Expanding the scope and implications of energy research: A guide to key themes and concepts from the Social Sciences and Humanities

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Review

Expanding the scope and implications of energy research: A guide to key themes and concepts from the Social Sciences and Humanities

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ABSTRACT

This paper provides an overview of key themes and concepts within energy-related Social Sciences and Humanities (energy-SSH) research in Europe. It aims to use this overview as an introduction for those producing strategies and interventions to advance energy and sustainability transitions in practice as well as for newcomers to the field of energy-SSH research, such as Science, Technology, Engineering and Mathematics (STEM) researchers. This paper builds on four extensive literature reviews from the EU Horizon 2020 SHAPE ENERGY project on four energy topics derived from the EU's Strategic Energy Technology Plan (EU SET-Plan) priorities: energy efficiency, low-carbon energy supply, energy system optimisation and transport decarbonisation. Based on a cross-cutting analysis of these four literature reviews, this paper discusses the evolution of and recent developments across energy-SSH research. It highlights two interrelated stories of scholarly expansion concerning the role of people in low-carbon energy transitions, illustrated with an example on demand-side management, and points towards future energy-SSH research and policy priorities.

1. Introduction

Over the last decade, there has been increased attention in Social Sciences and Humanities perspectives and research approaches to energy problems in Europe and beyond. New journals, new conferences, new research networks and an increase in funding opportunities all point towards thriving and diverse academic communities. The EU's Framework Programmes (e.g. Horizon 2020) have been based on responding to the crucial societal challenges that the EU has prioritised, such as the transition to low-carbon energy systems. Yet, evidence suggests that EU energy policy has and is still largely being formulated based on insights from disciplines within Science, Technology, Engineering and Mathematics (STEM), while energy-related Social Sciences and Humanities (energy-SSH) have been significantly underrepresented and commonly overlooked [1,2]. Scholars have repeatedly pointed to a status gap between SSH and STEM. For instance, SSH is less prevalent in concepts used in technology development projects [3], with respect to methodological tools and in publications [4]. This is mirrored in energy policy target-setting, which is virtually always framed in terms of technological development and roll-out[1] and with a significant potential for policy making innovation based on SSH insights [5].

Hence, whilst institutional conditions for energy-SSH appear to have improved, its relative impact on policy and governance agendas (vis-à-vis STEM) is still low. We would strongly argue that this is a missed opportunity, especially given that various disciplinary perspectives have illustrated that energy transitions are fundamentally socio-technical (meaning that society and technology affect each other and co-evolve) in both their underlying processes and outcomes [6–8]. Indeed, the transformation of technology happens in tandem with changes in culture, behaviour and practice, and thus only reiterates the need for SSH input into policymaking and related governance arrangements.

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[1] Commission Communication 2015/6317/EC Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation, [online] Available at: [Last accessed 30 November 2018]. https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v8_0.pdf

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Energy-SSH covers a wide range of disciplines that study social phenomena (norms, values, perceptions, institutions, practices etc.) that organise how people interact with the energy system, and/or study fundamental issues of equity, fairness, duty, faith, ethics and attribution in context of the energy system [9,2]. Indeed, the Horizon 2020 Platform: *Social sciences and Humanities for Advancing Policy in European Energy* (SHAPE ENERGY) ,[2] as part of which this paper was written, lists the following disciplines: Business, Communication Studies, Demography, Development, Economics, Education, Environmental Social Science, Gender, History, Human Geography, Law, Philosophy, Planning, Politics, Psychology, Science and Technology Studies, Sociology, Social Anthropology, Social Policy, and Theology. With this paper, we seek to bring energy-SSH perspectives and insights closer together in a format that is useful for those who produce strategies and interventions to advance energy and sustainability transitions in practice. Hence, our target audience is practitioners working to develop research and innovation policy and calls for research and innovation funding. However, we also aim to give newcomers to energy-SSH – for instance, STEM researchers, but certainly not exclusively – a taste of how SSH can contribute to the understanding and realisation of sustainable energy transitions, which often are perceived as technical rather than as socio-technical challenges.

This paper combines and develops the knowledge gained from a set of four literature reviews carried out as part of the SHAPE ENERGY project, which resulted in the publication of four extensive 'annotated bibliographies' (from now referred to as 'the bibliographies'). Based on a cross-cutting analysis of these four bibliographies, this paper discusses the evolution and recent developments across energy-SSH research. This is done by developing two interrelated stories of scholarly expansion concerning the agency and the role of people in low-carbon energy transitions. By doing this, this paper aims to highlight important insights from energy-SSH that can be useful for energy policy and to a greater extent should be taken into consideration when new priorities for research and innovation funding is being discussed.

This paper is organised as follows: Section 2 describes how four teams of scholars in the SHAPE ENERGY project built the four bibliographies and how we, the authors of this paper, analysed the bibliographies. Section 3 provides a brief overview of the four bibliographies. In Section 4, we go deeper into one of the topics that cuts across the four bibliographies, namely how people have been and are currently understood as part of low-carbon energy transitions within energy-SSH. Through two interrelated stories of scholarly expansion on the topics of energy demand and energy production, we delve into an analysis of recent developments within energy-SSH. These developments are then illustrated through the example of demand-side management. Section 5 summarizes the main points of the paper and points towards future (energy-SSH focussed) policy and research priorities.

2. Methodology

2.1. Boundaries and foci

In this article, we – a group of energy-SSH scholars brought together through the Horizon 2020 Platform: *Social sciences and Humanities for Advancing Policy in European Energy* (SHAPE ENERGY) – present a qualitative review of four annotated bibliographies compiling predominantly European energy-SSH research literature on the following four energy topics:

- Energy efficiency and using less [10];
- Competitive, secure, low-carbon energy supply [11];
- Energy system optimisation and smart technologies [12];
- Transport sector decarbonisation [13]

The four topics are based on issues of noted importance within the EU's energy research and innovation policy frameworks. Specifically, these four energy topics were derived from the stated priorities of the EU's Strategic Energy Technology Plan[3] (SET-Plan), and the constituent boundaries were then used for the four literature reviews (see Table 1 below). The SET-Plan was launched in 2008 and, since then, has directed e.g. the funding opportunities (including both content/foci and budget spends) of the EU Horizon 2020′s energy work programmes. Essentially, the SET-Plan states the research and innovation priorities that will allow the EU to achieve its ambitious energy and climate targets (Tables 2–5).

In undertaking the reviews for the four bibliographies - which aimed to provide the foundations to better connecting academic research and its related research/innovation policy discourses - the bibliography authors found it critical that the aforementioned technologically-led topic boundaries remained flexible and, at times, intentionally blurred. Otherwise, it would be a struggle to meaningfully and fruitfully incorporate energy-SSH research into a structure that is dominated by energy technologists. As noted by Coutard and Shove [14], research and policy discourses routinely split matters of energy demand and matters of energy supply, which treat each as separate sites for inquiry and intervention; in reality, demand and supply are intertwined, and rigid categorisations are thus not helpful when seeking to bring both 'the social' as well as 'systemic' considerations into the debate. Moreover, much of the seminal energy-SSH research deals with fundamental ontological issues of how society is ordered and what that means for the influences that underlie human action – as such, these sorts of debates cut across energy topics. Obviously, through focusing on the contributions of energy-SSH to the four aforementioned SET-Plan-inspired energy topics, other topics, which also may deserve to be in the focus of policymakers and other potential users of energy-SSH, have been excluded. We, nevertheless, regard these four energy topics as a useful framework for this review article as the aim of this paper is to raise new approaches to the policy agenda defined in the SET-Plan and to provide practitioners developing research and innovation policy, STEM-researchers and other newcomers, with energy-SSH insights regarding the potential contributions of SSH for understanding and facilitating energy transitions.

