Topical Review

Energy infrastructure, NIMBYism, and public opinion: a systematic literature review of three decades of empirical survey literature

Sanya Carley, David M Konisky, Zoya Atiq and Nick Land

Paul H O’Neill School of Public and Environmental Affairs, Indiana University, Bloomington, United States of America

E-mail: dkonisky@indiana.edu

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Abstract

Public support is a key determinant of whether any energy project is developed in democratic countries. In recent decades, scholars have extensively examined levels of support and opposition to energy infrastructure, often with a focus on so-called Not-in-My-Backyard (NIMBY) sentiments. As the need for energy infrastructure grows, so does the need to extract insights and lessons from this literature. In this systematic literature review, we evaluate decades of research to identify important trends in topical focus, research findings, and research design. We find a disproportionate focus on wind energy, followed by solar, fossil fuels, and transmission, with most studies conducted in the United States or United Kingdom, and that individuals are more often supportive of energy projects than they are opposed. Scholars have examined the role of many factors in understanding attitudes toward energy infrastructure, and often find knowledge, trust, and positive perceptions about the benefits of projects to be positively correlated with support for projects, although with variation across energy types. NIMBY attitudes differ widely in approach and are often plagued by problematic research designs that limit inferences and the generalizability of findings. We provide a detailed discussion of these limitations and suggest areas in which the literature can expand.

1. Introduction

A global energy transition is underway. This transition is facilitated by countries that seek to mitigate climate change and other environmental problems associated with fossil fuel extraction and use, and also capitalize on technological innovations and market opportunities to accelerate the deployment of cleaner, renewable fuels. Of course, the pace of change varies enormously. Countries’ transition paths vary depending on their unique constellations of economic, political, and social circumstances [1–4]. These and other factors influence the types of policy mechanisms that they are willing to use, as well as how aggressive they are in hastening the transition. A good illustration is the heterogeneity in the Nationally Determined Contributions that each country advanced as part of the Paris Agreement on climate change [5]. Yet, other developments in energy markets are pushing in the opposite direction. Recent technological advancements, especially hydraulic fracturing, have also spurred the immense growth of fossil fuel production in some countries. In the United States for example, from 2000 to 2015, domestic production of natural gas and oil increased by 43% and 59%, respectively [6], and the United States has now surpassed Saudi Arabia and Russia to become the leading producer of oil in the world [7].

One important factor shaping what countries decide to do with their energy markets, and how quickly, is public demand. Citizens act as consumers, and in democratic countries as voters, and their support for different energy sources [8]. At the local level, public preferences are particularly important since energy infrastructure, whatever its form (e.g. power plants; transmission lines), requires officials to find locations for specific projects. In totalitarian regimes, government officials and state-supported enterprises can often unilaterally make siting decisions and force affected citizens to relocate. By contrast, in democracies, government
officials and private companies often must negotiate with local communities and find ways to alleviate concerns that may arise from the impacts—real or perceived—of infrastructure projects.

Local opposition can be an obstacle for the developers of energy infrastructure projects and the government agencies that permit them. Often, local opposition is portrayed as Not-In-My-Backyard or NIMBY objection. Although the traditional definition of NIMBY refers to the sentiment in which one supports something in general or in the abstract, but not if it is to be located close by [9], it is often broadly construed to reflect any type of locally-based opposition. Although numerous scholars have criticized the concept of NIMBYism as being invalid, pejorative, lacking meaning, overly simplistic of more complicated dynamics, and an inaccurate depiction of reasons behind opposition to locally-placed energy infrastructure [9–18], popular media accounts, as well as many peer-reviewed articles on the topic of public acceptance of energy infrastructure, still reference and study the NIMBY concept. NIMBY, for those that use the term, objections may arise from any number of concerns, including environmental impacts [9, 16, 19], visual appearance and noise [20, 21], diminished property values [10, 19, 22], disruption of place attachment [17, 23, 24], procedural factors [25], or broader political preferences [26]. The weight of these concerns may differ depending on the energy type in question. For example, opposition to wind energy may be based more on visual appearance concerns whereas fossil fuel extraction and use may pertain more to worries about environmental and health impacts.

For decades, scholars from diverse disciplines, such as economics, geography, political science, psychology, sociology, and urban studies and planning, have examined what drives public support and opposition to energy infrastructure. Yet, despite extensive attention, no study has yet to provide a systematic review of the most relevant empirical literature, and drawn insights from a full range of energy facility types about levels of support and opposition, with particular attention to the NIMBY concept. Specifically, no study to our knowledge has evaluated findings across energy sources or identified common factors that influence support across different energy types. Further hampering our understanding of how the public views energy infrastructure, is that scholars have employed heterogeneous research designs despite sharing the same objective to uncover those factors that influence local support or opposition. This lack of consistency in research approach complicates efforts to synthesize results (i.e. ‘we do not know what we know’), impedes the use of research to inform decision-making, and inhibits the development of an agreed upon strategy for determining if NIMBY is in fact an important determinant of project opposition.

