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Review

Whither policy innovation? Mapping conceptual engagement with public policy in energy transitions research

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ABSTRACT

A transition to sustainable energy will require not only technological diffusion and behavioral change, but also policy innovation. While research on energy transitions has generated an extensive literature, the extent to which it has used the policy innovation perspective – entailing policy entrepreneurship or invention, policy diffusion, and policy success – remains unclear. This study analyzes over 8000 publications on energy transitions through a bibliometric review and computational text analysis to create an overview of the scholarship, map conceptual engagement with public policy, and identify the use of the policy innovation lens in the literature. We find that: (i) though the importance of public policy is frequently highlighted in the research, the public policy itself is analyzed only occasionally; (ii) studies focusing on public policy have primarily engaged with the concepts of policy mixes, policy change, and policy process; and (iii) the notions of policy entrepreneurship or invention, policy diffusion, and policy success are hardly employed to understand the sources, speed, spread, or successes of energy transitions. We conclude that the value of the policy innovation lens for energy transitions research remains untapped and propose avenues for scholars to harness this potential.

1. Introduction

The research on energy transitions delves into qualitative, quantitative, or geospatial shifts in how energy is sourced, delivered, or utilized [1–6]. There is broad consensus in the literature that public policy plays a key role in initiating, accelerating, or supporting these activities and, thereby, energy transitions [7–9]. To better understand the relationships of the policy context, policy process, policy design, and energy transitions, scholars have appealed for closer synthesis among the literature on energy research, public policy, and sustainability transitions. Some avenues proposed for this include the use of concepts from policy studies in energy research [10], the adaptation of policy process theories to analyze the politics of transitions [11], the development of a strand of interdisciplinary research on policy mixes through integration of innovation studies and policy studies [12], the application of the research on policy transfer to study internationalization of socio-technical transitions [13], and the engagement with the notion of policy feedback for co-evolutionary assessment of policy mixes and socio-technical transitions [14].

Policy innovations that address "the root causes of… problems instead of the symptoms" will be key for sustainability transitions, generally, and energy transitions, specifically [15]. Policy innovation can be viewed as a multidimensional concept involving three perspectives: policy invention, policy diffusion, and policy success [16]. Policy invention entails a radical change in policy objectives or instruments leading to a new policy [17], and policy diffusion denotes the (potential) spread of policy from one jurisdiction to other interdependent jurisdictions [18]. Meanwhile, the notion of policy success recognizes the diverse outcomes of public policy and emphasizes the need to analyze these through ex-post evaluation [19,20].

Taken together, in a polycentric context – such as that of energy transitions – these can create a virtuous cycle of experimentation and learning that helps catalyze systemic transformation. The study of policy innovation is, therefore, useful for understanding the relationship(s) between public policy and energy transitions and for creating knowledge on accelerating energy transitions [21–23]. This is not to say that this lens should replace other approaches to studying public policy in energy transitions – or even that innovation is always desirable [24] – but only that its use has high positive and normative relevance for the scholarly community and merits further attention. While existing studies

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have reviewed conceptual engagement with public policy in energy transitions research broadly [10–12,25], whether, to what extent, and how the literature on energy transitions has used the policy innovation lens specifically remains unclear.

The objective of this study is to shed light on policy innovation in energy transitions research. We pose the question: "(to what extent) does energy transitions research address policy innovation?" Here, we use the term energy transitions research broadly to refer to publications that mention the phrase 'energy transition' *or* the term 'energy' in the context of socio-technical transitions in their title, abstract, or keywords. To answer the question, we collect relevant bibliometric data of over 8000 publications on energy transitions and analyze it using a combination of topic modelling, term frequency analysis, term co-occurrence analysis, and a manual review. While this approach does not lend itself to an in-depth conceptual or narrative synthesis, it allows us to obtain a bird's eye view of the literature and systematically quantify the prevalence of themes, the mention of terms, and the co-occurrence of concepts in a large body of research. We contribute to the literature by: (i) identifying and ranking the key themes in energy transitions research; (ii) mapping the conceptual engagement with public policy in this scholarship; and (iii) proposing avenues for future research to harness, and further develop, the policy innovation lens.

This article is structured as follows. In Section 2, we elaborate on the notion of policy innovation and emphasize its relevance for energy transitions research. Subsequently, we present the methods of data collection and analysis (Section 3). Section 4 presents the results of the study, including an overview of our dataset to set the context, the key themes in energy transitions research, and conceptual engagement with public policy in this scholarship. Finally, we conclude with an interpretation of the findings, a discussion of their implications, and avenues for future research (Section 5).

2. Why policy innovation?

In policy studies, public policy has been conceived as a combination of objectives and instruments, with each of these comprising a nested hierarchy of abstract (high-level), operationalizable (program-level), and on-the-ground (specific) elements [26]. Building on this, Howlett [17] proposes that change(s) at the abstract or operationalizable level in either policy objectives or policy instruments constitutes policy innovation. While this conceptualization makes a distinction between incremental, minor, or routine change on the one hand and fundamental, major, or rare change on the other hand, it adopts an output-centric view of policy innovation, i.e., of policy as a product. Further, it does not clarify whether such a change must be new or whether reversion to the old also constitutes policy innovation. In a more encompassing conceptualization, Jordan and Huitema [24] define policy innovation as "the process and/or product of seeking to develop new and/or widely adopted, and/or impactful policies, when existing ones are perceived to be under-performing."

Jordan and Huitema [16] suggest that the policy innovation lens comprises three perspectives on public policy: invention, diffusion, and success (see also [23]). The policy invention perspective focuses on the adoption of new policies (or new objectives or tools therein), often through experimentation and learning. Meanwhile, the policy diffusion perspective delves into processes that contribute to, or hinder, the spread of policies to other jurisdictions and resulting changes in the policy. The policy success perspective focuses on examining policy outcomes through careful ex-post evaluation. These perspectives have received attention – albeit, often in isolation – in the field of policy studies.

