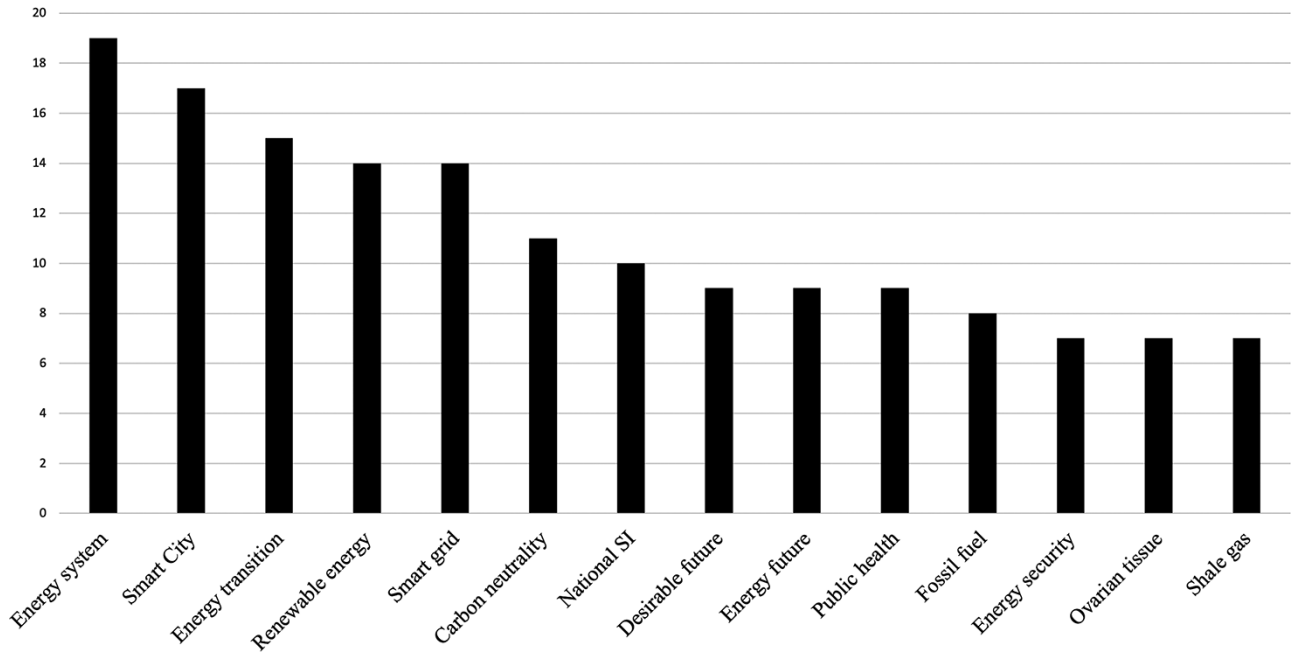


Figure 2. Distribution of phrases according to the frequency in 135 analysed abstracts—own elaboration.

focus is on the political, local, or global energy actors rather than a wider group of social actors. Whether it is enough to focus on certain actors while referring to the collective beliefs about the society remains open. The presence of the transition, change, and vision keywords indicates that imaginaries in analysed research have a normative dimension. *Imaginaries* facilitate or stop specific changes. The role of practices and their collocation with the keyword alternative could be essential elements that understand the performativity of sociotechnical imaginaries. The imaginary of alternative practices could be an important element of co-producing the future (Longhurst and Chilvers 2019). Apart from the above-mentioned study outcomes, the rest could conclude that most analysed abstracts follow the definition provided by Jasanoff and Kim and focus on the role of technology as a crucial asset for the state to create a desirable future and prove itself to society. The distribution of phrases (Fig. 2) in the analysed abstract suggests that energy-related issues and smart city are important concepts regarding sociotechnical imaginaries research. It is worth noticing the frequency of terms such as public health and ovarian tissue. This could indicate the potential of widening the analysis to the broader spectrum of topics.

5.1 Sociotechnical imaginaries in energy research

Since 2009, the number of articles concentrating on Jasanoff and Kim's concept in the context of energy studies rose to 43 in 2019. The rising trend present in Fig. 3 indicates a growing interest of energy-Social Sciences and Humanities (SSH) scholars in the idea.[1] It is worth demonstrating that the development of the *Energy Research & Social Science* journal, which focuses on the energy-related social sciences, resonates with the number of articles concerning the concept published in it. Twenty-one of them used the more comprehensive definition introduced in 2015 (Jasanoff and Kim 2015). Seventeen authors referred to the first conceptualisation of sociotechnical imaginaries present in Jasanoff and Kim's works in 2009 and 2013 and focused on the cross-national comparison.

Similar to the cluster analysis, also frequency lists (Fig. 4) point to the strong technology and policy foci of sociotechnical imaginaries. The most popular among the investigated phrases was the smart grid. Which plays a significant role in the technological development for optimising the energy use. At the same time, the two next have a clear connotation with the policy of decarbonisation. Taking into account the most frequently occurring keywords in all analysed 43 research papers, it is justified to state that sociotechnical imaginaries are in close connection to specific keywords: *technology*, *policy*, *future*, and *vision*, which means the analysed studies are in coherence with its original definition by Jasanoff and Kim. The analysis of 135 abstracts and the qualitative inquiry of 43 energy-related articles confirme the above mention tehnological focus in terms of keywords coherence and main topics. Sociotechnical imaginaries in energy research lean towards the future, and when it comes to energy future, they become a valuable tool to understand, govern, and perform energy transition. As SIs lean towards the future, they are a powerful tool for answering the questions about energy futures—how the energy transition is understood, governed, and performed.

6. Main theoretical backgrounds of sociotechnical imaginaries in energy studies

6.1 Social practice theory

The authors of analysed works explained sociotechnical imaginaries referring to 10 significant theories and concepts. The popular one among them was the social practice theory (SPT). For SPT, the main object of investigation is the action of people (Sovacool and Hess 2017a). The use of the SPT frame allows the researcher to focus on analysing the intersection

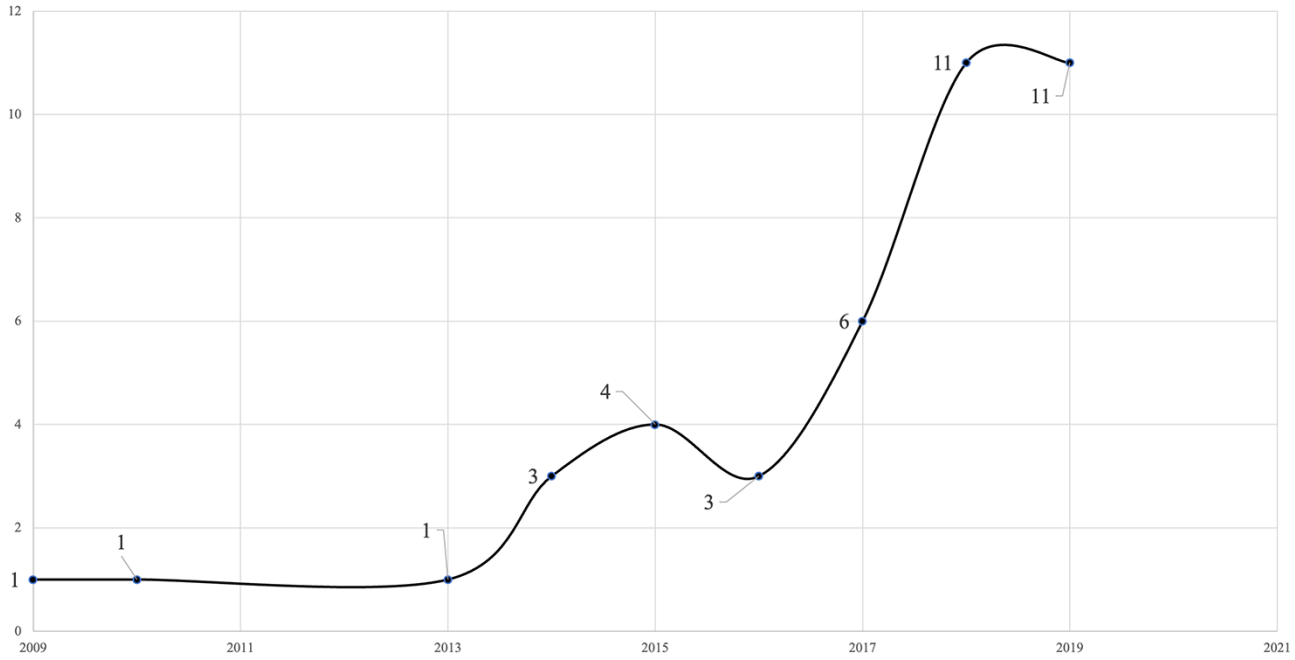


Figure 3. Total number of analysed publications with the keyword topic: sociotechnical imaginaries related to energy studies.
Source: own research.

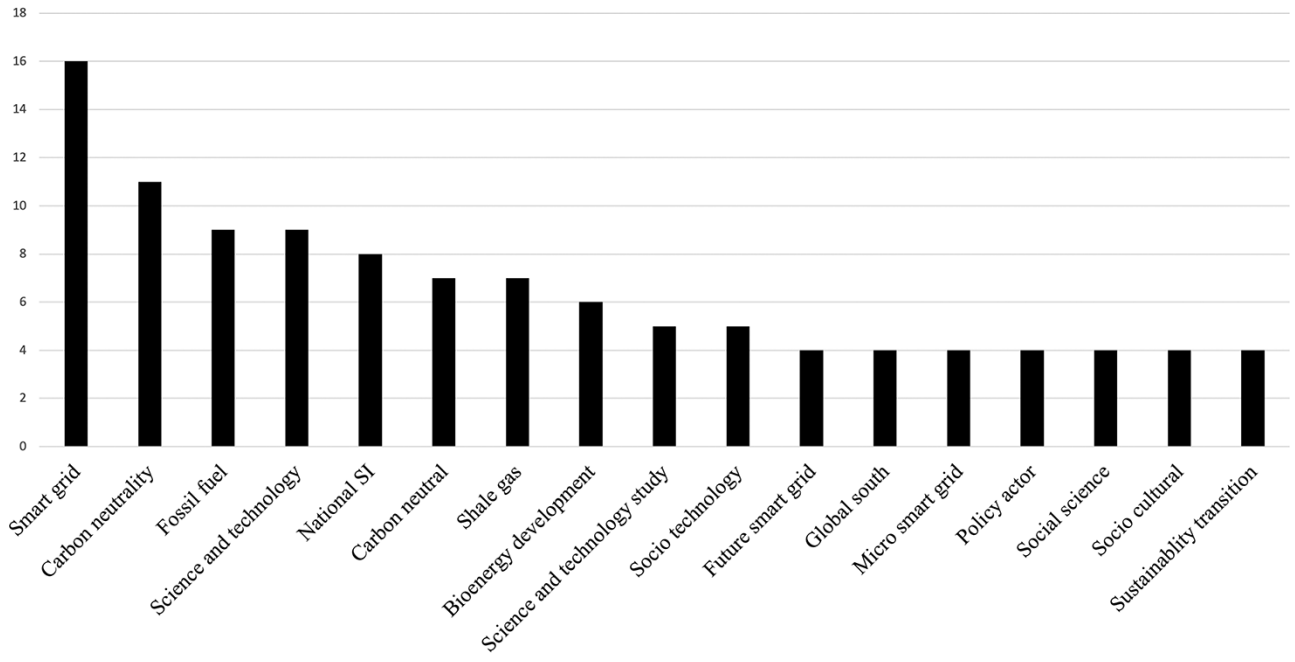


Figure 4. Distribution of phrases in sociotechnical imaginaries articles related to energy studies.
Source: own research.

of materiality (i.e. technology), competencies (i.e. knowledge), meanings assigned to certain items, as well as relations between particular practices (Shove et al. 2012; Schatzki et al. 2001). The SPT highlights the collectively shared knowledge shaping the terrain of choices, actions, and social order (Reckwitz 2004).