2.2. Reviews for and content analysis of annotated bibliographies

Four teams of scholars representing a wide range of SSH disciplines and European countries undertook the reviews resulting in the publication of the four extensive annotated bibliographies on the four energy topics [10–13]. In light of the enourmous amount of energy-SSH literature addressing the four energy topics,[4] the bibliographies did not attempt to provide a comprehensive overview of existing literature. Rather than aiming for a quantitative presentation of metrics, the bibliographies present a selection of literature based on impact and diversity criteria and derived from systematic database searches as well as through advice from a wide range of academic experts. Using this as a basis, summaries of each selected publication were provided as part of demonstrating its relevance for the respective policy area(s). Thus, these bibliographies present a 'taste of energy-SSH' and demonstrate its diversity and potential to address energy policy related issues.

[2] www.shapeenergy.eu

[3] Commission Communication 2015/6317/EC Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation, [online] Available at: [Last accessed 30 November 2018]. https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v8_0.pdf

[4] Just to demonstrate the large amount of Social Sciences and Humanities work in this area: a quick search on 'energy security' (just one small subtopic of one of the bibliographies) on scopus, the largest database for peer-reviewed literature, gave more than 2000 hits (already filtered to only include research from SSH disciplines).

Table 1
SHAPE ENERGY topics, Energy Union R&I and Competitiveness priorities and SET-Plan key actions.

SHAPE ENERGY topics	*Energy Union R&I and Competitiveness priorities* & SET-Plan key actions
Energy efficiency and using less	*Develop and strengthen energy-efficient systems* Action 5: Develop new materials and technologies for, and the market uptake of, energy efficiency solutions for buildings Action 6: Continue efforts to make EU industry less energy intensive and more competitive.
Competitive, secure, low-carbon energy supply	*Number 1 in renewable energy* Action 1: Sustain technological leadership by developing highly performant renewable technologies and their integration in the EU's energy system: Action 2: Reduce the cost of key technologies
Energy system optimisation and smart technologies	*The future smart EU energy system, with the consumer at the centre* Action 3: Create technologies and services for smart homes that provide smart solutions to energy consumers. Action 4: Increase the resilience, security and smartness of the energy system
Transport sector decarbonisation	*Diversify and strengthen energy options for sustainable transport* Action 7: Become competitive in the global battery sector to drive e-mobility forward Action 8: Strengthen market take-up of renewable fuels needed for sustainable transport solutions

Obviously, the disciplinary backgrounds and thematic foci of the teams of scholars who undertook the reviews influenced the selection of literature. However, a bias towards certain disciplines has been mitigated by intentionally consulting experts from other disciplines, and asking them for (deviant) ideas on what relevant literature to include.

The four energy topics differ both in span and disciplinary coverage. Hence, each merited a slightly different approach to searching, selecting, and categorizing the literature.[5] Overall, the four teams of scholars all utilised the following three sampling strategies for collating literature under each of the four energy topics:

- Teams used databases (such as Scopus, Science Direct, Google Scholar and Social Science Citation Index) to search for literature (published up to spring 2017). Topic-specific databases, such as the eceee library[6] and the Transport Research Board Database[7] were also consulted. In these database searches, teams filtered for different SSH disciplines in order to ensure a broad disciplinary coverage.
- Teams looked to previous reviews of energy-SSH research for inspiration for relevant literature and categories within the four energy topics.
- Teams consulted the aforementioned SHAPE ENERGY network of SSH scholars for advice on relevant literature, from their areas of expertise.

As the purpose of the bibliographies was to highlight impact and plurality of SSH insights, the selection of literature for the four reviews was based on the twofold aim of including: (1) seminal publications, for instance indicated by high numbers of citations or publication in journals with high impact factors, and (2) publications representing disciplinary, gender, and geographical diversity. Quality assessments by the teams and novelty were also selection criteria. As a consequence of aiming for disciplinary diversity and, in particular, of aiming to highlight disciplinary contributions that may have been underrepresented in (and overlooked by) energy policy to date, Economics research was deemphasized in the bibliographies as Economics perspectives have traditionally dominated mainstream policy approaches [4,10–13].

Categories and sub-categories to structure the literature were developed based on a grounded approach to qualitative thematic analysis [15,16]. Hence, each bibliography has slightly different categories (see Section 3). Being *annotated* bibliographies, each selected publication was listed under the respective category with a brief summary presenting its main arguments, perspectives, concepts and/or policy recommendations. Further, the different energy-SSH approaches were emphasized in accessible summaries for each category and sub-category and an Executive Summary was provided for each bibliography too, which similarly aimed to increase the useability of the bibliography by policy-facing organisations.

For this paper, we undertook a qualitative content analysis of the four bibliographies looking particularly at cross-cutting topics and concepts. We found that a central cross-cutting theme concerned how people have been and are currently understood as part of sustainability transitions within energy-SSH. Thus, in Section 4 of this paper, we go deeper into this theme and discuss certain developments and emerging research areas within energy-SSH.

3. Key areas of SSH-energy research: four annotated bibliographies

In this section, we provide an overview of the four bibliographies [10–13] on the four energy topics. These are topics to which SSH studies have made significant and broad contributions.

3.1. Energy efficiency and using less [10]

SSH scholars working within the broad area of the first topic, *Energy efficiency and using less,* focus on the demand side of the energy system. This includes research on increasing energy efficiency, by means of technologies [17], practices [18,19] and end-user behaviour [20,21]. Concerning the disciplinary coverage of this topic, a wide range of SSH disciplines have been utilised, and thus different approaches to and framings of energy efficiency and using less are represented [10].

It is noteworthy that each discipline represented in this bibliography frames the problems of energy efficiency and using less differently. The Economics perspectives are, however, adopted widely, especially in policy, closely followed by the Sociological perspectives, while other disciplines such as Urban Studies and Industrial Design are only slowly becoming part of this body of energy-SSH research.

The bibliography authors observe that much of the research concentrates on new technologies, such as feedback devices and smart meters, rather than on the more everyday technologies such as water heaters or washing machines. Hence, SSH researchers urge for an increased focus on everyday material objects and cultures that shape the ways users can engage in energy efficiency and demand reduction. Further, it is noteworthy that exceptions in terms of analytical focus - i.e. deviants, others, non-users, excessive users, or low-energy practices, such as music making or sports - are not in the focus of the majority of studies and therefore deserve more attention.

New areas of research related to this energy topic focus on innovative demand-side initiatives, services/business models and markets such as peer-to-peer, DIY, and community approaches to engagement. However, SSH researchers urge research and policy to pay more attention to energy justice and energy poverty related to energy

[5] Please refer to the annotated bibliographies for a more detailed description of the respective methods employed.
[6] https://www.eceee.org/library/
[7] http://www.trb.org/Main/Home.aspx

Table 2
Categories and subtopics of the annotated bibliography "Energy efficiency and using less" [10].