Policy invention – more generally, policy change – has been analyzed in the literature on the policy process. Although the policy process is characterized in several – even incompatible – ways, scholars broadly agree that it is a multi-actor, multi-dimensional process occurring over a long time-period [27,28]. The most widely known 'theories' of the policy process include the policy stages heuristic [29–31], the multiple streams framework [32], the institutional analysis and development framework [33], the advocacy coalition framework [34,35], punctuated equilibrium theory [36], policy feedback theory [37], and the narrative policy framework [38]. These aim to explain both policy stability and policy change, and usually make a distinction between incremental change and radical change.

The policy invention perspective is important for explaining and promoting energy transitions as it can shed light on the characteristics that lead to the creation of policy alternatives, the adoption of new policies, and the co-evolution of policy and technology. Illustratively, Llamosas, Upham [39] use the multiple streams framework to show that 'regime resistance' has thwarted efforts to introduce policy innovation in the energy system in Paraguay. Similarly, Karapin [40] argues that the veto power of fossil-fuel interests hinders policy innovation at the federal and the state level in the United States, slowing the energy transition. Also, Carmon and Fischhendler [41] explain the lack of stringency in the policy design on renewable energy targets based on the 'friction' between bureaucrats and politicians during the policy process. In assessing a 'successful' case, Argyriou [42] demonstrates that a combination of socioeconomic characteristics, political orientations, and third-sector entities drive policy innovation in commercial energy efficiency in Philadelphia.

Jordan and Huitema [23] emphasize the activities of policy entrepreneurs as a potential source of policy invention. Policy entrepreneurship – defined as "the coupling activities of like-minded individuals with different skills, knowledge and positions that take place simultaneously or at different stages in the policy process" [43] – has indeed been acknowledged as a key source of policy change within nearly every theoretical lens mentioned above [44–49]. Broadly, the literature of policy entrepreneurship has recognized it as a collective or institutional act [50–56] and identified the attributes, strategies, and influence of policy entrepreneurs in the policy process [57].

The study of policy entrepreneurship in the energy transitions can help ascertain the resources, strategies, and activities that contribute to policy invention and its diffusion. Albeit in the case of water policy, Huitema, Lebel [58] find that policy entrepreneurs contribute to water transitions, although their degree of influence depends on the institutional setting. The authors argue that individuals can play a role in these processes through idea development, exploitation of windows of opportunity, venue shopping, coalition building, and network management. Relatedly, Goyal, Howlett [59] synthesize research on policy entrepreneurship using the multiple streams framework to delineate six types of individual or collective entrepreneurs relevant to energy transitions: the problem broker, the policy entrepreneur, the process broker, the political entrepreneur, the program champion, and the technology innovator. The authors show how these different types of entrepreneurs contributed to a policy innovation in the energy-water nexus in India.

The spread of (new) policies to other jurisdictions, too, has been examined using multiple theories in policy studies. Among others, these include policy assemblage [60], policy mobility and mutation [61], and policy translation [62]. While each of these offers unique insights into the processes by which policies spread – and their influence on policy design – the notions of policy diffusion [63,64] and policy transfer [65,66] are arguably the most mainstream. The literature on policy diffusion has focused mainly on the 'mechanisms' that explain patterns of horizontal diffusion (i.e., at the same level) or vertical diffusion (i.e., between hierarchically different levels) [67]. In contrast, the scholarship on policy transfer has emphasized the role of lesson drawing in this process [65,68]. Increasingly, scholars have argued for a synthesis of the research on diffusion and transfer to develop a better understanding of why and how policies spread [69,70].

The diffusion perspective is essential for energy transitions research as it can reveal the dynamics that facilitate the scaling up and scaling out of novel policies. For instance, Zimm [71] analyzes the global diffusion of policies concerning electric vehicles to find the socioeconomic characteristics, political factors, and international mechanisms that can accelerate the transition to electric vehicles. Relatedly, Goyal [72] synthesizes policy diffusion and policy transfer and conceptualizes both using the multiple streams framework to explain the slow adoption of building energy codes in India. At the intersection of research on policy transfer and sustainability transitions, Pitt and Jones [13] introduce 'scaling up and scaling out' as a new mechanism of transfer and identify the conditions under which it can lead to success. Morton, Wilson [73] find that household characteristics such as age, education, building type, and household size influence the subnational 'diffusion' of energy efficiency assessment in the United Kingdom. Bhamidipati, Haselip [74] document the process of policy 'translation' through which a coherent policy outcome was achieved in the case of renewable energy in Uganda. Recently, Heyen, Jacob [75] have argued for closer integration between the research on policy transfer and sustainability transitions to catalyze transformative change.

The notion of policy success recognizes that, despite its positive connotation, invention does not necessarily translate into success on the ground, and policy outcomes should – therefore – be analyzed carefully [76]. While the early literature on the topic adopted a rationalist approach to policy evaluation, subsequent research has advanced a constructivist approach too [77]. In an attempt to bridge these, McConnell [20] has defined a policy as successful if "it achieves the goals that proponents set out to achieve and attracts no criticism of any significance and/or support is virtually universal" and proposed a heuristic to assess success empirically. Such a view of policy success emphasizes the multidimensional nature of policy effects, spanning the program (such as the achievement of stated objectives), the process (such as procedural justice), and the politics of public policy (such as electoral repercussions) [20,78–82].

A study of policy success can, therefore, help present a nuanced account of the various effects of a policy, distinguish policies that have desirable outcomes in specific contexts from those that do not, and steer transitions towards justice and sustainability [83–85]. Illustratively, through a comparison of coal phase-out in Germany and the United Kingdom, Brauers, Oei [86] show that policy outcomes are affected by several actors, such as industries, environmental groups, and the government. In the case of the transition from solid fuels in South Africa, Matinga, Clancy [87] find that symbolic use of policy explained the non-implementation of the pro-poor energy policy of the South African government. In another example, Fontaine, Fuentes [88] use the policy design framework to show that the (intended) lack of congruence within the policy mix can help actors resisting change and undermine policy outcomes. Relatedly, in their evaluation of the energy efficiency policy mix in Finland, Kivimaa, Kangas [89] find that incoherence during policy implementation decreases effectiveness.

