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Review

# Visualizing social acceptance research
# A bibliometric review of the social acceptance literature for energy technology and fuels

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ABSTRACT

This paper conducts content and bibliometric analysis of 857 articles representing the knowledge domain for the social acceptance of energy technology and fuels. The objective is to identify basic trends and characteristics in the literature, identify current research fronts and pivotal papers therein, and map these fronts to their respective intellectual bases. We accomplish this by analyzing metadata, keyword use and citation networks within our dataset. We conclude with an evaluation of influence, structure, and collaboration and interdisciplinary dialogue in the field.

## 1. Introduction

Social acceptance of energy and fuels is a research area of increasing size and importance, situated approximately at the intersection of two much larger bodies of literature: the diffusion of new technology and/or innovations [1], and the social scientific study of energy and policy [2]. Using a definition provided by a recent conceptual review of the field, we can define acceptance as, "a favourable or positive response (including 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)" [3]. Broadly speaking, the interest of the "knowledge domain" under consideration in this paper is in understanding and/or explaining acceptance of energy technologies and fuels.

This is an area of study that has experienced rapid growth in the past decade. Perhaps because of this growth, concerns have been raised over the methodological or theoretical rigour of the field [4], over the coherence of core concepts like NIMBYism [5–8], over the assumptions underpinning the interest in wind power in particular [9], and over the nature of acceptance itself [10]. It is unsurprising, therefore, that among the most influential papers in this field one finds a number of reviews and frameworks that aim to summarize and synthesize the many different theoretical and methodological approaches to social acceptance of energy technology and fuels [3,4,11–14].

Reviews and frameworks are useful for combining and condensing a wide range of research into a single, comprehensive structure, highlighting generalizable findings, pointing out gaps or weaknesses in a body of literature, and suggesting future directions for research. In short, they seek to produce order out of (what is perceived as) disorder and – intentionally or not – seek to enforce that order on future research in the field. The aim of this paper is not to produce another framework per se, but rather to provide a global and empirical visualization of the knowledge domain for the social acceptance of energy technology and fuels through a multi-step process involving content and bibliometric analysis. We conclude our paper by reflecting on the implications of our findings for understanding evolving structure and shifting influence, and for the promise of collaboration and interdisciplinary dialogue in the field.

## 2. Domain visualization

The idea that a systematic, global, and theoretically and methodologically neutral perspective of a knowledge domain can provide insight into its structure and evolution is not new [15–17]. Visualization, in seeking to "reveal realms of scientific communication as reflected in the scientific literature and the citation paths woven by individual scientists in their publications," is one method for conducting such a domain analysis [15,18]. To do so, domain visualization makes use of citation analysis techniques that date back to the mid-20th century when the first scientific citation indexes were being developed [19].

One of the main goals of this analysis is to measure and assess *similarity* between works within an area of literature in order to identify 'sub-domains' in the larger knowledge domain (i.e., research

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communities within the field that are tightly connected). There are two main approaches to doing so: bibliographic coupling and co-citation analysis. Bibliographic coupling draws connections between papers based on the number of times they cite the same publications [20]. The strength of this connection thus increases with the number of common sources cited. Co-citation, on the other hand, draws connections between the cited references themselves, based on the times they are cited together by other papers [21]. The basic premise of either approach is that similarity between papers within a network (represented by the strength of connections between them) is likely to be higher within the sub-groupings in the literature than between them. Accordingly, we can proceed to identify communities within the literature after extracting the citation networks by running some basic network analysis algorithms (i.e., the Louvain community detection algorithm[1]).

Doing so can thus help to identify specialities within a knowledge domain. Information science generally distinguishes between two 'citation half-lives' of articles: classic articles with persistently high citations and transient articles that 'peak' in a short period of time [23,24]. The nature of influence and the significance of these types of articles is different, and is encapsulated by a related distinction between *research fronts* within a body of literature, and their respective *intellectual bases*. Price observed that scientists tend to cite more recently published papers, which he termed the 'immediacy factor' [24]. A research front consists of 40–50 commonly cited, recent articles, and thus represents 'state of the art' thinking in a research field. The intellectual base, on the other hand, consists of the older, 'classic' works that current research draws upon for theoretical and methodological structure. In short, according to Persson, "in bibliometric terms, the citing articles form a research front, and the cited articles constitute an intellectual base" [25]. A "speciality" within an intellectual field can thus be defined, according to Chen, as a "time variant mapping between a research base and its intellectual base" [23]. Both bibliographic coupling and co-citation analysis have been used to visualize research fronts [23,26,27]. In this paper, we use the former method to identify the fronts, and the latter method to identify their respective intellectual bases.