This paper seeks to address these issues. First, drawing from a systematic literature review, we describe and analyze the existing empirical literature on public support for energy technologies, with emphasis on studies in the literature that examine the idea of NIMBY attitudes. Second, we offer a set of lessons learned from this literature, and propose a research design for future work that we think can help build a stronger knowledge base around this important area of inquiry.

2. Methodological approach

To better understand public support and opposition for energy infrastructure, ‘and specifically the role of NIMBY sentiments, we performed a systematic literature search and thematic analysis of all available, survey-based empirical studies published since 1990.

We conducted the literature search in 2017 exclusively within five academic search engines that contain the vast majority of journals focused on these topics: Google Scholar, JSTOR, EBSCO, LexisNexis, and Science Direct. Our Boolean search terms included either ‘NIMBY,’ ‘public opinion,’ ‘public support,’ ‘public acceptance,’ ‘public perception,’ ‘attitudes,’ ‘proximity,’ or ‘LULU,’ along with energy resource terms such as ‘energy,’ ‘energy technology,’ ‘electricity,’ ‘transmission,’ ‘pipelines,’ ‘nuclear,’ ‘wind,’ and ‘natural gas’. We present the full Boolean search in table A1 in the appendix (available online at stacks.iop.org/ERL/15/093007/mmedia).

A recent article by Gaede & Rowlands [64] mapped the vast literature on social acceptance research, but its focus was more conceptual (see Wolsink [27] for a critique). Schively [38] reviewed the literature on NIMBY, but did not emphasize energy technologies. Boudet [32] reviewed literature on public perceptions of all energy technologies, including large-scale infrastructure types and also consumer-oriented technologies. Petrova [10] and Rand and Hoen [18] provided detailed and thoughtful analyses of the literature on support and opposition to wind energy infrastructure. Our study resembles most closely the latter three articles, but with a sample of articles across all energy types. The present analysis responds to calls made in these articles for more studies that cover a range of energy types [18] and trends in support and opposition over time [32].

We excluded studies on support and opposition to consumer-oriented energy technologies, such as energy efficiency products and electric vehicles. Although, incidental to our search, we did include in our analysis one study that contained information about electric vehicles [30]. Similarly, we do not include studies on related topics such as chemical weapons and the siting of other locally unwanted land-uses.

We chose 1990 as a cutoff point following an initial scan of the literature, which revealed very few empirical studies before this year. There is some relevant literature on NIMBY attitudes, but it focuses on local land uses other than energy, such as hazardous waste disposal facilities.
From the list of possible articles retrieved through the search, in step 1, displayed in figure 1, we read the title of all articles and then the abstract of those articles with titles that expressed a focus in any way on public perceptions of energy infrastructure. Two different researchers conducted this search and we compared their results to find an overlap of over 94% of the articles. The combined sample included 188 studies published between 1990 and July, 2017 that were, at the most general level, relevant to NIMBYism and energy support or opposition. The objective of our approach was to be systematic and comprehensive, but we cannot—and do not—claim that our search criteria or process generated an exhaustive list of relevant articles.

With this sample of studies, in step 2 we reviewed each article to ensure that it fit our criteria for inclusion, which necessitated that the article: (1) focus on public perception, support, or opposition toward an energy infrastructure type (e.g. a power plant, transmission line, solar farm, hydraulic fracturing well); and (2) include some quantitative, empirical analysis on data collected through a survey. We limited our analysis to survey-based quantitative studies because we had originally set out to perform a meta-analysis, including a meta-regression analysis on the specific subject of NIMBY attitudes toward energy. Fulfilling this objective proved infeasible because of the immense heterogeneity in research designs, which we discuss extensively below. Even in absence of a formal meta-analysis, however, we elected to include only survey-based quantitative studies to ensure consistency of general research approach and therefore our ability to code consistently across the studies for the factors discussed in this article. In addition, survey research is the most common way to assess individual opinions in studies in a large-scale manner [27]. Articles that were topically germane, but did not fit our criteria included law reviews, non-data driven descriptions of energy resources, single case studies, qualitative analyses, and conceptual studies. Two separate researchers conducted this exercise; for any case that resulted in inconsistent coding, the full research team convened to resolve the inconsistency.

This sorting process left us with 64 articles, which we then separated in step 3 into two categories based on whether they focused on: (1) general support for an energy type or infrastructure (14 articles); or (2) proximity-specific support (i.e. NIMBYism) for an energy type or project (50 articles). Two studies displayed overlapping characteristics and we therefore counted them in both categories. Although we classify the latter category as NIMBY studies, and the vast majority of studies within this category claim to account for NIMBYism in some fashion, not all of these studies explicitly claim to measure NIMBYism or set out specifically to identify the effect of geographic proximity on support for an energy technology. For example, a study by Clarke et al [28] finds that people are more likely to support oil and natural gas development via fracking the farther they are away, but they do not characterize this finding as reflecting NIMBY sentiments. We also further sorted the NIMBY studies into categories in step 4.

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4 Upon completing the collection of the full sample of articles, we determined there was insufficient data for such a formal exercise. We found that, despite many authors claiming to measure NIMBY sentiments, very few included NIMBY relevant variables in their regression analyses. This finding led to our deeper inquiry into the research design used in our final sample of articles, as presented in the results section below.