SIs in that context were recognised in three different ways: as crucial constructive elements in the organised field of social practice (Gross et al. 2019a; Cloke et al. 2017; Miller 2019a), a trigger to inspire social identities and practices (Santos Pereira et al. 2018a; Levenda et al. 2019a), and a tool to govern and influence social practices (Ryghaug and Toftaker 2016; Kuchler 2017a). In the light of SPT, sociotechnical imaginaries can be transformed through critical interrogation into *social practice imaginaries* understood as a forecast of the social practices based on the current trends in everyday life (Strengers et al. 2019a). Social practice imaginaries could be an important analytical tool in forecasting future

scenarios. They could also help answer how sociotechnical imaginaries of future practices determine the present research and development policies.

6.2 Co-production

The second most popular theory was co-production. The concept that scientific ideas or artefacts are at the same time co-produced with representations, identities, discourses, and institutions (Jasanoff 2004) has often been used as a theoretical background for the sociotechnical imaginaries notion. Jasanoff and Kim also indicated this approach. Co-production wa onnect civic epistemologies and sociotechnical imaginaries to understand how technoscientific and political orders are co-produced within the uptake of sociotechnical imaginaries (Santos Pereira et al. 2018a; Santos Pereira et al. 2017). This notion was also used to study how user representations are constructed and co-produced in policymaking (Ryghaug and Toftaker 2016). Co-production helped to understand how imaginaries of laypersons or the public in a broader sense are present in stakeholders' strategic processes. In simple words, how stakeholders imagine users during technological processes. Co-production is linked with the normative dimensions. Longhurst and Chilvers suggest that vision and imaginaries, which are descriptive and exploratory, could be normative and co-produce social and political order (Longhurst and Chilvers 2019).

6.3 Sociology of expectations and sociotechnical imaginaries performativity

Another promising approach is the sociology of expectations. Brown and Michel introduced this concept after analysing in-depth interviews of policymakers, public and private researchers, and clinical surgeons on the future of xenotransplantation (transplantation of animal tissues and organs to humans; Brown and Michael 2003). The authors show how expectations could influence research and the future development of entire technologies. They have a significant influence on the future and indicate the development direction and help coordinate interests. Expectations are more local, project-, or industry-specific, while sociotechnical imaginaries are much more stable and constitute a broader vision of the better and desirable future. Imaginaries performativity enables the performativity of expectations. As such, expectations are not performative because of their circulation in the public sphere but performative because of sociotechnical imaginaries (Korsnes 2016a). For instance, the widely present sociotechnical imaginary of energy future based on renewable sources enables the performativity of expectations that are active in more local and industry-specific targets and strategies. The related strand of the literature of the sociology of expectations could explain the performative mechanisms of sociotechnical imaginaries (Ballo 2015a; Borup et al. 2006; Rip et al. 1998; Karhunmaa 2019a). Sociotechnical imaginaries performativity could be analysed regarding their repeated reproduction in different dimensions (Gross et al. 2019b), for instance, in the acts of power (legal acts, political decisions, and fund allocations) coalition building or fostering the innovation (Graf and Sonnberger 2020; Gross et al. 2019b; Miller 2019). The performativity of sociotechnical imaginaries can be observed by adopting certain social norms, practices, policies, research, and fund allocation. Imaginaries influence people's choices and make scientific knowledge legitimate and rigorous (Tozer and Klenk 2018a). The answer to how imaginaries are performative and how they can influence societies, policies, and everyday lives is fundamental. From the mechanisms of the sociology of expectations, through general assumptions of multilevel perspective, *Foucauldian* governmentality, to prefigurative activism, the authors seek processes that enable imaginaries to influence social processes.

Marius Korsnes, the author of the article 'Ambition and ambiguity: Expectations and imaginaries developing offshore wind in China', bases his argumentation about the performativity of imaginaries and expectations on Berkhout's (2006) work. Following this argumentation, imaginaries can become performative only while attractive or relevant for a wide range of interests. Moreover, future visions are performative as they have the power to convince a wide range of social actors to a change (Korsnes 2016a; Skjølsvold 2014).

The performativity of sociotechnical imaginaries can be understood by the mechanism provided in numerous research done in expectations. Unlike the sociology of expectations, sociotechnical imaginaries act on a much broader scene, enabling the expectations to be performative. Sociotechnical imaginaries are performative in the sense that they help to mobilise resources or justify certain costs. They can merge hopes, concerns, and risks to fulfil a certain kind of future (Engels and Münch 2015). Performativity of specific sociotechnical imaginaries can be measured by assessing their impact on real-time policies, strategies throughout pop culture, media, and widely adopted societal visions of the future (Tozer and Klenk 2018b). The role of sociotechnical imaginaries is crucial to understand the co-production of science, technology, and society (Gross et al. 2019b).

Nevertheless, the dominant sociotechnical imaginary, which once was an essential factor in creating the future, can be changed by system changes or major worldwide disasters (Santos Pereira et al. 2017, 2018b; Bayer and Felt 2019). The process of changing the dominant sociotechnical imaginary could also occur from down-top perspective, as was proved by the case in The Philippines and Thailand (Marquardt and Delina 2019). To become widely recognised, collectively held, and performed, sociotechnical imaginary must have the performative power and be constantly reperformed in the policies, strategies, technology, and societal practices (Miller 2019a; Wentland 2016).

6.4 Utopia

As a sociological method, utopia is present in the works of Ernst Bloch (1988) and Ruth Levitas (2013). According to Ruth Levitas, utopian thinking is not only a delusion, but it can also be a sociological method, especially when sociology faces limitations in the study of ideas about the future. Utopia, despite technological fragmentation, refers to the holistic perception of collective practices and social imaginations (Levitas 2013). To eliminate those threats, societies create a vision about their future based on utopia and dystopia (Sovacool and Hess 2017a). This is associated with using utopia as a sociotechnical method and creating a safe future under control through pop culture, media, and policies (Levitas 2013). Utopia could be even regarded as a significant factor in political and economic concerns about the future (Jennifer and Kline 2017a) (Marquardt and Delina 2019a).

It helps societies designate development paths and could be a driving force for transitions and an analytical concept helpful to assess the potential of different visions (Kuchler 2014a). The concept has strong ties with future technological change (Strengers et al. 2019b). Some sociotechnical imaginaries could limit the utopian vision (Karhunmaa 2019a; Kuchler 2014a), while others, in their essence, are utopian (Wentland 2016).

6.5 Multilevel perspective

The theory of multilevel perspective, often called sociotechnical transition theory, could offer an essential input into the sociotechnical imaginaries concept. This approach focuses on the interactions between three levels: the landscape, the niche, and the regime (Geels 2002; Schot and Geels 2008). The answer to the question about the place of sociotechnical imaginaries in the sociotechnical transition is important to fully understand the mechanism of those changes in the dominant system. Only one out of 43 articles selected for this analysis focuses on this theory and links it with Jasanoff and Kim's concept. The authors of the article 'The politics of imaginaries and bioenergy sub-niches in the emerging Northeast U.S. bioenergy economy' focus on the struggle between different imaginaries and their paths towards inclusion into a broader energetical system. The authors describe the struggle of different imaginaries within the same niche and their interaction with the dominant (regime) imaginary. Actors within the niche propose different energy transition scenarios, argue only in the technological context, and challenge rival technology's material and symbolic features (Burnham et al. 2017). Different actors within the same niche envision their future technologies and solutions with the concept of what is good and desirable for society. Nevertheless, placing the Sociotechnical Imaginaries in relation to the Multi-Level Perspective needs further consideration.

6.6 Governmentality

Using the notion of governmentality proposed by Michel Foucault (Foucault 1977), Magdalena Kuchler tries to answer the question about the mechanism of materialising sociotechnical imaginaries, their visibility, performativity, and transformation into practice (Kuchler 2017b). Governmentality in the *Foucauldian* sense is a micro-political analysis of power. Power is understood as the process of propelling *action upon action*. For instance, technological development could be interpreted in the sense that the government creates a playground in which the rules and pitch size are set in advance. This understanding of concept of power and its implications over modern societies helps us discover sociotechnical imaginaries' mechanism. Using the notion of governmentality analysis, we can assume that national or multinational governmental institutions through different sociotechnical imaginaries can potentially govern and control the future by setting the 'rules and playground' in which societies imagine the future in a certain way. Magdalena Kuchler, in her article, uses two aspects of governmentality: *rationalities of government* to understand how new energy technology became reasonable and *technologies of government* to operationalise those rationalities through practices and visions of different actors and institutions (Kuchler 2017b).