CATEGORIES	SUBTOPICS	LITERATURE[13]
Using energy	Behaviour	Kollmuss & Agyeman, 2002; Dietz et al., 2009; Gaspard and Martin, 2016; Garabauau-Moussaoui, 2009; Ehrhardt-Martinez and Laitner, 2009; Marechal, 2009; Chatterton and Wilson, 2013; Duijn et al., 2013; Poortinga et al., 2003; McDonald et al., 2006
	Practices	Gnoth, 2013; Shove et al., 2014; Jensen et al., 2011; Royston, 2015; Naus et al., 2015; Zelem & Beslay, 2015; Subremom, 2014; Radanne et al., 2016
	Time and rhythm of energy consumption	Shirani et al., 2013; Torriti, 2017; Spurling, 2015; Jalas, 2002; Crary, 2013; Jalas, 2012
	Engagement and empowerment	Wallenborn, 2007; Heiskanen et al., 2015; Jellama & Mulder, 2016; Marres, 2011; Geelen et al., 2013; Fink et al., 2011
	Acceptability and adoption	Judson et al., 2015; Souami & Kasdi, 2015; Walker et al., 2014; Heering et al., 2007; Hyysalo et al., 2013; Ornetzeder & Rohracher, 2006; de Vries et al., 2016
	ICT, data, and feedback technologies	Laget, 2008; Blomqvist & Thollande, 2015; Castri et al., 2014; Rotmann et al., 2011; Beloglazov et al., 2012; Røpke & Christensen, 2012; Brandon & Lewis, 1999; Buchanan et al., 2015; Yang & Newman, 2012; Fischer, 2007; Felicetti et al., 2015; Ehrhardt-Martinez et al., 2011; McCoy & Lyons, 2017; Vassileva et al., 2012; Hargreaves et al., 2013; Klopfert & Wallenborn, 2011
	User scripts	Akrich, 1992; Wilhite, 2007; Jelsma & Knot, 2002; Jelsma, 2004; Lilley et al., 2010; Gaye & Wallenborn, 2014; Throndsen, 2017; Royston, 2015; Ivory, 2013; Maranta et al., 2003; Wilhite & Wallenborn, 2013
	Global impact on local level	Debeir et al., 1991; Aune et al., 2016
Users of energy	Different people, different approaches?	Wyatt, 2013; Urban & Scasny, 2012; Brounen et al., 2012; Gaspar & Antunes, 2011; Vassileva & Campillo, 2014; Sutterlin et al., 2011; Tjorring, 2016
	Non-residential sites	Gerstberger et al., 2016; Pereira et al., 2014; Staddon et al., 2016; Christina et al., 2014; Olsthoorn et al., 2017; Trianni et al., 2014; Sekki et al., 2017; Ornetzeder et al., 2016
	Changing roles and new players	Matschoss et al., 2015; Parag, 2015; Rudinger, 2017; Muller et al., 2011; Rae & Bradley, 2012; Heiskanen et al., 2010
	Leadership, champions and ambassadors	Martiskainen, 2017; Marchand et al., 2015
	Intermediaries	Moss, 2009; Maneschi, 2013; Parag & Janda, 2014; Nolden et al., 2016
Distribution of costs and benefits	The landlord-tenant dilemma	Charlier, 2015; Banfi et al., 2008; Högberg, 2014; Nair et al., 2010; Milin & Bullier, 2011; Bullier & Milin, 2013
	Socio-economic divide	Milne & Boardman, 2000; Mangold et al., 2016; Heyman et al., 2011
	Poverty	Beretta, 2014; Darby, 2012; Day et al., 2016; Moser, 2013; Guertler, 2012; Urge-Vorsatz & Herrero, 2012; Hong et al., 2009; Katsoulakos, 2011; Dubois & Meijer, 2016
	Multiple benefits	IEA, 2014; Kerr et al., 2017; World Green Building Council, 2014; Heyman et al., 2011; Foy, 2012
Market and institutions	Business models	Al-Salah & Mahroun, 2015; Plepys et al., 2014; Bocken et al., 2014; Hiteva & Sovacool, 2017; Nilsson et al., 2012; Gouldson et al., 2015; Lombardi & Schwabe, 2017; Burger & Weinmann, 2012; Lorenz et al., 2012; Gallo & Gianfrate, 2011; Freeman et al., 2017; Porter & Kramer, 2011; Luekefett & Binder, 2012
	Rebound Effect	Némoz & Wallenborn, 2012; Hertwich, 2008; Galvin, 2015; Gillingham et al., 2016; Copiello, 2017; Galvin, 2014; Galvin & Sunikka-Blank, 2016; Saunders, 2013; Maxwell et al., 2011
	Degrowth and decoupling	Latouche, 2003; Bithas & Kalimeris, 2013; Wallenborn, 2009; Csereklyei & Stern, 2015; Martínez-Alier et al., 2010; Capellan-Perez et al., 2015; Wilhite, 2016
	Responsibility division	Hennicke, 2013; Grandclement et al., 2015
	Norms, values and institutions	Bouillet, 2014; Wahlström et al., 2016; Breukers et al., 2016; Alberts et al., 2016; Fornara et al., 2016 ; Liu et al., 2016; Amasyali & El-Gohary, 2016; Schultz et al., 2007
Policy, transitions and governance	Transitions and governance	Jensen & Zandersen, 2016; Bosman et al., 2014; Sorrell, 2014; Winskel & Radcliffe, 2014; Kivimaa & Kern, 2016; Verbong et al., 2016; Seyfang et al., 2014; Quitzau et al., 2012; Kivimaa et al., 2017; Energy Cities, 2016a; EnergyCities, 2016b; Cihuedo et al., 2015
	Policy instruments	Galarraga et al., 2013; Energy Cities, 2017; Allcott et al., 2014; Bolton & Foxon, 2015; Waitt et al., 2016; Guerassimoff & Thomas, 2014; Middelkoop et al., 2017; Ringel et al., 2016; Covenent of Mayors, 2015; Tsvetanov & Segerson, 2013; Sachs, 2012; Heiskanen et al., 2013; Groesser, 2014; EnergyCities, 2011; Banyai, 2013; Rousseaux et al., 2011
	Demand-side management	Apajalathi et al., 2015; Murtagh et al., 2014; Darby & McKenna, 2012; Goulden et al., 2014 ; Lassalle et al., 2016 ; Burchell et al., 2014
	Justice	Chatterton et al., 2016; Simcock & Mullen, 2016; Walker & Day, 2012; Heffron et al., 2015
	Monitoring, evaluating and learning	Pearson et al., 2014; Patterson, 1996; Mourik et al., 2015; Pickl et al., 2016; Neij & Åstrand, 2006; Gynther et al., 2012, Vine et al., 2014; Wade & Eyre, 2015; Hobson et al., 2014; Luederitz et al., 2016; Heiskanen & Matschoss, 2016; Moser et al., 2015; MacLaury et al., 2012; Burchell et al., 2015; Watson et al., 2015; Backhaus et al., 2010

[13] See Appendix A in Supplementary materials for full references (in the same order as they appear in the table).

efficiency.

Other examples of policy-relevant insights in this bibliography include that SSH researchers advocating for policies targeting energy efficiency in households should target the structural elements of household energy demand, such as markets, institutions and policies, in addition to household actions. Interventions should address the complex interplay of technology, material culture, institutions, norms and values [10].[8]

[8] See [10] for more policy-relevant insights from energy-SSH about energy efficiency and using less.

3.2. *Competitive, secure, low-carbon energy supply [11]*

The topic *Competitive, secure, low-carbon energy supply* addresses the aim of transforming energy supply and increasing the share of renewable and low-carbon energy and conversion technologies for electricity, heating and cooling. SSH scholarship within this topic has a particular focus on understanding transition processes and the role of different actors, such as citizens, businesses, industries, planners, and policymakers, in energy transitions [11].

The bibliography demonstrates the diversity of disciplinary approaches (see SHAPE ENERGY list of SSH disciplines in introduction) relevant for understanding low-carbon energy transitions. It highlights

Table 3
Categories and subtopics of annotated bibliographies "Competitive, secure, low-carbon energy supply" [11].

