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Citizen Science and Citizen Energy Communities: A Systematic Review and Potential Alliances for SDGs

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Abstract: Citizen science and citizen energy communities are pluralistic terms that refer to a constellation of methods, projects, and outreach activities; however, citizen science and citizen energy communities are rarely, if ever, explicitly aligned. Our searches for "citizen science" and "energy" produced limited results and "citizen science" and "energy communities" produced zero. Therefore, to outline a future direction of citizen science, its potential alliances with energy communities, and their collaborative contributions to the Sustainable Development Goals, we performed a systematic literature review and analysis of "public participation" and "energy communities" using the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRIMSA) guidelines. The results show four pathways through which current public participation in energy communities might be more explicitly aligned with citizen science projects: benefits and values, energy practices, intermediaries, and energy citizenship. Each of these pathways could engage citizen scientists in qualitative and quantitative research and increase scientific literacy about energy systems. Our call for citizen science to supplement current forms of participation builds from the "ecologies of participation" framework, itself an extension of co-productionist theories of science and technology studies. We conclude with a discussion of affordances and barriers to the alliances between citizen science and energy communities and their potential contributions to SDGs 7: Affordable and Clean Energy, 11: Sustainable Cities and Communities, 13: Climate Action, and 17: Partnerships for the Goals.

Keywords: citizen science; citizen energy community; sustainable development goals; renewable energy community; public participation; community energy; energy citizenship; energy democracy; smart meters

1. Introduction

Citizen science democratizes knowledge, often by including members of public in the collection and analysis of scientific data [1,2]; energy communities democratize power, often by giving members of open organizations opportunities to plan, finance, own, or manage energy systems and services [3–6]. Both practices promote public engagement, challenge top-down infrastructures, and work to transform passive consumers of information (or energy) into active coproducers and stewards. In the European Union (EU), energy communities seem to be edging closer to citizen science. In 2019, the EU Clean Energy Package with the revised Internal Electricity Market Directive (EU) 2019/944 specifically recognized a framework for citizen energy communities and renewable energy communities [7]. Renewable energy communities are slightly more restricted in terms of membership, governance, and proximity to the community-owned project. Thus, renewable energy communities could be considered a subcategory of citizen energy communities. The categories are another indication of the central role of citizens in the clean energy transition.

Despite the public outreach, problem framing, data gathering, policy making, and other shared similarities, citizen energy communities rarely, if ever, describe their actions as "citizen science." As far as we are aware, the term "citizen science" has also not been used to describe the actions of community energy projects or their common antecedent, renewable energy cooperatives. Recognizing the gap between citizen science and citizen energy communities begs the following questions: How might citizen energy communities practice citizen science? What existing practices of citizen science and energy communities might be better aligned so that, together, they can maximize their potential impacts on the clean energy transition?

We perform a systematic literature review and use the results to argue that citizen energy communities can form better alliances with citizen science and, together, help achieve SDGs 7: Affordable and Clean Energy; 11: Sustainable Cities and Communities; 13: Climate Action and 17: Partnerships for the Goals. Each of these SDGs and the broader goals of shifting to a cleaner, smarter, and more distributed energy grid requires massive structural change. Individual citizens can contribute time, expertise, and finances to build local, sustainable, decentralized energy infrastructure. These contributions have been shown to generate visible social, economic, and environmental benefits [8–14]. The methods and practices of citizen science and citizen social science can further clarify, highlight, and disseminate these benefits.

Fresh views of the relationships between citizen science and energy communities can help researchers and organizers build resilience that extends beyond the distribution lines, solar panels, and smart sensors to fortify both community bonds and global citizenship. More directly, energy communities might adopt citizen science practices to help gather data about the technical and social aspects of their networks, to give feedback that increases efficiency and community acceptance, and to show direct and supplementary contributions to sustainable development. Clarifying such links can also show the relationships between the benefits of local energy actions and the sustainability goals meant to protect the entire planet. In other words, citizen science can help read and amplify the links between citizen energy communities, energy citizenship, and the SDGs.

