Towards a cross-paradigmatic framework of the social acceptance of energy systems

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Abstract

As the significance of public opinion and practice for energy system change has become more widely understood, an expanding body of work is investigating drivers of social and public acceptance of a wide diversity of energy technologies, both infrastructure and end-user applications. The literature is large and spans multiple contexts, methods, theoretical and disciplinary perspectives and paradigms. While this diversity is in many ways healthy, experience suggests that it can be confusing for those without close knowledge of its constituent parts. Here we set out a framework for thinking about energy technology 'acceptance' that is relatively neutral in normative and theoretical terms, while acknowledging that a full integration of perspectives and complete theoretical neutrality are not possible. We do not claim a comprehensive review base, but draw on our experience to illustrate the diversity of what we regard as the more influential perspectives in the literature.

Keywords

Public and social acceptance; public opinion; energy technology; energy infrastructure

Highlights

- We illustrate a framework for thinking about acceptance of energy technology
- A focus on acceptance contexts and actors minimizes theoretical subscription
- Fundamental disciplinary and methodological differences cannot be fully bridged
- We discuss aspects of commensurability when drawing on multiple disciplinary perspectives

1 Introduction

Energy and environmental targets imply significant changes to energy systems. In particular, decarbonising those systems while ensuring sustainable, affordable supply, has major ramifications for publics asked to accept new energy infrastructure and technologies and to change patterns of demand [1]. Related public opinion, perceptions, acceptance, attitudes, behaviour, values and practices have all become matters of importance for governments, the energy industry and academics alike [2] [3][4][5]. In particular, the way in which some renewable and non-renewable energy infrastructures have faced opposition from the local communities where they are constructed, while others coexist harmoniously with local communities[6][7][4], has contributed to an increasing interest in understanding the factors driving societal and public reactions. In general in the energy field, social acceptance has increasingly come to be regarded as a one issue among many that shape the successful implementation of new developments and policies. In a sense, social acceptance has become one of the most policy-relevant social science concepts in the field of energy technologies.

In line with this tendency, a substantial number of sociological and psychological studies have investigated, in the last decades, the levels and drivers of social and public acceptance of a wide diversity of energy technologies and applications. These studies have taken place in multiple contexts, from the country level to the local and household level. Sociological approaches have generally not used or emphasized the term ‘acceptance’, but the insights gained nonetheless have a strong bearing on understanding energy technology and policy acceptance (e.g. [8]). Often, though, acceptance has been more centrally a part of the researchers’ perspective, as in nationally representative or case specific attitude surveys [9][10]. The number of relevant studies is substantial: even the number of nationally-specific studies, i.e. in a single country, can run to hundreds and span public attitudes and levels of acceptance with respect to nuclear energy, hydrogen, CCS, wind, biomass plants and other renewable and low carbon energy technologies [11][12]. Similarly, a wide variety of studies based on different approaches and methodologies, mainly case studies, have been thematically-focused, addressing key elements involved in the interaction between energy developments and host communities [13].

This recognition that public acceptance is an influence on technology development, installation and use has raised many questions about the complexity of processes shaping public responses to energy technologies and infrastructures at different levels [2]. It has also raised questions about its policy and practical implications [14] and about the conceptual, definitional and methodological basis of research on social and public acceptance in this area [15] [16] [17]. Although there have been significant contributions in terms of describing the social and public acceptance of various energy technologies in multiple contexts, as well as in terms of understanding the factors influencing this, there arguably remain not only conceptual and analytical issues yet to be clarified and pursued, but also the matter of competing or alternative paradigms has become somewhat vexed in the sense of sometimes becoming polarized in terms of preferred perspectives [18].

Our contribution in this area is intended firstly to be definitional and typological, something that we view as being important for enhancing the effectiveness of acceptance work [19]. This call for a revisiting of definitions of public acceptance of technologies in general is not new [20]: the latter is from 1987, refers to the “significant definitional problems attached to each of the concepts ‘public’, ‘acceptance’ and ‘new technologies’ and the need to provide working definitions of these. Secondly, though, we also aim to set out a simple framework intended to bridge perspectives through its generality, while recognizing that at specific levels of attributed causality and conception, sociological, psychological and technical accounts have marked and ultimately irreconcilable differences [21][22]. Yet despite these differences, there are points of contextual connection in sociological and psychological accounts of energy-related behavior [23] [24] [25]. That is, while epistemological and perspectival differences cannot be bridged in their own terms, their referent contexts are shared, even if these are characterized in different ways.

There are other proposals for synthesizing the variety of contextual and psychological factors operative in this context [26] [27], both in agreement with each other and built upon here by drawing on Wustenhagen et al [15]. However we seek to add to such syntheses in several ways. Firstly by emphasizing, distinguishing and classifying in terms of the main levels at which acceptance can be studied, and distinguishing the main classes of referential object, distinctions that are apparently simple, but which nonetheless we consider too often obscured by variable-level and cases-specific detail. Secondly, we provide an overview of a number of theories and perspectives that we believe to be influential, reflecting personal involvement in and perceptions of the field, rather than bibliometric study. Thirdly, we also discuss the differing policy implications of alternative perspectives. For example, while sociological perspectives arguably have considerable explanatory value, they also pose significant policy challenges, ultimately implying wholesale changes to deep social structures [22]. The psychological focus on changing attitudes and behavior through messaging may be viewed by contrast as insufficiently attentive to structural context, but it is not difficult to see why this may be a more attractive option for those responsible for policy budgets in this context.

It is notable that one of the more pragmatic accounts of practice theory as set alongside other perspectives is [28], which takes a direction towards recognizing the value of multiple levels of analysis that we would encourage, is in the grey rather than academic literature. While there is in general a recognition of the need for more systematic research on social and public acceptance of energy technologies, driven by a perceived need for coherent theoretical frameworks, explicit definitions of concepts and the use of innovative methodological tools [29] [30] [16] [15] [31] [32], it is arguably not straightforward to produce integrative frameworks that are both clear and comprehensible for non-specialists, while also being satisfactory to those either with strong disciplinary affiliations in the social sciences, or to those simply aware of the real differences in the ways in which different perspectives within the social sciences approach ‘acceptance’ of energy technologies.