6.7 Prefigurative activism

Jeans Marquardt and Laurence L. Delina, during their research on energy transitions in Thailand and the Philippines, proposed to connect sociotechnical imaginaries and prefigurative activism. The concept of prefigurative activism describes the phenomena of social activation, thanks to a solid alternative vision of the future (Marquardt and Delina 2019a). Both authors argue that the community in Phetchaburi (in Thailand), which is implementing renewable energy projects, and strong local community resistance against the coal-fired electric plant on Palawan Island in the Philippines, could be used as an example of social mobilisation through prefigurative activism. This resistance has helped establish alternative visions of the energy future through sociotechnical imaginaries in a broader context (Marquardt and Delina 2019a). The authors use the notion of sociotechnical imaginaries as a key to understanding the role of knowledge, social order, and power production. Marquardt and Delina stress out that prefigurative activism could be 'at least' partially understood as a sociotechnical imaginary in action (Marquardt and Delina 2019a). Their three-step concept of energy transition based on envisioning performance and consolidation connects both notions. Future-oriented activism, influenced by sociotechnical imaginary of alternative futures and supported by technological breakthroughs (e.g.for example new renewable energy solutions), is performative concerning the national energy policies. That leads to the creation and establishment of alternatives, contesting dominant energy networks, and changing dominant power relations. As a consequence, the energy transition is implemented, resulting in new norms and regimes. Sociotechnical imaginaries, fostering changes, influence the whole process.

6.8 Conflicts

However, according to their definition, sociotechnical imaginaries are collective visions that enable technoscientific practices and policies. It does not mean that in certain societies or social groups do not exist alternative imaginaries contesting those dominant ones. The outcomes of Smith and Tidwell's study had significant inputs into Jasanoff and Kim's concept. They based their research on the anthropological work on energy and the assumption that people interact with energy, not as a monolith. Still, peoples attitudes towards the energy system depend on their societal position. The authors are trying to recognise and understand the role of transnational/national sociotechnical imaginaries in their ever. Researching ethics and future energy system visions of miners and people living in mining areas resulted in distinguishing different imaginaries of blue-collar workers (energy producers) from the dominant sociotechnical imaginary of energy consumers (Smith and Tidwell 2016a). As recognised during qualitative analysis, theoretical assumptions suggest that many authors used several different theoretical approaches to place their research on sociotechnical imaginaries in context. However, 10 different concepts were identified. They all create a comprehensive and solid theoretical base describing crucial mechanisms of imaginaries within society. Those different approaches and terms flexibility also suggest the opportunity for further research on the concept development in the context of utopia, risk, or reflexive modernisation (Beck 2014). Further investigations

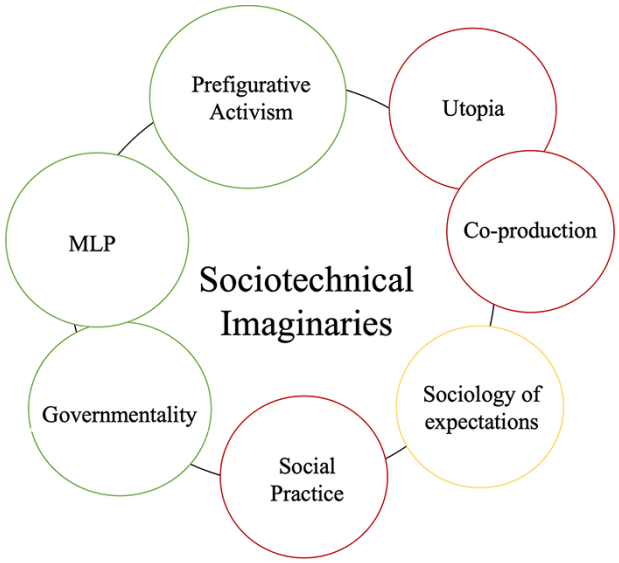


Figure 5. Theories and related concepts identified during the analysis of selected articles and their relations. Own elaboration.

should also be done, putting more emphasis on reflection on relations between sociotechnical imaginaries and public reason together with a focus on civic epistemologies and bioconstitutionalism (Jasanoff 2011a, 2012).

The outcomes of this study demonstrated that the concept is still alive. It is widely used and put into context with different theories (Fig. 5). However, new theoretical perspectives are supporting the existence and foundations of sociotechnical imaginaries. Researchers need to avoid traps that could result in inconsistent theoretical or epistemological assumptions. It is worth noticing the importance of the SPT alongside this study's results that suggest the presence of sociotechnical imaginaries mainly in the knowledge areas rather than in practices. In turn, this raises the necessity of putting more emphasis on conducting research more focused on practices. Another example of inconsistencies could be the system perspective present in a significant number of analysed abstracts and articles, together with an interpretative paradigm in which imaginaries are embedded. Moreover, sociotechnical imaginaries are identified at many societal levels and become a unifying factor that sets goals for particular social groups. Still, the way that each entity or social actor performs his imaginary through specific policy or practice can be different (Karhunmaa 2019b). In simple terms, it means that each imaginary can manifest itself in distinct ways, which causes a significant problem for scientists while determining an imaginary.

7. Social realities in which sociotechnical imaginaries are studied

It is a challenge to analyse the operationalisation of the concept systematically. For the purpose of this paper, operationalisation is understood as an expression of the theoretical and conceptual design in various empirical dimensions. That is why the author proposes to analyse how the sociotechnical imaginaries are studied throughout the source of data, time dimensions, and the level of analysis.

Table 1. Most frequently used research materials in all 43 analysed articles. Own elaboration.

Research material	Cases (research papers)
Scientific literature analysis	43 (17)
Government/stakeholders documents or strategies	22
Media discourse	13
NGO's documents, strategies, position papers	5
Conferences, workshops observations	5
Fieldwork observations	2

As illustrated in Table 1, most authors took the path set by Sheila Jasanoff and Sang-Hyun Kim. They focused on government as well as significant energy system stakeholders. A considerable number of authors focused on analysing imaginaries through interviews, documents, and strategies. Furthermore, even major theoretical concepts can be explored to understand the processes of sociotechnical imaginaries creation. Seventeen papers were explicitly focused not only on summarising scientific literature on that field, but the literature review was a research purpose in itself. Twenty-two papers used media discourse analysis to retrieve the significant dominant assumptions about the future of the energy system with the support of technoscientific achievements. Only five articles analysed the non-governmental organisations' views on the energy system.

Figure 6[2] shows that the most common co-occurrence of research material appeared when authors searched for a sociotechnical imaginary in government and stakeholders' documents and scientific literature analysis. Another common element reviewed to find sociotechnical imaginaries was media discourse analysis and non-governmental organisations' statements and documents. The results of that part of the study suggest that the authors focused only on governmental documents, strategies, and expert knowledge. A minimal number of papers seeking imaginaries during the fieldwork observation and no research in pop culture narratives cause a significant gap in scientific knowledge. Searching for imaginaries of progress and future only in state documents, media coverage, or expert knowledge and at the same time avoiding pop culture products limit the range of answers about the circulation of sociotechnical imaginaries in the public sphere as well as their origins.

Moreover, only seven out of 43 analysed papers took a methodological approach that clearly shows the data analysis plan, the particular components of each imaginary (metaphors and language figurativeness), and how certain elements are connected. The remaining ones focus instead on a catalogue of imaginaries without referring to their origins, components, or language elements constituting them. This example is a significant knowledge gap and creates a scientific need to create a coherent list of boundaries that would enable us to define specific future visions as imaginaries.

7.1 Where can we find sociotechnical imaginaries in the future or the past?

Sheila Jasanoff and Kim Sang-Hyun introduced the sociotechnical imaginaries concept by analysing political narratives and most relevant historical events. While both scholars introduced this notion by studying nuclear power regulations in

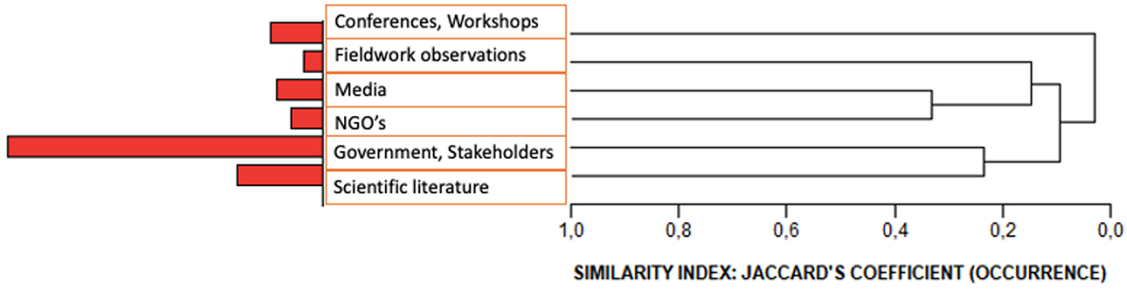


Figure 6. Coding co-occurrence research material used in analysed articles. Own elaboration.

the Republic of Korea (South Korea) and the USA, Portuguese and Austrian scholars had a similar focus to understand the role of sociotechnical imaginaries through historical analysis. Portuguese academics analysed the history of nuclear energy debates in the Portuguese parliament (Santos Pereira et al. 2017, 2018b). Austrian scholars Florian Bayer and Ulrike Felt followed a similar research design to analyse the nuclear energy imaginary as a crucial factor in creating Austria's post–World War II future (Bayer and Felt 2019). In addition, a significant focus on historical events and narratives is present in the work by Abraham Tidwell and Jessica Smith. The authors reviewed energy security as an American sociotechnical imaginary and stressed the importance of the genealogical approach (Tidwell and Smith 2015). What is more, there are some works by Nathan Kapoor on imaginaries of electricity in Victorian Brittan or by Jennifer L. Liberman and Roland R. Kline on electrical utopian novelists and their imaginaries of energy future (Kapoor 2019; Jennifer and Kline 2017a).

Nevertheless, the genealogical approach is not dominant. The vast majority of authors decided to dedicate their works to present discourses, policies, and narratives. The majority of authors followed Jasanoff's and Kim's definition, but there is a lack of projects trying to understand the origins of each imaginary. There is a need to further develop research into imaginaries roots and visions that enabled their emergence. The authors mainly created a catalogue of existing imaginaries without answering how they become visible, collective, and institutionally stabilised. Most of the analysed articles focused on what those collectively held visions are, how we can describe them, and how they are present in certain documents, media discourses, and political decisions. For those authors, it was essential to find an answer to how they perform, influence, and shape global, national, or regional policies. The majority of authors focused on creating a catalogue of individual sociotechnical imaginaries rather than answering how the dominant ones compete with the alternative ones or how the process of uniting visions and elaboration of sociotechnical imaginaries looks like.