The remainder of this article is organized as follows: in the next two sections of this introduction (Sections 1.1 and 1.2), we review the development of citizen science and its relationship to the SDGs, and then turn to the more recent growth of energy communities. These sections help to highlight the respective relevance of citizen science and energy communities and the urgency of aligning them.

In Section 2, we describe the methods of a systematic review using the PRISMA guidelines. PRISMA offers a method for systematic literature reviews including a specific check list and the four-phase flow diagram. It is the widely accepted method for systematically filtering and reviewing peer-reviewed research. For our review, we used Web of Science and Scopus databases and incorporated additional references based on a search with specific criteria. We began with a search for keywords for "citizen science," and "energy communities" (along with synonyms) and retrieved zero results. Instead of pursuing a so-called "empty review" [15] which can be valuable in itself for identifying research gaps, we shifted focus to query how "participation" and "energy communities" might be molded into suggestions for potential citizen science-energy community activities. In Section 3, we provide the results of our literature review and offer four areas where citizen science can align with and elevate the impacts of energy communities: benefits and values, energy practices, intermediaries, and energy citizenship. In the conclusion, we address some affordances and constraints of these alliances and how they might demonstrate connections between citizen energy communities and SDGs 7, 11, 13, and 17. Finally, we call for further research to explore which communication channels, methods, and technologies citizen scientists might use to amplify the impacts of energy communities and their direct and supplementary contributions to SDG indicators. Our results indicate the paths forward for new, original alliances between citizen science and citizen energy communities. Such alliances can make powerful contributions to the SDGs and to the broader energy transition, which, in the wake of the COVID-19 pandemic, must be just, swift, and sustainable.

1.1. Citizen Science and the SDGs

Before analyzing the potential alliances between citizen science and citizen energy communities, we flush out these terms and offer some insights into how they relate to the SDGs.

Citizen science engages professionals and volunteers from diverse backgrounds and with varying levels of expertise to advance our collective understanding of the natural world. While also practiced under synonymous terms such as "voluntary monitoring," "open science," or "community-based participatory research," citizen science can take place in formal and informal settings such as laboratories, city streets, forests, oceans, and online. This dynamic approach to research, teaching, and community engagement has been traced to the "amateur science" of the nineteenth century, which included towering individual figures such as Charles Darwin. Today, it is more commonly associated with collective data gathering, especially that which takes place in nature. For example, the Audubon Society's Christmas Bird Count began in 1900 and is the longest running citizen science project. It has enrolled approximately 70,000 individual volunteers to count 64 million birds [16].

Although the specific terminology continues to be developed and refined [17], the general term "citizen science," was established in the last decades of the twentieth century. In one of the first book-length examinations, *Citizen Science: A Study of People, Expertise, and Sustainable Development*, Alan Irwin argued that citizen science draws from "contextual knowledges" which can include non-scientific understandings. Irwin encouraged practitioners to be "reflexive in terms of the uncertainties and limitations but also the constructive possibilities for science within everyday life" [18] (p. 167). For the present argument, it is important to note that Irwin explicitly framed his connections between science and citizenship as a response to the 1987 UN Report Our Common Future, which popularized the term "sustainable development" and formed the inspiration for the SDGs [19]. Citizen science and the SDGs were born of the same moment, so to speak, and, as we hope to show, their symbiotic growth is necessary for the ongoing energy transition.