With the above in mind, and reflecting the view that it is preferable to set out even a simple framework rather than leave those new to the literature to make their own sense of it over time, the purposes of this paper are: (a) to provide a broadly applicable analytical framework for the study of the social acceptance of energy technologies, infrastructures and applications; and (b) to identify a set of definitional research challenges and questions intended to support further research across paradigms. The intention is to provide an analytic framework that is of broad relevance, rather than to be strongly subscriptive to, or advocative of, any particular theoretical perspective. That said, we are very aware that concepts cannot be wholly theory-free and that this inevitably colours attempts to be integrative, even if this is at a general and referential level.

As the term 'acceptance' would seem to have its origins in the discourse of technology diffusion, we take the diffusion concept of acceptance as a starting point in our discussion of theory below. Overall, the analytic framework aims to encapsulate a broad range of acceptance usage and conceptualization, distinguishing rather than conflating, with a view to aiding specificity. While cautious of advocating the mixing of ontologies [33], we have sympathy for the bricoleur's pragmatic principle of acknowledging value in a range of perspectives [34] and hence the value not only of deploying multiple perspectives and methods to shed different types of light on different aspects of a problem, but also of finding ways by which the knowledge gained thereby can be at least partially integrated.

The paper is structured as follows. In section 2, we describe our method, introduce the role of social acceptance in technology implementation and adoption and set the scope of the study. Section 3 provides the elements of an analytical framework for studying the social acceptance of energy technologies. Section 4 discusses some of the methodological challenges that, in our view, the psycho-social research on the social acceptance of energy developments faces.

2. Materials and methods

2.1 Scoping

In terms of bounding the study, our analysis is intended to be relevant to both sociological and psychological accounts, but it is illustrative rather than comprehensive. We are cognisant the variety of disciplinary and indeed paradigmatic perspectives applied to understanding individual and societal reactions to energy technologies and developments [35] [23], but focus primarily on those perspectives that we perceive to be notable. These perspectives include economics (emphasizing rational choice models, investment behaviour and pricing policy); environmental sociology (emphasizing equity, process, policy and institutions; also practice and habit-related theory; and social norms); and social psychology (emphasizing motivation; risk perception; place and identity; and behavioural theories connecting norms, values, behavior and a variety of mediating variables)[1]. Examples are chosen so as to illustrate the approach, again using informed judgement rather than any codified method.

To support our analytical framework as well as our view of key methodological challenges, we refer to examples of conceptual studies from the above perspectives, supported by a broader selection of empirical studies dealing with the social and public acceptance of energy technologies in various contexts (see <appended Table 1>). The selection of the latter studies is based firstly on the presence of explicit, acceptance-specific conceptual development, drawn from academic database search with the keywords [social acceptance or public acceptance or public attitudes and energy technologies or <a range of specific energy technologies>]. In addition to the explicit,

[1] A comparative, summary account of policy and project-based interventions drawing on some of these perspectives can be found here: http://www.ieadsm.org/ViewTask.aspx?ID=17&Task=24&Sort=0

acceptance-specific selection criteria above, we have sought to provide comparison across energy technology types. The studies examined relate to acceptance of seven types of energy technologies at the three different levels identified in our analytical framework below: wind power (onshore and offshore); carbon capture and storage (CCS); biomass; nuclear; tidal; hydrogen; solar energy (photovoltaic and thermal). These particular technologies, while not a comprehensive list, include the main low carbon technologies typically considered at or near market and hence referred to in international energy scenarios (e.g. [36]).

3 Theory

3.1 Alternative approaches to the social acceptance of technologies

In this section we summarise a variety of acceptance-related perspectives, as a precursor to a general framework. The primary, but not exclusive, focus is on energy technology acceptance. Table1 summarises some notable contributions, with the selection reflecting our experience rather than (for example) citation indices.

One of the first modern[2] references to technology acceptance in general may be in the context of technology implementation and adoption from the perspective of the diffusion of innovation model [37]. This simplistic but arguably nonetheless influential, linear view sees acceptance as occurring during the second and the third stages of a technology adoption process (the persuasion and decision stages), at which point individuals (or any other decision making unit) are held to form a favorable or unfavorable attitude toward the innovation and to take a decision to adopt or reject the technology. Acceptance or rejection is also viewed as following a knowledge stage, when individuals, stakeholders and decision makers are exposed to the technology, and precedes the following stage of confirmation and the actual use of the innovation. An implementation and subsequent confirmation stage follow, when the individuals, stakeholders and decision makers finalize their decision to continue using the technology, and are the last steps of the process of adoption [37].

From this perspective, generally focused on the application level (according to our analytical framework below), for a particular technology to be implemented in and by a given group, it has to be first accepted, that is, positively evaluated, by the members of that group. Similarly the inverse is also possible. Although arguably of more value as a heuristic for drawing attention to particular aspects of acceptance than as a literal representation of the processes involved, this general approach underpins much research on technology acceptance in energy and other sectors, ranging across, for example: information technology [38], driver support systems [39], genetic manipulation [40] and nanotechnology [41].

The heuristic also allows us to locate much of the psychological and behavioural economics literature at the persuasion and decision stages, with differing perspectives

[2] We do not consider historic instances of technology rejection here [110], though there are parallels.

and emphases in relation to the causality and processes involved. By contrast, the sociological literature gives greater emphasis to the ways in individuals are connected to - and are in part a product of – their social and physical (including technological) environments. Table 1 provides examples of disciplines, theoretical perspectives, illustrative authors and corresponding synopses of how acceptance is viewed. As studies sometimes draw on more than one perspective, authors and studies may share the attributes of more than one category. As stated, examples are based on author judgement of their value to those not familiar with the entirety of the literature, principally by virtue of their clearly representing a particular perspective. The content is also informed by previous reviews [11][12].