7.2 Global, national, or regional?

Sheila Jasanoff and Sang-Hyun Kim introduced the sociotechnical imaginaries concept with its strict connection to the state, even calling them *national sociotechnical imaginaries*. The authors emphasise that one of the underlying assumptions of sociotechnical imaginaries research is that they can be identified by cross-national comparison (Jasanoff and Kim 2009; Jasanoff and Kim 2013). The perspective on this issue has changed in the book *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power.* Jasanoff and Kim changed their view on the concept. They underlined that sociotechnical imaginaries could be analysed not only in the state but also in regional, transnational, or even private organisation context (e.g. big international corporations; Jasanoff and Kim 2015). Contrary to previous research on sociotechnical imaginaries, Tidwell and Tidwell also proposed a shift in this dimension. The authors suggest including into consideration not only policies, strategies, and political speeches but also small entities and people's behaviours—in simple terms, to confront those sociotechnical imaginaries present in national or multinational discourses with *real people* (everyday lives) cultural models, attitudes, and practices (Tidwell and Tidwell 2018).

Analysed research papers were also coded to verify their attitudes towards understanding sociotechnical imaginaries in their national, regional, or transnational context. Twenty articles focus on understanding the concept as nation-specific, analysing energy future and vision on the nation-state level. There are also articles combining regional and transnational approaches, for instance, the study of urban views on energy transition (Miller 2019a; Tozer and Klenk 2018a) air quality action plans between London, Hong Kong, and San Francisco (Gross et al. 2019b) as well as the Carbon Neutral Cities Alliance framework (Tozer and Klenk 2019).

There is a work focusing on a transnational comparison of sociotechnical imaginaries using the European Research Programme Framework and its support for energy-related projects (Throndsen 2017). There is also an Arab peninsula context: the analysis of the energy system development of the Gulf Country Cooperation council (Günel 2018a).

What is more important in the overall context is a paper analysing the global imaginaries of 'Plan B' (imaginary of geoengineering as a last hope to mitigate climate change effects; Corry 2017).

The regional aspect in investigating sociotechnical imaginaries is also crucial to answer the question about the origins of dominant collectively held visions of the future (Levenda et al. 2019b). Several articles dealt with regional imaginaries of bioenergy systems in some areas of the USA (Burnham et al. 2017; Schelhas et al. 2018; Smith and Tidwell 2016a).

As we can see, most authors try to search for sociotechnical imaginaries on the national level. There is a lack of empirical works on regional imaginaries and cross-comparative reviews comparing the local, regional, national, and transnational dimensions of Jasanoff and Kim's concept. It is vital to develop such an approach further. In layman's terms, local and national social actors have individual imaginaries. Still,

Table 2. Most frequently used research methods in all 43 analysed articles. Own elaboration.

Method	Cases (research paper)
Interviews	18
Content analysis	13
Discourse analysis	7
Participatory observation	6
Case study	6
Grounded theory	4
Backcasting	1
Ethnographic research	1
Corpus linguistic comparison	1
Bibliometric	1
Narrative-based evidence	1
Focus group interview	1
Group discussion	1
STIR—sociotechnical integration research	1
Textual network analysis	1
Historical analysis	1

the way those imaginaries are performed and implemented in policies or practices on different levels is significantly different (Karhunmaa 2019a). That is why developing research on sociotechnical imaginaries in that direction seems to be crucial.

8. Epistemology of sociotechnical imaginaries research

According to the results shown in Table 2, in most research papers analysed for this article, the dominant research method was to interview key actors, stakeholders, and ordinary people.

Semi-structured interviews were conducted with relevant social actors:

1. Stakeholders, politicians, and experts (Korsnes 2016a; Miller 2019a; Wentland 2016; Ballo 2015b; Barandiarán 2019; Levidow and Papaioannou 2013a; Engels and Münch 2015; Delina 2018)
2. Scientists, activists, and lay citizens (Santos Pereira et al. 2018b; (Schelhas et al. 2018; Mutter 2019a, 2019b; Marquardt and Delina 2019).
3. Non-governmental organisations (NGO)'s and energy sector experts (Ryghaug and Toftaker 2016; Simmet 2018

Not surprisingly, the second most frequent method was content and discourse analysis focused on finding sociotechnical imaginaries in media, strategies, and policies. The differences between the research material used in the content and discourse analysis are shown in Table 3.

Participant observation was an essential element of six articles. Researchers were observing: the participants and actual conferences and energy-related events (Karhunmaa 2019b; Korsnes 2016a; Simmet 2018a), electric vehicle stakeholders, and experts work (Wentland 2016), as well as ethnographic fieldwork in small communities in Thailand and The Philippines. They also examined the everyday lives of those living in Colorado's uranium-rich Western Slope and Wyoming's coal-rich Powder River Basin (Marquardt and Delina 2019a; Smith and Tidwell 2016).

Alongside participants' observation, the third most frequently used method was the case study. In all cases, it was a broader method that also included the participant's observation. Four research designs explicitly use the grounded theory approach (Korsnes 2016a; Tozer and Klenk 2018b, 2019; Wentland 2016). The rest of the methods were just used in single cases. It is worth noticing a very interesting approach—sociotechnical integration research (STIR). This is a laboratory method that enables in-depth cooperation between social scientists and technological experts. It is designed to integrate the social science perspective into a natural science research design. This methodological approach allows for resolving technological issues together with co-produced social problems in one place (Fisher 2007). Focusing on the work of urban scientists to develop smart energy cities could be an essential factor for detecting the sociotechnical imaginaries that shape the development of smart cities (Richter et al. 2017). The results from this section of the analysis clearly show that most authors focused on searching for imaginaries in political documents and expert knowledge. There is a lack of empirical research that would consider future visions present in pop culture products and ordinary people narratives. What is more vital, the ethnographical research that could facilitate the answer about the origins of sociotechnical imaginaries and the process of transforming individual visions into imaginaries is absent.

9. A broader approach for sociotechnical imaginaries. A way towards public reasons

An extensive spectrum of topics in which those collective, normative visions of the future are researched shows significant study potential. From the beginning, the definition provided by Jasanoff and Kim has been developing over time. The concept was introduced in 2009 and gained its final shape in 2015. Since then, it has become an analytical tool to consider future visions and the role of technology as a crucial co-production element in society, even though the idea of sociotechnical imaginaries is relatively new. Nevertheless, it is rooted deeply in the history of sociology and philosophy. Starting with Weberian *Verstehen* up to social imaginaries, Jasanoff and Kim's concept links political and cultural theories and sociotechnical systems This approach enables the possibility to answer the question about the performativity of technology and imaginaries in social systems. Furthermore, the author proposes that the concept can be seen in a broader spectrum, using the notion of *public reason*. Jasanoff created a matrix that enabled us to understand how the state justifies its exercises of power over society using the concepts of civic epistemologies, sociotechnical imaginaries, and bioconstitutionalism. Institutionalised practices by which members of the society judge and put the knowledge into practice (civic epistemologies), as well as the outcomes of the interplay between life and legal aspects (bioconstitutionalism) together with the visions of the future (sociotechnical imaginaries), are fundamental to understand modern societies.

As the study results show, there is a shortage of such comparative research focusing on *public reason*. Only two articles selected for this analysis connected the sociotechnical imaginaries in a broader perspective of civic epistemology and its role in shaping the sociotechnical imaginaries. The results manifesting the birth of pluralistic civic epistemology in Portugal after the collapse of the fascist regime that

Table 3. Comparison of content analysis with discourse analysis in all 43 analysed articles. Own elaboration.

Method	Research material	Research paper
Content analysis	• National and local parliamentary debates • Energy policy documents • Relevant literature review • Strategies and plans	(Karhunmaa 2019b), (Santos Pereira et al., 2018b), Longhurst and Chilvers, (2019), Tidwell and Smith (2015, (Gross et al. 2019b), (Kuchler 2017a), (Delina 2018a), Graf and Sonnberger (2020), (Kuchler 2014b), (Levidow and Papaioannou 2013a)
	• Utopian novels • Media materials	(Lieberman Jennifer and Kline 2017a) Barandiarán (2019)
Discourse analysis	• Climate governance texts • Local stakeholders' strategies • Action plans • Official webpages	(Tozer and Klenk 2018b), (Ballo 2015a), (Levenda et al. 2019a), Tozer and Klenk (2019)
	• Media reports • Written and verbal communication during the STIR procedure	(Marquardt and Delina 2019a) Richter et al. (2017)

affected the public reasoning on nuclear energy in that country (Santos Pereira et al. 2018b) could be an essential path to follow while researching the sociotechnical imaginaries or public reasons in democratic and authoritarian societies. However, the answer to the question of how specific sociotechnical imaginary resonates with particular civic epistemology and bioconstitutional relations remains still without an explanation. The concept present in the analysed research pieces can be perceived as more focused on knowledge and discourses rather than on practices. At the same time, SPT was the most commonly used hypothesis in reflection on sociotechnical imaginaries, which could be interpreted as a significant path to follow in future research. Although sociotechnical imaginaries in discourses are widely researched, their presence in social practices with their sets of research methods seems underrepresented.

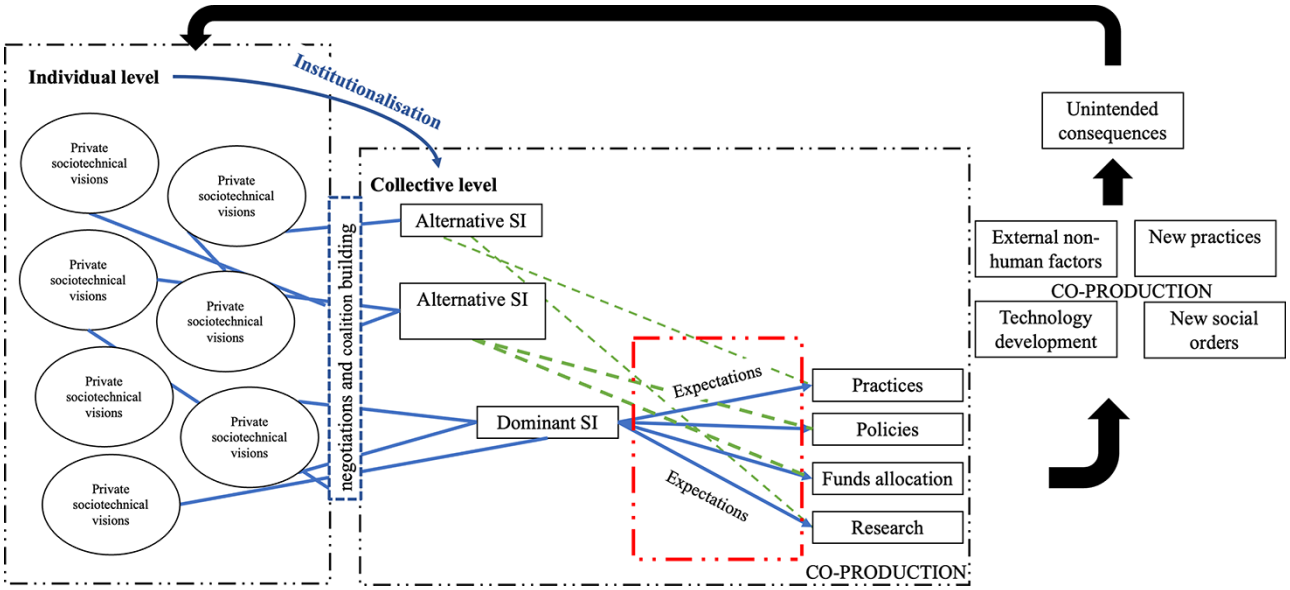
Another blind spot is sociotechnical imaginaries in pop culture. We need to answer the question concerning the consistency of dominant and alternative imaginaries, which could help to gain a broader view and comparative perspective in different contexts. None of the authors looked deeper into the connections between sociotechnical imaginaries and bioconstitutionalism. The majority of papers looked for imaginaries in legal acts and documents, but neither took the *legal-science interplay* approach. The *public reason* term as a meta context that will connect all the concepts mentioned above into a more comprehensive analytical term could be an essential input into the STS scientific field. Imaginaries are inextricably linked with regulations, knowledge-making processes and practices. That is why it is crucial to use the broader term *public reason* that comprises sociotechnical imaginaries, civic epistemologies, bioconstitutionalism, and all the relations among them.

