

Review

Investigating Ties between Energy Policy and Social Equity Research: A Citation Network Analysis

Andrew Chapman ^{1,*}, Timothy Fraser ² and Melanie Dennis ³

¹ International Institute for Carbon Neutral Energy Research, Kyushu University, Fukuoka 8190395, Japan

² Department of Political Science, Northeastern University, Boston, MA 02115, USA; fraser.ti@husky.neu.edu

³ Department of Mathematics, Dartmouth College, Hanover, NH 03755, USA; melanie.n.dennis.gr@dartmouth.edu

* Corresponding: chapman@i2cner.kyushu-u.ac.jp

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Abstract: Just over twenty years ago, the Kyoto Protocol brought nations together to address the emergent issue of climate change. To support the development of energy policy, a number of academic fields were strengthened, particularly surrounding sustainable development and the economic, environmental, and social aspects of sustainability. This research focuses on the social aspects of energy policy, beginning with climate justice, through to the emergence of energy justice and the notion of a just transition. Through a bibliometric analysis of 5529 academic studies incorporating energy policy and social equity across relevant academic fields, strong ties among five distinct schools of thought were identified. Interestingly, energy transitions scholarship appears distinct from most social equity and energy justice related scholarship. There is a need to better integrate disparate schools of thought in order to achieve a just transitions framework able to address inequities in energy policy outcomes in the Paris Agreement era and beyond.

Keywords: energy policy; social equity; bibliometric analysis; citations; networks

1. Introduction

The establishment of the Kyoto Protocol in 1997 recently heightened international awareness of climate change. As a result, national governments, states, and cities around the world have implemented energy policies aiming to reduce greenhouse gas (GHG) emissions. These policies seek to encourage economic development which is cognizant of environmental improvement. Developed countries were expected to shoulder the majority of the burden of meeting climate change mitigation targets and to support developing countries in their adaptation efforts (UNFCCC 2018). In addition to climate change mitigation, scholars and policymakers also emphasized sustainable development and the importance of the social aspects of sustainability (including social equity) alongside environmental and economic concerns around this time (e.g., Campbell 1996; Matson and Carasso 1999; Wheeler 2002).

The evaluation of social equity has received significant attention in energy policy and environmental studies under a variety of monikers, themes, and schools of thought. While researchers have discussed the themes of climate justice, environmental justice, and energy justice individually, the divisions, clustering, and overlap of these evaluation methodologies remains unclear and understudied.

This paper undertakes a review, analyzing issues relevant to the social equity impacts of energy within the fields of energy policy and environmental studies. The analysis undertaken precedes the advent of the Kyoto Protocol and resultant international focus on climate change, to the present day. Critical factors, theoretical approaches, and ‘schools of thought’ which emerged over time are identified, along with a determination of any crossover, shared, or unique aspects of each.

The review aims to identify any shortcomings in these approaches in terms of (1) implications for energy policy and (2) robustness in terms of addressing sustainability evaluation in a holistic manner.

Additionally, it establishes a timeline of energy policy and social equity scholarship to clarify shifting priorities over time, logical connections between approaches or theories, and the development of each approach in terms of global reach and research network establishment.

Section 2 describes the landscape of climate change awareness, sustainable development, and evaluation of sustainability, particularly regarding social equity aspects in broad terms. Section 3 takes this narrative and develops a methodology to investigate the emergence, focus, and any connections between academic approaches over time, utilizing a combination of literature review and network analysis. Section 4 describes results and discusses the relevance of findings, identifying gaps and potential future focus areas. Section 5 presents the conclusions, limitations of the study, and future work.

2. Background of Climate Change Awareness and Sustainability Evaluation Frameworks

Climate change awareness was recently brought to the fore following the enactment of the Kyoto Protocol, as scholars, policy entrepreneurs, and signatory states began debating how to fulfill the GHG emission reductions promised in the agreement. The Protocol marked the first concrete steps taken in the conference of parties of the United Nations Framework Convention on Climate Change since its establishment in 1992 (Gupta et al. 2007). It also set precedent on discussions of equity in climate policy by establishing the principle of “common but differentiated responsibilities and respective capabilities” (CBDRRC). Criticism of the agreement also initiated one of the first major debates over equity in climate and energy policy, about whether developed or developing states should bear the burdens of climate change countermeasures internationally, and whether developed states such as the United States should commit before developing countries (Okereke 2008).

Aiming to maximize economic growth among these differentiated responsibilities, scholars and policymakers in developed and developing states initiated debate over ‘sustainable development’, creating a cacophony of new, often contradictory meanings (Kidd 1992; Giovannoni and Fabietti 2014). Public awareness grew as policy entrepreneurs competed to dominate the agenda of the environmental movement. “Ecological activists” decried the market-based mechanisms of “smart growth reformers”, who both in turn were critiqued by “ecomodernists” who aim to decouple energy use from growth (Nisbet 2014). Debates over whether the state, the market, or civil society should administer climate policy introduced new questions of equity and burden.