Table 1 An illustrative selection of perspectives on acceptance of energy technologies

Discipline	**Perspective and illustrative authors**	**Synopsis**
Economics	Choice models (e.g. Labay & Kinnear [42])	▪ Individuals form preferences regarding energy technologies by making trade-offs between the various attributes of those technologies. ▪ Consumers are expected to act based on logically determined and articulated preferences of utility
	Behavioural economics (e.g. Frederiks et al [43]	▪ Modifies the above assumptions of economic rationality to account for psychological factors
Sociology and human geography	Equity, process, policy and institutions (Walker) [44]; practice & habit as part of social structuration [(Shove, Southerton) [45] [46][47]; socio-demographics and lifestyles (Claudy [48]; environmental conflict and land use planning systems (Haggett [49], Upham and Shackley [50], Wolsink [51], van der Horst and Toke [5]; user-driven innovation [52], etc)	A wide-ranging set of perspectives that include attention to: ▪ The social, economic, political and technological context of individuals that shape and constrain attitudes and behavioural responses to low-carbon energy and associated risks ▪ 'Practices' approaches from the sociology of consumption, in which behaviour, habits and routines are viewed as shape attitudes, rather than vice versa ▪ Participatory engagement, structures of ownership, the distribution of benefits and other institutional factors ▪ Various types of social influence processes, including social norms ▪ Socio-demographic characteristics such as age, gender and social class ▪ Lifestyles, habits and needs ▪ Resistance as a function of local, contextual factors

		▪ Technology users as shaping rather than 'accepting' innovations
Social psychology	Theories of planned behavior and norm activation (De Groot and Steg [53]); risk perception (Pidgeon et al [54]); environmental concern, values, norms, behavior (Stern [55]); place identity and attachment (Devine-Wright [10]); social representations (Castro [56], Batel [14])	A wide range of models and perspectives, focusing on, for example: ▪ Attitude, social and personal norms, perceived behavioral control and intention ▪ Personal, emotional attachments to places and their role in individual identity ▪ Subjective judgments of the characteristics and severity of technological risk
Cultural theory	Application of Mary Douglas' cultural theory approach (West et al [57]);	▪ Cultural worldviews as attitudinal determinants
Frameworks and methods-driven work	The eclectic energy cultures approach (Stephenson et al [58]); communications theory and information processing (Brunsting et al [59]); use of Q-sort to characterize positions (Cuppen et al [60]); use of informed choice questionnaires [61]; etc	▪ Many studies, often in the grey literature, take no explicit theoretical stance, although attitude theory is usually implicit. The examples listed here are conscious of theory, but either seek to avoid strong mono-theoretical subscription or are heavily methods-driven.

Note to Table 1: the relevant literature numbers thousands of papers and these are a personal, illustrative selection. Substantial reviews are available that also consider tangentially relevant perspectives such as science and technology studies [11][12]. Further examples of individual papers are referred to in the main text.

As alluded to elsewhere in the paper, some if not many of the differences in perspective cannot be bridged in their own terms. For example, from a psychological perspective, attitudes are a key focus and are typically held to be comprised of three components: cognition (knowledge and beliefs), affect (emotional response) and behaviour (past and current behavioural response). These three components have also been ascribed to risk perceptions, as a particular form of attitude [62]. From a behavioural economics perspective [63], economic and 'rational' decision-making by citizens is flawed and stands to benefit from insights from the psychological literature. This can be contrasted with approaches that favour deliberative decision-making [64]. Yet from a sociological perspective, behaviour is not viewed as driven by conscious deliberation or 'choice'. In contrast to commonly used theories in social psychology (e.g., the Theory of Planned Behaviour [65]), behaviour is not viewed as preceded by intention, but as the product of habit, 'routines' or practices that structure society [66][22]. Given this variety, of which there is more than we list here, it should not be difficult to see why our efforts at integration are targeted at the limited purpose of aiding comprehension through a categorisation based on the contexts of acceptance.

3.2 Basic elements of an analytical framework

Why retain the term 'acceptance' in the context of energy technologies? Principally because the widespread use of the term makes it difficult to dispense with when seeking to provide and justify a classificatory overview. Despite the varied volume of work on social acceptance in relation to new energy technologies, the concept of acceptance itself has very often been taken for granted [14][67]. Researchers and stakeholders alike use the concept of acceptance to refer to a range of objects: in relation to lay public attitudes towards types of energy technology, either in the abstract or implicitly or explicitly in relation to policy support; in relation to the position of policy actors on investments in specific energy technologies; in relation to support and opposition of specific energy developments at the local level; and/or in relation to the diffusion of energy applications at the household or the organizational levels. The concept of acceptance is also treated as a process disconnected from other dimensions of social reaction, or as simply an indicator of success. All of these uses and others are found in the papers that we have reviewed <Appended Table 1>, in addition to those cited in Table 1.

In order to develop a framework with which to classify studies of social acceptance and hence assist particularly those new to thinking about social acceptance research in relation to energy, it is clear that we need to first start with a conceptualization of social acceptance that is as neutral as possible, while acknowledging that there are limits to what is possible in terms of theoretical neutrality. With this in mind we suggest the following definition of acceptance: "a favourable or positive response (including attitude, intention, behaviour and – where appropriate - use) relating to a proposed or in situ technology or socio-technical system, by members of a given social unit (country or region, community or town and household, organization)".

Acceptance thus defined first implies that a technological artefact or socio-technical system is developed or proposed. At its simplest, the concept of acceptance may then have a passive connotation and be used to simply denote the lack of an oppositional response. However, acceptance may also denote stronger, positive dimensions, such as support, interest, even admiration and so on. Acceptance tends to be regarded as one of the key dimensions of social reactions to energy technologies because developers need the acceptance, the willingness to accept and the actual use of their developments by external individuals and decision units. However even if we accept that acceptance is the key psycho-social dimension in the process of diffusion of energy technologies, acceptance is just one part of the broader phenomenon of how individuals, groups and societies interact with energy developments [68][69]. In short, acceptance involves multi-dimensional, dynamic processes that are not only obscured by the single term, but which different perspectives view as the outcome – or part of – a variety of processes.