5 The focus of this study is how proximity to a development conditions the relationship between political ideology and support for oil and natural gas development; the authors find that the greater the distance away from a potential development site, the stronger the association between political ideology and support.
based on the way that they account for NIMBY in their research design, as described in greater detail below. We include a full listing of these studies in the appendix in table A2.

Because many of the articles studied several different energy types or facilities, we discuss both the count of articles as well as the count of the ‘line items’ in the articles. In most cases, a line item reflects a separate regression model in a statistical analysis. For instance, if an article studied a solar facility, a wind farm, and a coal power plant, and each energy facility had its own regression model, we would count this as one article and three line items. Some articles contained many line items, such as a study conducted by Kaldellis et al [29] that had nine line-items and another by Chen et al [30] that had eight. Moreover, if the survey data measured support about a particular energy facility in the abstract versus a local project visible to the participant, through separate regression models, we counted the article having separate line items. For example, the article by Carlisle et al [31] had three line-items because public support for utility scale solar was measured and modeled generally in the U.S., in close proximity to the respondents’ residence and near the respondent but not necessarily visible. A final distinction for line items was based on cross-country comparison of the same type of infrastructure within a single article. The final sample that we analyzed for the present analysis included 64 articles that translated into 139 line items, of which 38 pertained to general support for an energy type and 101 pertained to NIMBYism. We present all line item counts in brackets in figure 1.

For each study and line item, we coded the year it was published, the type of energy analyzed, the level of support found in the results (i.e. positive, negative, or neutral), the inclusion and relationship with public support for several variables of interest, and, for those studies on NIMBYism, whether NIMBY sentiments were found.

It is important to note that our literature search process and criteria limit the inferences that we can draw. One shortcoming of our approach, for example, is that we restricted our search to articles that appeared in academic search engines, without subsequent snowball sampling for related articles. This approach constrained the number of articles in our final sample, excluding those published in journals not indexed in the search engines we used. Further, our choice to only include survey-based articles with quantitative measures of support, opposition, or NIMBYism may also come at some cost. These criteria result in the exclusion of books and in-depth case studies, among other research designs. These studies often contain more nuance in explaining what influences public perceptions in specific cases [12, 32], and their omission may affect our conclusions if these studies reach systematically different conclusions than the survey-based studies. These limitations notwithstanding, we argue much can be learned from a comprehensive review of survey-based studies.

3. Results

In this section, we begin with a discussion of general trends over time, main findings about support for specific types of energy, and the factors that influence such support. We then focus specifically on the NIMBY articles, trends across these studies, and limitations frequently encountered in the design of NIMBY studies.

3.1. General trends over time, by energy type, and by location

Figure 2 displays the number of related articles published each year over the period of our study. The first thing to note is that, although our literature search began with the year 1990, no studies met our inclusion criteria until 2005. More specifically, although we captured numerous studies about public perceptions of energy infrastructure and/or NIMBY sentiments from earlier years in our search, upon close examination they did not meet our criteria for more detailed analysis. As figure 2 shows, very few articles were published before 2006. Beginning in 2007, the number of articles increased significantly. This timing coincides with a general increase in renewable energy and natural gas developments across the world. In addition, the uptick in research likely also reflects innovations and cost efficiencies in conducting survey research (i.e. mainly the widespread adoption of online surveys), which created more opportunities for researchers to study public attitudes. In the most recent years, the data indicate that there have been around 10 articles published each year on public acceptance or opposition toward energy infrastructure.

Figure 3 graphs the types of energy infrastructure that authors have studied over time. This graph plots line items, since several studies analyze more than one type of energy. While authors have focused on a full range of energy types, public opinion toward wind energy is by far the most commonly studied over time (as also confirmed by Ellis et al [12] and Petrova [10], among others). This emphasis on wind power is perhaps not surprising. In many parts of the world, wind has been the fastest growing source of renewable energy over the past decade. The siting of wind turbines and farms has also proven challenging in many places, due to concerns such as decreases in property values, diminished aesthetics, shadow flicker, and other possible health effects [10, 25, 33–37]. Scholars have also studied nuclear energy facilities steadily over time, for a total of 15 survey-based support
and/or NIMBY line items. In recent years, the literature has turned to the topics of solar energy, the fastest growing topic of inquiry since roughly 2014, as well as transmission and distribution lines, and fossil fuels. Within the fossil fuels category, hydraulic fracturing is the most commonly studied (not displayed explicitly in the figure).

A key distinction across studies is whether they focus on actual, planned, or hypothetical facilities. Table 1 presents the distribution across these categories, and shows that the largest percentage of articles, at 60%, studied hypothetical facilities. The second most common approach, at 50%, was actual energy facilities. Only 13% of studies considered facilities that are in the planning phase and not yet built.