By the late 2000s, scholarship highlighted the effects of industrial pollution in the cities and towns of developed countries. Activists and scholars highlighted particulate matter (PM) emissions from coal-fired power plants as not only a GHG emission issue but also a health issue that disproportionately burdened underserved communities (Higginbotham et al. 2010; Ma 2010). Civil society organizations such as the Sierra Club used this evidence to pressure policymakers to restrict fossil fuel power plants and, when unable, to shame corporations into making their ‘sustainable development goals’ more sustainable (Abate 2010; Newell 2008). This provoked increasing attention from activists, scholars, and the media about equity issues in transnational production, in which developed states have exported the production of emissions through manufacturing to developing states such as China and India (Mason 2008).

These discussions in policy and activist spheres bled over into scholarship, provoking the emergence of several schools of study exploring the social outcomes of energy and climate change policy. The earliest of these was known as environmental justice, preceding the Kyoto Protocol, concerned with the fair treatment and meaningful, unrestricted involvement of stakeholders in the development, implementation and enforcement of environmental policies (EPA 2018). Environmental justice arose from a grassroots movement in the USA (Capek 1993), initially to contest the siting of polluting industries in disadvantaged communities (Walker and Bulkeley 2006). This concept was formalized through an executive order (EO) by then President Clinton (EO12898 1994), charging government agencies with the task of “identifying and addressing the disproportionately high and adverse effects of its programs, policies and activities on minority and low-income populations” (EPA 2018).

Following on from environmental justice, the notion of ‘climate justice’ emerged in the early 2000s, coinciding with the 6th Conference of Parties (COP6), seeking to hold developed nations accountable for climate change and to provide redress for developing nations that bear a large portion of the costs (Pettit 2004). Climate justice seeks to provide a fair basis for the division of responsibilities in solving a common, global problem and the meeting of obligations to current and future generations through attention to distributive and procedural aspects (Bulkeley et al. 2013). Both the environmental and climate justice movements have been criticized as only achieving limited success, in terms of environmental improvement and normative policy impact due to their overly broad definition and scope (Heffron et al. 2015).

Building on both environmental and climate justice, the concept of energy justice emerged in the early 2010s with respect to policy, aiming to improve upon the former concepts through greater manageability, and a focus on energy issues, leading to environmental benefits (Jenkins 2018). Energy justice is concerned with three key tenets: Distributive justice, recognition justice (similar to climate justice), and procedural justice—the engagement of all stakeholders in energy policy decision making processes (Jenkins et al. 2016).

Most recently, the concept of a ‘just transition’ toward a low-carbon economy has gained attention, attempting to encapsulate the perspectives of environmental justice, climate justice and energy justice movements into a single stream and to unite these efforts in order to increase public acceptance (Heffron and McCauley 2018).

3. Methodology

Building from this background in climate change awareness and sustainability evaluation, a timeline begins to emerge, with approximate stages identifiable as environmental justice, climate justice, energy justice, and, most recently, the notion of a just transition. Each of these streams of scholarship continue, and there is significant overlap within each. In order to delve deeper into each of these research streams, and to achieve the goals of this study, a technology aided literature review is introduced, using specific keyword combination searches within the Web of Science document search tool. Figure 1 outlines the methodology utilized in this study.

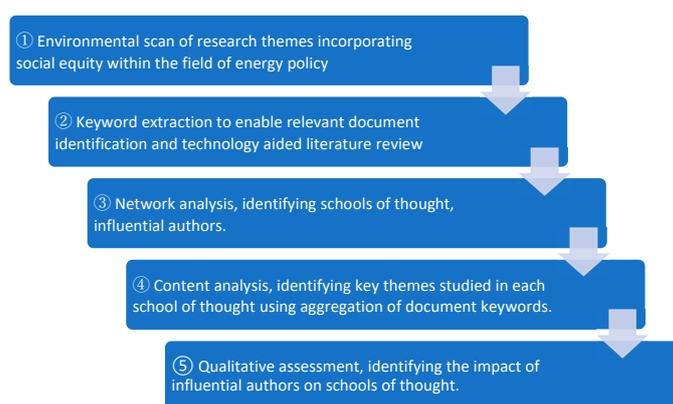


Figure 1. Research methodology.

Here, “keyword extraction” refers to searching scholarly databases for articles matching specific scholarship themes. “Network analysis” refers to visualizing the citation patterns and finding clusters among documents and authors analyzed. Finally, “content analysis” refers to reclassifying document keywords into broader themes and counting these themes among clusters for quantitative comparison.

3.1. Keyword Extraction and Document Identification

Based on the historical context offered in Sections 1 and 2, and the quoted literature, keywords were extracted to inform a technology aided literature review which underpins the network analysis.

The keywords identified are detailed in Appendix A, sorted by overarching theme. The top-level terms are energy policy and social equity, the focus of this study. Building on the background section offered above, additional terms relevant to each school of thought along the climate change awareness and sustainability evaluation timeline are extracted. These second-level terms (described as categories in Appendix A) include: Technology, adaptation and mitigation, environment, policy, justice, equity, and politics. Subsequently, 90 author-identified terms relevant to each category were included to ensure a broad combination of themes covering each of the identified schools as self-reported by authors in these fields.