10. A way forward. A new approach towards the concept of operationalisation

The growing interest of researchers dealing with sociotechnical imaginaries created different approaches to the research using the concept. The differences between theories and concepts that researchers drew on became significant, proving the universality of Jasanoff and Kim's idea. Similarly, various notions were used to explain the performativity of imaginaries, raising doubts about the stability of the concept. At the beginning of this article, the author defined *stability* as '…it does not mean invariability but consistency in understanding the phenomenon itself, methods of its research and the purpose of these studies. This applies to both the concept complexity, as well as to the understanding formation and functioning of imaginations processes'. As indicated in the study results, it is justified to state that although the understanding of the notion is consistent, the methods of its investigations are different. Researchers did not use the same techniques regarding the exploration of sociotechnical imaginaries. They did not follow the same patterns while judging whether certain elements are their part. Although the performativity of imaginaries could be understood from different perspectives, this aspect is well described. Indeed, there is a lack of research that deals with the processes of imaginaries formation.

There are also differences between the level of analysis, whether sociotechnical imaginaries should be considered on a global, national, regional, or local scale. The majority of authors choose one dimension and avoid a cross-level comparison. The results showed that despite the enormous amount of work done in national and cross-national comparison, there is a need to conduct wide-scale research and compare sociotechnical imaginaries across the different levels and scales. Since sociotechnical imaginaries could be present on such different levels as policies, strategies, and everyday practices (Sovacool and Hess 2017), a question about the struggles of different sociotechnical imaginaries on diverse levels remains valid. For instance, there is a need for multi-dimensional research that should reveal the mechanisms enabling particular sociotechnical imaginaries to be dominant. Despite the significant amount of work done to set theoretical and empirical backgrounds for their performativity, there is still a demand to develop coherent performativity measures. It will enable us to judge whether a particular sociotechnical imaginary impacts an individual policy, discourse, or strategy.

Drawing on the outcomes of this study and proposed umbrella theoretical approach of public reason (Section 10), the author developed a figure called 'sociotechnical imaginaries cycle' to show the mechanisms of their influence upon society. The developed integrated model builds on the concept of private visions proposed by Berkhout (2006), narrowed to



Graph 2. Sociotechnical imaginaries cycle. Own elaboration.

the visions of social development associated with technology and called by the author private sociotechnical visions.

As the author proposed in Graph 2, some sociotechnical imaginaries that originate from private sociotechnical visions are getting stability throughout the institutionalisation (understood as negotiations and coalition building of different private sociotechnical visions) and start to be publicly reperformed in official institutional (governmental, NGOs, and other institutions) statements, documents, legal acts, goals and strategies, or pop-culture products by various actors. SIs are performed through the actors' actions and are expressed by the actors. However, in some way, they become external to individuals, being objectified, and shared collectively. In the proposed model, I do not exclude the actors. Instead, I focus on the imaginaries treating actors as involved in them, shaping them and being shaped by them.

The dominant imaginary, usually together with the alternative imaginaries, influences practices, policies, funds, and research (Delina 2018a). Here, the concept of expectations (see Section 6.3) is a crucial factor. Expectations triggered by sociotechnical imaginaries stimulate actors and mobilise the resources for specific tasks and projects. In this sense, expectations are more project- and goal-oriented, whereas sociotechnical imaginaries are broader and create certain expectations.

The role of alternative imaginaries is also crucial. They can be represented by various NGOs, alternative groups of interest, and even artistic expressions in pop culture. The influence of alternative imaginaries co-produces new social orders and technological advancements in certain areas. Even though they are niche, their partial impact on practices, policies, funding, and research can lead to many unintended consequences, creating new sociotechnical imaginaries and making the other one dominant. A vital example here can be the emergence of new possible development paths against the dominant regime in Thailand and the Philippines (Marquardt and Delina 2019).

The main mechanism that makes sociotechnical imaginaries collectively held and stable is the interrogation of the private sociotechnical visions through negotiations and coalition building into institutionally stabilised collectively held visions of the future. The measuring of their real impact on practices, policies, funds allocation, and research can be traced by a comprehensive comparative analysis of practices, policies, fund allocation, and selected research directions.

11. Conclusion and policy implications

This research shows a significant scientific development of the sociotechnical imaginaries concept since 2009. Its foundations, rooted in the social imaginaries, imagined democracies, coproduction, and Actor–Network Theory, created a new way of analysing the future vision connected to technological development (see Section 3). However, since the concept gained significant popularity, its operationalisation and theoretical background began to be varied. From SPT, expectations, utopia, Foucauldian governmentality, or MLP, sociotechnical imaginaries began to operate both in interpretive paradigm (in which their authors place them) and in the system perspective (see Section 7), which significantly questions the concept of stability and its foundations. Building on those theoretical approaches, authors, however, were consistent in selecting certain epistemologies: focusing on state documents and interviews and leaving the whole spectrum of research material, i.e. documents (statements, goals strategies of NGOs, and other non-governmental institutions) as well as pop culture. Based on those results, the author proposes a broader theoretical frame based on the public reason term (see Section 10) and a sociotechnical imaginaries cycle (see Graph 2), which could facilitate the understanding of the sociotechnical imaginaries formation, performativity, relations between dominant and alternative ones, as well as potential changes to its structure.

The focus on narratives and imaginaries is getting traction in energy research. It became the second most important research question theme in the 100 Social Sciences and

Humanities priority research questions for renewable energy in Horizon Europe (von Wirth et al. 2020). Understanding the role of imaginaries and narratives in energy transitions and political processes is an important issue. However, difficult to capture, being a sort of magnetic wave behind fund allocation, policies, research, or political agenda, they could be a significant element of shaping the policy agenda. Making them tangible and visible is a crucial step to make them useful for policymakers. Dominant sociotechnical imaginaries are usually in relation to the alternative ones. Recognising them, using the model proposed by the author, might be a potential input in improving the transformation policies. The awareness of the existence of various imaginaries can facilitate the translation of international policies into national or local ones. Finally, capturing imaginaries can facilitate shaping the temporality of the policies.

The imagined point in the horizon shaping people's desires and actions can be an essential element of why certain policy timelines are forecasted only to the specific point in time. For some actors, the deadline for transforming the energy system must end in 10 years, and some claim that the 2050 or 2060 goal is reasonable. This research showed that authors differently perceived borders of the future. For some, 5–10 years were a borderline of the forthcoming (Gross et al. 2019b; Günel 2018b). They confirmed that a similar point in time as a reference for a sociotechnical imaginary could be present in different cultural, social, and geographical contexts (Gross et al. 2019c). Some futures ended in 2062 (Corsini et al. 2019) or in 2050 (Delina 2018; Levidow and Papaioannou 2013b; Lieberman Jennifer and Kline 2017a; Strengers et al. 2019b), 2036 (Delina 2018a), as well as in 2030 (Corsini et al. 2019; Kuchler 2014b, 2017a; Wentland 2016). At the same time, other researchers did not specifically refer to the notion of time and left the future as an open-ended perspective. Perceiving the temporality of the future imaginaries as a research goal itself can facilitate understanding the different perceptions of the future. As we can see, understanding imaginaries can help comprehend those processes, and this article was designed to help summarise methods, contexts, and research material where imaginaries could be captured.

Funding

This work was supported by the Jagiellonian University Doctoral School in the Social Sciences (Grant number 23/04/2020).

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

Acknowledgements

The author is grateful for the support and help of Professor Aleksandra Wagner, Katarzyna Rabiej-Sienicka, Ph-D, and Grzegorz Bryda, Ph-D, as well as all the members of the Department of Social Communication at the Institute of Sociology, Jagiellonian University. The author also wishes to acknowledge the editor and reviewers gratefully.

Notes

1. The rising trend is present in many other scientific fields. The author is pointing to the dynamics of the trend rather than exact numbers.
2. Observations were divided into two categories: fieldwork observations understood as observing everyday practices of certain social actors as it is present in Smith and Tidwell (2016a) and Marquardt and Delina (2019a) and observation of sector-related events and conferences as it is present in Karhunmaa (2019a), Korsnes (2016b), Simmet (2018a), Strengers et al. (2019a) and Wentland (2016).

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Appendix A. List of 135 abstracts downloaded from the Webofknowladfe.com website that were used to the analysis.