Thus, the perspectives of policy entrepreneurship or invention, policy diffusion, and policy success can shed light on the interplay between public policy and energy transitions. In the next section, we describe how we locate and quantify the use of these perspectives – and the policy innovation lens – within energy transitions research.

3. Methods

We conduct a bibliometric review and computational text analysis for this study using bibliometric data – i.e., data on authorship, institutional affiliation, publication title, abstract, keywords, cited references, and so on – collected from the Web of Science database.

As our interest was in capturing the body of work on energy transitions – and not only research referring to public policy or policy innovation – we searched the titles, abstracts, and keywords of the publications in the Social Sciences Citation Index (SSCI) and the Book Citation Index-Social Sciences and Humanities (BKCI-SSH) for the following: (electricity *OR* energy *OR* power *OR* renewable *OR* smartgrid) *AND* (MLP *OR* "multilevel perspective" *OR* SNM *OR* "strategic niche management" *OR* "technological innovation system*" *OR* TIS *OR* transition). We iteratively revised the query based on a scan of the resulting dataset in each round. Our final query reflected three key changes. First, we qualified the presence of the term 'power' as it resulted in numerous articles on geopolitics and international relations not related to the energy domain. Second, we included a variant of the term 'smartgrid' ('smart grid') to incorporate additional literature. Third, we excluded articles mentioning the term 'transition' in another context not directly relevant to the energy domain.

Consequently, our final search query – executed on July 05, 2021 – was: (electricity *OR* energy *OR* "power generation" *OR* "power system*" *OR* renewable *OR* smartgrid *OR* "smart grid*") *AND* (MLP *OR* "multi-level perspective" *OR* SNM *OR* "strategic niche management" *OR* "technological innovation system*" *OR* TIS *OR* transition) *NOT* ("demographic transition*" *OR* "energy intake" *OR* "land?cover transition*" *OR* "land?use transition*" *OR* "nutrition transition*" *OR* "phase transition*"). While this reduced the number of irrelevant articles significantly, several still remained. We addressed this problem by employing topic modelling (see below) to identify themes not pertaining to energy transitions by clustering publications based on their titles and abstracts. Specifically, we found two themes – the first about health and nutrition and the second about forestry, land cover, and land use – that were not relevant to energy transitions. After removing publications for which one of these was the most prominent theme, our final dataset consisted of 8442 publications that self-identify as pertaining to energy transitions or to energy in sustainability transitions (Fig. 1).

To begin with, we conducted a bibliometric analysis to obtain an overview of our dataset and validate our search strategy. For this, we used the *bibliometrix* package [90] in the R programming environment to examine scientific activity over time, authorship, institutional collaboration, and scientific production by country. Subsequently, we used topic modelling to identify the main themes in energy transitions research. Topic modelling is an unsupervised machine learning technique for 'discovering' latent themes (or *topics*) in a document collection based on the distribution of terms, i.e., words or phrases, in the text [91]. Specifically, we used the structural topic model to account for correlation among topics, incorporate document-level metadata for topic discovery, and implement the analysis in the R programming environment using the *stm* package [92]. To select the number of themes for this analysis – an input to the topic model – we examined models ranging from 10 to 25 themes using the *searchK* function in the *stm* package and chose the model with 15 themes, based on the held-out likelihood and semantic coherence of the alternatives.

To prepare the dataset for computational text analysis, we employed the following procedure. First, we tokenized, annotated, and lemmatized the publication text (i.e., titles and abstracts) using the *udpipe* package [93]. Second, identified commonly occurring phrases in the text and, where applicable, replaced sequences of words with phrases to increase the coherence of the analysis. Third, we removed the parts of speech that do not contain domain-relevant information – such as conjugations, determiners, and pronouns – from the text. Also, we removed terms that lend little discriminating power to our analysis but occur frequently in the English language or in our dataset ('stop words'). Fourth, we implemented stemming, using the *SnowballC* package [94], to reduce terms to their root form and further enhance the coherence of our analysis.

Once our analysis highlighted that policy innovation was not a key theme in this literature, we examined conceptual engagement with public policy by counting mentions of 'policy' OR 'polici', distilling terms that represent key concepts in policy studies, and investigating term co-occurrence to understand the context of their use. Our key aim in this analysis was to map public policy lenses that have been employed in energy transitions research and answer whether policy innovation was one among them.

The limitations of this study should, however, be borne in mind while interpreting the results of these analyses. First, as we searched the SSCI and the BKCI-SSH in the Web of Science database for identifying

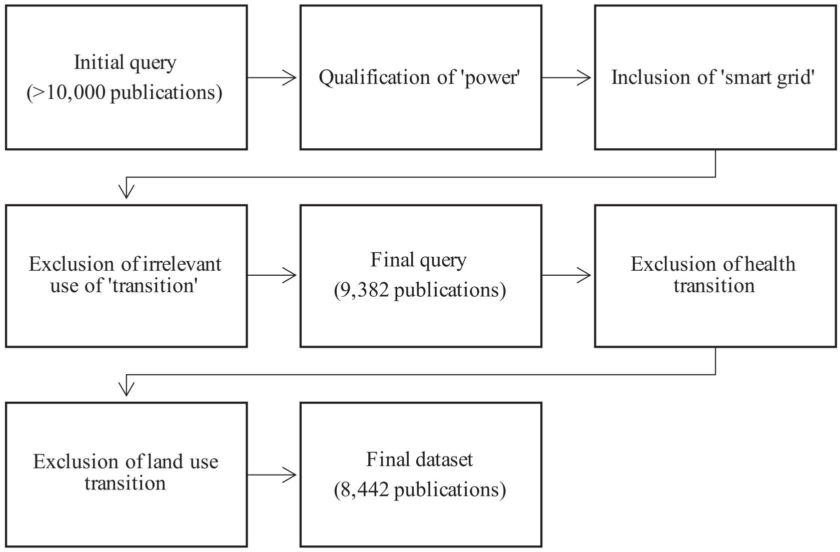

Fig. 1. The steps for selecting publications on energy transitions.