CATEGORIES	SUBTOPICS	LITERATURE[14]
Politics	Governing low-carbon energy transitions	Kemp et al. 1998; Geels & Schot, 2007; Shove & Walker, 2007; Normann, 2015; Hildingsson & Johansson, 2016; De Jong, 2011; Smith et al., 2005; Geels, 2014; Verbong & Loorbach, 2012; Bolton & Foxon, 2015
	Policy instruments, policy mixes and regulation	Kanellakis et al., 2013; Jacobs, 2013; Gullberg & Bang, 2015; Dóci & Gotchev, 2016; Rygg, 2014; Lehmann & Gawel, 2013; Reichardt & Rogge, 2016; Del Río, 2014; Johnston & Van Der Marel, 2016; Abad Castelos, 2014
	Planning and land use	Cajot et al., 2017; Chanard et al., 2011; Balta-Ozkan et al., 2015 ; Papaza, 2016 ; Mc Laren Loring, 2007 ; Lee, 2017 ; Leibenath & Otto, 2013 ; Demazière, 2014 ; de Waal & Stremke, 2014 ; Christie et al., 2014; Kerr et al., 2014
	Energy security	Winzer, 2012; Gracceva & Zeniewski, 2014; McCollum et al., 2013; Nepal & Jamasb, 2013; Parag, 2014; Knox-Hayes et al., 2013; Sovacool & Tambo, 2016; Bradshaw, 2010; Umbach, 2010; Hayashi & Hughes, 2013
Publics	Attitudes and acceptability	Wüstenhagen et al., 2007; Zoellner et al., 2008; Karlstrøm & Ryghaug, 2014; Perlaviciute & Steg, 2014; L'Orange Seigo et al., 2014; Walker et al., 2014; Ladenburg et al., 2013; Delicado et al., 2014; Devine-Wright, 2009; Burningham et al., 2015; Heidenreich, 2015
	Energy citizenship	Walker et al., 2011; Devine-Wright, 2007; Rasch & Köhne, 2016; Sarrica et al., 2014; Whitmarsh et al., 2011; Barrios-O'neill & Schuitema, 2016; Christen & Hamman, 2014; Bauwens, 2016; Li et al., 2013; Heiskanen et al., 2015
	Consumers and prosumers	Palm & Darby, 2014; Shove, 2003; Wilhite et al., 2000; Schot et al., 2016; Janda, 2011; Heiskanen et al., 2010; Ellsworth & Reid, 2016; Olkkonen et al., 2017; Parag & Sovacool, 2016; Ritzer, 2015
	Ethics and religion	Miller, 2014; Rasmussen, 2011; Köhrsen, 2015; Lothes Biviano et al., 2016; Taebi et al., 2012; Bergen, 2016; Hillerbrand & Peterson, 2014; Gamborg et al., 2014; Hope & Jones, 2014; Bergmann, 2015
	Energy justice	Jenkins et al., 2016; Heffron & McCauley, 2014; Heffron et al., 2015; Fuller & McCauley, 2016; McCauley et al., 2016; Yenneti, 2016; Reames, 2016; Liljenfeldt & Pettersson, 2017; Simcock, 2016
Markets	Innovation and R&D	Brook et al., 2016; Garud & Karnøe, 2003; Karnøe & Garud, 2013; Neij et al., 2017; Sørensen, 2013; Heiskanen et al., 2015; Sovacool, 2010; Fuchs, 2014; Levidow et al., 2013; Kostakis et al., 2013
	Commercialisation, industry and business	Apajalathi et al., 2017; Andrade & de Oliveira, 2015; Al-Najjar & Anfimiadou, 2012; Foxon, 2011; Hahn et al., 2010; Mekhilef et al., 2011; Karlsson et al., 2016; Boons et al., 2013; Kindstrom et al., 2017; Lund, 2009
	Energy markets	Soytas & Sari, 2003; Bayanova, 2016; Edenhofer et al., 2013; Apergis & Payne, 2012; Helm, 2014; Movilla et al., 2013; Schleicher-Tappeser, 2012; Eurelectric, 2016
	Energy prices	Ketterer, 2014; Sadorsky, 2012; Sari et al., 2010; Koch et al., 2014; Hirth, 2013; Würzburg et al., 2013; Clò et al., 2015; Dütschke & Paetz, 2013; Kalkuhl et al., 2013; Campiglio, 2016; Olsson & Hillring, 2014
Pasts and futures	Histories of energy	Solomon & Krishna, 2011; Augustoni, 2014; Illich, 1973; Mumford, 1934; Missemer, 2012; Banks, 2015; Beuse et al., 2000; Kaldellis & Zafirakis, 2011; Jansson & Uba, 2015
	Sociotechnical imaginaries and expectations	Jasanoff & Kim, 2013; Gjefsen, 2013; Smith & Tidwell, 2016; Sovacool & Ramana, 2015; Cherry et al., 2017; Nissilä et al., 2014; Skjølsvold, 2014
	Energy scenarios	Meyer et al., 2012; Jørgensen & Jørgensen, 2009; van den Bergh et al., 2015; Hughes et al., 2013; Giampietro & Sorman, 2012; Hofman & Elzen, 2010; Verbong & Geels, 2010; McDowall, 2014; Mathy et al., 2015; Winskel and Radcliffe, 2014

[14] See Appendix B in Supplementary materials for full references (in the same order as they appear in the table).

contributions from disciplines such as Ethics, History, Theology, and Anthropology, which have not received much attention as significant contributors to energy research and policy [4,2].

Noteworthy insights from this bibliography include the call from SSH researchers for broader, more holistic and systemic perspectives rather than focusing merely on specific energy technologies. This involves a broader focus on innovations that include citizen initiatives and citizen engagement in energy transitions. Regardless of the specific topic addressed - whether it was energy security or land use planning - the importance of citizen involvement and taking into account citizens' concerns and perspectives is repeatedly emphasized. This emphasis also implies that SSH research should increasingly address the actors and processes responsible for citizen engagement and related issues such as energy justice and ethics.

The broad perspective towards competitive, secure, low-carbon energy supply is also demonstrated by the significant interest in Transitions Studies and the respective aim to gain a better understanding of transitions and how to manage and govern them. In this context, the Multi-Level Perspective (MLP) with its tenet of transitions as interactions between the niche, regime and landscape levels, plays a prominent role. On a critical note, however, SSH researchers stress that research within the MLP framework should facilitate a deeper consideration of individual/organizational actors and their practices, as well as politics and power, for instance, which are often are overlooked. Further, researchers urge both research and policy to address the established actors involved in current energy systems and how they can contribute to energy transitions.

Finally, the literature stresses that energy transitions are long-term processes, which are challenging to govern as they involve many different social, environmental, economic and technical aspects. More focus on SSH research both about histories of past transitions and visions and scenarios for future transitions may contribute as reminder of the holistic perspectives needed in order to better understand and enable transitions to energy systems with competitive, secure and low-carbon energy supply [11].[9]

3.3. *Energy system optimisation and smart technologies [12]*

The topic of *Energy System Optimisation and Smart Technologies* addresses the integration of renewable energy sources into the energy system through the application of Information and Communication Technology (ICT) – often referred to as 'smart' technologies. Sumpf et al. [12] argue that such 'smartification' of the energy system brings a new set of societal conditions and consequences of particular interest to SSH scholars, such as affordability of energy, societal experiments and visions, social aspects of sustainability, and the role of users into focus. Disciplinary perspectives from Economics, Sociology, Science and Technology Studies Psychology, Politics, Ethnography, Development, Environmental Social Science, Geography, Planning, Law and History are represented in this research [12].

Noteworthy insights from this bibliography include that researchers acknowledge that techno-economic accounts focusing on financial cost/benet analyses are highly represented also in the literature on energy system optimization and smart technologies. Consequently, research on regulation, governance, policy initiatives, communities, social practices

[9] See [11] for more policy-relevant insights from energy-SSH about competitive, secure, low-carbon energy supply.

Table 4
Categories and subtopics of annotated bibliography "Energy System Optimisation and Smart Technologies" [12].