To identify academic journal articles which fall under investigated themes, terms from the review focus and keywords from precedential scholarship theme were searched in combination. This utilized the AND syntax in a search incorporating the article title, abstract, and keywords for documents within the date range of 1975–2018, as far back as Web of Science could provide. All results for each search term combination were retained, while duplicates across search term combinations were removed from the final pool of documents, including review papers, books, and book chapters (conference proceedings were excluded). Two hundred searches were conducted combining each primary term (numbered 1 to 3 in Appendix A) with each secondary scholarship theme (labelled by category in Appendix A). Of 7211 original search results, 5529 were kept (77%). The original search results and final results used in our analysis are available in the Web of Science Results section of our Supplementary Data package.

Ideally, this process helped to identify the majority of relevant fields of research related to energy policy and social equity; however, the authors recognize that no search of scientific documents will be exhaustive.

3.2. Network Analysis

Network analysis was employed to study the occurrence of research clusters within our research boundary. Network visualization has been used to study citation networks in renewable energy (Jeong et al. 2015), climate change (Haunschild et al. 2016), and global health (Cash-Gibson et al. 2018), among others. In this study, bibliometric networks of scholarly impact were visualized using the VOSviewer software package Version 1.6.7, using best practices identified by Van Eck and Waltman (2014).

Network data were generated based on bibliometric data downloaded from Web of Science, as identified by search terms (See Networks in Supplementary Data). To ensure the most accurate visualizations possible, where able, thesauruses of all known variations of author names were used (see Thesaurus in Supplementary Data). Research clusters of documents and authors were mapped using bibliographic coupling and co-citation analysis. Text co-occurrence displays links between words in paper titles or abstracts that frequently appear together in the same documents, creating a thematic map of the field. Bibliographic coupling displays links between documents or authors that cite the same sources, such that network clusters highlight typical authors in each field, illustrating the schools of thought. Co-citation displays links between authors that are both cited by the same document, such that network clusters tend to highlight the most influential authors in each field. Minimum citations, total terms, and thresholds are detailed in Appendix B. These results are outlined using cluster visualizations and a content analysis of keywords for research clusters in the following section.

4. Results and Discussion

Trends in scholarship on energy policy and social equity are evaluated below using a three-part analysis. First, network analysis was employed to highlight the themes discussed together using text co-occurrence. Second, network analysis and content analysis of research clusters identified through bibliographic coupling was undertaken. Third, network visualizations of clusters of authors most frequently cited together in the field were produced and analyzed. Fourth, in light of these visualizations, developments in the literature were reviewed qualitatively, focusing on identified influential authors.

4.1. Text Co-Occurrence Network Analysis Findings

First, a network of the top 1437 most relevant terms in energy policy and social equity titles and abstracts was produced, drawing from 86,210 total terms from 5529 total papers. Nodes in this network are terms that appear most frequently together in titles and abstracts. Terms that appear more often together are clustered together by color, while the size of nodes reflects the number of times a term occurs. This network, displayed in Figure 2, highlights clusters of research around four themes. Terms such as social equity, city, resident, practice, and justice frequently co-occur together (in red), while a more technically focused part of the literature (in green) focuses on electricity, emissions, mitigation, and fuel sources. Finally, in between these clusters exist pockets of energy consumption research (yellow) and literature in response to nuclear crises and disasters (blue). With this thematic frame in mind, the schools of thought around energy policy and social equity were examined.

4.2. Bibliographic Coupling Network Analysis and Content Analysis Findings

Second, using bibliographic coupling of 5529 documents, a network of the top 1000 documents with the most links between documents that share the same references was produced. Nodes in this network are published documents. Two or more documents are clustered closer to one another if they cite the same work. The size of nodes reflects the number of citations that each article has received, while the position of each node reflects the documents with which it shares the most references. As a result, this network, shown in Figure 3, describes the ten main clusters of research on energy policy and social equity. We focused on the eight dominant clusters, excluding the remainder due to a low number of documents (<50). (Although notable studies such as [Dempsey et al.'s \(2011\)](#) application of social equity to sustainable development appear in these excluded clusters, they share many fewer common references than other clusters. As a result, these were not included in the analysis of schools of thought).

To describe these eight main clusters, a content analysis of keywords associated with these documents was employed. Over 4000 keywords were grouped into larger themes to enable systematic analysis. The top 100 most frequently occurring keywords among the 1000 documents in the network were identified, followed by consolidating related terms into 76 distinct clusters, and then identified the 15 keywords per cluster that authors used most frequently within that cluster. Clusters with disproportionately more of one keyword than other clusters are providing valuable specialization which is absent in the rest of the field. If two clusters have the same share of a certain keyword, it means they are studying the same topic, but they are not citing the same sources. These clusters are outlined in order of number of documents below in Table 1, describing clusters according to their top 15 keywords.

Most importantly, this research allows for the identification of research 'silos', where researchers are studying the same topics but not referencing the same sources. These can be seen where a node in one cluster lacks any links with a node in another cluster. Our research identified several major topics which are being studied separately over two or more clusters.

There are several key takeaways from this content analysis and bibliographic coupling analysis.

First, only two clusters specifically cited social equity among their top keywords. These are the yellow cluster (4th largest), which focuses on policy studies, governance, and social equity, and the purple cluster (5th largest), which focuses on energy justice and social equity. The works most emblematic of the yellow cluster (those with the highest link count) include [Dharshing \(2017\)](#), which looked at residential PV adoption rates, [Eagle et al. \(2017\)](#), who looked at social marketing strategies, and [Cirone and Urpelainen \(2013\)](#), who looked at the role of government disunion in energy policy disarray. By contrast, the purple cluster's most emblematic works include [Fuertey et al. \(2016\)](#), which looked at the role of institutions in wind policy decision-making, [Newell et al. \(2017\)](#), who looked at the role of networks of organizations in renewable power deployment process design, and [Mignon and Rudinger \(2016\)](#), who looked at barriers to establishing renewable cooperatives.