the literature, relevant studies that are not listed in these indices are not included in our analysis. Second, although a wide variety of policy areas, problems, and themes are relevant to energy transitions. Our search strategy focused only on studies that self-identified as pertaining to energy transitions or to energy in sociotechnical transitions. Consequently, relevant studies that did not mention our search terms in their title, abstract, or keywords are not included in our analysis. Third, while our reliance on computational text analysis allowed us to analyze a large dataset, its findings are premised on lexical – rather than semantic – similarities with the concepts of interest to us. In contrast, manual text analysis would have enabled more fine-grained analysis, but would have limited the size of the literature that we could have reviewed. Fourth, we selected studies to illustrate the themes in the research based not on their centrality to the field, but on their topic proportion(s), the diversity of studies within the themes, and our prior knowledge of the theme. Fifth, we did not validate the findings with other scholars active in energy transitions research or policy studies.

4. Results

4.1. An overview of the dataset

In this sub-section, we present a brief overview of our dataset to show that our search strategy identified the relevant literature and set the context for the analysis.

As mentioned earlier, the final dataset consists of 8442 publications on energy transitions. The earliest publications in this research area – written in the aftermath of the oil crisis – discussed the impending energy transition, resource scarcity, sustainable energy, and the role of public policy [95–99]. While research activity was moderate during the previous century, it witnessed sustained growth after 2005 and has increased exponentially since 2015 (Fig. 2), possibly indicating a policy-driven and normative response to the declaration of the Sustainable Development Goals (SDGs) and the adoption of the Paris Agreement on climate change.

As per our dataset, over 18,000 scholars have authored publications on energy transitions. Of these, approximately 400 have more than five publications and over a hundred scholars have 10 or more publications in this area, indicating an active research community. The most published authors in this dataset include B. K. Sovacool [4,100,101], F. Krausmann [102,103], B. Q. Lin [104,105], M. P. Hekkert [106,107], and D. P. van Vuuren [108,109]. Noticeably, among the most prolific scholars in this field, only D. J. Hess and F. Kern engage actively with

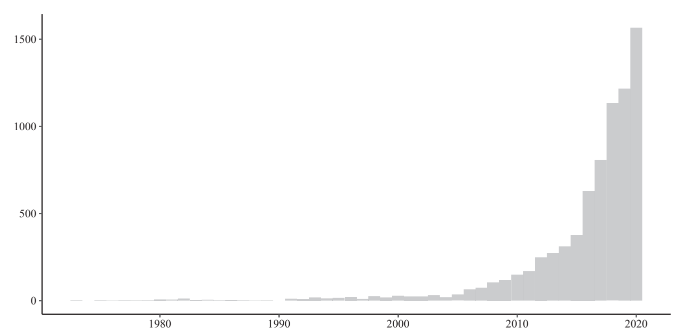

Fig. 2. The number of publications on energy transitions over time. Publications for the year 2021 are not shown in the figure for consistency.

policy studies or political science, while the rest focus on science & technology studies, philosophy, or other social sciences (Table 1).

Although scholars publishing in this research area represent over 4000 research institutions, approximately only 130 institutions worldwide are mentioned on 25 or more occasions.[1] A look at the top institutions in this area – the University of Sussex, Utrecht University, the University of Leeds, the Delft University of Technology, and the University of Oxford – reveals a large European (specifically, British and Dutch) presence in this field. A co-authorship network among the top 30 institutions shows the presence of three clusters: the first of institutions

Table 1
The most prolific authors in energy transitions research based on our dataset.

Author	Publications	Author	Publications
B. K. Sovacool	81	P. Kivimaa	23
F. Krausmann	37	R. Raven	23
B. Q. Lin	32	D. J. Hess	21
M. P. Hekkert	29	F. Kern	21
D. P. van Vuuren	27	J. Markard	21
T. J. Foxon	26	S. Ginrich	20
F. W. Geels	24	M. Martiskainen	20

[1] We count multiple authors from an institution or multiple publications by an author as distinct occurrences.

mainly in the Netherlands and Scandinavia, the second of institutions primarily in the United Kingdom, and the third of institutions in China and the United States (Fig. 3). With the exception of China, the only non-OECD countries among the top 30 in scientific activity are India (19), Brazil (22), and South Africa (27). This reveals a geographic bias in scientific activity – and, possibly, focus – in energy transitions research.

4.2. Key themes in energy transitions research

We analyze the topics in the literature to ascertain whether public policy (and more specifically, policy innovation) is a prominent theme. A topic model reveals the presence of various analytical approaches and empirical issues that have been covered in the literature on energy transitions (Fig. 4).

The most prevalent theme in the dataset is Theme 1 on 'Socio-technical transition.' The primarily focus here is the conceptual advancement of sustainability transitions and its empirical application to climate change or the energy system. Illustratively, studies in this theme delve into the role of agency [110], community energy [111], community leadership in grassroots innovation [112], ecologies of participation [113], the geographies of transitions [114,115], intermediaries [116], and the role of non-traditional actors [117].

The challenge of transitioning away from high-carbon energy, specifically, is deliberated on in more detail in Theme 2 on 'Fossil fuel dependency', wherein scholars focus on topics such as energy security [118], the future of coal, oil, and shale gas [119–122], lesson drawing from historical transitions [123,124], and pathways for emerging economies [125]. Relatedly, 'Climate change mitigation' is discussed predominantly in Theme 5. Studies in this theme analyze topics concerning decarbonization alternatives [126–128], national climate ambition [129–132], net-zero energy system [133], and the role of public policy [134].