CATEGORIES	SUBTOPICS	LITERATURE[15]
System integration of consumers through smart technologies	Smart metering and demand-side management	Darby, 2010; Goulden et al., 2014; Higgenson et al., 2014; Lassalle et al., 2016; Nachreiner et al., 2015
	Prosumers and energy citizens	Devine-Wright, 2007; Ellsworth-Krebs & Reid, 2016; Gangale et al., 2013; Geelen et al., 2013; Wallenborn & Klopfert, 2011
	Acceptance and refusal of smart technologies	Batel et al., 2013; Buchanan et al., 2016; Ellabban & Abu-Rub, 2016; Marres, 2012; Wolsink, 2012
	System security, privacy and control	Döbelt et al., 2015; Fell et al., 2014; Hansen & Hauge, 2017; King & Jessen, 2014; Winter, 2015
Defining, envisioning and critiquing smart technologies	Historical accounts of energy system optimisation	Hughes, 1992; Jefferson, 2015; Mayntz, 2009; Trentmann, 2009; Solomon & Krishna, 2011
	Typologies and critiques of smart technologies	Bigerna et al., 2016; Levinson, 2010; Luque-Ayala & Marvin, 2015; Towsend, 2013; Wilson et al., 2015
	Socio-technical imaginaries and visions of smart energy systems	Ballo, 2015; Groves et al., 2016; Köktürk & Tokuç, 2017; Strengers, 2013; Tricoire, 2015
	Socio-technical modelling of and scenarios for smart grids	Börjeson et al., 2006; Connolly et al., 2016; Fortes et al., 2015; Yanev et al., 2013; Zio & Aven, 2011
Societal conditions and consequences of consumer integration into smart energy systems	Affordability and energy justice in smart grids	Alexander, 2010; Darby, 2012; Jenkins et al., 2016; Oldfield, 2011; Wolsink, 2013
	Value-oriented design and user integration in smart grids	Katzeff & Wangel, 2015; Ribeiro et al., 2012; Sahakian, 2011; Skjølsvold et al., 2017; Strengers, 2014
	Smart cities, communities and city living labs	Bibri & Krogstie, 2017; Burchell et al., 2014; Canzler et al., 2017; Hodson & Marvin, 2010; Späth & Rohracher, 2010
	Green ICT and life-cycle-assessment	Khor et al., 2015; Jorge & Hertwich, 2014; Moretti et al., 2017; van Dam et al., 2013; Nyborg & Røpke, 2011
Policy, markets and system dynamics in smart grids	ICT-based business and market developments	Bhagwat et al., 2016; Giordano & Fulli, 2012; Hall & Foxon, 2014; Roos et al., 2014; Shomali & Pinkse, 2016
	Agent-based modelling of smart grids	Howell et al., 2017; Macal & North, 2014; Malik & Lehtonen, 2016; Ringler et al., 2016; Rixen & Weigand, 2014
	Innovation, diffusion and transition research	Bruns et al., 2010; Muench et al., 2014; Naus et al., 2015; Skea, 2013; Vesnic-Alujevic et al., 2016
	Policy-making and regulation for smart grids	Connor et al., 2014; Oseni & Pollitt, 2017; Rawlings et al., 2014; Römer et al., 2012; Schaechtele & Uhlenbrock, 2011
	Legal challenges for smart grids	Angenendt et al., 2011; Borlick, 2011; Giacomarra & Bono, 2015; McDonald & Cranor, 2008; Quinn & Reed, 2010

[15] See Appendix C in Supplementary materials for full references (in the same order as they appear in the table).

and user-centric design, including critical issues such as privacy intrusion, is called for [12].

Based on a deconstruction of overly optimistic visions of smart societies, many SSH researchers urge caution in considering the (financial and socia costs and benefits of smart technologies. Instead, a focus on historical accounts and future scenarios and visions, and on definitions, typologies and critiques of smart energy systems, will contribute to a more holistic, diverse and realistic picture. Further, SSH research in this area adds a specific focus on consumers, users and citizens, often related to demand-side management or the acceptance of smart technologies. Acknowledging the socio-technical make-up of the energy system, researchers across many topics and disciplines emphasize the importance of cooperation between techno-economic and SSH approaches for a successful smart grid realisation [12].[10]

3.4. *Transport sector decarbonisation [13]*

The topic of *Transport Sector Decarbonisation* involves different modes of transportation (car, train, walking, cycling, etc.), fuels, infrastructures and professional sectors. Buchmann et al. [13] find that transport sector decarbonisation is a much researched topic among SSH researchers across disciplines such as Psychology, History, Human Geography, Sociology, Economics and Urban Planning, but also intersectional disciplines such as Tourism and Gender studies.

SSH research on the decarbonisation of the transport sector encompasses studies of different transport modes and modal shifts. Interesting aspects of this include which transport modes are being replaced through other modes and what the overall emission effects of such modal shifts might be (e.g. bikesharing replacing walking, but producing higher emissions; see [22]. Another important strand of research has focused on the way certain low carbon transport modes are being politically marginalised (e.g. rickshaws, roller skating; see e.g. [23,24]).

SSH research highlights connections that embed high carbon lifestyles in our society, such as the relation between the frequency and distance travelled for work or pleasure and the career and social capital associated with this. Thus, the most emission-intensive and environmentally damaging 'travels' have also been most often socially rewarded (see e.g. [25,26]). In the same vein, Brand and Preston [27] show that the wealthiest and most educated people have a disproportionately larger carbon footprint and thus environmental damage from their travels, and point to this being an area where political intervention is needed. Pro-environmental attitudes do not necessarily manifest as low emissions travel, but can, instead, give 'license' to pollute more during vacation (see e.g. [28]). Researchers also point out that long distance travel has become a normalised and ritualised behaviour, for example to mark special life events (see [29]).

Other examples of policy-relevant insights from this bibliography include pointing out that much SSH research on Transport Sector Decarbonisation concerns individual consumer choices, focusing on attitudes towards technologies or policies, and factors that may determine transport mode preferences. In contrast, a closer look at the role of car corporate lobbying and interactions between national governments and EU policies is urged [13].[11]

[10] See [12] for more policy-relevant insights from energy-SSH about energy system optimization and smart technologies.

[11] See [13] for more policy-relevant insights from energy-SSH about transport sector decarbonisation.

Table 5
Categories and subtopics of annotated bibliography "Transport Sector Decarbonisation" [13].

CATEGORIES	SUBTOPICS	LITERATURE[16]
	Overviews of transport decarbonisation	Bernardino et al., 2015; Chapman, 2007; Goldman & Gorham, 2006; Hickman & Banister, 2004; Moriarty & Honnery, 2013; Santos et al., 2010; Schwanen, 2016; Schwanen et al., 2011
Transport modes	Walking Walking and walkability Walking and safety Interventions to increase walking	DeBordeauhuij et al., 2011; Forsyth, 2015; Forsyth & Southworth, 2008; Middelton, 2011; Belding & ElSherief, 2015; Cuttler & Malone, 2005; Stratford, 2016; Giles-Corti & Donovan, 2003; Whitelegg, 2001
	Cycling Cycling and cyclists Interventions to increase cycling What's next for cycling? Velomobiles, cargo bikes, rickshaws	Aldred, 2012; Heinen et al., 2010; Furness, 2010; Fishman et al., 2013; Koglin & Rye, 2014; Pucher et al., 2010; Cox & van de Walle, 2007; Riggs, 2016; Tiwari, 2014
	Public transport: bus and rail How people use and experience public transport Interventions to increase public transport	Augé, 1986; Guiver, 2007; Guo, 2011; Joireman et al., 2004; Lyons et al., 2008; Newman et al., 2013; Schivelbusch, 2014; Clayton et al., 2016; Currie & Wallis, 2008; Fearnley, 2013; Hodgson et al., 2013
	Personal fuelled transport: the car, motorbikes and mopeds Drivers and driving Interventions in car use What's next for personal transport? Electric vehicles	Dalby & Paterson, 2006; Hiscock et al., 2002; Lucas & Schwanen, 2011; Mattioli et al., 2016; Abrahm et al., 2011; Behrendt et al., 2010; Eskeland & Feyzioglu, 1997; Innocenti et al., 2013; Kent & Dowling, 2013; Schwanen et al., 2012; Wright & Egan, 2000; Austin et al., 2010; Howarth, 2012; Kopp, 2011; Kuhnimhof et al., 2012; McDonald, 2015; Tertoolen et al., 1998; Wadud et al., 2016; Bodin et al., 2015, Calef & Goble, 2007; Kahn, 2007; Klöckner et al., 2013; Ryghaug & Toftaker, 2016; Ryghaug & Toftaker, 2014; Sovacool & Hirsh, 2009; Wentland, 2016
	Flying and tourism	Barr et al., 2011; Becken, 2017; Cohen & Gössling, 2015; Hall et al., 2017; Higham et al., 2014; Lassen, 2010; Luzecka, 2016; Rosa, 2003; Randles & Mander, 2009
Topics cutting across transport modes	Trade and freight Container shipping Surface freight Urban freight	Birtchnell & Urry, 2015; Martin, 2013; McKinnon, 2016; Steinberg, 1999; Carrara & Longden, 2016; Eom et al., 2012; Gregson, 2015; McKinnon, 2015; Birtchnell et al., 2013; Cohen-Blankshtain & Rotem-Mindali, 2016; Garnett, 2015; Ho et al., 2016; North, 2010; Rosqvist & Hiselius, 2016; Visser et al., 2014
	Historical transport and change processes Early bicycle invention and climate change The historical electric car and replacing the animal Reactions to and repercussions of new transport technology	Gaboriau, 1991; Lessing, 2003; Reid, 2014; Geels, 2005; Høyer, 2008; Tarr & McShane, 1997; Kline & Pinch, 1996; O'Rourke & Williamson, 2002; Thraikill, 2010; Wheelersburg, 1987
	Fuels Diesel, taxation Alternative fuels Fuel hype and rebound effects	Bogelund, 2007; Holamn et al., 2015; Shipper & Fulton, 2013; Sterner, 2007; Hansen, 2014; Iles, 2013; Raman, 2013; Font Vivanco et al., 2014; Melton et al., 2016; Polimeni et al., 2008; Ruef & Markard, 2010
	Built environment and transport Designing towns and cities: land density and urban planning Transport infrastructure: roads, parking and other places	Bart, 2010; Cervero, 1995; Hiltunen & Rehunen, 2014; Holden, 2007; Mees, 2010; Shove et al., 2015; Wagener, 2013; Augé, 1995; Chan & Shaheen, 2012; Dalakoglu & Harvey, 2012; Godefrooij & van Goeverden, 2011; Hermann & Kodransky, 2011; Merriman, 2016; Percoco, 2014
	Institutions and stakeholders	Anderton, 2017; Clemente & Gabbioneta, 2017; Gössling et al., 2016; Gulbrandsen & Raaum Christensen, 2014; vanlier & Macharis, 2015; Lindenthal, 2014; Marsden et al., 2014; Mikler, 2005
	Social inclusion and ethics Social differences Reframing debates on social differences	Brand & Preston, 2010; Carlsson-Kanyama & Linden, 1999; El Hanandeh, 2013; Milbourne & Kitchen, 2014; Motte-Baumvol & Nassi, 2012; Shrestha et al., 2016; Sirén et al., 2010; Steinbach et al., 2011; Vinz, 2009; Hanson, 2010; Levin, 2009; Mattioli, 2016; Melin, 2008; Mullen & Marsden, 2016; Perie, 2009; Schwanen, 2017
	Paradigms and transport research	Avineri, 2012; Cairns et al., 2014; Creutzig, 2016; D'Andrea et al., 2011; Gudmundsson, 2003; Schwanen, 2016 ; Sheller & Urry, 2006; Stephenson et al., 2015; Whitmarsh, 2012; Watson, 2012