Figure 4 graphs the location of the sample used in each study. This figure reveals that the vast majority of studies have focused on public sentiments in either the United States (28 total) or the United Kingdom (10 total), although it is important to emphasize that many of these studies analyzed specific regions or populations within these countries and not the country as a whole.6

### 3.2. Support, acceptance, and opposition

Given our focus on public support for energy types and facilities, we tallied the number of line items in each study according to whether the average respondent in the study reported support, opposition, or a neutral stance. We present these results in figure 5. These data reveal that the public is generally more positive than negative about most types of energy infrastructure. This is especially the case regarding renewable energy. In the case of solar and hydropower, studies reveal positive respondent support. Wind energy, as highlighted elsewhere as well (see, e.g. Rand and Hoen [18]), also receives a resounding amount of public support in survey analyses. Patterns of support for wind are especially notable given the intensity of local opposition to new wind farms in many locations. Not all energy types, however, receive such overwhelming positive support. Studies of transmission and distribution lines tend to find more opposition than support, which is also the case in all of the studies on waste to energy infrastructure projects. With respect to fossil fuels, studies are mixed; in half the analyses there is more positive than negative support, but there is also more opposition in about a third. Not reflected in this figure is the fact that many of the fossil fuel studies pertain to natural gas, especially since the advancement of hydraulic fracturing in the United States, and these studies tend to find more support for natural gas compared to studies of other fossil fuels, such as coal and oil [7]. Findings about nuclear energy suggest an even split between support and opposition for this energy type. The small number of neutral responses for many energy types is also worth noting; this suggests that people, on average, tend to hold fairly strong views of energy, even toward technologies that one may not know much about or understand well such as transmission lines or waste to energy.

While these data reveal that individuals are generally more supportive of energy types and facilities than they are in opposition, they do not provide

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6Given that many of these journals are published in either the United States or the United Kingdom, it is perhaps unsurprising that many of the articles focus on cases from these countries.
any insights into what factors influence such reactions. To gain leverage on this question, we coded each study that included statistical analysis in the form of correlations or regression analysis (39 out of the 64 article sample and 85 line items out of the 139 line item sample) to first identify the main independent variables used by analysts to predict public support, and then to characterize their effects on support. In table 2, we present a count of the main independent variables used in each
modeling exercise, as sorted according to the type of energy infrastructure under analysis. The first column presents the energy type, the second presents the total count of line items for that energy type, and the third through ninth columns present a count of line items that include each independent variable.

This exercise reveals that the majority of studies, across all energy types, control for the gender of the respondent, an interesting finding given that few studies focus predominantly on the relationship between gender and energy infrastructure support. It is fairly common for scholars to include benefits and drawbacks in their models but appears much less common in the case of nuclear, fossil fuels, and transmission and distribution line studies. Scholars also include drawbacks in their models more often than they include benefits, especially in the case of wind studies. Studies on nuclear and transmission and distribution lines more commonly include measures of trust than benefits and drawbacks. Renewable energy studies, on the other hand, do not typically include measures of trust. Variables such as knowledge, political ideology, and partisan identification are relatively less likely to appear in formal modeling of energy support or opposition, though scholars often analyze knowledge in studies of transmission lines, and political orientation in studies of solar power, fossil fuels, and nuclear power. Figure 6 builds on the information provided in table 2 (presented as red bars) with additional insights on: (1) whether those line items that included an independent variable detected any statistical significance (orange bars); and (2) out of those that are statistically significant, whether the variable was positively related to support for the energy infrastructure type (blue bars). As an example interpretation, the upper left corner reveals that 31% (26 total) of all line items from studies that presented a regression or correlation analysis included knowledge as an independent variable. Of those 26 line items, in 77% of the cases (20 total), the knowledge variable is statistically significant. Of those that detect statistical significance, in 95% of the cases being knowledgeable about an energy type is associated with an increase in support; in 5% of the cases, having knowledge is associated with opposition.

Figure 7 separately reports similar information for political ideology and partisan identification. Our review finds that measures of political ideology (usually an indicator of liberal-conservative ideological
leaning) or partisan identification (in the U.S. context, for instance, Democrat or Republican affiliation) are regularly included in studies, though with some variance across energy types. In the case of political ideology, scholars include it in 40% of the line items of renewables, 20% for wind, 13% for solar, 22% for nuclear, and 23% for fossil fuels. Partisan identification appears in just 13% of wind energy line items, but 63% of solar cases, 44% of nuclear cases, and 54% of fossil fuel cases.