Arguably, the term 'acceptance' is as problematic as it is difficult to dispense with. As Batel et al [14] argue: "if we keep focusing on this term (social acceptance)—either purposefully or not—we are not only perpetuating the normative top-down perspective on people's relations with energy infrastructures, but we are also potentially ignoring all the other types of responses to those, such as support, or uncertainty, resistance, apathy, among others". Ricci et al. [67] also take the view that "'acceptance' itself is problematic as a concept" and that the current conception of acceptance "is too narrow and misses other key aspects and dimensions by which people make sense of new technologies and 'consume' them". One can reject the term NIMBYISM for its theory-laden, empirically dubious assertion of a simplistic relationship between proximity and objection [70]. Acceptance however, while in many ways equally simplistic in its obscuring of objects and processes, is arguably at least somewhat more neutral in its attribution of cause and more general in its breadth of application.

Having provided an operational definition of acceptance, we can establish three general principles relating to the social acceptance of energy technologies:

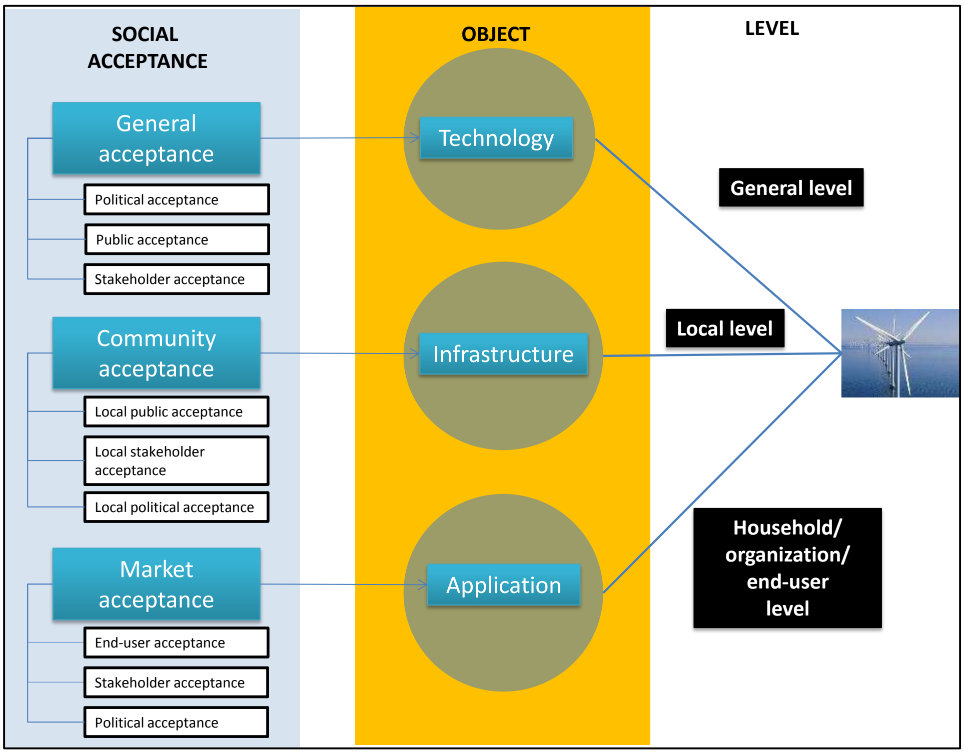
i. The social acceptance of a technology can be analyzed at three levels: macro, meso and micro, typically corresponding to: (a) the general, policy or country level; (b) the community, town or other geographically defined level; and (c) the individual entity level, such as households or organizations. These levels tend to correlate with different objects of acceptance: respectively, types of energy supply technology; specific energy infrastructure proposals or installations; and on-site energy applications that may be demand or supply side).
ii. Social acceptance at the three levels may refer to the following differentiated components – depending on the subject of the acceptance: (a) public acceptance in the sense of individual consumers and citizens; (b) stakeholder acceptance in the sense of organizations without formal political objectives, but with an interest in the outcome; (c) political acceptance in the sense of policy support by governmental levels, agencies and political parties.
iii. The internal structure of individual acceptance is composed of attitudinal elements (attitudinal acceptance), behavioral intentions and actual behaviors (behavioral acceptance). Acceptance includes beliefs and feelings (cognition and affect) about and in relation to an energy supply technology, infrastructure development or application, but also the willingness to accept or use the technology, and actual (public-sphere and private-sphere) behavior.

It is clear from the above that there are different levels or units of analysis with respect to acceptance. For example, a country may reject nuclear energy as a matter of policy, or a local community may oppose a specific shale gas project, or homeowners may or may not install small-scale wind energy applications. All these processes refer to the social acceptance of specific technologies, but the different levels at which social acceptance is referred to involve different processes and components of social acceptance. While it is not our purpose to detail the many different theoretical perspectives that have been developed to help explain these processes (for example, different political science accounts of policy formulation or sociological accounts of societal structuration [66]), distinguishing between the three levels of analysis is an essential step in definitional process. Previous efforts to differentiate the various levels include [71][15] [72] [73] [31]. Reviewing these, our selection of empirical studies, the illustrative studies in Table 1 and taking the above principles into account, we concur with previous proposals of three typical levels of acceptance analysis, particularly that of Wüstenhagen et al [15], and develop this as follows:

1. Acceptance at the level of an energy supply technology at the policy or national level (social acceptance). At this level, acceptance research has typically sought to understand the levels of social (including the general public, policy makers, civil society organizations, experts, private organizations, etc.) acceptance at the country, state or regional level towards a particular energy supply technology. The technology is typically considered in general and in aggregate. For example, a particular country may or may not accept (invest, support, etc.) nuclear energy or offshore wind. Individuals and representatives in this country may perceive that the technology may, or may not, be acceptable at a general level.
2. Acceptance of an energy infrastructure or facility at the local level (community acceptance). At this level, acceptance research has sought to understand the reaction of communities (comprising local decision makers, local stakeholders and local citizens) towards particular, proposed energy infrastructure. Research questions are related to the reaction of a community (a city, a small town, etc.) towards a specific energy infrastructure. For example, the reaction of a community towards a wind development, a proposed CO_2 storage site, a shale gas extraction project, etc. The focus here is on the interaction of a community (including the individuals and the stakeholders that shape it) with physical fuel extraction, supply, production, conversion or storage infrastructure, or a project proposal in relation to these.
3. Acceptance of an energy application at the household and organization level (market acceptance). Research at this level has sought to investigate the reaction of actual and potential end-users and stakeholders (such as householders, investors or plant managers) towards particular demand and supply side energy applications (e.g. micro-generation technologies or more efficient appliances). The object of acceptance here is typically a specific energy application that can be installed within a home, business or organization and to which utility criteria are applied.