[16] See Appendix D in Supplementary materials for full references (in the same order as they appear in the table).

4. Concepts of agency in energy-SSH

In the previous section, we briefly outlined the main features of the four SHAPE ENERGY bibliographies on four key energy topics. In this section, based on a cross-cutting analysis of the four bibliographies, we aim to demonstrate some of the developments within energy-SSH over the last decades. We do this through zooming in on a selected theme that is central in the four bibliographies as well as in current energy policy discussions, namely: how people are understood as part of low-carbon energy transitions. This theme is pertinent across different SSH-energy research areas, and will increase in importance over the coming years. This is evident from current prioritizations in EU funding schemes, as increasing the share of renewable energy production is seen as moving energy technologies closer to people's everyday lives. Hence, people are expected to take on new and more active roles in the energy system, which is reflected in e.g. the SET-Plan where delivering a consumer-centric energy system with active market participation on behalf of consumers and prosumers are regarded as key goals.[12]

In the following, we will present established trends and ongoing debates in energy-SSH research. We have structured the discussion in two related sections followed by an illustrative example. The first section (4.1) discusses energy demand and energy use in households. The second section (4.2) focuses on energy production discourses and the role of publics in energy production. The overall developments derived from these two interrelated stories of scholarly expansion will be illustrated with an example on demand-side management (4.3).

[12] Commission Communication 2015/6317/EC Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation, [online] Available at: [Last accessed 30 November 2018]. https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v8_0.pdf

4.1. Focusing on behavioural change, practices and users in energy demand

The acknowledgement that new technologies alone will not deliver a more sustainable energy system, but that such a system as well relies on peoples' energy use, often leads to an interest in people as consumers or customers, and an instrumental focus on how to change energy behaviour. Behaviour is a well-explored, but also debated concept among energy-SSH researchers. Behavioural Economics and (Environmental) Psychology represent large bodies of work that have sought to better understand behaviour change in the transition to low-carbon societies [10]. This research often focuses on individuals and on understanding how different characteristics affect behaviour, such as socio-economic status, environmental attitudes, attitudes towards policy, cultural norms and motivations of users and residents, size and composition of the household, and physical characteristics of dwellings [30–35].

Many of the studies that draw on Psychological theories focus on social norms and peoples' attitudes and belief systems that are seen to spur specific pro-environmental behaviours or energy (technology) choices, for instance choice of transport mode or energy consuming equipment. This literature has repeatedly focused on the observation that there is often a gap between peoples' awareness of climate change and how people act. This is commonly referred to as the 'awareness-action-gap' [20,36] or the 'value-action gap' [37]. Instead of relying on so-called information deficit models, suggesting that people need more information to behave more energy efficient or use less, this 'gap' rather points to the argument that information provision to raise awareness about environmental issues does not necessarily instigate behavioural change.

The focus on demographics and behavioural prediction methods within some parts of the energy-SSH community (especially common within Psychology and Behavioural Economics) hinges on the assumption that directly influencing energy behaviour at an individual (rather than societal) level can reap significant changes. There is thus a wealth of existing research to draw on when it comes to fostering behavioural change and the abovementioned value-action gap. The so-called rebound effect has become widely discussed and researched within this area. The rebound effect is also known as Jevons' paradox and was presented as early as in 1865, in relation to the coal efficiency of trains [38–40]. The concept rests upon an idea that if there are efficiency savings in one area, the money, time or energy saved will eventually be spent on activities that might be even more carbon intensive. For example, if travelling the same distance becomes cheaper due to increased fuel efficiency, the idea is that the demand for travelling will rise and people will choose to travel further [38] (see [13], Section 9.3). In this perspective, people are mainly interpreted as economic agents interested in maximising their rewards from efficiency improvements.

There are different definitions of rebound effects and no consensus on how they should be calculated [41,42]. Galvin [43] argues that a focus on rebound effects avoids proper examination of peoples total energy consumption because lower income groups often use far less energy than higher income groups, while at the same time showing higher rebound effects. There is a related debate concerning whether higher energy consumption is caused by rebound effects or by economic growth and rising incomes, especially amongst low-income groups [43,44]. Thus, the discussions of rebound effects both serve to highlight the complex relationship between people's use of energy and economics, as well as pointing towards the importance of looking at how groups of people respond differently to different measures and in the end use different amounts of energy.

More recently, there has been a concerted move in energy-SSH research away from this primary focus on individual behaviour. Indeed, some argue that a focus on individuals may not lead to the widespread societal change needed to transform societies and that a focus on individual behaviour also gives consumers too much responsibility for change, while the agency of policymakers and corporations are undermined (see e.g. [45]). Moreover, and in relation to the so-called practice turn in social theory [46], these alternative perspectives move away from focusing typically on energy use as an individual choice, to considering how most energy-related practices are embedded in society and are formed by culture and meanings, materials and technologies, institutions, and infrastructures [47,48], (see also [10], Section 1.2). Thus, the Theories of Practice approaches highlight that energy use in itself is seldom something users consciously engage with. Instead, energy use is a derived demand interlocked in many practices, such as driving to work or cooking a meal, and associated with objectives such as keeping clean or comfortable [49–53,19]. According to this perspective, in order to change how (energy) practices are performed, we have to understand how practices are socially organized, how they evolve over time and how they are reproduced by society (see [13], Section 13).