Adopting a more nexus approach, Theme 3 on 'Economy and energy' highlights the complex relationship among the economy, energy production and use, and the environment, often in the case of China [135–141]. Studies in this theme also explore the effects of technological progress on energy use [142]. Relatedly, studies in Theme 4 on 'Resource flows' conduct lifecycle analyses relevant to energy production or use [143], examine the food-energy-water nexus [144,145], and advance scholarship on measuring resource efficiency [146,147]. This theme has also witnessed research activity on bioeconomy [148] and circular economy [149–151].

Some themes shed light on the relationship between energy transitions and society. Theme 7 on 'Industry and innovation', for example, discusses the role of business in influencing technology or service innovation [152–158] as well as the influence of the energy transition on corporates [159]. Meanwhile, Theme 13 on 'Behavior and consumption' engages with the demand for energy. Illustratively, studies in this theme delve into topics surrounding participation in community energy initiatives [160], electric vehicles [161–164], smart grids [165,166], social acceptance, and willingness to pay [167]. Similar to Theme 13 in its focus on behavior, Theme 14 delves into 'Energy access' at the household level, with studies examining energy inequity and poverty [168–170], fuelwood use [171], household preferences for energy [172,173], willingness to pay [174], and the effect of access on social development [175,176].

Several themes are concerned with the role of renewable energy in energy transitions. Theme 9 on 'Renewable energy integration' delves into the potential [177], sociotechnical feasibility [178–181], and benefits of high renewable energy penetration [182], as well as the regulatory and technology alternatives for realizing it [183–185]. While studies in Theme 9 focus more on solar energy, Theme 11 concentrates predominantly on the role of 'Wind energy' by studying the diffusion of clean energy [107,186–188], project implementation and social acceptance [189,190], and energy planning and policy at the local, national, or supranational level [191–193]. The use of the technological innovation system perspective is also prominent in this theme. Relatedly, Theme 15 on 'Financing and investment' is concerned with realizing

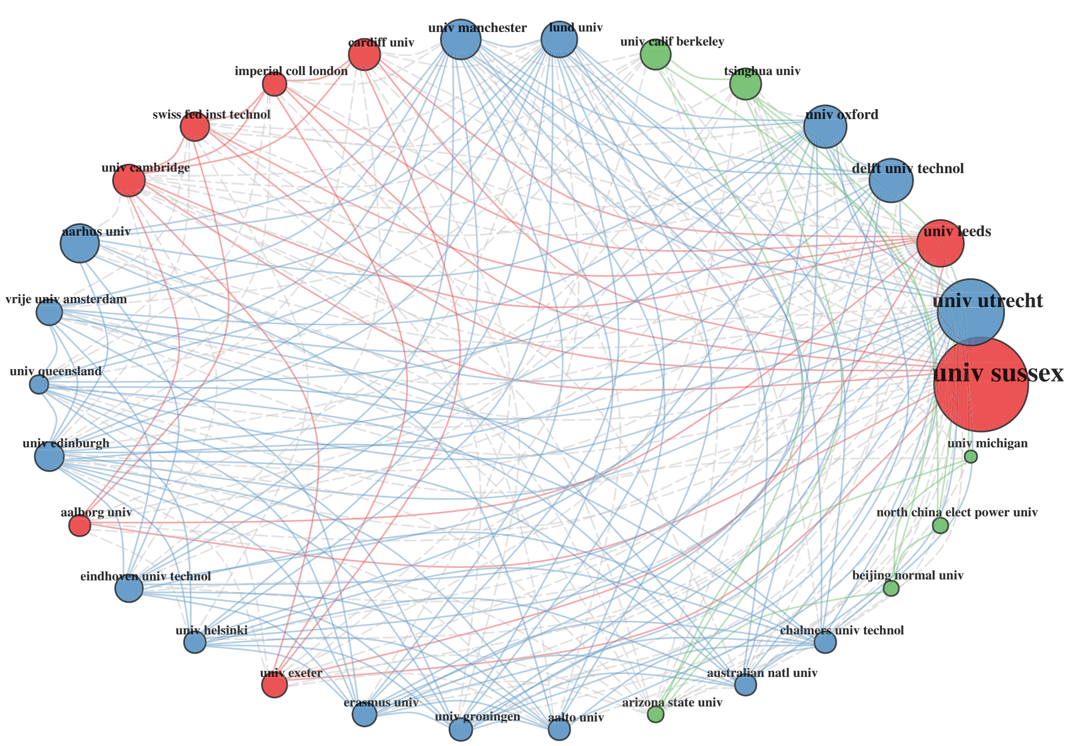

Fig. 3. Inter-institutional collaboration among the top 30 institutions in energy transitions research. Here, collaboration is defined as a co-authorship relationship. A link between two nodes indicates a co-authorship relationship. Node size indicates the number of co-authorship relationships identified in the dataset. Nodes are clustered using the Louvain method based on the edges connecting them.

Fig. 4. The main themes in energy transitions research. Themes are arranged in descending order of prevalence, from left to right and top to bottom. The key terms associated with each theme are arranged based on probability of occurrence within the theme (x-axis) and exclusivity to that theme (y-axis).

renewable energy on the ground through an emphasis on competitiveness of renewable energy [194], energy financing [195–197], renewable energy investment [198–201], the role of electricity utilities [202], and policy advice [203].

With an interest in predicting, anticipating, or responding to the future, Theme 10 on 'Energy modelling' is concerned with trend analysis and short-term forecasting [204] of phenomena such as energy consumption [205,206], energy demand [207], energy market volatility [208], price of energy [209,210]. While several studies use econometrics for these, the use of machine learning techniques, such as artificial neural networks or support vector machines, has also become increasingly popular. In contrast to Theme 10, Theme 12 on 'Energy future' focuses on long-term scenario building to address uncertainty in energy transitions [211–218].