Figure 1 summarises the above as a conceptual map, which is classificatory, focusing on the contexts of acceptance rather than focusing on theory or process.

Figure 1 A context-based classification of types of energy technology acceptance



3.3 Social acceptance as a multi-actor phenomenon

At the three different levels, social acceptance can be considered a multi-actor phenomenon. Social acceptance may refer to the evaluative response of any decision unit in a society, ranging from individual members of the public; professional end-users; the many types of civil society group (including community groups, non-governmental organizations (NGOs), labor unions, indigenous groups, charitable organizations, faith-based organizations, professional associations, and foundations); companies and industry associations, politicians, academia, etc.

At the general and at the local level, it is useful to differentiate between three key groups of actors or social subjects to which acceptance refers: individual members of the public; organized political groups; and organized stakeholder groups (commercial, non-commercial and mixed). Hence, we can distinguish three dimensions or components of social acceptance at both levels, namely political acceptance, stakeholder acceptance and public acceptance. The classification is inevitably a heuristic in that an individual actor may fall into more than one group, given the social role that they play at a particular time. It is for this reason that we have differentiated by organizational level and social function rather than individual role, the former being less flexible than the latter (organisations tend to have formally constituted or more strongly instituted missions than individuals, who have multiple roles). Thus the actors in Table 2, which provides a summary mapping of actor groups and social acceptance, may belong to more than one group.

Table 2. Actor groups and social acceptance at the three levels

		Level		
		General/Policy	**Local/Community**	**Household/Organisation/ End User**
Actor group	**Political**	National acceptance (by national, formally instituted decision makers)	Local political acceptance (by local, formally instituted decision makers)	User acceptance (by individual citizens with views on energy policy)
	Stakeholder	Stakeholder acceptance (by other nationally active market and nonmarket policy groups)	Local stakeholder acceptance (by other locally active market and nonmarket policy groups)	Stakeholder acceptance (by commercial and other organized users)
	Public	Public acceptance (by the general population as citizens with views on national policy)	Local public acceptance (by the local population as citizens with views on national policy)	End-user acceptance (by household, organization and individual end-users)

According to this classification, regulatory and political organizations operating at different scales, from local to national or international, provide a first component of societal acceptance. Political acceptance refers to the attitude or behavioral response towards the implementation or adoption of a proposed technology by decision makers and key members of the political system in a given society, community or town. Stakeholder acceptance refers to the members of the stakeholder groups in a social unit, that is, in a particular country or town. This might include the various groups of civil society, companies and industry associations that can affect or be affected by the proposed technology or development. Stakeholder acceptance constitutes another key component of social acceptance with profound effects on technology implementation as well as on the ways energy technologies and policies are framed [31]. Finally, public acceptance refers to the attitude or behavioural response to the implementation or adoption of a proposed technology held by the lay public of a given country, region or town. Individuals act as citizens who react in different ways to energy policies, technologies and infrastructures developed in their countries or cities (Stern, 2014).

At the household and organization level, acceptance by the end-users, including professional-users and lay-users, actual and potential, is the key component of social acceptance. This is often referred to, at this level, as market acceptance [15] but it also has psychological, social and political dimensions. End-users are active players who decide on appropriate technology for their particular circumstances, therefore influencing social acceptance in aggregate. Besides end-user acceptance, stakeholder acceptance also plays a role in this level. Here, it can refer to the acceptance by investors, technicians, industry representatives, local government officials, community representatives or any other category of individuals that can affect or be affected by the proposed energy application.

4 Research challenges and directions

4.1 Methodological diversity and tacit assumptions

Having built, from the review of empirical and conceptual studies, an analytical framework with which to both study and classify studies of the social acceptance of energy technologies, infrastructures and applications, a number of methodological and analytical challenges require consideration. In the following sections, we review some of these challenges and propose recommendations in terms of research directions and also practical resolution. The research challenges listed are not intended to be exhaustive in terms of social and behavioral research in relation to energy (broader lists are available elsewhere [74]), but rather consist of issues that are arguably important in the context of achieving multi-perspectival insights on acceptance.

Research of public attitudes towards energy technologies has relied on a wide variety of designs and methods. In our selective review are examples of experimental and quasi-experimental designs (e.g.[75] in relation to CCS and [76] in relation to nuclear energy); observational and correlational designs based on conventional surveys [77]; information choice questionnaires [78] and Q-method [79]; case-specific questionnaires [80]; qualitative designs based on case studies and qualitative field studies (with interviews and focus groups) [81] and mixed method designs combining questionnaires and interviews of end-users [82].

Research diversity is not a challenge or problem per se, arguably indicating a healthy research field; however drawing consistent interpretation from results obtained via diverse methods and perspectives does raise a number of questions regarding complementarity and integration. Each design and method produces a particular type of knowledge, framed in a particular way, with a different purpose, scope, limitations and conditionality [83]. Yet use of mixed methods within a single research design, or attempts at the integration of results from different studies, does raise a number of issues.

This is most stark when combining work typically labelled as either qualitative or quantitative. For example, case study research can be defined as “a research strategy which focuses on understanding the dynamics present within single settings” [84]. Case studies allow in-depth examination of process and situational factors, but generalizable inferences are tentative [85] and perhaps best made at an abstract level, with general relevance primarily being to other cases where similar processes operate [86]. Case-oriented researchers are often interested in the causal processes involved in particular outcomes in specific cases, such that they need to be sensitive to time, place, agency and process [87][88]. By contrast, large scale surveys offer statistical representativeness and the potential for inferential models, though necessarily based on a relatively shallow level of questioning, highly conditional on question phrasing. Laddering – probing of reasons for responses is uncommon as it complicates analysis of questionnaire results, with qualitative response options in large scale questionnaires often delivering information that is difficult to use.