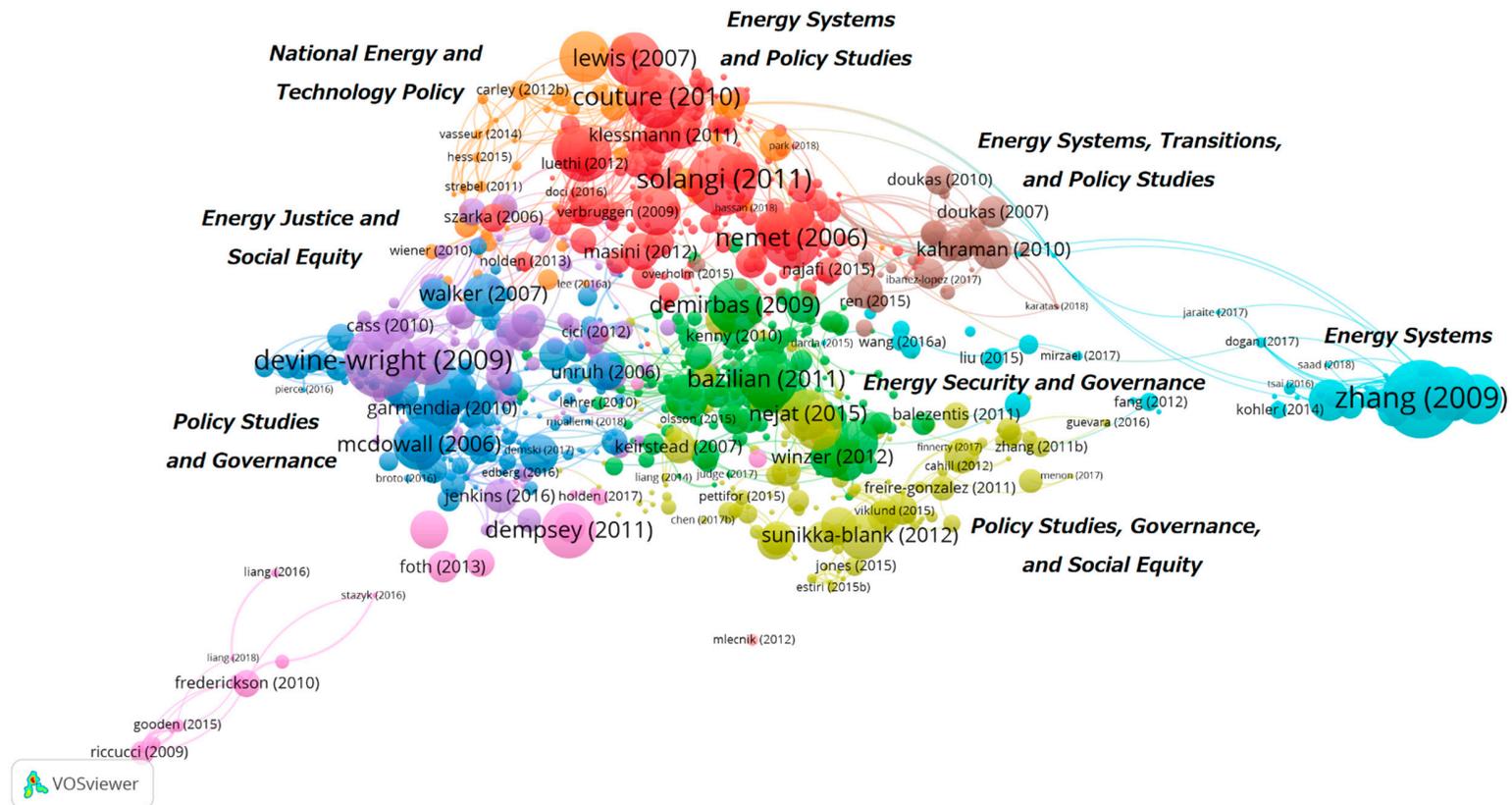


Figure 3. Bibliographic Coupling of documents (size of nodes by number of citations).

These two clusters are quite separate from one another, neighboring research on energy systems and policy studies (red) and policy studies and governance (blue). Twenty-six percent of all uses of social equity as a keyword come from these two adjacent clusters. This indicates the existence of two distinct schools of thought not in deep dialogue with one another on social equity research. The yellow social equity cluster focuses on social equity research in politics, political institutions, and public perception. Meanwhile, the purple social equity cluster focuses on energy justice (91%), social acceptance (86%), and community energy (80%). These visions of social equity in energy policy are divergent. The latter looks at community-level issues, representing a strong trend in the EU towards questions of ownership and equity.

Second, this study highlights a significant amount of energy policy research (in gray and light blue clusters in Figure 3) which is still quite separate from academic efforts on social equity. These clusters that focus on energy systems, transitions, and policy studies rarely refer to social equity research, indicating gaps for future research.