Another recent development within energy-SSH research (with obvious similarities to the practice turn discussed above) highlights the diversity of and relationships between energy users and other actors, their needs and abilities, and their potential roles in low-carbon transitions [32,54,55]. This includes research addressing the specific role of actors - such as pioneering consumers [56], leaders and ambassadors [57], middle actors or intermediaries [58–61] and prosumers [62–65] - into advancing energy transitions. Particularly, research on different groups of intermediary actors has grown considerably during the last years, including as systemic intermediaries, regime-based transition intermediaries, niche intermediaries, process intermediaries, and user-intermediaries [66] in transitions.

Users have for long been seen as agents of technological change within fields such as Media and Cultural studies. Indeed, the SCOT (Social Construction of Technology) approach [67], Feminist approaches, and the History of Technology all initiated an early 'turn to users' [68]. Technology Studies and Gender Studies also reflect a shift in conceptualizing users from passive recipients of technology to active users that work to appropriate technologies into everyday life [[68], pg. 5]. In fact, Schot et al. [55] have developed a typology of user roles that describe and characterize the hybrid and diverse roles users have in transition processes. They distinguish between five types of users in energy transitions on the basis of their role as being user-consumers, user-citizens, user-inventors, user-deliberators, or user-legitimators, thereby showing that users contribute to the innovation and evolution of emerging niches in designing, modifying and testing technologies. As such, Schot et al. [55] illustrate how users engage in a wide range of activities spanning from lobbyism and working politically to advance the success of particular niches to incorporating innovations in their daily lives and creating new practices and symbolic meaning to rising niches.

Many energy-SSH researchers have been preoccupied with how users are conceptualized in technology design and with describing user-technology relations. Some of these studies were introduced by scholars drawing upon semiotics to study how users were represented by designers [68,69]. More recent debates in energy-SSH have addressed how designers configure users in the design of smart energy technologies. One example is the way designers often tend to see users as rational, interested or competent 'resourceful' men. Strengers [70] has criticized this stereotype and suggested that designers should open up and be more attentive to other, perhaps more realistic, types of users. In this respect, energy-SSH researchers have repeatedly pointed out that users may act differently from designers' expectations and that there is a need to include socio-technical knowledge in technology and design education [71].

The bodies of work mentioned above have to a great extent centered around explaining energy demand related issues - although many later developments in Theories of Practice and socio-technical focused perspectives do highlight the interplay of energy demand and supply. The next section focuses on people as key actors in discussions primarily concerning energy supply. We find a similar type of progression here as in the SSH research presented in Section 4.1 as discussions of public acceptance and public participation also seem to move from an individually-oriented perspective towards more collective and complex framings of the ways in which publics do and can engage with energy technologies.

4.2. From public acceptance to public (material) participation in low-carbon energy production

Energy-SSH deals with the roles people get and take in energy transitions and how peoples' participation is facilitated. Within this field of enquiry, a large number of SSH studies from disciplines - such as Psychology, Sociology, Science and Technology Studies, and Human Geography - deal with public acceptance and the acceptability of new energy technologies and systems. While some scholars differentiate between the terms 'acceptance' (of ex-post outcomes) and 'acceptability' (of ex-ante processes), these differences are often blurred [72,73]. In order to bring clarity into the frequently used, but rarely defined, acceptance terms, Wüstenhagen et al. [74] introduced the concept of 'social acceptance' with its three dimensions - 'social-political acceptance', 'community acceptance' and 'market acceptance' - each involving different actors and levels of acceptance. The authors argue that social acceptance needs to be taken seriously if renewable energy policies are to be successful. Their conceptualization of social acceptance is widely used in energy-SSH research and beyond, although still contested [75–78].

The aim of much of the research in this area is to understand the factors that explain the acceptance, acceptability, support, opposition, and/or rejection of technologies and systems, where acceptance usually relates to conforming practice and societal norms concerning what is acceptable/unacceptable. Explanatory factors range from economic aspects [79], community benefits [80] and political party preferences [81], to aspects of environmental justice, such as involvement in decision-making and planning processes as well as fairness and trust [79,82]. While studies often focus on a very limited number of factors, a thorough understanding of acceptance requires the consideration of both psychological and contextual factors, and hence a cross-disciplinary approach [83].

Many SSH researchers have critically examined the concept of acceptance in the context of low-carbon and renewable energy technologies. For instance, Batel et al. [84] discuss different facets of the term 'acceptance' and demonstrate that acceptance is not the same as 'support', which they assert is crucial for technology adoption and behavioural change. They argue that public responses (e.g. resistance, apathy or uncertainty) deserve increased attention by the research community. Furthermore, an exclusive focus on acceptance/acceptability has been criticized for depicting people as passive recipients of technology, rather than active participants in the transition. It understates the different roles people can take in relation to energy transitions and the different ways people act upon, negotiate, interpret, reframe, make sense of, and deal with new technologies and systems [85,55,86].

Related to this is the large amount of literature which critically engages with the widely used concept of NIMBY (Not-In-My-Backyard) as explanation for a lack of acceptance. This concept suggests that people generally claim to promote renewable energy technologies, but that they selfishly reject them when they are planned close to their homes. While NIMBYism has been difficult to identify empirically [87,88] and has been declared inappropriate and misleading as analytical tool by a large number of SSH researchers [88–90], it is still widely represented among policymakers, developers and other renewable energy actors in their constructions of publics [91,92].

Alternative perspectives to NIMBYism include a focus on place attachment and identity. Devine-Wright [93], for example, describes opposition to renewable energy developments (e.g. wind farms) as place-protective actions caused by disruptions to places to which people are emotionally attached. He proposes that policymakers should be conscious of and engage with people's place attachment and identity, and aim to design new projects and processes that can be interpreted as place enhancements rather than disruptions. Following this, energy-SSH research, especially within Human Geography, has shown the importance of embedding low-carbon energy projects in specific local contexts [94,95].

Although many studies still address acceptance/acceptability issues, there has clearly been a turn towards studying public engagement and participation in energy transitions. The concept of energy citizenship [85,86] exemplifies this growing strand of SSH research, arguing that energy transitions require active citizen participation and not only passive acceptance, thus also turning the focus towards collective political engagement in addition to issues of energy consciousness, literacy, behaviour and practices. During the last years, SSH researchers have increasingly been involved in looking for new ways to engage people in low-carbon energy transitions; for example in the development and implementation of renewable energy technologies. This focus on new ways of organizing, preparing for, inviting, and (not the least) empowering people to participate, is also based on the insights that emerge from studies that regard energy use as interlocked in practices of everyday life, as presented in Section 4.1.

Decision-making processes and people's participation in these have been a particular focus of SSH literature. The concept of energy justice, for example, emphasizes the importance of considering the distribution of benefits and burdens, the recognition of all parts of society and fair decision-making processes related to energy developments and services [96,97]. From the Planning disciplines there have also been attempts to open up and transform traditional planning processes, and a large number of studies emphasize the importance of citizen participation in planning processes and how such processes might become more successful through participation [98,99].

One way to engage people, noted by energy-SSH researchers, may be by including neighbourhoods or communities instead of focusing on single individuals [100]. A relatively new area of research focuses on user innovations in so-called 'energy communities'. Here, user innovations are regarded as entangled with learning processes at the community level in terms of evolving technical identity but also related to community building activities [101,102] (see [10], Section 1.5). Energy communities may involve Peer-to-Peer support and Do-It-Yourself groups and are regarded as a promising way to intervene in the development and dissemination of low-carbon energy technologies, such as solar collectors [103]. The idea of the prosumer – an actor which both consumes and produces energy [104,64,105] – has gained increased attention and may also be part of an energy community perspective.

Place-specific interventions in cities may be another way to engage people into energy transitions. A growing strand of energy-SSH scholarship, as well as a core focus of many urban planning practitioners, is the study of (smart) city development and urban experimentation, which is often referred to as *urban laboratories* or *living laboratories* in order to emphasize their experimental character [106–108]. The idea is to engage energy users in more sustainable living, and that policymakers, researchers and practitioners may draw upon experiences from these laboratories and up-scale the lessons learned. Heiskanen and Matchoss, [109] for example, discuss technocratic and inspirational learning in such experiments and how to use learning across sites to upscale.