Mixed method studies seek to combine depth and breadth, but require additional resource, need to be careful to ensure internal consistency [86] and often raise objections or concerns [89]. Our position is that combining results obtained via different methods requires care not so much due to differing research epistemologies per se [90], but rather because the distinction between qualitative and quantitative work is not as sharp as is often assumed [91]. That is, as Gorard argues: "research involving numbers is as interpretivist, and about meaning and judgement as much, as research without numbers" [92]. The similarities chiefly arise from the way in which numerical scales enclose and omit aspects of phenomena (often individual experience), just as qualitative research may condense qualitative information to themes through coding, with omission perhaps to a lesser degree (ibid). What matters in this context are the judgements involved in constructing both quantitative scales and qualitative themes and the subsequent direction of attention and choices as to what is salient. In short, little should be taken for granted when bringing results together.

Theoretical diversity further compounds issues of commensurability. For example, take the example of public responses to CCS that emphasize the role of information and rational choice [78] on the one hand and trust on the other [93]. Studies often attend to different aspects of a research problem, but whether their implications should be treated as alternatives or complements in a quasi-summative way is debatable. We might conclude, in this example, that both trust and information are important in the context of CCS (which they undoubtedly are). Yet this does not do full justice to either study. If extensive, guided provision of information is able to lead respondents to reluctantly accept CCS, though not in preference to renewables [78], should we conclude that a lack of trust can be overcome if sufficient information is provided? To do so would be to contradict the widespread critique of the (information) deficit model in relation to behaviour change [94], yet it is also likely that information does play an important role in this and related contexts, particularly where scientific and technical knowledge matter [95]. In all likelihood the roles of information and trust are nuanced, conditional, interactive, dynamic and variable. It is in these and other interactions that there is particular potential for further research. Add to this other theoretical perspectives even within social psychology, such as place attachment, with its own correlates [10], and one can see that even a single example raises questions about knowledge integration and also the limits to this [96].

A further concept that merits discussion in the context of the social acceptance of energy is that of “pseudo opinions” and “non-attitudes” [97] [98]. Particular energy technologies may often be unfamiliar to publics. A (proposed) development may be new to a locality or the technology itself may be novel. Either way, individuals may have a low level of awareness and/or knowledge of the technology on which they are asked to comment and their attitude or opinion is liable to change as they learn more. It is this high instability and responsiveness to contextual change that has led researchers to use the terms “pseudo opinions” and “non-attitudes” [78][99][100].

Techniques used to improve the depth of respondent knowledge include: i) using an Information-Choice Questionnaire (ICQ) [78] or similar, whereby participants are provided with a substantial level of neutral information about the technology; ii) the use of reconvened focus groups with stimulus materials [99][101]; and iii) the analysis of automatic mental associations and implicit attitudes [102], aimed at capturing instinctive reactions to attitudinal objects. In general the use of online panels by market research and polling firms also offers the opportunity to provide textual and graphical information to respondents at relatively low cost. To this one might add Q method, which aims not to provide neutral information, but which does nonetheless inform respondents of a wide range of opinion on a topic when presenting its ‘concourse’ [103].

Despite these methodological options, the concept of pseudo-opinions raises some quite fundamental questions. In particular is the matter of what context one considers to be ‘realistic’, valid or reliable when questioning respondents. If people form and express opinions on a particular technology or proposal on the basis of highly limited information in real word settings, for example on the basis of exposure to short news articles, then a one hour focus group or a 20 minute questionnaire that provides neutral information is arguably not so dissimilar [104]. Overall, the matter draws attention to the dynamic and changeable nature of attitudes, something that needs to be borne in mind, whatever one’s method, epistemology or ontology.

4.2 Multi-disciplinary frameworks and truth claims

The fundamental incommensurability of propositions developed for different purposes and – at the extreme – with different ontologies, raises the matter of competing truth claims. Arguably and briefly, the most relevant theories of truth in this context may be viewed as the coherence and correspondence approaches. While the former is concerned with coherence between propositions, the latter is concerned with the correspondence of propositions with the nature of a world posited as existing independent of human minds [105]. In arguing for frameworks that see value in drawing together insights from multiple perspectives, achieving propositional coherence is in principle more problematic than achieving correspondence coherence. Satisfying the demands of correspondence coherence requires empirical evidence, while satisfying the demands of propositional coherence requires truth conditions that are more difficult to meet when the world or an aspect of the world is understood very differently.

As emphasised, then, just as understanding and characterising energy technology acceptance more fully requires consideration of how best to bring different types and sources of knowledge together in a way that accounts for methodological assumptions, so does acknowledgement of the value of alternative (we think complementary) perspectives raise real conceptual challenges at the point of use – if one implicitly or explicitly (knowingly or unknowingly) holds propositional coherence to be a test of truth claims. Arguably, therefore, to simultaneously acknowledge the fundamental incommensurability of different perspectives while making use of the insights of multiple perspectives requires either neglect of their underpinning theory (not a problem for some) or the belief that despite reflecting different perspectives of – in this case the phenomenon that we term acceptance – a given study has revealed insights that have some reliable correspondence with an independent reality.

The option presented here – use of a general, category-based approach focussed on the context of acceptance (see also [106] and the energy cultures framework [58]) - takes the latter view. It deliberately seeks to minimise theoretical subsumption, juxtaposing insights, albeit with some loss of theoretical integrity from contributing perspectives, but with the objective of minimising this. Hence while categorisation does in some cases lose aspects of the identity of contributing perspectives, this loss is arguably far smaller than that incurred with the alternative of prioritising the terms of a preferred contributory perspective, or prioritising the terms of another perspective with a strong theoretical core. Following these latter approaches maintains theoretical coherence at the cost of foregoing insights that are incompatible at a theoretical level.

Drawing on multiple perspectives and insights by definition requires attention to a wide range of factors. To some extent it reflects a philosophy of holism [107] implicit in the bricoleur's approach [34] referred to initially. However, holism being an ultimately unrealisable ideal [107], we would position this type of eclectic framework within a pluralist philosophy of knowledge, preferably supportive of an interactive pluralism that seeks a dialogue among perspectives [108].