Third, although many scholars are studying sustainability policy, urban sustainability, climate adaptation, and energy, some may not be using the same keywords. This points to a coordination issue in the field, one that scholars such as Heffron and McCauley’s “just transitions” concept seeks to remedy. It is currently difficult to identify scholars across clusters that study the same equity-related topics because many are using different keywords.

Table 1. Schools of thought by Top 15 author keywords (cluster colors from Figure 3).

Cluster	Name	Top 15 Themes
Cluster 1 (Red)	Energy Systems and Policy Studies	feed-in tariff, solar PV, investment, renewable energy policy, distributed generation, innovation, electricity generation, uncertainty, photovoltaics, technology diffusion, Pakistan, policy, wind power, renewable energy, electricity
Cluster 2 (Green)	Energy Security and Governance	biofuel, energy security, European union, energy systems, regulation, shale gas, climate change policy, renewables, bioenergy, carbon tax, uncertainty, governance, environmental policy, japan, risk
Cluster 3 (Blue)	Policy Studies and Governance	policy change, advocacy coalition framework, politics, public opinion, framing, institutions, nuclear energy policy, energy transition, nuclear power, Germany, energy systems, environment, public policy, governance, hydropower
Cluster 4 (Yellow)	Policy Studies, Governance, and Social Equity	rebound effect, barriers, energy efficiency, energy intensity, buildings, energy use, china, public perception, social equity, energy consumption, energy economics, sustainability, political economy, co2 emissions, institutions
Cluster 5 (Purple)	Energy Justice and Social Equity	energy justice, social acceptance, community energy, environmental justice, public perception, shale gas, equity, wind power, japan, sustainability, political economy, decision-making, renewables, renewable energy, environmental policy
Cluster 6 (Light Blue)	Energy Systems	panel cointegration, cointegration, economic growth, granger causality, causality, energy consumption, energy use, co2 emissions, Pakistan, carbon tax, electricity market, hydropower, system dynamics, environment, energy economics
Cluster 7 (Orange)	National Energy and Technology Policy	policy diffusion, renewable portfolio standard, electricity market, photovoltaics, electricity generation, environment, carbon tax, environmental policy, nuclear energy policy, politics, technology diffusion, energy, Pakistan, regulation, electricity
Cluster 8 (Mauve)	Energy Systems, Transitions, and Policy Studies	analytic hierarchy process, multi-criteria decision making, decision-making, sustainable development, electricity, distributed generation, Pakistan, renewable energy, renewable energy policy, sustainability, nuclear power, energy, energy transition, climate change policy, energy policy

4.3. Co-Citation Analysis of Authors

Next, an analysis of authors most often cited together by the same document (co-citation) was undertaken. A network of the 1000 authors most co-cited was produced, incorporating authors who were cited more than 20 times (Table 2). Co-citation analysis tends to reflect influential authors in the field, whereas bibliographic coupling tends to reflect schools of thought more broadly. This network displays a set of 9 unique clusters. Their coloring is unrelated to the coloring in the previous analysis and is reflected in Figure 4.

Table 2. Influential authors and citations by top 10 most co-citations (coloring linked to Figure 4).

Cluster 1 Transitions (Red)	Citations	Cluster 2 Energy Law (Green)	Citations	Cluster 3 Social Acceptability (Blue)	Citations
Sovacool, B	522	IEA	2121	Jacobsson, S	160
Geels, F	219	EIA	831	Haas, R	156
Smith, A	152	OECD	343	Mitchell, C	185
Unruh, G	85	IPCC	354	Toke, D	127
Walker, G	163	World Bank	576	Wustenhagen, R	117
Markard, J	71	Stern, N	118	Frondel, M	92
Kemp, R	96	United Nations	158	IRENA	145
Stirling, A	100	Grubler, A	71	Del Río, P	136
DTI	204	Edenhofer, O	86	REN21	102
Wolsink, M	124	EPA	130	Lipp, J	55
Cluster 4 Energy Emissions (Yellow)	Citations	Cluster 5 Climate Policy (Purple)	Citations	Cluster 6 Energy Policy (Light Blue)	Citations
Wang, Q	91	Sorrell, S	200	Demirbas, A	234
Lin, B	109	Jaffe, A	122	Dincer, I	112
Apergis, N	141	Rogers, E	98	Madlener, R	48
Lenzen, M	96	Geller, H	63	Streimikiene, D	92
Costantini, V	34	Greening, L	81	Saidur, R	59
Zhang, Z	46	Brown, M	84	Kaygusuz, K	156
NDRC	157	Shove, E	130	Ackermann, T	39
Wang, Y	50	Fischer, C	78	Kaldellis, Jk	58
Grossman, G	44	Stern, P	118	Doukas, H	76
Andrews-Speed, P	36	Gillingham, K	78	Komor, P	39
Cluster 7 EU Energy Policy (Orange)	Citations	Cluster 8 Energy Finance and Policy (Mauve)	Citations	Cluster 9 Renewable Energy Promotion Policies (Pink)	Citations
EC	1622	DECC	462	Wiser, R	147
Eurostat	197	Helm, D	114	Carley, S	104
WEC	123	Grubb, M	76	Bird, L	61
BP	127	Foxon, T	110	Rabe, B	86
Goldthau, A	81	Lund, H	174	Palmer, K	41
Yergin, D	72	Ekins, P	52	Menz, F	47
Loschel, A	43	Fouquet, R	45	Byrne, J	59
Cherp, A	51	OFG	91	Delmas, M	29
Finon, D	50	Agnolucci, P	37	Yin, H	30
Blyth, W	28	Strbac, G	42	Bolinger, M	31