The data shown in figure 7 do not reveal the direction of the relationships, but we did capture this information in our coding. In analyses of support for fossil fuels and nuclear power that consider political ideology, it is always a statistically significant correlate, with ideological conservatives supporting both energy types. In the case of wind energy, it is ideological liberals that are more likely to support this technology, though this pattern does not emerge with respect to solar or renewable technologies generally. Partisan identification is routinely included and appears to be a statistically significant factor in analyses of solar, nuclear and fossil fuels, and, less regularly, analyses of wind. All of these studies are in the context of the United States, and show that Democrats support solar 100% of the time, and nuclear power and fossil fuels, just 33% and 25%, respectively. Republicans do not support solar in any of the instances, but they do support nuclear 67% and fossil fuels 75% of the time. Several patterns emerge in the data presented in figures 6 and 7. First, perceptions of benefits are almost always statistically associated with support. Even though scholars examine drawbacks more than benefits, drawbacks...
are statistically significant less often (68% of cases in which they are included vs. 97% for benefits). It is worth noting that seemingly lower importance of drawbacks is primarily driven by solar studies, which tend to consider drawbacks but rarely find them to be statistically significant with levels of project support. Second, greater knowledge about an energy infrastructure type almost always leads to positive impressions of it. However, scholars often do not consider the role of knowledge at all (only 31% of the time), and usually only in studies about transmission and distribution lines. Moreover, knowledge does not emerge as a particularly important correlate of support of wind or fossil fuels but is very important for the support of solar and transmission and distribution lines. Third, gender is the most often included variable we examined, though it appears to be the least important factor. Of most note, women are more likely to oppose nuclear power and fossil fuels, but more likely to support transmission and distribution lines. Fourth, trust is an especially important factor when considered. Higher levels of trust are associated
with more support for wind in 100% of the cases in which its included, as well as for transmission and distribution lines in 87% of cases, for fossil fuels in 80% of cases, and for nuclear in 75% of cases. Studies of support for nuclear tend to omit measures of benefits (only 22% consider them). Of those that do include it, only 50% of the time is it statistically significant, suggesting that perceived benefits of nuclear are not critical to one’s perceptions of nuclear. The perceived drawbacks, on the other hand, are far more important; in 75% of the cases in which an analyst includes drawback measures, s/he finds statistical significance. Fifth, political ideology and partisan identification emerge as important determinants of support for several of the energy types in our sample of studies. Moreover, we find that studies often include either a measure of political ideology or partisan identification (and sometimes both), though not always. Partisan identification was included in 63% of cases of solar followed by 54% of fossil fuels and 44% of nuclear cases. Of these cases, we find that individuals that identify as a Republican or an ideological conservative tend to support fossil fuels and nuclear power, whereas Democrats and ideological liberals tend to disfavor those technologies and instead support solar and wind power. These results both lend insights into what drives public impressions of energy types and facilities, and suggest more broadly how scholars contributing to this literature frame the discussion about energy public opinion. The differences likely reflect both the multifaceted nature of public attitudes toward energy as well as variation in the central questions and leading theoretical frameworks across the social scientific disciplines from which scholars working in this area come.

3.3. NIMBYism

Scholars have investigated the NIMBY phenomenon in the context of energy infrastructure siting—as well as many other contexts [38]—for many decades. As is evident from figures 2 and 3, there has been a surge in empirical inquiry in this area since the mid-2000s, even while the core concept of NIMBYism has been challenged by several leading scholars in the field [9–18, 22].

Survey-based studies of NIMBY attitudes toward energy infrastructure tend to employ one of three strategies for examining how—and if—geographic proximity to an energy technology shapes attitudes, with the key distinction of how they measure NIMBYism. The most common measurement strategy is to study a specific population that is in close proximity to either an existing energy technology or an area where such a technology is likely to be sited. We refer to this as an ‘over-sampling approach’ where studies over-sample in host communities during the data collection process since residents of these communities are the people who will most likely be impacted directly by the energy development and they will also have relatively higher levels of knowledge about the specific project. Examples include an article by Greenberg [39] that evaluated attitudes toward nuclear power and a study by Jones & Eiser [40] that evaluated attitudes toward potential wind farms. In practice, after sampling a population in close proximity to an infrastructure project, a researcher could include a binary independent variable in a regression model that indicates that a respondent is within this group as compared to a control group outside of the over-sampled region as supported as a research design by Rand and Hoen [18], or could instead focus exclusively on this geographically close sample and consider the differences in general level of support for an energy resource and support for a local facility that relies on that resource.

Another frequent approach is to measure distance between an individual and the actual or proposed location of an energy infrastructure type. Some studies rely on perceived or self-reported distance (e.g. 45), whereas others use actual distance (e.g. 63) or a proxy based on the individual living within a defined distance of a facility [41] or within a host area based on a postal zip code or county (e.g. 36, 48). We classify this approach as the ‘distance approach’. A researcher can then evaluate, such as through regression analysis, whether people living in closer proximity to an energy type express different opinions than those living farther away. Evidence consistent with this conclusion is viewed as supporting NIMBYism.