5 Conclusions

While a wholly unified account of the dynamics of social acceptance of technologies is implausible, with the on-going diffusion and installation of renewable and low carbon energy technologies in the last decades, social acceptance has become a matter of considerable interest among stakeholders and a variety of academic disciplines. Yet despite the wide use of the term 'acceptance' in relation to energy developments within and without academia, definition and meaning of the term has been often taken for granted. Seeking to provide guidance for those relatively new to the literature, we have defined social acceptance and have presented an analytical framework for its study in relation to energy technologies, infrastructures and applications. Specifically, we have defined acceptance as: "a favourable or positive response (including attitude, intention, behavior and – where appropriate - use) relating to a proposed or in situ technology or socio-technical system, by members of a given social unit (country or region, community or town and household, organization)”.

We have proposed an analytical framework for acceptance that makes, first, the distinction between three levels of social acceptance (general, local and household/organizational/ end user levels) based on the distinction between the acceptance of an energy technology, an infrastructure or an application; second, the characterization of social acceptance as a multi-actor phenomenon; and third, the characterization of the internal structure of individual acceptance.

In proposing this framework, we use as categories contexts of acceptance, in this way seeking to minimize theoretical subscription and hence maximise applicability across perspectives. We have acknowledged that the term ‘acceptance’ risks oversimplifying the interactions between societies, communities, collective actors and individuals and energy technologies and further risks perpetuating a normative top-down perspective of these relationships. Inevitably, simple concepts detract attention from related but implicit considerations. Nonetheless, we view the term ‘acceptance’ as having widespread resonance and hence as difficult to replace. The term and the processes that it denotes have significant implications on the field of energy policy and technology adoption and implementation, as well as for the quality of life of individuals, communities and societies.

A widely applicable framework allows different analytical perspectives to be integrated at a surface level. The social sciences have tended to frame energy acceptance studies from particular perspectives [23], rather than engaging in an interdisciplinary, problem-oriented effort to develop an integrative understanding of the social acceptance of energy technologies [31]. Yet no single analytical approach provides a framework for analysing more than a fraction of individual and social phenomenona, or for underpinning reliably successful policy interventions [109] [23] [58]. While complete unanimity of theoretical perspectives in this context is not possible, there is arguably a role for conceptual frameworks that categorise the many factors identified as influencing social and public acceptance of emerging energy technologies [71]. Not least, such frameworks are able to span categories of acceptance of energy technologies and to facilitate and encourage simultaneous consideration of the multiple influences on attitudes and behaviours. This in turn is a precondition for seeking to understand the relative and interacting effects of variables of interest to most energy social science researchers, regardless of discipline [31]. We offer our framework and thoughts on associated research problems and directions in this light.

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Annex Table 1. Descriptions of a selection of studies on the social and public acceptance of energy technologies reviewed for this report

Author, year, reference	Location	Type of energy technology	Level of analysis	Object of the study	Research question	Method	Sample
Poumadere et al., 1995	USA and France	Nuclear energy (fission)	General	Public acceptance	To test the widespread assumption that the French show higher levels of acceptance for nuclear power production on their territory.	Survey	In each country, 1500 persons responded to a 155 item questionnaire
Steg et al., 2005	Groningen, The Netherlands	Energy policies and renewable energy technologies	General	Public acceptance	Examine factors influencing the acceptability of energy policies and technologies aimed to reduce the emission of CO_2	Survey	A total of 300 surveys were distributed at different locations and times in Groningen, a city in the north of the Netherlands.
Moula et al., 2013	Finland	Renewable energy technologies	General	Public acceptance	What is the level of awareness of energy efficiency efficiency in terms of renewable energy sources and technologies	Survey questionnaire	A survey of 50 citizens living in Helsinki, Espoo and Vantaa.
De Best-Waldhober et al., 2009	Netherlands	Different technologies	General	Public acceptance	How people would evaluate and choose between seven mitigation options after having been thoroughly informed.	Information-Choice Questionnaire (ICQ)	A representative sample of the Dutch public (n =971)
Visschers et al., 2011	Switzerland	Nuclear power stations	General	Public acceptance	To investigate a broad model to explain people's acceptance of nuclear power stations. They focus on people's risk and benefit perceptions, affective feelings and trust.	Survey	817 (66.8%) inhabitants of the German-speaking part of Switzerland and 405 (33.2%) inhabitants of the French-speaking part were interviewed, by telephone.
L'Orange et al. 2011	Switzerland	CCS	General	Public acceptance	Whether information about monitoring of CCS sites would have a reassuring or alarming effect on laypeople with little prior knowledge of CCS	Experimental Survey	A survey of 200 residents of Switzerland.
Kim et al., 2014	Cross-country	Nuclear energy	General	Public acceptance	To identify the influences that exist on the level of public acceptance and reluctant acceptance of nuclear power, and how the effects of these factors depend on experience in operating nuclear power plants and the geographical, environmental, and cultural conditions of a country	Survey	20,803 respondents from 19 countries
Achterberg et al. 2010	The Netherlands	Hydrogen	General	Public acceptance	The relationship between the information one has about the hydrogen technology, how one is culturally predisposed and the way one judge's hydrogen technology.	Survey	N=2121 Representative sample of the Netherlands