With a different perspective and analytical focus from the above, Theme 6 on 'Politics and power' emphasizes the contested nature of energy transitions. Illustratively, studies in this theme delve into topics such as collective action [219], conflict between business and civil society [220], energy democracy [221], energy discourse [222–224], energy practices [225], social movements [226], and public participation [227]. Finally, only Theme 8 explicitly focuses on 'Governance and policy' with studies examining topics such as electricity market reform [228], governance capacity [229], policy implementation [230,231], policy process [232], renewable portfolio standards [233], and regulatory inefficiency [234].

This analysis shows that several themes acknowledge the importance of policy. This is further corroborated by examining the most frequently occurring terms related to policy within each theme (Table 2). While the most common use of policy is descriptive, the notions of policy process (Theme 1 on 'Sociotechnical transition'), policy change (Theme 6 on 'Politics and power'), policy tool (Theme 7 on 'Industry and innovation' and Theme 10 on 'Energy modelling'), policy mixes and policy instrument (Theme 8 on 'Governance and policy'), and policy design (Theme 12 on 'Energy future') have been invoked in the literature. However, policy innovation itself is not a prominent theme in the research and only theme 8 on 'Governance and policy' (with median prevalence in the dataset) focuses explicitly on public policy. To understand the extent to which studies in this – and the remaining themes – address policy innovation, we analyze the conceptual engagement with public policy in this literature.

4.3. Conceptual engagement with public policy

Although the word policy has been mentioned over 9000 times in this dataset, either by itself or as part of a phrase, its most common occurrences indicate descriptive use of the term. These include policy areas – such as 'energy polici' ($n > 600$), 'climate [change] polici' ($n > 450$), 'environmental polici' ($n > 150$), 'renewable energy polici' ($n > 100$), and 'innovation polici' ($n > 75$) – or terms suggesting policy relevance rather than policy analysis, such as 'policy mak[er/ing]' ($n > 800$), 'policy impl[ication]' ($n > 150$), 'public polici' ($n > 100$), and 'policy recommend[ation]' ($n > 75$). The frequently occurring terms indicating plausible conceptual engagement with public policy include 'policy mix[es]' ($n \sim 200$), 'policy instru[ment]' ($n \sim 150$), 'policy design' ($n \sim 90$), 'policy chang[e]' ($n \sim 90$), 'policy process' ($n \sim 50$), and 'policy go[al]' ($n \sim 50$). In contrast, terms such as 'policy innov [ation]' ($n \sim 25$), 'policy outcom[es]' ($n \sim 20$), and policy 'evalu [ation]' ($n \sim 19$) have been mentioned on few occasions and terms such as policy entrepreneurship, policy invention, policy diffusion, policy transfer, and policy success find hardly any mention in this literature.

A correlation network of concepts from policy studies with 10 or more occurrences in the dataset is shown in Fig. 5. As seen in this figure, a large strand of the literature delves into policy design in the form of policy instruments, policy mixes, or policy packages. While some studies investigate individual policy instruments [235–237], others also recognize that different policy instruments can interact with one another. Kern and Howlett [238], for example, argue that characteristics of policy mixes – such as consistency, coherence, and congruency – influence socio-technical outcomes in (energy) transitions (see also, [239]). The notion of policy mixes has, consequently, witnessed conceptual and empirical advancement, with scholars viewing it as a multidimensional concept consisting of processes, elements, and characteristics and operationalizing it to capture the interaction(s) of public policy and energy transitions [240,241]. In addition, the concept has been used normatively, for example, to advocate for policy mixes that facilitate creation of the new with 'destabilization of the old' [242] or foster energy democracy [243]. Recently, the integration of the concept of policy mixes with that of policy feedback has been proposed to examine the co-evolution of policy mixes and sustainability transitions [14].

The notion of policy change has been discussed in the context of energy transitions, albeit often descriptively. Several studies do, however, engage with the concept – especially using the advocacy coalition framework [34] – while examining regime dynamics in the energy system [244,245]. In an example of a study synthesizing policy change and policy mixes, Li and Taeihagh [246] conduct a temporal analysis of policy design, instruments' interaction, and evolution of mixes in China during 1981–2020. More generally, Kern, Kuzemko [247] develop a framework to measure policy (paradigm) change while Schmidt and Sewerin [248] propose an approach to measure policy (mix) change in the context of energy transitions.

Relatedly, the policy process has received some attention in energy transitions research. Studies have documented, for example, the difference in the (energy) policy process between the national and the

Table 2
The most frequently occurring terms related to policy in each theme.

1: Sociotechnical transition	**2: Fossil fuel dependency**	**3: Economy and energy**	**4: Resource flows**	**5: Climate change mitigation**
Policy process	Energy polici	Policy impl[ication]	Policy mak[er/ing]	Climate polici
Policy intervent[ion]	Policy decis[ion]	Environmental polici	Policy analysi[s]	Policy mak[er/ing]
Policy mak[er/ing]	Policy act[ion]	Policy mak[er/ing]	National polici	Policy scenario
Policy docu[ment]	Policy opt[ion]	Policy recommend[ation]	Policy strategi	Policy relev[ance]
Policy analysi[s]	Economic polici	Economic polici	Environmental polici	Policy recommend[ation]
6: Politics and power	**7: Industry and innovation**	**8: Governance and policy**	**9: Renewable energy integration**	**10: Energy modelling**
Energy polici	Innovation polici	Energy polici	Policy mak[er/ing]	Policy scenario
Policy mak[er/ing]	Policy mak[er/ing]	Policy mix[es]	Policy decis[ion]	Policy mak[er/ing]
Policy chang[e]	Policy support	Policy instru[ment]	Policy recommend[ation]	Policy tool
Industrial polici	Policy perspect[ive]	Policy mak[er/ing]	Policy support	Policy perspect[ive]
Climate polici	Policy tool	Environmental polici	Policy impl[ication]	Economic polici
11: Wind energy	**12: Energy future**	**13: Behavior and consumption**	**14: Energy access**	**15: Financing and investment**
Policy mak[er/ing]	Energy polici	Policy mak[er/ing]	Policy impl[ication]	Policy impl[ication]
National polici	Policy mak[er/ing]	Policy impl[ication]	Policy intervent[ion]	Effective polici
Energy transition polici	Policy impl[ication]	Policy intervent[ion]	Policy mak[er/ing]	Policy mak[er/ing]
Local polici	Policy design	Policy develop[ment]	Energy efficiency polici	Policy support
Policy impl[ication]	Policy develop[ment]	Policy recommend[ation]	Energy polici	Policy opt[ion]