In recent decades, citizen science has become more widespread. The 3000 projects and events registered on the website, SciStarter.com at the end of 2018 indicate this surge in popularity [20]. Irwin's emphasis on citizen science as the cultivation of contextualized knowledge was later expanded by Bonney et al. [21], who viewed citizen science as engaging the public with research activities and promoting scientific literacy through education and outreach. The events and educational campaigns are supplemented by hands-on activities in which participants engage in problem-formation, data gathering and processing, and even designing and implementing science-informed policies. In comparison with scientific communication or public understanding of science, citizen science, "provides greater potential for citizens to shape and improve solutions, supporting the co-evolution of social and technical aspects" of sustainability transitions [2] (p. 8). While often understood in terms of the contributors' expertise and participation, citizen science activities are more than monitoring, surveying, and point-in-time counts to gauge a specific species or environmental phenomena. Reviewing the latest iterations of citizen science, Strasser et al. [1] offer a typology of five epistemic practices: sensing, computing, analyzing, self-reporting, and making. Their typology recognizes that new computer technologies, communication networks, and the internet of things expand existing models of citizen science and challenge fixed hierarchies of participation. The typology also suggests how citizen science has scaled traditional research efficiently and at relatively low cost. In the twenty-first century, citizen scientists often use crowdsourcing, which uses web platforms to enlist large pools of participants to share ideas or complete microtasks such as labelling proteins or solving nucleotide puzzles [22]. The field of crowdsourced citizen science is rapidly evolving [23]. Approximately 1.9 million volunteers have contributed to 229 crowdsourced projects on Zooniverse [24]. Still, not all "crowd" contributions are strictly online; crowds that visit science centers and museums can also contribute to citizen science [25].

The benefits of citizen sciences are numerous. Citizen science allows scientists to gather data and conduct experiments that may otherwise be limited by financial and labor constraints. Of course, benefits also include contact with research communities and a healthier more open research environment. Ideally, citizen science builds public trust in scientists and scientific research as participants can see and understand how their contributions impact research, innovation, public policy, and society at large. Participants also gain increased scientific literacy, which can allow them to use their scientific knowledge to engage with policy and policymakers [26].

The benefits also range beyond the collection of data or acquisition of scientific knowledge. One study of a citizen science initiative in Bangladesh sorts benefits into five "capital stocks" and shows how increased awareness and understanding of local rainfall contributed to "human capital," which, in turn, contributed to climate adaptation [27]. In another study, interviews with 72 citizen-science participants in projects related to monitoring air and water quality, counting wildlife, and measuring precipitation events revealed that most viewed engagement in terms of experiential learning, new knowledge, and "increased awareness of the connectivity of living things" [28] (p. 675). Still, the emotional connections within the research group and relationships between participants and project leaders were also identified as key to sustaining commitment to the project and enhancing awareness of environmental sustainability.

The many potentially positive outcomes places citizen science at the crossroads of scientific and civic interests; the collaborations increase knowledge and make clear, direct, real world impacts. This is part of the reason why governing bodies have shown increasing support for citizen science. In 2016, the European Commission identified citizen science as one of the priorities for achieving more open, public facing scientific practices. The priority status was further indicated in the H2020 funding program objective "Science with and for Society (SwafS)." The two prepositions "with" and "for" hint at the importance of collaboration with a range of stakeholders and to provide impacts for discourse communities beyond academia. A recent EU report highlights the achievements of various citizen science projects in H2020 and argues that the pending Horizon Europe work program should continue to support citizen science as a way to connect science to collective values and interests [29]. Furthermore, the initial strategic plans for Horizon Europe indicate the potential for "multi-stakeholder living labs" that can be assessed through "science-based tracking mechanisms and methods," which implies the use of citizen science to evaluate impact [30].

With its potential to expand field research, access the power of crowds, and strengthen community bonds, citizen science can make important contributions to sustainability transitions and the attainment of the SDGs. An analysis of 127 citizen science projects in Germany revealed that many of those involving applied research contributed to SDG 15 "Life on Land" and SDG 4 "Quality Education" [31]. However, none of the 127 projects addressed SDG 7 "Affordable and Clean Energy." Another analysis of existing metadata and work plans of the 244 SDG indicators suggest citizen science has contributed to five SDGs and could contribute data for an additional 76 indicators, including three indicators from SDG 7 and nine indicators from SDG 11, "Sustainable Cities and Communities" [32]. Fraisl et al. note current and future citizen science projects related to malaria incidence, water quality, air pollution, and "forest area as a proportion of total land area" could strengthen reports. They authors do not mention citizen science projects that involved energy or that might contribute to the SDG 7, but they do suggest citizen science data could make "supplementary contributions" for Tier I Indicators 7.1.1, 7.1.2, and 7.2.1 [32].

Connections between citizen science and specific energy-related SDGs and indicators are in the initial stages of development. Here, we offer a reminder that energy undergirds most efforts at sustainability and the energy sector is a crucial driver of economic and social change. Energy also requires massive technological, social, and political networks and thus requires the kinds of global partnerships outlined in SDG 17.