No.	Publication type	Authors	Title	Journal	Publication year
1	Journal Paper	Jewitt C., Mackley K.L., Price S.	Digital touch for remote personal communication: An emergent sociotechnical imaginary	*New Media & Society*	2019
2	Journal Paper	Miller T.R.	Imaginaries of sustainability: The techno-politics of smart cities	*Science as Culture*	2019
3	Journal Paper	Shortall O.	Cows eat grass, don't they? Contrasting sociotechnical imaginaries of the role of grazing in the UK and Irish dairy sectors	*Journal of Rural Studies*	2019
4	Journal Paper	Bocci P.	Utopian conservation: scientific humanism, evolution, and island imaginaries on the Galapagos Islands	*Science Technology & Human Values*	2019
5	Journal Paper	Graf A., Sonnberger M.	Responsibility, rationality, and acceptance: How future users of autonomous driving are constructed in stakeholders' sociotechnical imaginaries	*Public Understanding of Science*	2020
6	Journal Paper	de Hoop E., van Oers L., Becker S., Macrorie R., Spath P., Astola M., Boon W.	Smart as a global vision? Exploring smart in local district development projects	*Architecture and Culture*	2019
7	Journal Paper	Mutter A.	Obduracy and change in urban transport-Understanding competition between sustainable fuels in Swedish municipalities	*Sustainability*	2019
8	Journal Paper	Engels F., Wentland A., Pfotenhauer S.M.	Testing future societies? Developing a framework for test beds and living labs as instruments of innovation governance	*Research Policy*	2019
9	Journal Paper	Bach A.S., Krolokke C.	Hope and happy futurity in the Cryotank: Biomedical imaginaries of ovarian tissue freezing	*Science as Culture*	
10	Journal Paper	Jasanoff S., Kim S.H. (eds)	Dreamscapes of modernity: Sociotechnical imaginaries and the fabrication of power	*Technology and Culture*	2019
11	Journal Paper	Felt U., Ochsner S.	Reordering the world of things: The sociotechnical imaginary of RFID tagging and new geographies of responsibility	*Science and Engineering Ethics*	2019
12	Journal Paper	Lupton D., Leahy D.	Reimagining digital health education: Reflections on the possibilities of the storyboarding method	*Health Education Journal*	2019
13	Journal Paper	Matos S.	Privacy and data protection in the surveillance society: The case of the Prum system	*Journal of Forensic and Legal Medicine*	2019
14	Journal Paper	Higham R.	Imagining the future of cell therapies: Clinical trials, innovation and the intersection of clinical-academic and commercial visions	*New Genetics and Society*	2019
15	Journal Paper	Papasozomenou O., Moss T., Soler N.G.	Raindrops keep falling on my roof: imaginaries, infrastructures and institutions shaping rainwater harvesting in Berlin	*Journal of Environmental Policy & Planning*	2019
16	Journal Paper	Ramiel H.	User or student: Constructing the subject in Edtech incubator	*Discourse-Studies in the Cultural Politics of Education*	2019
17	Journal Paper	Juhl J., Buch A.	Transforming academia: The role of education	*Educational Philosophy and Theory*	2019
18	Journal Paper	Shankar K.	The future of information studies: Reflections on sociotechnical imaginaries	*Bibliothek Forschung und Praxis*	2019
19	Journal Paper	Longhurst N., Chilvers J.	Mapping diverse visions of energy transitions: Co-producing sociotechnical imaginaries	*Sustainability Science*	2019

20	Journal Paper	Tarkkala H., Helen I.„ Snell K.	From health to wealth: The future of personalized medicine in the making	*Futures*	2019
21	Journal Paper	Karhunmaa K.	Attaining carbon neutrality in Finnish parliamentary and city council debates	*Futures*	2019
22	Journal Paper	Levenda A.M., Richter J., Miller T., Fisher E.	Regional sociotechnical imaginaries and the governance of energy innovations	*Futures*	2019
23	Journal Paper	Tozer L., Klenk N.	Urban configurations of carbon neutrality: Insights from the Carbon Neutral Cities Alliance	*Environment and Planning C-Politics and Space*	2019
24	Journal Paper	Corsini F., Certoma C., Dyer M., Frey M.	Participatory energy: Research, imaginaries and practices on people' contribute to energy systems in the smart city	*Technological Forecasting and Social Change*	2019
25	Journal Paper	Mutter A.	Mobilizing sociotechnical imaginaries of fossil-free futures - Electricity and biogas in public transport in Linkoping, Sweden	*Energy Research & Social Science*	2019
26	Journal Paper	Marquardt J., Delina L.L.	Reimagining energy futures: Contributions from community sustainable energy transitions in Thailand and the Philippines	*Energy Research & Social Science*	2019
27	Journal Paper	Wajcman J.	The digital architecture of time management	*Science Technology & Human Values*	2019
28	Journal Paper	Gross P.L., Buchanan N., Sane S.	Blue skies in the making: Air quality action plans and urban imaginaries in London, Hong Kong, and San Francisco	*Energy Research & Social Science*	2019
29	Journal Paper	Strengers Y., Pink S., Nicholls L.	Smart energy futures and social practice imaginaries: Forecasting scenarios for pet care in Australian homes	*Energy Research & Social Science*	2019
30	Journal Paper	Chang E.	Beyond workforce preparation: contested visions of 'twenty-first century' education reform	*Discourse-Studies in the Cultural Politics of Education*	2019
31	Journal Paper	Gerhold L., Schmidt T., Brandes E.	Making use of foresight to capture the co-evolution of security technologies and societal development	2019 IEEE International Symposium on Technology and Society (ISTAS)	2019
32	Journal Paper	Muravyov D.	Governing through imagination: Approaching internet governance in authoritarian contexts	*Internet Science*	2019
33	Journal Paper	Keidiia A.	Imagining internet in contemporary Russia: An attempt in operationalization of sociotechnical imaginaries	*Internet Science*	2019
34	Journal Paper	Forlano L.	Stabilizing/destabilizing the driverless city: Speculative futures and autonomous vehicles	*International Journal of Communication*	2019
35	Journal Paper	Barandiaran J.	Lithium and development imaginaries in Chile, Argentina and Bolivia	*World Development*	2019
36	Journal Paper	Pereira T.S., Fonseca P.F.C., Carvalho A.	Carnation atoms? A history of nuclear energy in Portugal	*Minerva*	2018
37	Journal Paper	Chamuah A.	For a aociology of Aadhaar	*Contributions to Indian Sociology*	2018
38	Journal Paper	Yang C.Y., Szerszynski B., Wynne B.	The making of power shortage: The sociotechnical imaginary of nationalist high modernism and its pragmatic rationality in electricity planning in Taiwan	*East Asian Science Technology and Society-An International Journal*	2018
39	Journal Paper	Meehan K., Klenk N.L., Mendez F.	The geopolitics of climate knowledge mobilization: Transdisciplinary research at the science-policy interface(s) in the Americas	*Science Technology & Human Values*	2018

(continued)

Appendix A. (Continued)

No.	Publication type	Authors	Title	Journal	Publication year
40	Journal Paper	Sigl L., Leisyte L.	Imaginaries of invention management: Comparing path dependencies in East and West Germany	*Minerva*	2018
41	Journal Paper	Smallman M.	Science to the rescue or contingent progress? Comparing 10 years of public, expert, and policy discourses on new and emerging science and technology in the United Kingdom	*Public Understanding of Science*	2018
42	Journal Paper				
43	Journal Paper	Simmet H.R.	Lighting a dark continent: Imaginaries of energy transition in Senegal	*Energy Research & Social Science*	2018
44	Journal Paper	Tidwell J.H., Tidwell A.S.D.	Energy ideals, visions, narratives, and rhetoric: Examining sociotechnical imaginaries theory and methodology in energy research	*Energy Research & Social Science*	2018
45	Journal Paper	Tutton R.	Multiplanetary imaginaries and utopia: The case of Mars one	*Science Technology & Human Values*	2018
46	Journal Paper	Sneltvedt O.	Experience the future in full-scale: Technological background relations and visions of the good society at the World's Columbian Exposition	*Technology in Society*	2018
47	Journal Paper	Grebenshchikova E.G.	Sociotechnical imaginaries of technoscience	*Voprosy Filosofii*	2018
48	Journal Paper	Kim E.S.	Sociotechnical imaginaries and the globalization of converging technology policy: Technological developmentalism in South Korea	*Science as Culture*	2018
49	Journal Paper	Molden O.C., Meehan K.	Sociotechnical imaginaries of urban development: social movements around traditional water infrastructure in the Kathmandu Valley	*Urban Geography*	2018
50	Journal Paper	Delina L.L.	Whose and what futures? Navigating the contested coproduction of Thailand's energy sociotechnical imaginaries	*Energy Research & Social Science*	2018
51	Journal Paper	Tozer L., Klenk N.	Discourses of carbon neutrality and imaginaries of urban futures	*Energy Research & Social Science*	2018
52	Journal Paper	Schelhas J., Hitchner S., Brosius J.P.	Envisioning and implementing wood-based bioenergy systems in the southern United States: Imaginaries in everyday talk	*Energy Research & Social Science*	2018
53	Journal Paper	Herrmann J.R., Krolokke C.	Eggs on ice: Imaginaries of eggs and cryopreservation in Denmark	*Nora-Nordic Journal of Feminist and Gender Research*	2018
54	Journal Paper	Aarden E.	Projecting and producing 'usefulness' of biomedical research infrastructures; or why the Singapore Tissue Network closed	*Science and Public Policy*	2017
55	Journal Paper	Ruotsalainen J., Karjalainen J. Child M. Heinonen S.	Culture, values, lifestyles, and power in energy futures: A critical peer-to-peer vision for renewable energy	*Energy Research & Social Science*	2017
56	Journal Paper	Pfotenhauer S., Jasanoff S.	Panacea or diagnosis? Imaginaries of innovation and the MIT model' in three political cultures	*Social Studies of Science*	2017
57	Journal Paper	Lupton D.	'Download to delicious': Promissory themes and sociotechnical imaginaries in coverage of 3D printed food in online news sources	*Futures*	2017
58	Journal Paper	Sovacool B.K., Hess D.J.	Ordering theories: Typologies and conceptual frameworks for sociotechnical change	*Social Studies of Science*	2017