Engaging people in low-carbon energy transitions may not only be a matter of getting the social processes right. Material objects, or 'things', also need to be taken into consideration [110,111]. For instance, Wilhite [112] critiques how discussions on the green economy and low carbon transitions fail to pay sufficient attention to the role of technologies and material cultures that embodies high-energy use. Marres [113] also mobilizes a material perspective in energy transitions when investigating 'material participation' and how engagement and participation is enabled by everyday technologies and objects. Political potential may be embedded in technologies and societal use of technological applications in particular settings, meaning that everyday use of green technologies may be regarded as articulations of a green political agenda [113,114,86].

Our discussion in Section 4 can be read as two stories of scholarly expansion. In one, we identify a move from individual consumers to practices and finally multiple actors. In the other, we discuss a move from acceptance to engagement, participation and (material) citizenship. These scholarly expansions have important implications for how one thinks about policy interventions. In the following section, we will look briefly at the consequences of such an expansion in one application area, namely demand-side management.

4.3. Illustrative example: demand-side management

The implementation of demand-side management (DSM), e.g. through smart meters, has typically been a strategy adopted by central energy actors such as electricity grid operators. The goal has been to instigate behaviour change at the demand-side of an energy system, e.g. by reducing and/or shifting the timing of energy consumption. This form of management has been analysed through a focus on the instruments mobilised to achieve changes on the consumer side by use of new technologies that give more accurate information, economic incentives (e.g. new grid tariff structures), different behavioural interventions (e.g. knowledge campaigns), or a combination of all these (see [10], Section 5.3). Smart grid development is one such form of demand-side management, where one of the aims is to shift demand from 'peak' hours of the day, the season or year, to times when there is less pressure on the electricity grid [115,116].

Early studies of such technologies tended to focus on the aggregation of individual behaviour change; how much could energy be shifted through the provision of new information or price incentives? As an example, Darby [117] compared direct feedback technologies with indirect feedback and found direct feedback to be more efficient. Implicitly, such perspectives rest on the assumption that new information triggers behaviour change and provide important cues about the effects of different interventions. These assumptions about the relationship between interventions and behaviour has later been challenged. Through a domestication perspective, scholars have highlighted the complex and shifting ways that households interact with demand-side management technologies, such as in-home displays, to show that use and sense-making shifts over time [118]. Therefore, scholars like Klopfert and Wallenborn [119] argue that technology users should be involved in designing the devices to be implemented in their own homes, and that users should own the generated data.

Further, through the social practice turn, a focus on individual behaviour has been supplemented with a focus on collective practices. Such studies have emphasized the relationship between the rhythms and synchronicity of everyday lives and electricity demand peaks [120]. The result has been a focus not on individual behaviour, but on different elements that make up and mediate practices [121]. With such a perspective, new ideas have also emerged about how to change demand, e.g. through re-conceptualizing DSM as co-management, or through broadening the scope of interventions to also target a much wider repertoire of actors and technologies that shape practices [122].

The focus on a wide set of actors that shape energy demand is also shared within a growing number of studies anchored in Science and Technology Studies that focus on DSM. As an example, Pallesen and Jenle [123] studied not only how householders respond to new interventions, but also how a series of actors works to produce and organize consumers that display many of the qualities associated with homo economicus. Such studies tend to emphasize that activity on the demand-side of the energy system is co-produced by a series of actors and technologies, and that actors from a wide array of collectives mobilize different tools, competences and strategies to do so (e.g. [124,125]). Such approaches, then, also highlights that DSM interventions are shaped by the rationalities and logics of established sectors, and often incumbent actors such as traditional energy providers and electricity grid operators. Hence, interventions to change demand-side activity can also target the working practices and assumptions of such actors in order to stimulate new forms of experimental efforts.

In parallel to these discussions, many scholars have also focused on unintended and undesirable consequences of peak electricity pricing schemes and other DSM-instruments. As an example, such schemes might have unjust distributional effects, and through this they might strengthen existing patterns of social and economic stratification [126]. Further, such instruments might also disrupt household routines, for example important family routines such as having a meal together [127]. This feeds into broader discussions about energy and climate justice, and the potential political roles that instruments for DSM might have beyond affecting energy behaviour. Key questions include who should decide, based on what criteria, who can afford not to change, and who are forced to change. In sum, this brief example illustrates different ways through which energy-SSH can provide new and unexpected insights to an issue like DSM, highlighting aspects like behaviour, social practices and societal rhythms, the co-production of change by a series of actors and justice aspects.

5. Conclusion: developments in the energy-SSH research field

This paper aimed to bring insights from energy-SSH research to those designing research and innovation policy and funding programmes in the energy field. We hope it may additionally serve as a resource for STEM researchers in need of specific competences, for newcomers to energy-SSH, and also for others interested in a broad overview of what insights and perspectives energy-SSH research offers. To do so, this paper first gave a descriptive overview of energy-SSH research building on four central bibliographies that were structured on the basis of the EU's Strategic Energy Technology Plan (SET-Plan). Based on a cross-cutting analysis of the four bibliographies, we zoomed in on the different concepts of energy agency and how people are understood in low-carbon energy transitions. Through two stories of scholarly expansion of that theme focusing on energy demand and energy supply, we demonstrated some of the main developments within energy-SSH over the last decades.

We identified that there has been a move within energy-SSH research: from perspectives stemming from psychological understandings (which, in the beginning to a large degree also reflected a focus on the individual and socio-economic variables), towards more sociological understandings and furthermore plural understandings of energy issues. This move within energy-SSH is based on insights from a whole range of fields such as Human Geography, Anthropology, STS, and Innovation Studies. We have pointed to an evolving understanding of the role of people in low-carbon energy transitions, and a development from viewing people as consumers, towards seeing people as parts of complex socio-technical energy systems that give room for a myriad of ways to participate in low-carbon energy transitions. By this shift of focus, energy-SSH contributed to showing the complexity of people and their energy practices, thus giving a broader understanding of what problems they are facing in everyday life.

For policy, this has clear implications. As energy-SSH research has evolved, it has become clearer that the complex relationship between technology and society means that this is a socio-technical challenge where technology and society must be tackled in tandem, and that there is no simple technological solution to low-carbon energy transitions. Relatedly, this paper has emphasized the possibilities that are attainable through socio-technical research and we will argue this is surely where energy-SSH communities should focus their efforts in engaging with the EU's SET-Plan and associated energy research and innovation programmes, such as the forthcoming Horizon Europe. Indeed, this is one of the core contributions of the paper: through pragmatically working within the (technologist-led) boundaries of existing funding commitments set by policy/political institutions, we have drawn out important insights from energy-SSH. In turn, we hope that these insights can be incorporated into practical policy development exercises at EU-level and beyond, hence shaping future energy and transport policy agendas.

The process of identifying SSH-led priorities has further emphasized how energy-SSH is a wide field spanning many theoretical traditions, problem definitions and methodological conventions. Policymakers and research funders have somewhat artificially brought these diverse disciplines together under an e.g. 'energy-SSH' banner in Horizon 2020, as part of seeking to better account for society. Many of these research approaches are clearly at ontological odds with one another. Therefore, inevitable challenges exist when bringing such different perspectives into the same common pool of policy evidence.

In this article, we have sketched a trajectory where energy-SSH has moved from focusing on individual consumers and their choices to broader social practices. Further, we have seen a move towards a wider focus on the production of collective participation. A related turn has highlighted the importance of materiality, and experimental governance. Finally, there has been a strong move towards a focus on social justice.

These 'turns' that we have teased out from the literature only represent a small part of the richness within energy-SSH. We argue that embracing the policy insights offered by energy-SSH thus also involves embracing a heterogeneous view of energy-SSH, which is based on the realization that funding one energy-SSH project cannot yield one simple (policy) answer that all the many energy-SSH communities can get behind. We very much acknowledge that this evidence-gathering trait does not sit comfortably with mainstream policy and governance agendas. However, positioning policy-focused research funding in such a way, we argue, would enable new and more energy-SSH research voices to contribute to the policy debate on energy-related interventions and trajectories of change.

Declaration of Competing Interests

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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Supplementary material

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