The magnitude of such energy-projects often overshadows the potential contributions of local energy projects. For example, Castor el al. [33] created a Sustainable Development Goals Impact Assessment Framework (SDGs-IAE) to analyze the synergies and trade-offs between massive energy infrastructure and various SDG indicators. In their study, the 94-question survey and framework were applied to two ongoing power projects—the Hinkley Point C nuclear power plant in England and the Grand Ethiopian Renaissance Dam. The results visualize which SDGs might be enhanced and which might be limited by the projects' outcomes. While such tools offer stakeholders a broad view of energy's impacts on social, environmental and economic indicators, the tool seems mostly geared towards evaluating gigantic projects that cost billions of euros, depend on international collaborations, and take years and sometimes decades to plan and construct. The links between small-scale energy projects and the SDG indicators have received little to no scholarly attention. A nimbler framework will be required to show the impact of energy communities and the SDGs.

Clearer quality standards, accepted protocols, and universal tools—such as air quality sensors or traffic monitors—can allow citizen science to more effectively influence other scientists and policymakers [34]. Continually adapting standards and assessment frameworks helps to translate citizen data collected on the local level for better use by National Statistical Offices, which make reports to global SDG frameworks [35]. With regard to energy, environment, and sustainability, it seems that the most impactful results of citizen science have emerged from studies of transportation. With air sensors, traffic cameras, and automated number plate recognition software, citizens can monitor the movements of their own and others' vehicles and correlate these to pollution. Real-time monitoring of road conditions helps decrease traffic and also provides clearer assessments of air quality [36]. A similar campaign may be required to collect and share energy data that goes beyond the surveys used for SDG indicator 7.1.2, which determines what percentage of people in low- and middle-income countries use "clean fuels and technologies" (i.e., electricity as opposed to kerosene) for cooking, heating, and lighting.

The countries determined as "high-income" by the World Bank have access to technologies and smart devices to measure and show the cost and potential generation of the kilowatts that flow all around us. Collecting, sharing, and analyzing such data could directly contribute to SDG 7 and have a supplementary impact on SDG 9, 13, and 17. Collecting and analyzing such quantitative data seems at least as important as gauging the vehicles in our streets or the nitrogen dioxide in our atmosphere. However, the particulates floating through air have a distinct scientific value and environmental impact, but they are not a commodity in the same way as kilowatt hours, which have been traditionally controlled by massive, centralized utilities and, in neo-liberal markets, are bought and sold in markets with prices that fluctuate day by day and sometimes minute by minute. The challenge, then, is for citizen science and open science to break into the profitable and contested sector of energy data. This issue is discussed further in Section 4.

For now, it is clear that citizen science can advance various SDGs and specific SDG indicators. Yet before standardizing data generated by energy communities for uptake in SDGs reports, it must be collected. For this, citizen science might be more closely aligned with citizen energy communities.

1.2. Energy Communities and Community Energy

As decentralized socio-technical systems generate pathways for sustainability and energy transitions, energy communities expand individual energy choices and the collective power of the people. Examples of energy communities can include activities such as neighbors pooling their resources to install heat pumps or residents of rural villages installing wind turbines to serve their community and selling the excess power to the grid. Energy communities might also offer services related to electro-mobility such as e-bike or car charging stations. Historically, the most common type of energy community has been the cooperative, which is typically organized so that members have a stake in the ownership and control of energy resources and in which profits are either re-invested in the organization or distributed in the form of lower rates. There are approximately 3500 renewable energy cooperatives in the EU [37].

Energy communities are often organized around community energy projects and, in the early academic research on the subject, the term "community energy," seems be interchangeable with energy communities. Similar to "sustainable development" and "citizen science," early definitions of "community energy" were often tied to concepts of "energy citizenship." In 2007, Devine-Wright defined "energy citizenship" as an "awareness of responsibility" extending from the links between energy consumption and climate change along with an understanding of potential actions "including acts of consumption and the setting up of community renewable energy projects such as energy cooperatives" [38] (p. 72). The following year, Walker and Devine-Wright argued that community energy projects were often defined on an axis of process and outcome, with some interpretations focusing on the involvement of locals in the process, another on the outcome and the benefits derived, and a third "less concerned with whether or not a proposed project ticked the right 'community' boxes, but that it was actually going ahead and would lead to something productive and useful" [39] (p. 499). These initial views of energy citizenship and community energy projects have since been refined and expanded.