A third approach, which we refer to as the ‘dependent variable’ approach is to ask people directly if they are willing to support use of an energy infrastructure type if it were to be located in close proximity to where they live. This approach typically presents a hypothetical project for the respondent to consider. As an example, a survey question may read, ‘What would be your level of support for a new hydroelectric power project in your neighborhood,’ (for an example of similar phrasing, see Ribeiro et al [42], where ‘neighborhood’ is replaced with ‘freguesia’). Other terms used instead of ‘neighborhood’ include ‘region’, ‘community’, ‘county’, or a specific distance away such as ‘within 25 miles of your home’ such as in Ansolabehere and Konisky’s [19] comparative study of support for new coal, nuclear, natural gas, and wind farms.

\[\text{We did not include Karlstrom & Ryghaug [65] in this analysis since the political variables in the Norwegian context differ from those of the U.S. studies that comprises the rest of the studies in which political orientation is considered.}\]

\[\text{In most cases, these types of measures are also proxies, in that rather than measuring the distance from an individual's residence to a project, studies use the centroid of the zip code where an individual resides.}\]
Among the studies we compiled in our systematic literature review, we find that 32 studies use the over-sampling approach, 23 use the distance approach, and 9 use the dependent variable (DV) approach, as is also displayed in figure 1 above. Several articles employ more than one approach: 12 combine a sampling and distance approach; 1 combines a distance and dependent variable approach, and 1 combines a dependent variable and over-sampling approach. No study uses all three approaches. An example of a study that uses more than one approach is a study conducted by Olson-Hazboun et al [43], which first asks respondents about their general support for renewable energy, and then whether they would have voted for a local wind farm, if given the chance to vote. Each respondent also reported his/her proximity to the nearest wind farm. In the authors’ regression analysis, they first predict general attitudes and subsequently voting intentions for local wind, while controlling for perceived proximity in both regressions.

Studies of NIMBY also consider a wide range of energy technologies among geographically disparate populations. Figure 8 shows the distribution of research designs by energy technologies, and, for comparison, studies of general support. Here we can observe that scholars more often focus on NIMBY-ism than general support for most energy technologies, but especially for transmission and distribution lines, fossil fuels, wind, nuclear, and solar. Among the different NIMBY research designs, studies of wind, transmission and distribution lines and those technologies in the ‘other’ category more typically employ the distance approach. Solar is more often studied using an over-sampling approach, followed closely by the distance approach. All other technologies are spread fairly consistently across the three research designs.

Another way in which NIMBY studies vary is with respect to the geographic scope of survey samples. NIMBY studies range from a national or country-level scope to local communities, and scales in between (e.g. regions, states, etc).

Given all of the ways that these studies of NIMBY and energy infrastructure vary, it is perhaps not surprising that empirical findings are mixed. To illustrate, some studies have found that closer proximity is associated with lower support for projects (e.g. 2, 23, 50) other studies have found that closer proximity is associated with higher support for projects [26, 28, 39, 41, 44, 45], and, still other studies have found no association at all [46, 47]. Of course, these studies may reveal genuine differences in attitudes toward various energy technologies in different geographical settings.

The varied results in the literature may also reveal a certain elusiveness of the NIMBY concept itself. In this regard, it is important to note that few studies analyze what might be considered a classic definition of NIMBY, whereby an individual is supportive of a technology or land use in general, but opposed to a specific manifestation of it when it is located nearby. As noted by Wolsink [9], NIMBY requires both the acceptance of project in general as well as the rejection toward a specific project locally. Most proximity-based studies, however, regardless of how they measure proximity, capture the first part of NIMBY concept, but not the second part. In terms of research design, testing this classic conceptualization of NIMBY necessitates measurement of the effect of proximity in conjunction with general attitudes toward the infrastructure. In our sample, only a handful of studies have taken this general approach [22, 40, 48–53], and even fewer through formal statistical analysis [40, 48–50, 52]. For example, Jones and Eiser [40] examined the difference between the general attitude towards wind development and stated attitudes toward a proposed development, and Paydar et al [49] measured general attitudes toward unconventional gas development and then measured attitudes after providing additional information about a hypothetical project located two miles from respondents’ homes.

Overall, less than half of the NIMBY articles in our sample detect the presence of NIMBY sentiments, and fewer than one-quarter of the total studies find both that NIMBY sentiments exist and use the Wolsink conceptual definition. Of the 23 articles that find NIMBY sentiments to exist, 52% capture only the first part of the NIMBY concept pertaining to proximity, while the remaining 48% use a more complete definition of NIMBYism. Importantly, however, of those that identify NIMBY sentiments using the classic definition, less than half do so through a formal modeling analysis.

Thus, in our assessment, it is not clear that NIMBY, as traditionally defined, is often being evaluated. At best, we have a set of inconsistent findings regarding the weight that people give to proximity when considering their support or opposition to energy projects, but even these results are challenging to generalize from, given heterogeneity in the measurement of proximity and the diversity of technologies and study populations analyzed.

4. Discussion

Our systematic literature review of the survey-based, empirical literature on public support for energy infrastructure, and the specific role that NIMBY attitudes have in affecting this support, reveal several key themes. In addition, our review identifies important shortcomings and many opportunities for future work.

The first key theme that emerges is that there has been a proliferation of studies in recent years studying public attitudes toward energy infrastructure. This
increased attention clearly comes in response to the rapid changes occurring in the energy sector, and a genuine interest among scholars to better understand the constraints and opportunities that public engagement creates for these changes. In addition, innovations and cost-efficiencies in administering surveys has likely enabled more scholars to study public attitudes, by reducing barriers to entry to this type of inquiry.