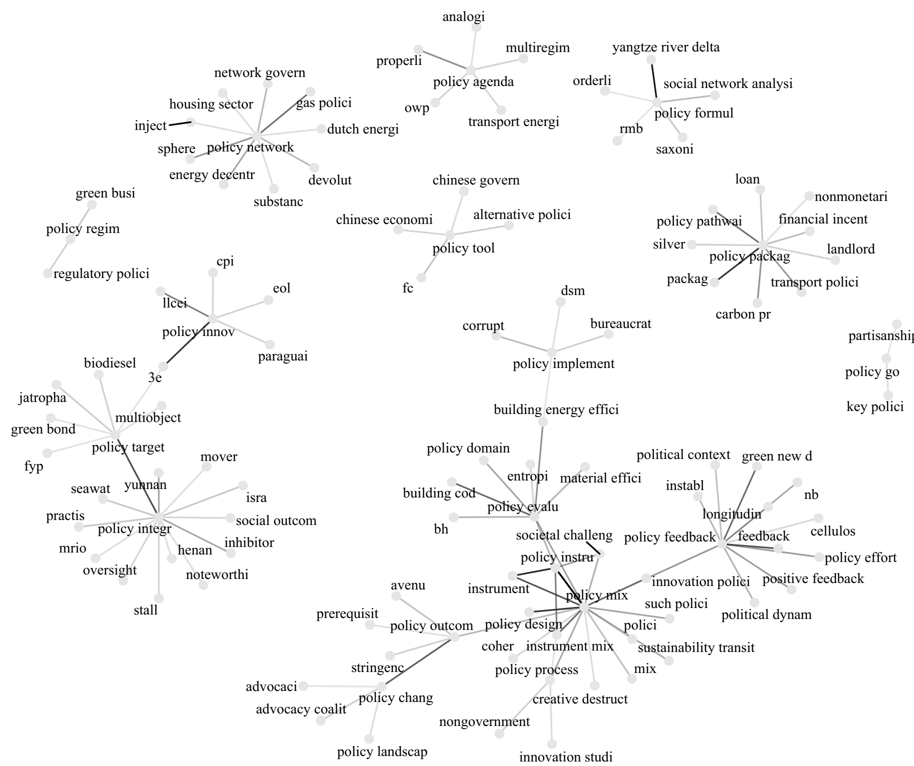

Fig. 5. Correlation network of concepts in policy studies. The nodes represent the phrases used in the literature. A link between two phrases indicates a correlation of 0.10 or more. The color intensity of the link indicates the strength of the correlation.

subnational level [249], the role of incumbent energy generating companies in lobbying for status quo [250], the challenge(s) of policy coordination given the complex, multi-objective, and uncertain nature of the energy system [251], the 'translation' of transnational policy to the national level, especially within the European Union [252], and the effect of inclusivity in the policy process on niche development [253]. A stage of the policy process, policy implementation has been studied, for example, in the context of contestation at the local level in the top-down push for energy infrastructure [254], challenges in translating national policy at the local level [255], and policy dismantling by veto players [256]. The notion of policy feedback, too, has been invoked to capture the influence of path dependence, politics, and vicious (or virtuous) cycles in governance and policy-making in the energy transitions [257–260].

This analysis shows that several studies use the term policy (and associated phrases) descriptively rather than analytically. Further, even among studies that demonstrate conceptual engagement with public policy, a majority focus on topics such as policy mixes, policy change, policy process, policy implementation, and policy feedback. Within the context of these topics, or otherwise, few studies have used the policy innovation lens and delved into phenomena such as policy entrepreneurship, policy invention, policy diffusion, policy transfer, policy outcomes, and policy success.

5. Discussion and conclusion

This study examined over 8000 publications on energy transitions to answer the question: (to what extent) does energy transitions research address policy innovation? Using topic modelling, we identified 15 themes in the literature (in descending order of prevalence): socio-technical transition, fossil fuel dependency, economy and energy, resource flows, climate change mitigation, politics and power, industry and innovation, governance and policy, renewable energy integration, energy modelling, wind energy, energy future, behavior and consumption, energy access, and financing and investment. Thus, while 'governance and policy' was discovered as a key theme – and studies in several other themes acknowledged the importance of public policy – policy innovation itself is not a prominent theme in this research.

To further understand the extent to which the literature has addressed policy innovation, we mapped conceptual engagement with public policy using term frequency analysis and term co-occurrence analysis. The analysis showed that although the term policy has been mentioned over 9000 times in our dataset, most uses of the term are descriptive rather than analytical. Further, while the notions of policy mixes, policy change, policy process, and – to a lesser extent – policy implementation and policy feedback have received attention in the literature, the policy innovation lens has hardly been used. Some studies have referred to notions of policy innovation, policy evaluation, or policy outcomes, but almost none have delved into policy invention, policy entrepreneurship, policy diffusion, policy transfer, or policy success, despite their relevance for energy transitions. On the whole, the findings indicate that we know little about policy innovation – and how to promote it – in the context of energy transitions.

Our findings are comparable to similar reviews conducted previously. Illustratively, in an exploratory review of research on energy policy in the Netherlands, Hoppe, Coenen [10] had found that policy studies' concepts were employed in only approximately one-fourth of the publications on the topic and that policy studies scholars had neglected energy policy to some extent. Similarly, in a bibliometric review of over 2700 publications on energy policy in India, Goyal [25] showed that while numerous studies emphasized policy relevance, analysis *for* policy and analysis *of* policy were both limited. Also, in their systematic review of nearly 200 social science studies on transformation for climate change mitigation (of which over 50% focused on energy), Moore, Verfuerth [261] found that only about half of the publications employed any theory and that only 17 publications used a theory from political science.