Like "citizen science," "community energy," does not stand for any single, fixed principle or essence but, like the polysemous communities it describes, is a collective name. These entities have roots in the twentieth century with rural electric cooperatives. A clearer notion of energy communities seems to have emerged after the Great Recession that began in 2008 as more individuals and groups sought more affordable, environmentally friendly, and locally controlled energy systems.

A recent EU report has identified at least 24 different approaches to developing energy communities, including various ownership and governance structures such as limited partnerships, development trusts, and foundations [37]. With their heterogeneous structures and activities, communities have been viewed as "incubators for pioneering initiatives addressing virtually all aspects of energy" [40]. Participants may contribute to the process of project development or in the sharing of collective benefits. Other definitions of energy communities often include technological aspects—e.g., renewable generation, decentralized distribution—and social aspects such as participative decision-making, community ownership, and the absence of federal government and major industry influence [41]. Energy communities often adopt an appropriate technological scale to fit local needs and include early, extensive, and continued community engagement [12].

Traces of these attributes and characteristics can be seen in the definition of "citizen energy community" found in Article 2 (11) of the EU Directive 2019/944 (recast Electricity Directive) which is part of the broader Clean Energy Package of 2019 [7]. The citizen energy community is self-organized and includes: (i) voluntary and open participation and democratic governance in which all members are adequately represented; (ii) a primary purpose to provide environmental, social community, or economic benefits to its members or the local area; and (iii) may engage in generation, distribution, aggregation, storage, charging (e.g., for electric vehicles), or energy efficiency (including building renovations). The definitions give consumers and prosumers the legal authority to organize; it remains to be seen how citizen energy communities might utilize methods such as citizen science to further demonstrate their benefits and impacts on the broader energy transition and sustainable development.

2. Methods

To help understand the potential alliances between citizen science and citizen energy communities, we planned a comprehensive, systematic literature review of articles with the keywords "citizen science" and "energy communities" (along with synonyms, such as "community energy," as shown in Appendix A). Our initial results—or lack thereof—required a slight adjustment to the PRIMSA guidelines for a systematic literature review. The objective, four-stage process—selection, screening, eligibility, and articles included in analysis—has proven effective for visualizing the academic output related to various environmental issues [42,43].

In recent years, systematic literature reviews have shown the relations between energy-related search terms. For example, Filippo et al. offer a bibliometric analysis of overlaps between "energy efficiency" and "citizen science" in SCOPUS and Cordis Databases [44]. They found that of the 265 "energy efficiency" projects under the EU's Seventh Framework Program, only seven, or 2.7% also mentioned "citizen science." These EU-funded projects had a relatively low publication output and the authors suggest that the low output may have been due to their strong involvement with industry, which might have shifted the intended target for results. They did find that 54% of the 336 academic articles since 1980 that have some mention of “energy efficiency” and “citizen science” were published between 2015 and 2018, suggesting that these fields are beginning to overlap.

Meanwhile, to understand how “moral values” influence public acceptance of “smart grid” technologies, Milchram et al. did a systematic review of 49 academic articles published between 2009 and 2017. Their review found that acceptance of smart grid technology was directly tied to values such as security of supply, transparency, and, above all, environmental sustainability. The smart grid’s “contribution to the environmental sustainability of energy systems” was the most often cited driver of acceptance, while barriers included data privacy, data security, (mis)trust, health, justice, and reliability [45] (p. 9). These studies suggest the value of combining seemingly distinct sets of search terms in order to understand how researchers view public engagement with energy transitions.

For our review, we used the Harzing’s Publish or Perish application (version 7.10) and included the Web of Science and Scopus databases in our searches [46]. Our search terms included “citizen science” and “energy communities” with various synonyms, as shown in Appendix A. We limited our search to two decades, 2000–2020.