					Following "framing theory" argue that these cultural predispositions could be the key to understand why low levels of knowledge about hydrogen could in fact coincide with high levels of support.		
Aas et al., 2014	Norway, Sweden and the United Kingdom	High-voltage powerlines	General and local	Public acceptance	To investigate public responses to transmission lines in three selected countries, through considering some key factors relevantfor understanding acceptance or opposition, notably issues of trust, familiarity and distinctions between general and local acceptance	Survey	A representative sample of the adult population in the three countries (N: 5107)
Zoellner et al., 2008	Germany	Grid-connected larger PV ground-installed systems, biomass plants and wind turbines	General	Public acceptance	The article addresses the public acceptance of certain renewable energies (grid-connected larger PV ground-installed systems, biomass plants and wind turbines) from a socio-scientific perspective.	Mixed methods	Qualitative interviews have been conducted with members of local authorities, operating companies of PV ground-installed systems, nature protection organizations, and members of citizens' initiatives.
Soland et al., 2013	Switzerland	Biogas plants	Local	Public acceptance	Description and explanatory factors in local acceptance of existing biogas plants in Switzerland	Survey	A survey of 502 citizens living near 19 biogas plants
Devine-Wright, 2011	Strangford Lough, Northern Ireland	Tidal energy convertor installation	Local	Public acceptance	Description of public beliefs about a tidal energy convertor installed in Strangford Lough.	Mixed methods	313 residents from Portaferry and Strangford
Thesen and Langhelle 2006	Greater Stavanger, Norway	Hydrogen vehicles and filling stations	Local	Local public acceptance, and End-users acceptance	Awareness and acceptability of hydrogen vehicles and filling stations	Survey	Back yard (-1km filling station) and Greater Stavanger
Sjöberg, 2004	Four municipalities in Sweden	Nuclear waste repository	Local	Local public acceptance	To study the attitudes and risk perceptions of people in four municipalities in Sweden where HLNW siting was being intensely discussed	Survey	2,548 local residents
Hall et al., 2103	Australia	Wind Farms	Local	Local social acceptance	To explore the 'social gap' between publicly stated support and individual local acceptance	Qualitative	27interviews including representatives from wind development companies(9); local government (5); community members ('local opposition') (4);community members

							('local support') (5); and turbine hosts(4)
Upham and S. Shackley, 2006	Devon, UK	Biomass plant	Local	Social acceptance	To describe the perceptions of the developer, agencies and local people involved in the planning of a proposed bioenergy gasifier	Survey, interviews and focus groups	Local residents, stakeholders and protestors
Dütschke, 2011	Ketzin and Vattenfall, Germany	CCS	Local	Social acceptance and adoption	The cases of Ketzin and Vattenfall are compared regarding project properties, communication strategies and public perception, as well as local context and history in order to identify factors that contributed to the respective positive or negative reaction.	Interviews	Information on the cases was collected through internet sources, e.g. project web sites, internet sites of opponents, and media archives, mainly from local newspapers. 13 in-depth interviews were conducted with relevant stakeholders.
Venables et al., 2009	Bradwell-on-Sea and Oldbury-on-Severn, UK	Nuclear power plants	Local	Public acceptance	To explore the acceptability of nuclear power plants	Q-Methodology	People ($n = 84$) drawn from communities near to two nuclear power stations in the United Kingdom
Sinclair and Löfstedt, 2001	Sutton, UK	Biomass plant	Local	Public acceptance and trust	To investigate factors underlying trust in the various 'institutions' in the biomass planning debate.	Mixed methods	Sixty Sutton residents were interviewed on three consecutive days outside the village mini-supermarket using a convenience sample methodology. The sample included 36 females and 24 males with an age and education distribution representative of the area
Bollinger and Gillingham, 2012	State of California, USA	Solar Photovoltaic Panels	End-user, household	End-user adoption	Peer Effects in the Diffusion of Solar Photovoltaic Panels	Correlational study	Secondary data on solar PV installations
Schelly, 2014	State of Wisconsin, USA	Residential solar electric technology	End-user, household	End-user acceptance, market acceptance	What motivates homeowners to adopt residential solar electric technology	Semi-structured interviews	48 homeowners
Mallet, 2007	Mexico City	Solar water heaters	End-user, household	Market acceptance	The role of technology cooperation in the adoption of renewable energy innovations	Interviews	Stakeholders and end users
Wiedman et al., 2009	Germany	Renewable energies	En user, household	Public acceptance, End-user acceptance	To provide a detailed picture of the private end user's decision process, using the classical concept of attitude research to	Survey	182 residents from Germany

					identify individual acceptances		
Chen et al., 2010	Norway	Biomass, pellet stoves	End-user, household	End-user acceptance and adoption	What influences households' decisions to invest in new heating equipment, and which factors determine what type of equipment they choose	Survey	1860 residents from Norway
Heagle et al., 2011	Ontario, Canada	Small wind turbine for residential usage	End-user, household	Social acceptance	Examine the social barriers, policies, and incentive programs for residential and small business small wind projects in Ontario	Case study	Secondary data
Mourato et al., 2004	London	Hydrogen	End-user, taxi drivers	End-user acceptance	Investigation of attitudes towards hydrogen as a fuel, potential demand for joining a fuel cell hydrogen taxi demonstration project and the purchase intention of a future production fuel cell vehicle	Mixed methods	100 taxi drivers from London
Egbue and Long 2012		Electric Vehicles	End-user, individuals	End-user acceptance and adoption	What are the socio-technical barriers to consumer adoption of electric vehicles? How much influence does sustainability have on Electric Vehicles purchase decision?	Survey	The target population comprised mainly of current owners of CVs with the intention of capturing opinions, perceptions and attitudes of individuals who are prospective owners of EVs. 481 responses were used for further analysis.
Wüstenhagen et al., 2007	--	Renewable energy technologies	--	Conceptual	--	--	--
Devine-Wright, 2007	--	Renewable energy technologies	--	Conceptual	--	--	--
Flyn, 2007	--	Energy, Hydrogen	--	Conceptual	--	--	--
Wolsink, 2007	--	Wind	--	Conceptual	--	--	--
Ricci, 2008	--	Hydrogen	--	Critical/narrative review	--	--	--
Prades et al., 2008	--	Fusion energy	--	Critical/narrative review	--	--	--
Prades et al. 2009	--	Wind Energy	--	Critical/narrative review	--	--	--
Gupta et al., 2011	--	Emerging technologies	--	Systematic review			

Huijts et al., 2012	--	Energy technologies		Review	--	--	--
Batel et al., 2013	--	Highvoltage powerlines.	--	Conceptual			
Stern, 2014	--	Energy	--	Conceptual	--	--	--
Perlaviciute and Steg, 2014	--	Energy technologies	--	Review	--	--	--
Selma et al., 2014	--	CCS	--	Systematic review	--	--	--