Our study hints at several reasons for why the analysis has unfolded in this manner. First, a look at the most prolific scholars in this field reveals that few have a background in policy studies. This may be the case as energy transitions research is largely normative in nature, with limited engagement of the social sciences [262], while policy studies have a more (post-)positivist and interpretivist orientation. A change in the status quo, however, will require greater participation of policy studies scholars in energy transitions research as well as more interest in concepts in public policy (including the policy innovation lens) from researchers studying energy transitions.

Second, and relatedly, our bibliometric review indicated that scientific activity in this research area is Europe-centric and select institutions – in the Netherlands and the United Kingdom, particularly – play a dominant role in advancing the scholarship, with limited institutional and country collaboration. While this is problematic for the advancement of the scholarship, it also has an implication for the engagement with policy studies. In a review of publications in a top policy sciences journal, Goyal [263] had found that nearly 80% of the corresponding authors were based in North America (see also [264]). A concerted effort at diversification of theoretical perspectives and/or pan-Atlantic collaboration may then be necessary for cross-fertilization in energy transitions research and policy studies.

Third, traditional theories of the policy process (and other concepts in policy studies) may be perceived as having limited applicability in explaining phenomena in complex sociotechnical systems. Lovell [265], for example, argues that theories of the policy process must incorporate the role of technology in order to explain radical policy change in a sociotechnical system involving durable infrastructure, such as the low-energy housing sector in the United Kingdom. In another study, Lovell, Bulkeley [266] lament the ability of theories of the policy process to explain change in a context involving the convergence of multiple policy areas and/or networks (such as climate change and energy). Similarly, Kern and Rogge [11] find theories of the policy process to be unsuitable for examining sociotechnical transitions due to their focus on single policy instruments (rather than instrument mixes) and lack of attention to policy outcomes.

Fourth, and relatedly, fragmentation in policy studies could be another reason for its sparse application (and perceived limited applicability) in energy transitions research. For example, our co-occurrence analysis showed that the notion of policy mixes has been frequently combined with those of policy evaluation/outcomes, policy feedback, and policy process, thereby moving towards a holistic framework of analysis. In contrast, concepts such as policy agendas, policy formulation, policy goals, (to a lesser extent) policy implementation, policy innovation, policy networks, and policy regimes have been used largely in isolation. This problem of fragmentation of concepts in policy studies has been previously highlighted as a reason for its untapped potential in creating and mobilizing policy-relevant knowledge [267–269].

While this criticism of policy studies is largely valid, recent research has shown that theories of the policy process can be adapted – and even advanced – through applications in complex sociotechnical systems. Goyal, Howlett [59] and Goyal, Howlett [270], for example, have adapted the multiple streams framework to explain a policy invention in energy-water nexus in India and the emergence of the General Data Protection Regulation in the European Union, both of which involved significant policy-technology interaction (see also [271]). Similarly, Dolan [272] has (re-)introduced the notion of partial couplings within the multiple streams framework to explain policy change at the convergence of disaster management and climate change adaptation. Also, Schmid, Sewerin [245] have synthesized the advocacy coalition framework with policy feedback theory to link policy change with policy outcomes and subsequent coalition change in the case of the German energy transition. Relatedly, Goyal [273] has conceptualized policy success using the multiple streams framework to show how the coupling among problem, policy, and politics led to political success despite programmatic failure in the case of the solar energy policy in Gujarat, India.

The policy innovation lens can, in fact, help address fragmentation in policy studies and leverage the growing interest in synthesizing policy studies and transitions research. In a polycentric context, the processes of invention, diffusion, and success (or failure) often occur simultaneously in different jurisdictions around the world, making it imperative to understand whether and how they influence one another. Therefore, apart from the importance of the three perspectives on policy innovation, the lens as a whole emphasizes the need to study invention, diffusion, and success in an integrated manner. Further, it calls for combining notions around the policy context (such as policy paradigms and policy regimes), policy actors (such as policy entrepreneurs and policy networks), policy characteristics (such as policy design, and policy processes (such as policy adoption, policy implementation, and policy feedback) to explain long-term policy outcomes.

How, then, should scholars apply – and further develop – the policy innovation lens for energy transitions research? In this study, we identified some publications applying the three perspectives – entrepreneurship or invention, diffusion, and success – individually to cases in energy transitions. Future research should intensify their use in diverse contexts in order to create generalizable knowledge on policy innovation in energy transitions. In the case of policy success, attention should also be paid to the process and political outcomes of public policy and not only its programmatic outcomes.

In addition, we found that the notion of policy mixes has been used more commonly in energy transitions research. A synthesis of the policy innovation lens with this concept can facilitate the conceptual advancement of both and the empirical advancement of energy transitions research. For example, scholars could study questions such as: what is policy invention in the context of policy mixes? why are some policy mixes more credible, coherent, comprehensive, or consistent that others? how does policy entrepreneurship influence the characteristics of policy mixes? how do policy mixes influence the diffusion of public policy? (see also, [274]) and, how do the different characteristics of policy mixes influence programmatic, process, and political success?

Finally, analytical frameworks from the field of science & technology studies have been used more extensively in energy transitions research as indicated by the key themes identified in this study. Scholars should examine synergies between these frameworks and the policy innovation lens to understand the roles of policy invention, diffusion, and success in sociotechnical transitions systematically. In a recent study, for example, Derwort, Jager [275] have complemented the use of the multilevel perspective with that of the multiple streams framework to show that, in the case of the German energy transition, policy innovation resulted from an interplay between socio-technical and political dynamics. Scholars could build on this approach to further synthesize perspectives on policy innovation with those on sociotechnical change.

To conclude, this study reviewed over 8000 publications on energy transitions to identify the key themes in the scholarship, map conceptual engagement with public policy, show the dearth of research on policy innovation in the literature, and propose avenues for addressing this gap in the future.

Declaration of competing interest

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

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