Domain visualization also allows us to measure the influence of certain authors, journals and papers in a way that goes beyond simple citation counts. Because domain visualization portrays a body of literature as a network, we can then calculate the centrality of the nodes (i.e., papers, cited references) within − a metric that quantifies the importance of a node's position in the network. The most commonly used centrality metric is betweenness centrality, a measure of the percentage of the number of shortest paths in a network to which a given node belongs [28]. Because the strength of connections between nodes in a network is often higher within sub-groupings than between them [29], nodes that are found along the paths that connect these groupings typically have higher betweenness centrality values, signifying that they are important in bridging two different communities. According to Chen, measuring centrality can allow a research to identify "pivotal points" between different specialities, tipping points in an evolving network [23].

In identifying specialities, key works, and the structure connecting them, domain visualization thus serves a pedagogical use as well. It can help new researchers become more familiar with the structure of field of knowledge and to identify existing areas of research that are most relevant to addressing the questions and problems they are looking to answer. It can also help those already working in the field to identify gaps and potential areas for collaboration and future research. We intend to use it to supplement existing perspectives on the knowledge domain for the social acceptance of energy and fuels with fresh insight on the influence, structure, and extent of collaboration in the field.

### 2.1. Perspectives on the social acceptance knowledge domain

To our knowledge, there have been no previous attempt at visualizing the knowledge domain for the social acceptance of energy and fuels using the bibliometric methods described in Section 2 – the closest we could find to comprehensive domain analysis was Sriwannawit and Sandström's large-scale bibliographic coupling analysis of the technology diffusion literature [1], and Sovacool's content analysis of over 4000 research articles published in leading energy journals between 1999 and 2013 [2]. Neither of these papers engage directly with the literature on social acceptance (Sriwannawit and Sandström do identify a 'technology acceptance' cluster in the diffusion literature, though it appears to be associated mainly with the information sciences literature on technology adoption in the workplace, i.e., the "technology acceptance model"). In the absence of large-scale bibliometric analysis of the knowledge domain, we can fall back on widely-cited, review-oriented papers – particularly those that offer "frameworks" – to understand how researchers working in this area understand the structure, main issues and future direction of the field.

Perhaps the widest-cited such paper is the introductory article to the 2007 special issue of *Energy Policy* on social acceptance by Wüstenhagen et al. [14], which introduces the three dimensions of social acceptance: *socio-political, community, and market acceptance.* The authors describe the defining characteristics of acceptance in each dimension, and provide examples of existing research. They describe socio-political acceptance as acceptance "on the broadest, most general level", noting that both policy and technology are subject to social acceptance of this nature [14]. Acceptance of this kind is associated with general public opinion, and the attitudes of key stakeholders and policy-makers [30]. Community acceptance they describe as the "specific acceptance of siting decisions and renewable energy projects by local stakeholders, particularly residents and local authorities" [14], and the arena in which debates around NIMBYism unfold [31]. Important considerations underlying acceptance in this dimension include perceptions of procedural and/or distributional justice with regards to project siting or renewable energy policy, and the extent of trust in project proponents, government or other key stakeholders. Lastly, market acceptance they associate with the process of market adoption of an innovation, and link to the decisions of consumers to purchase green electricity contracts [32], the decisions of investors to invest in wind power, or intra-firm acceptance of renewable energy innovation. They conclude by highlighting a number of suggestions for future research in each dimension, noting that understanding of market acceptance is particularly 'under-researched' at the moment [14].

Another widely cited framework paper is the 2005 article by Devine-wright, which reviews existing research on perceptions on wind power with the aims of critically assessing the literature and developing an "integrated, multidimensional framework to guide future work" in the field [4]. Based on the author's review of the literature, he identifies four research questions being addressed in the field and, on the basis of these, an additional two, overarching, "key" questions – does NIMBYism explain wind farm opposition, and does local involvement in wind farms increase local support? Devine-wright found that many studies were "poorly grounded" in social science theory, fragmented in their approaches to conceptualization and analysis and, as such, that it was difficult to identify the relative importance of different aspects in shaping perceptions of wind power. He finds four further "deficiencies" with the literature at the time: 1) Lack of research in non-industrialized countries; 2) A lack of valid and reliable quantitative methodological tools for operationalizing perceptions of wind farms; 3) Simplistic conceptualization of the notions of 'public' and 'community'; and, 4) A marked absence of explanatory theoretical frameworks. To correct these deficiencies, the author advocates for greater interdisciplinary

[1] The Louvain method for extracting communities from large networks is one method among others to represent modularity in the network. Modularity is essentially a measure of the density of connections between nodes – nodes within communities have dense connections with others 'internal' to the community, and sparse connections with nodes considered internal to other communities [22].