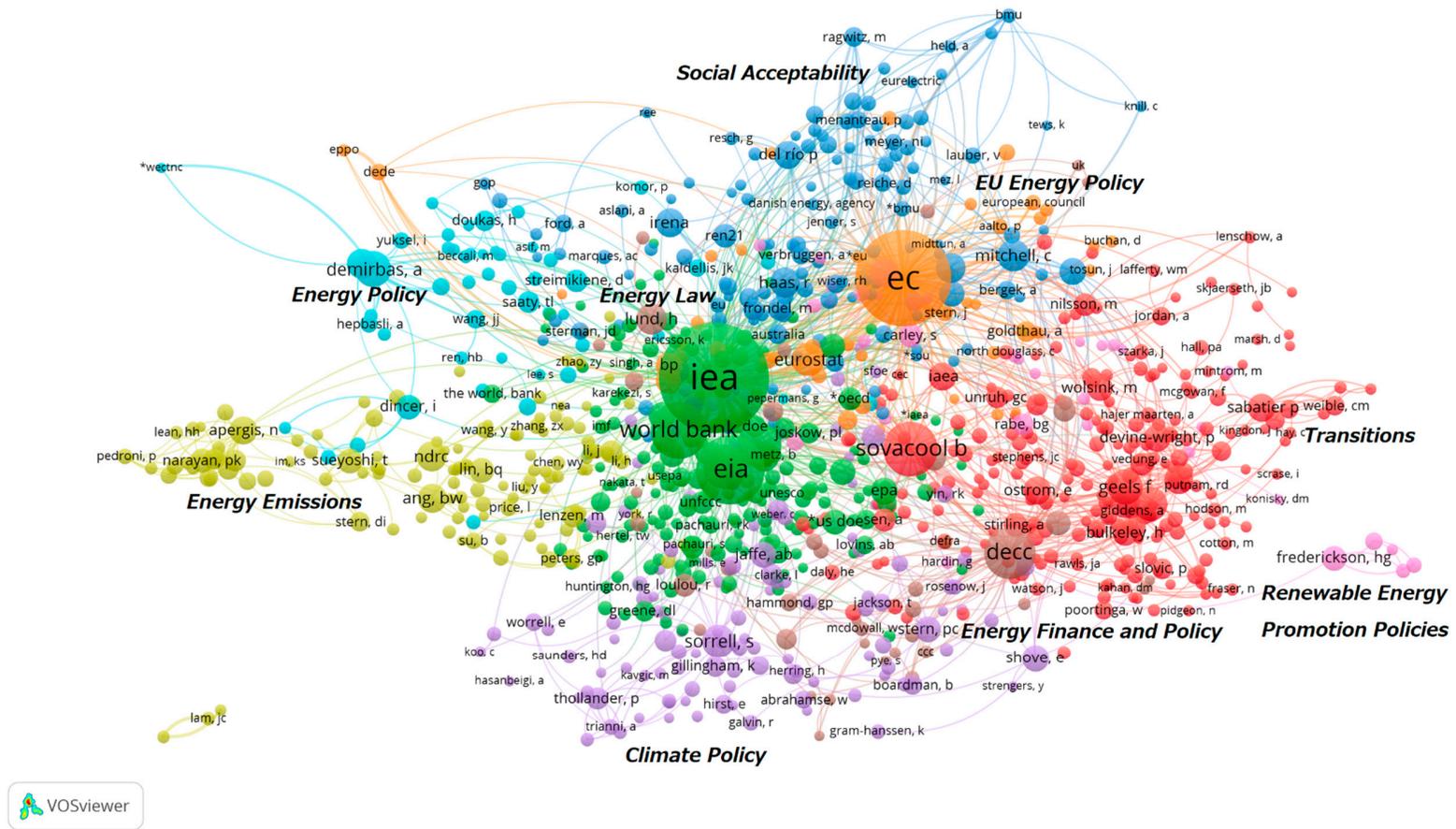


Figure 4. Authors most often cited together (size as number of citations).

This network reveals that despite the clear silos of research demonstrated by the bibliographic coupling analysis, authors from across the network have their work cited together with the work of certain key leaders in the field, such as Sovacool and Geels or Walker and Kemp. However, several clusters remain more the domain of technical literature focusing on energy transitions. For example, Dincer leads as a top scholar in the light blue cluster, focusing on transitions to alternative energy sources such as hydrogen, while Cherp focuses on energy transitions in the orange cluster. This suggests that a few authors that are well known are seeing their work read outside their cluster, while the majority are not and are seeing their work left more isolated. This is particularly the case for the energy justice and energy transitions clusters, which, as in the bibliographic coupling analysis, are quite distant and distinct from all other clusters. Finally, several national and international governing bodies are also highly co-cited in the literature on social equity in energy policy. For example, the European Commission is highly cited in the orange cluster, while the International Energy Agency (IEA), World Bank, and US Energy Information Agency are top co-cited sources in the green cluster. In summary, this visualization describes that a few key authors hold the field together, but these key authors are the exception to the rule.