59	Journal Paper	Kuchler M.	Post-conventional energy futures: Rendering Europe's shale gas resources governable	*Energy Research & Social Science*	2017
60	Journal Paper	Cloke J., Mohr A., Brown E.	Imagining renewable energy: Towards a social energy systems approach to community renewable energy projects in the Global South	*Energy Research & Social Science*	2017
61	Journal Paper	Gardner J., Webster A.	Accelerating innovation in the creation of biovalue: The cell and gene therapy catapult	*Science Technology & Human Values*	2017
62	Journal Paper	Burnham M., Eaton W., Selfa T., Hinrichs C., Feldpausch-Parker A.	The politics of imaginaries and bioenergy sub-niches in the emerging Northeast US bioenergy economy	*Geoforum*	2017
63	Journal Paper	Shelton T.	The urban geographical imagination in the age of Big Data	*Big Data & Society*	2017
64	Journal Paper	Throndsen W.	What do experts talk about when they talk about users? Expectations and imagined users in the smart grid	*Energy Efficiency*	2017
65	Journal Paper	Pereira T.S., Carvalho A., Fonseca P.F.C.	Imaginaries of nuclear energy in the Portuguese parliament: Between promise, risk, and democracy	*Public Understanding of Science*	2017
66	Journal Paper	Milan S., ten Oever N.	Coding and encoding rights in internet infrastructure	*Internet Policy Review*	2017
67	Journal Paper	Sample M.	Silent performances: Are repertoires really post-Kuhnian?	*Studies in History and Philosophy of Science*	2017
68	Book	Adrian S.W.	Sperm stories sociotechnical imaginaries of sperm donation and sperm banking in Denmark	*Assisted Reproduction Across Borders: Feminist Perspectives on Normalizations, Disruptions and Transmissions*	2017
69	Journal Paper	Centemeri L.	From public participation to place-based resistance. Environmental critique and modes of valuation in the struggles against the expansion of the Malpensa airport	*Historical Social Research-Historische Sozialforschung*	2017
70	Journal Paper	Faulkner A.	Bioinformatics Imaginaries in the engine-room of genomic health policy: Integration and heterogeneity in India and the UK	*Science and Technology Studies*	2017
71	Journal Paper	Richter J.A., Tidwell A.S.D., Fisher E., Miller T.R.	STIRring the grid: Engaging energy systems design and planning in the context of urban sociotechnical imaginaries	*Innovation-The European Journal of Social Science Research*	2017
72	Journal Paper	Wentland A.	Imagining and enacting the future of the German energy transition: Electric vehicles as grid infrastructure	*Innovation-The European Journal of Social Science Research*	2016
73	Journal Paper	Hooge S., Le Du L.	Collaborative organizations for innovation: A focus on the management of sociotechnical imaginaries to stimulate industrial ecosystems	*Creativity and Innovation Management*	2016
74	Journal Paper	Ryghaug M., Toftaker M.	Creating transitions to electric road transport in Norway: The role of user imaginaries	*Energy Research & Social Science*	2016
75	Journal Paper	Smith J.M., Tidwell A.S.D.	The everyday lives of energy transitions: Contested sociotechnical imaginaries in the American West	*Social Studies of Science*	2016
76	Journal Paper	Korsnes M.	Ambition and ambiguity: Expectations and imaginaries developing offshore wind in China	*Technological Forecasting and Social Change*	2016

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Appendix A. (Continued)

No.	Publication type	Authors	Title	Journal	Publication year
77	Journal Paper	Levidow L., Papaioannou T.	Policy-driven, narrative-based evidence gathering: UK priorities for decarbonisation through biomass	*Science and Public Policy*	2016
78	Journal Paper	Aspria M., de Mul M., Adams S., Bal R.	Of blooming flowers and multiple sockets: The role of metaphors in the politics of infrastructural work	*Science and Technology Studies*	2016
79	Journal Paper	Tidwell A.S.D., Smith J.M.	Morals, materials, and technoscience: The energy security imaginary in the United States	*Science Technology & Human Values*	2015
80	Journal Paper	Ballo I.F.	Imagining energy futures: Sociotechnical imaginaries of the future Smart Grid in Norway	*Energy Research & Social Science*	2015
81	Journal Paper	Pidoux V.	A new classification for better care. The promises of the translational psychiatric neuroscience	*Comptes Rendus Biologies*	2015
82	Journal Paper	Jiang L.J.	IVF the Chinese way: Zhang Lizhu and post-Mao human in vitro fertilization research	*East Asian Science Technology and Society-An International Journal*	2015
83	Journal Paper	de Saille S.	Dis-inviting the unruly public	*Science as Culture*	2015
84	Book	Felt U.	Sociotechnical imaginaries of the internet, digital health information and the making of citizen-patients	*Science and Democracy: Making Knowledge and Making Power in the Biosciences And Beyond*	2015
85	Book	Wong R.Y., Jackson S.J.	Wireless visions: Infrastructure, imagination, and US Spectrum policy	Proceedings of the 2015 ACM International Conference on Computer-Supported Cooperative Work and Social Computing (CSCW'15)	2015
86	Journal Paper	Pollock A.	Places of pharmaceutical knowledge-making: Global health, postcolonial science, and hope in South African drug discovery	*Social Studies of Science*	2014
87	Journal Paper	Kuchler M.	Sweet dreams (are made of cellulose): Sociotechnical imaginaries of second-generation bioenergy in the global debate	*Ecological Economics*	2014
88	Journal Paper	Kim S.H.	The politics of human embryonic stem cell research in South Korea: Contesting national sociotechnical imaginaries	*Science as Culture*	2014
89	Journal Paper	Unverzagt K., Mayer M.	The elephant observing the dragon: Sociotechnical imaginaries of satellite technology and the Sino-Indian security dilemma	*Korean Journal of Defense Analysis*	2014
90	Journal Paper	Eaton W.M., Gasteyer S.P. Busch L.	Bioenergy futures: Framing sociotechnical imaginaries in local places	*Rural Sociology*	2014
91	Journal Paper	Taylor-Alexander S.	Bioethics in the making: Ideal patients and the beginnings of face transplant surgery in Mexico	*Science as Culture*	2014
92	Journal Paper	Hoskins A.	The mediatization of memory	*Mediatization of Communication*	2014
93	Journal Paper	Flear M.L., Pickersgill M.D.	Regulatory or Regulating Publics? The European Unions Regulation Of Emerging Health Technologies and Citizen Participation	*Medical Law Review*	2013
94	Journal Paper	Jasanoff S., Kim S.H.	Sociotechnical imaginaries and national energy policies	*Science as Culture*	2013
95	Journal Paper	Levidow L., Papaioannou T.	State imaginaries of the public good: Shaping UK innovation priorities for bioenergy	*Environmental Science & Policy*	2013
96	Journal Paper	Pickersgill M.	Connecting neuroscience and law: Anticipatory discourse and the role of sociotechnical imaginaries	*New Genetics and Society*	2011
97	Journal Paper	Walker G., Cass N., Burningham K., Barnett J.	Renewable energy and sociotechnical change: Imagined subjectivities of 'the public' and their implications	Environment and Planning A	2010

98	Journal Paper	Jasanoff S., Kim S.H.	Containing the atom: Sociotechnical imaginaries and nuclear power in the United States and South Korea	*Minerva*	2009
99	Journal Paper	Carolan M.	Automated agrifood futures: Robotics, labor and the distributive politics of digital agriculture	*The Journal of Peasant Studies*	2020
100	Journal Paper	Lustig, C.	Intersecting imaginaries: Visions of decentralized autonomus systems	Proceedings of the ACM on Human-Computer Interaction	2019
101	Journal Paper	Gesing F.	The politics of artificial dunes: Sustainable coastal protection measures and contested socio-natural objects	*Journal of Geographical Society of Berlin*	2019
102	Journal Paper	Sadowski J., Bendor R.	Selling smartness: Corporate narratives and the smart city as a sociotechnical imaginary	*Science Technology & Human Values*	2018
103	Journal Paper	Kapoor N.	Who has seen the wind: Imagining wind power for the generation of electricity in victorian britan	*Technology and Culture*	2019
104	Journal Paper	Mossfeldt Nickelsen N.C.	Imagining and tinkering with assistive robotics for the disabled	*Paladyn*	2019
105	Conference Paper	Karjalainen J., Heinonen S., Shaw M.	Peer-to-peer and circular economy principles in the fourth industrial revolution (4IR) - New risks and opportunities	*IEEE*	2019
106	Conference Paper	Recke M.P.	Sociotechnical Imaginaries and their metrification that shape public policy towards high-growth entrepreneurship in Hamburg, Germany	*ECIE*	2019
107	Journal Paper	Wittock N., Hustinx L.	Negotating risk-group categorization and the co-production of blood safety: The evolution of sociotechnical imaginaries mobilized in the public debate on the deferral of men who have sex with men as blood donors in Belgium	*BioSocieties*	2019
108	Journal Paper	Schiolin K.	Revolutionary dreams: Future essentialism and the sociotechnical imaginary of the fourth industrial revolution in Denmark	*Social Studies of Science*	2019
109	Journal Paper	Kenney M., Mamo L.	The imaginary of precision public health	*Medical Humanities*	2019
110	Journal Paper	Spektor M.	Imagining the biometric future: Debates over national biometric identification in Israel	*Science as Culture*	2020
111	Journal Paper	Bayer F., Felt U.	Embracing the 'atomic future' in post World War II Austria	*Technology and Culture*	2017
112	Journal Paper	Castillo G.	Hippie modernism: Curation and knowledge production	*Curation and Knowledge Production*	2019
113	Journal Paper	Lawrence C.	Heralds of global transparency: Remote sensing, nuclear fuel-cycle facilities and the modularity of imagination	*Social Studies of Science*	2019
114	Journal Paper	Avide E.	The birth of Mass transit system or the impetrative of technology: a look back at the design of suburban transitions in the 1970s	*Planning Perspectives*	2019
115	Journal Paper	Schwarzkopf S.	Magic towns: Creating the consumer fetish in market research test sites	*Consumer Culture Theory*	2019
116	Journal Paper	Hansen M.H., Li H., Svarverud R.	Ecological civilization: Interpreting the Chinese past, projecting the global future	*Global Environment Change*	2018
117	Journal Paper	Gunel G.	The backbone construction of a regional electricity grid in the Arabian Peninsula	*Engineering Studies*	2018

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Appendix A. (Continued)