Although a trend toward more inquiry is evident, the focus of studies in many respects has been quite narrow. Our coding of studies, for example, found a disproportionate emphasis on wind power, and particularly the use of that technology within the United States and the United Kingdom. This is not surprising given the rather quick and widespread deployment of wind energy, and the fact that the siting of wind turbines often has been controversial, despite our finding that the majority of wind studies reveal positive sentiments. Nevertheless, it is potentially problematic to generalize about either public support for energy, and specific concepts such as NIMBYism, if much of the empirical work comes from the study of a single technology, wind or otherwise. A promising development in the literature, however, is that scholars have begun to study other technologies in recent years with equal vigor, including what might be considered frontier technologies such as carbon capture and sequestration and energy storage. Increasing attention has also turned to traditional technologies and infrastructure types such as fossil fuel extraction, especially natural gas extraction sites from the use of hydraulic fracturing, and pipelines and transmission lines.

The extant literature is also narrow in an additional way. By and large, scholars employ research designs that study single cases, projects, or hypothetical uses of an energy technology. In most instances, researchers craft a survey to examine attitudes toward a single energy technology or to understand attitudes toward a specific manifestation of that technology. These types of studies may be well-designed to achieve internal validity, and may provide significant detail about public responses, but they do not enable generalization with any reasonable confidence. As we discuss more below, this problem is exacerbated by the lack of consistency in research design, which also makes it virtually impossible to make generalizations confidently across studies.

An alternative approach would be to design studies that are explicitly comparative, as also advocated by Rand and Hoen [18]. Qualitative studies in the literature commonly employ comparative research designs, and the work of McAdam and Boudet [54] illustrate the dividends of this type of approach for understanding public response to energy siting issues. In the survey context, we think scholars can pursue similar comparative approaches in a couple of ways. First, scholars could study multiple cases of a single type of technology. For example, scholars could use a single research design (e.g. the same survey instrument) to study support for multiple solar projects or transmission lines. The larger the number of cases, the more leverage researchers will have to assert external validity. A second comparative approach would be to study multiple cases of different energy technologies. For instance, an analyst could use a single research design to investigate attitudes toward a variety of technologies (e.g. different types of generation). This type of approach provides another avenue for allowing generalization, as well as for identifying whether attitudes differ across technology types. Surveys that adopt a comparative approach will require larger samples which, of course, will be more resource intensive for researchers. However, the increasing availability of high-quality internet-based samples provides opportunities to pursue more ambitious research designs that can pay real analytical dividends.

A second theme that emerges from our study is that people tend to be supportive of most types of energy, although there are important exceptions. In studies of attitudes toward waste to energy and transmission and distribution lines, there is some to significant opposition. Studies of fossil fuels and nuclear find both opposition and support. Notwithstanding these exceptions, across most energy technologies that have been the subject of investigation, scholars find much of the public to be supportive of new energy infrastructure. Most notable of course is the strong support for renewable technologies such as solar and wind power, on average across the studies. Primary factors driving support and opposition
are trust, perceived benefits and drawbacks, knowledge, and political orientation. To the degree that these factors, and the resulting preferences, weigh heavily on the minds of citizens and voters, they send signals to government officials and private sector energy providers about the types of technologies that people are likely to embrace and those they are likely to resist. Of particular note, trust appears to be an important though complicated determinant of support across all studies, a finding that is consistent with past work in the qualitative literature that has found, for example, that mistrust in government agencies and project developers is associated with objections to wind farms [12]. In this analysis, we coded for trust in various institutions such as government agencies, project developers, and private landowners, with many studies finding that trust in these and other institutions is an important factor in project support. Given its prominence, we think it is a subject ripe for future inquiry.

The high rates of support found in the literature may seem to contradict what is often portrayed as significant opposition to new energy infrastructure. For example, highly publicized debates in the United States, over the Keystone XL Pipeline, the Dakota Access Pipeline, the Cape Wind Project, and the Yucca Mountain nuclear waste repository, may leave an impression that such opposition is commonplace. Although opposition, at least among a vocal minority, is evident in these and other cases, such sentiments may in fact be less widespread among the general public.

A third theme that emerges from our review is the extreme heterogeneity in the research designs that scholars use in this literature in areas such as the measurement of proximity and NIMBY attitudes, survey sampling strategies, geographic scope, and the theoretical questions that are examined. The variation in approaches is especially stark in the area of NIMBY studies. It is not an exaggeration to say that no two studies are exactly alike. The heterogeneity is not surprising, since the scholars contributing to this body of research come from a wide variety of disciplines. In fact, the differences in approach, in many respects, are justified given the different theoretical aims that scholars bring to questions of energy technology, use, and public engagement. Yet, there is also a cost to the lack of a standardized approach in that it is more difficult to summarize central findings. Although project and context specific factors are important to consider when evaluating public attitudes toward energy projects, advancing scholarly inquiry also requires the identification of generalizable principles (if they exist), as well as the conditions where these principles hold. Standardized approaches can also facilitate the translation of research into practical information to share with stakeholders.