4.4. Qualitative Assessment and Linkages Between Influential Literature

Based on the analyses of documents and authors in Sections 4.2 and 4.3, influential literature in each of our assessed clusters can be identified. Influential authors are highlighted and their impact on the schools of thought identified by our bibliographic coupling networks is described. Influential works are defined as those with the most citations by other authors, including those in and outside of our network analysis. This enables a qualitative assessment of the approaches taken in each cluster for the evaluation of energy policy and social equity.

Beginning with the energy systems and policy studies cluster in our bibliographic coupling network, five papers were especially influential due to high citation counts. These include the Solangi et al. review of global solar energy policy (Solangi et al. 2011), Nemet's review of photovoltaic cost reduction factors (Nemet 2006), Couture and Gagnon's analysis of feed in tariffs and investment (Couture and Gagnon 2010), Lipp's three-nation European RE policy review (Lipp 2007) and Lewis and Wisser's international comparison of wind energy policy (Lewis and Wisser 2007). Review-type papers are garnering the highest amount of total citations within this cluster, and the age of the paper appears to also influence overall citation count. Of these five most highly cited papers, one (Lipp) is especially influential outside of this school of thought, showing up as one of the top 10 co-cited authors working on the social acceptability of energy sources (cluster 3) in the co-citation analysis.

In the energy security and governance cluster, five papers also stood out, including an integrated modeling approach to the energy–water–food nexus (Bazilian et al. 2011), a consideration of biomass' contribution to sustainable energy development (Demirbas et al. 2009), modern energy systems modeling by Pfenninger et al. (2014), and the conceptualization and measuring of energy security (Sovacool and Mukherjee 2011; Winzer 2012). Of these, Pfenninger et al. (2014) had strong linkages within and across clusters, specifically with the policy studies and governance cluster. Additionally, Sovacool was also recognized as an influential author in our co-citation analysis in terms of transitions studies.

For the policy studies and governance cluster, six papers were prominent, including a review of hydrogen futures literature (McDowall and Eames 2006), a number or interlinked evaluations of public perceptions and risk toward nuclear, energy security, and climate change issues (Pidgeon et al. 2008; Corner et al. 2011; Bickerstaff et al. 2008), and community impacts upon renewable energy policy (Walker et al. 2007), as well as a paper exploring carbon lock in industrializing nations (Unruh and Carrillo-Hermosilla 2006). This group of authors was not well linked with other clusters, and only Unruh was deemed an influential author, also featuring prominently in the transition studies co-citation analysis.

In the cluster focusing on social equity in addition to policy studies and governance, three papers dominated the landscape in terms of citations. Two of these were review papers, regarding energy efficiency economics and policy (Gillingham et al. 2009) and residential sector energy consumption, emissions, and policy (Nejat et al. 2015). The other assessed the gap between performance and energy consumption (Sunikka-Blank and Galvin 2012). Of the most cited papers within this cluster, Gillingham also features as an influential author in terms of climate policy.

The energy justice and social equity cluster is relatively broad in the number of topics covered, and three papers stand out in terms of citations. First, and most dominant is a paper which revisits 'not in my back yard' (NIMBY) issues and place-protective action (Devine-Wright 2009), second is a survey paper investigating public perceptions of hydraulic fracturing (Boudet et al. 2014), while the third is a relatively recent conceptual review of energy justice tenets (Jenkins et al. 2016). As seen in previous clusters, age of documents tends to positively influence citation count, and over time, it is possible to note a shifting priority from stakeholder issues to the emergence of energy justice as a concept. None of the most highly cited authors in this cluster are considered influential across concepts, suggesting the existence of a silo within this cluster.

Within the energy systems cluster, which is quite distant from the other sectors considered, four papers are leaders in this school of thought, focusing on energy consumption, emissions, and economic growth or output in China (Zhang and Cheng 2009) and Central America (Apergis and Payne 2009), and modeling in developing nations (Mahadevan and Asafu-Adjaye 2007). The fourth paper focuses on modeling of electricity demand using a Turkish case study (Erdogdu 2007). One author (Apergis) is also considered the third most influential author in terms of energy emissions research.

The national energy and technology policy cluster, which overlaps heavily with the energy systems and policy studies cluster, has only two papers which stand out. Both of these deal with renewable energy policy, firstly focusing on effectiveness in the US (Carley 2009), and secondly addressing challenges in China (Wang et al. 2010). Carley, whose work dominates this cluster, is also the second most influential author in the renewable energy promotion policies research cluster.

Finally, in the relatively compact energy systems, transitions and policy studies cluster, three papers are most highly cited. All three deal with the selection of renewable energy sources with subthemes of fuzzy multicriteria methodology (Kahraman and Kaya 2010), selection criteria in the developing nation of Pakistan (Amer and Daim 2011), and analytical hierarchy process selection considering sustainable development in Malaysia (Ahmad and Tahar 2014). None of these authors are considered influential outside of this cluster.