No.	Publication type	Authors	Title	Journal	Publication year
118	Journal Paper	Dodge J.	Nightmares and dreams: Contested framing of unconventional fossil fuels	*Oxford Handbook of Energy and Society*	2018
119	Journal Paper	Hsu J.-Y.	Hsinchu technopolis: A sociotechnical imaginary of modernity in Taiwan?	*Critical Sociology*	2017
120	Book	Dimond R., Stephens N.	Legalizing mitochondrial donation: Enacting ethical futures in UK biomedical politics		2018
121	Journal Paper	Kovacic Z.	Governing informality through representation: Examples from slum policies in Brazil and South Africa	*Cities*	2018
122	Journal Paper	Meghani Z.	Genetically engineered animals, drugs and neoliberalism: The need for a new biotechnology regulatory policy framework	*Journal of Agricultural and Environmental Ethics*	2017
123	Journal Paper	Suarez Diaz E., Garcia-Deister V., Vasquez E.E.	Populations of cognition: Practices of inquiry into human populations in Latin America	*Perspectives on Science*	2017
124	Journal Paper	Weiner K., Martin P., Richards M., Tutton R.	Have we seen the geneticisation of society? Expectations and evidence	*Sociology of Health and Illness*	2017
125	Journal Paper	Corry O.	The international politics of geoengineering: The feasibility of Plan B for tackling climate change	*Security Dialogue*	2017
126	Journal Paper	Mager A.	Search engine imaginary: Visions and values in the co-production of search technology and Europe	*Social Studies of Science*	2016
127	Book	Olbrich P., Witjes N.	Sociotechnical imaginaries of big data: Commercial satellite imagery and its promise of speed and transparency	*Big Data Challenges*	2016
128	Journal Paper	Mikami K.	State-supported science and imaginary lock-in. The case of regenerative medicine in Japan	*Science as Culture*	2014
129	Journal Paper	Williamson B.	Educatiing the smart city: Schooling smart citizens through computational urbanism	*Big Data & Society*	2015
130	Journal Paper	Lukkarinen J.	Farm in the energy transition-On the construction of futures of dispersed energy production	*Terra*	2015
131	Journal Paper	Rommetveit K., Gunnarsdóttir K., Strand R. et al.	The Technolife project: An experimental approach to new ethical frameworks for emerging science and technology	*International Journal of Sustainable Development*	2013
132	Journal Paper	Williamson B.	Energy ideals, visions, narratives, and rhetoric: Examining sociotechnical imaginaries theory and methodology in energy research	*Energy*	2018
133	Journal Paper	Lieberman J.L., Kline R.R.	Dream of an unfettered electrical future: Nikola Tesla, the electrical utopian novel, and an alternative American sociotechnical imaginary	*Configurations*	2017
134	Journal Paper	Kim S.H.	Science, technology and the imaginaries of development in South Korea	*Development and Society*	2017
135	Journal Paper	Williamson B.	Computing brains: Learning algorithms and neurocomputation in the smart city	*Information, Communication & Society*	2015

Appendix B. List of 43 energy related articles downloaded from the Webofknowladfe.com website that were used to the analysis.

No.	Title	Year	Author	Affiliation	Journal
1	Ambition and ambiguity: Expectations and imaginaries developing offshore wind in China	2016	Marius Korsnes	NTNU	*Technological Forecasting & Social Change*
2	Attaining carbon neutrality in Finnish parliamentary and city T council debates	2019	Kamilla Karhunmaa	University of Helsinki	*Futures*
3	Blue skies in the making: Air quality action plans and urban imaginaries in London, Hong Kong, and San Francisco	2019	Patrick Léon Gross, Nicholas Buchanan, Sabine Sané	University of Freiburg, University College Freiburg	*Energy Research & Social Science*
4.	Carnation atoms? A history of nuclear energy in Portugal	2018	Tiago Santos Pereira1 • Paulo F. C. Fonseca2 • Anto ́nio Carvalho1	University of Coimbra	*Minerva*
5.	Containing the atom: Sociotechnical imaginaries and nuclear power in the United States and South Korea	2009	Shaila Jasanoff, Sang-Hyun Kim	Harvard University	*Minerva*
6.	Creating transitions to electric road transport in Norway: The role of user imaginaries	2016	Marianne Ryghaug*, Marit Toftaker	NTNU	*Energy Research & Social Science*
7.	Culture, values, lifestyles, and power in energy futures: A critical peer-to-peer vision for renewable energy	2017	Juho Ruotsalainen*, Joni Karjalainen, Michael Child, Sirkka Heinonen	Finland Futures Research Center	*Energy Research & Social Science*
8.	Discourses of carbon neutrality and imaginaries of urban futures	2018	Laura Tozera,*, Nicole Klenkb	University of Toronto	*Energy Research & Social Science*
9.	Dream of an unfettered electrical future: Nikola Tesla, the electrical utopian novel, and an alternative American sociotechnical imaginary	2017	Jennifer L. Lieberman, Ronald R. Kline	University of North Florida, Cornell University	*Configurations*
10.	Embracing the 'atomic future' in post–World War II Austria	2019	Florian Bayer and Ulrike Felt	University of Vienna	*Technology and Culture*
11.	Energy ideals, visions, narratives, and rhetoric: Examining sociotechnical imaginaries theory and methodology in energy research	2018	Jacqueline Hettel Tidwella,*, Abraham S.D. Tidwellb	University of Georgia, Arizona State University	*Energy Research & Social Science*
12.	Envisioning and implementing wood-based bioenergy systems in the T southern United States: Imaginaries in everyday talk	2018	John Schelhasa,*, Sarah Hitchnerb, J. Peter Brosiusc	Southern Research Station - Athens, USA; University of Georgia	*Energy Research & Social Science*
13.	Heralds of global transparency: Remote sensing, nuclear fuel-cycle facilities, and the modularity of imagination	2019	Christopher Lawrence	Harvard University	*Social Studies of Science*
14.	Imaginaries of nuclear energy in the Portuguese parliament: Between promise, risk, and democracy	2017	Tiago Santos Pereira1 • Paulo F. C. Fonseca2 • Anto ́nio Carvalho1	University of Coimbra, University of Santa Catarina Brazil	*Public Understanding of Science*
15.	Imaginaries of sustainability: The techno-politics of smart cities	2019	Thaddeus R. Miller	School for the Future of Innovation in Society, The Polytechnic School, Arizona State University,	*Science as Culture*

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Appendix B. (Continued)

No.	Title	Year	Author	Affiliation	Journal
16.	Imagining and enacting the future of the German energy transition: electric vehicles as grid infrastructure	2016	Alexander Wentland	University of Berlin	*Innovation: The European Journal of Social Science Research*
17.	Imagining energy futures: Sociotechnical imaginaries of the future smart grid in Norway	2015	Ingrid Foss Ballo	University of Bergen	*Energy Research & Social Science*
18.	Imagining renewable energy: Towards a social energy systems approach to community renewable energy projects in the Global South	2017	Jonathan Clokea, Alison Mohrb, Ed Browna,*	Loughborough University, UK, University of Nottingham	*Energy Research & Social Science*
19.	'Lighting a dark continent': Imaginaries of energy transition in Senegal	2018	Hilton R. Simmet	Harvard University	*Energy Research & Social Science*
20.	Lithium and development imaginaries in Chile, Argentina and Bolivia	2019	Javiera Naramdoaram	University of California	*World Development*
21.	Mapping diverse visions of energy transitions: co-producing sociotechnical imaginaries	2019	Noel Longhurst Jason Chilvers	Science, Society and Sustainability (3S) Research Group	*Sustainability*
22.	Mobilizing sociotechnical imaginaries of fossil-free futures - Electricity and biogas in public transport in Linkoping, Sweden	2019	Amelia Mutter	Linkoping University	*Energy Research & Social Science*
23.	Morals, materials, and technoscience: The energy security imaginary in the US	2015	Abraham S.D.Tidwell Jessica M. Smith	Arizona State University	*Science, Technology, & Human Values*
24.	Obduracy and change in urban transport - Understanding competition between sustainable fuels in Swedish municipalities	2019	Amelia Mutter	Linkoping University	*Sustainability*
25.	Ordering theories: Typologies and conceptual frameworks for sociotechnical change	2017	Sovacool, Hess	University of Sussex, Vanderbilt University	*Social Studies of Science*
26.	Participatory energy: Research, imaginaries and practices on people contribute to energy system in the smart city	2019	Corsini, Certoma, Dyer, Frey	Pisa, Ghent, University of Waikato New Zealand	*Technological Forecasting & Social Change*
27.	Policy-driven, narrative-based evidence gathering UK priorities for decarbonization through biomass	2016	Less Levidow, Theo Papaioannou	Open University, UK	*Science and Public Policy*
28.	Post-conventional energy futures: Rendering Europe shale gas resources governable	2017	Magdalena Kuchler	Uppsala University	*Energy Research & Social Science*
29.	Regional sociotechnical imaginaries and the governance of energy innovations	2019	Anthony M. Levenda, Jennifer Richter, Thaddeus Miller, Erik Fisher	University of Calgary, Arizona State University	*Futures*
30.	Reimaging energy futures: Contributions from community sustainable energy transitions in Thailand and the Philippines	2019	Jeans Marquardt, Laurence L. Delina	Harvard	*Energy Research & Social Science*

31.	Responsibility, rationality and acceptance: How future users of autonomous driving are constructed in stakeholders' sociotechnical imaginaries	2020	Antonia Graf, Marco Sonnberger	University of Munster, University of Sttutgart	*Public Understanding of Science*
32.	Smart energy futures and social practice imaginaries: Forecasting scenarios for pet care in Australian homes	2019	Yolande Strengers, Sarah Pink, Larissa Nicholls	RMIT University, Australia	*Energy Research & Social Science*
33.	Sociotechnical Imaginaries and National energy Policies	2013	Sheila Jasanoff, Sang-Hyun Kim	Harvard University, Hanyang University	*Science as Culture*
34.	STIRring the gird: engaging energy systems design and planning in the context of urban sociotechnical imaginaries	2017	Jennifer A. Richter, Abraham S.D. Tidwell, Erki Fisher Thaddeus R. Miller	Arizona State University	*Innovation: The European Journal of Social Science Research*
35	Sweat dreams (are made of cellulose): Sociotechnical imaginaries of second-generation bioenergy in the global debate	2014	Magdalena Kuchler	Linkoping University	*Ecological Economics*
36.	The backbone: Construction of a regional electricity grid in the Arabian Peninsula	2018	Gokce Gunel	University of Arizona	*Engineering Studies*
37.	The politics of imaginaries and bioenergy sub-niches in the emerging northeast U.S. bioenergy economy	2017	Morey Burnham, Weston Eaton, Theresa Selfa, Clare Hinrichs, Andrea Felpausch-Parker	Idaho State University, Pennsylvanian State University, State University of New York	*Geoforum*
38.	Urban configuration of carbon neutrality: insights from the carbon neutral cities alliance	2019	Laura Tozer, Nicle Klenk	Durham University, University of Toronto	*Politics and Space*
39.	What do experts talk about when they talk about users? Expectations and imagined users in the smart grid	2016	William Throndsen	NTNU	*Energy Efficiency*
40.	Who has seen the wind. Imagining wind power for the generation of electricity in Victorian Britain	2019	Nathan Kapoor	University of Oklahoma	*Technology and Culture*
41.	Whose and what futures? Navigating the contested coproduction of Thailand's energy sociotechnical imaginaries	2018	Laurence L. Delina	Boston University	*Energy Research & Social Science*