Our review reveals that heterogeneity in research design is particularly problematic for answering the question of whether, and to what extent, NIMBY attitudes matter for understanding public opposition to energy projects. Without agreed upon definitions of NIMBY, conventions of measurement, and common strategies for survey sampling, it is difficult to accumulate knowledge. As a consequence, our review of scores of NIMBY studies leaves us unable to reach a firm conclusion, one way or the other, on the role of NIMBYism in explaining attitudes toward energy infrastructure in general, let alone on how this might differ across technologies or specific project characteristics.

This critique is not to suggest that scholars have failed to advance our understanding of how people, in variety of geographic contexts and scales, come to think about and make sense of energy technologies. Quite the contrary. Empirical research has clearly identified many critical features of energy attitudes, including the importance of place attachment [24, 55], prior familiarity about a technology [56], personal attributes such as demographics, worldviews, and environmental beliefs [19, 57–60], risk aversion [61, 62], and trust in government or industry [55, 62, 63]. Our analysis further reveals that perceptions of project benefits and drawbacks are also essential, and it is worth underscoring that to the extent that these perceptions are thought to be local in dimension, they are inter-related to the types of concerns that may explain NIMBY-like attitudes. Nonetheless, the diversity of approaches complicates efforts to distill the relative importance and boundary conditions of these explanations.

To advance the field, we propose two main strategies that scholars should employ to best study the role of proximity-based explanations, including the presence of any NIMBY-like sentiments. First, studies should adopt a common definition of what it means to have a NIMBY attitude. Interestingly, much of the literature in the energy context seeks to understand NIMBYism without first clearly defining it. Moreover, surprisingly few studies adopt the traditional definition of NIMBY, which requires that an individual be supportive of an energy infrastructure type in general, but be opposed to a specific use of that technology when it is to close proximity to where s/he resides. Simply studying the role of geographic proximity to a project, which is the modal approach in the literature, only measures the second part of the concept, neglecting the first part altogether. 9

9One specific way to implement this recommendation would be to ask two separate questions on a survey instrument: one question to measure an individual’s general support for an energy technology, and then a separate question on her or his support for a particular use (actual or hypothetical) of that technology near where she or he lives. In a regression analysis, a researcher could then use a multiplicative interaction term to determine whether residing in close proximity to the particular use of the project attenuates the relationship between support of the technology in general and its use nearby in particular.
A second strategy pertains to the measurement of geographic proximity. Recall that there are three broad ways that scholars measure proximity. First, scholars often study specific populations, or what might be referred to as ‘host communities,’ to either existing or potential energy projects. Second, scholars consider the distance (real or perceived) between study participants and an energy project. And, third, scholars directly ask people if they would support the use of a technology if it were to be located close to where they live. Each of these approaches has strengths and shortcomings, including the degree of difficulty to implement in survey research. In practice, each approach also suffers from a common problem in that they often do not include a relevant comparison group or groups. In the case of the dependent variable approach, studies most often do not vary the distance under consideration, nor is there a commonly agreed upon distance that scholars use in their studies. For example, a study may ask that whether a person supports the construction of a new power plant within a set distance of their home. An approach that varied this distance would provide a research with more analytical leverage to estimate the importance of proximity.

Similar problems often plague the other two common approaches, though here too they can in principle be designed to create variation on geographic proximity. This is most straightforward in the case of distance-based strategies, where a researcher can study people living at different distances (i.e. near, far, and in between) from an energy project. If, instead, a researcher only focuses on people living within a set distance of the project, it is difficult to assess the effect of geographic proximity in shaping their preferences. The sampling approach can achieve a similar goal, if done in a comparative way. That is, researchers should not just consider people living in close proximity to an energy project, but should also include in their analyses people living farther way. This approach enables comparisons of attitudes between people in these categories, thus providing another way to get at the effect of geographic proximity. A sampling approach that only studies a locally-affected population can certainly be informative for understanding local perceptions of a siting decision, but it does not contribute as much as to generalizable knowledge about the role of proximity to support for energy projects.

While we believe these strategies would pay dividends for better understanding the presence (or lack thereof) of NIMBY sentiments in the area of energy projects, we also think it is important to pursue similar questions with complementary qualitative research designs. Case studies and other qualitative approaches can provide additional insights into the role of trust, familiarity with the technology, perceptions of benefits and drawbacks, and other factors in project support. Similarly, qualitative work may more easily reveal other important factors, such as place attachment concerns, that survey researchers can then further explore in their studies. Collectively, these approaches can provide a more complete understanding of how people respond to energy technologies in general and specific projects that may be located near to where they live.

Improving the quality and consistency of research designs is important. From a scholarly standpoint, the enormous variation in theoretical and empirical approaches has generated a rich area of inquiry, but it has impeded the generalizability of findings. The implications for practice and policy are also consequential. Given the scale of new investments needed as part of a rapidly evolving energy transition, as well as the growing needs to replace aging energy infrastructure to alleviate energy poverty, understanding preferences toward energy, and the determinants of these attitudes, regarding NIMBYism or otherwise, are critically important to creating a just and inclusive path forward.

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID iDs

Sanya Carley @ https://orcid.org/0000-0001-9599-4519
David M Konisky @ https://orcid.org/0000-0002-1146-3938

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