5. Conclusions

This study extracted, visualized, and analyzed scholarship citation data through a bibliometric approach to systematically assess the study of social equity in energy policy and environmental studies. We visualized the most influential schools of thought and influential authors and described points of thematic crossovers, unique research foci, and problematic research silos. Scholarship on social equity in energy and environmental studies focuses around eight densely connected schools of thought, two of which dealt explicitly with social equity.

Significant crossover was identified between research clusters, evidenced both in quantitative and qualitative analysis and through the identification of duplicate studies in the network analysis searches; there are some areas in these networks which are understudied. Equity issues in terms of gender, race, income, and class received little explicit attention. Similarly, research on democracy, representation, and social acceptance of energy technologies occurs greatly in three schools of thought, but these works remain quite separated from work on energy transitions and energy systems.

There is some evidence of research silos occurring, particularly within the energy justice and energy transitions research clusters, where only the most influential of authors are being cited in other, related fields and cluster separately from other research themes. There is an identified need to better integrate the large body of equity related research from policy studies, urban sustainability, and energy justice schools with that of the energy economics, business and management, and energy transitions research areas. In addition, the age of papers (as expected) has an impact on the number of citations, and therefore, nascent or emerging fields may not be revealed by our analysis. In order to overcome some of the silos forming in these fields, joint research efforts between energy justice and other schools in order to better balance qualitative and quantitative approaches are needed. Opportunities exist here for joint workshops, conferences, and even structured approaches through national funding bodies. Ideally, joint research ventures should cross national boundaries to ensure that no single school is developing in isolation due to national priorities or internal policy influences.

Within each of the evaluated research clusters, leading papers, topics, and authors were identified, and for eight of the major schools of thought identified, six authors were also considered influential across co-citation networks. Two of these authors were considered influential in transitions research, suggesting that the energy transitions body of work, and indeed the relatively new concept of the 'just transition' may offer opportunities for future linkage between disparate academic groups and schools of thought.

This study faced several limitations. Our content analysis relied on article keywords (from authors) to characterize the thematic content of articles due to working with a large number of Web of Science results. Thus, our content analysis reflects how authors characterized their own work using keywords. Absences of some keywords reflect a lack of research on that topic, but they also could reflect coordination problems in assigning good keywords. Further, due to space limitations, this study could not review differences in methods for assessing social equity. Further, the network analysis excluded articles with zero links among other articles or authors. More effort is needed to bring these scholars together to maximize productivity.

In summary, this paper shows that scholars of equity in energy and environmental studies require much better coordination with energy policy research if we are to achieve a 'just transitions' framework that integrates the important research clusters identified in this study. A key first step would be to more clearly outline and critique the quantitative and qualitative methods of assessing social equity so as to develop a more broadly accessible repertoire of tools for scholars. Scholars can easily utilize the documents included in our network of the schools of thought to review differing methods preferences among research clusters. These documents and their citation data are listed by cluster in the Supplementary Data (see Content Analysis). By clarifying and coordinating the tools and themes we cover in energy policy and social equity studies, scholars can help policymakers to better compare, assess, and resolve inequities in post-Paris energy policy.

Supplementary Materials: The following are available online at <http://www.mdpi.com/2076-0760/8/5/135/s1>, Web of Science Results; Network Files; Thesaurus; VOSViewer Version 1.6.7 (<http://www.vosviewer.com/download>).

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Appendix A

Table A1. Document identification keywords for review focus, scholarship themes and tenets.

Primary Terms	Energy Policy OR Social Equity AND					
Categories	Secondary Terms					
<i>technology</i>	solar power	wind power	biomass	geothermal	hydropower	nuclear power
	tidal power	coal	oil	natural gas	pipelines	power plants
	fracking	technology	energy storage	CCS	carbon capture sequestration	hydrogen
	grid	decentralized	distributed		smart grid	
<i>adaptation and mitigation</i>	climate change mitigation	climate change adaptation	disaster	resilience	redundancy	diversity
	energy efficiency	energy conservation	emissions standards	energy security	energy transition	
<i>environment</i>	environment	climate change	climate	CO2 emissions	GHGs	greenhouse gas emissions
<i>policy</i>	climate policy	environmental policy	feed-in tariff	auction	carbon tax	cap and trade
	net metering	zero net energy	policy implementation	policy tool choice	design	innovation
	diffusion	efficacy	advocacy coalition	project finance	siting	
<i>justice</i>	environmental justice	energy justice	distributive justice	distributional justice	procedural justice	justice as recognition
	recognition justice	justice	climate justice	energy poverty		
<i>equity</i>	intergenerational equity	vulnerability	age	race	gender	sexuality
	religion	ethnicity	minorities	language	class	income
	inequality	education	global north	global south	sustainable development goals	equator principles
	equity	fairness	sustainability			
<i>politics</i>	public opinion	representation	social capital	public bads	place attachment	social acceptability
	equality	civic engagement	energy democracy	climate politics	environmental politics	ownership

Appendix B

Table A2. Network analyses performed.

Technique	Description	Min. Citations	Total Terms	Terms in Threshold	Terms Shown	Related Figures
Text Co-Occurrence	Links between words that occur frequently together	10	86,210	2395	1437	Figure 1
Bibliographic Coupling	Links between documents that share the same citations.	0	5529	500	1000	Figures 2 and 3
Co-Citation	Links between authors that are cited by the same document	20	110,572	386	1000	Figure 4

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