Two separate searches with “citizen science” and “energy communities” in the title words field and key words field retrieved zero results from both Scopus and Web of Science. We adjusted synonyms (as indicated in Appendix A) and still obtained zero results. We concluded that there may be no published research that examines the specific links between citizen science and energy communities. This is surprising, considering that a search for articles using “citizen science” in the title, abstract, and keywords published between 2000 and 2020 produces approximately 4800 (unfiltered) results on Web of Science and Scopus and a similar search using “energy communities” or “community energy,” produced approximately 800 results. We then did a search on SciStarter, Zooniverse, and EU-Citizen.science and again, we did not retrieve any results suggesting “energy communities” making an explicit collaboration with, or use of, “citizen science.” Citizen science and energy communities are established, in theory and practice, and yet they rarely, if ever, overlap.

Recognizing the limited connections between “citizen science” and “energy communities,” we considered that these kinds of energy projects may include participation activities that are akin to or that may qualify as citizen science without naming it “citizen science.” In other words, the split between citizen science and energy communities could be a matter of terminology and procedure, not practice. For instance, studies of “energy citizenship” are concomitant with citizen science principles of collaboration, education, and empowerment with regard to the electric grid [4,47,48]. Furthermore, methods that include more active participation such as energy storytelling and home energy audits might be considered citizen social science [49]. It appears that such methods have not yet been applied to particular citizen energy communities or renewable energy communities. Therefore, like the calls for further inter- and transdisciplinary citizen science to advance sustainability programs [50,51], we call for energy research to be better aligned with citizen science. Such alliances could allow citizens, energy managers and policymakers to better integrate different types of knowledge and forms of participation in their collective push to empower energy communities. Of course, not all research on participation or participatory acts count as citizen science, but it seems reasonable that at least some standardized and documented energy community activities include the kind of problem-formation, collaborative data gathering, and qualitative or quantitative analysis regularly practiced by citizen scientists.

Therefore, to identify potential alliances, we proceeded with a review based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [52]. In the next section, we describe the results of four stages: identification, screening, eligibility, and qualitative synthesis Figure 1.

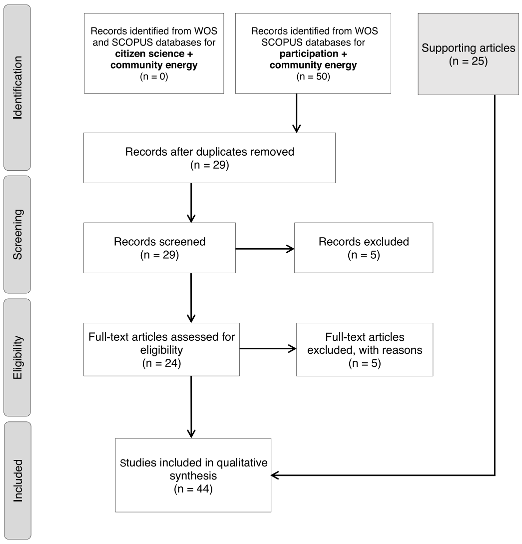

Figure 1. PRIMSA is a detailed method for literature reviews that includes four stages shown on the left: identification, screening, eligibility, and then qualitative analysis of included articles. In the middle column are the descriptions and results of each stage. The figure is based on Prisma Diagram, which has been adapted from the following: Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med. 6(7): e1000097 [52].

3. Results and Analysis

Our revised search in Publish or Perish using keywords "public participation" (with synonyms) AND "energy communities" (with synonyms) produced 50 raw results and 29 results after removing duplicates. The 29 results of this identification stage were subjected to a first reading of the title and abstract and screened during the eligibility stage. For the screening stage, we removed publications that did not address human-made energy systems or did not seem to include either a theoretical discussion or practical application of public participation in a concrete, local energy project. For the most part, the articles eliminated during this stage concerned the potential for public consolation during regional energy planning activities. The filtered list included 24 journal articles. In the next stage, we read the 24 articles and did another screening for relevance to the discussion of participation and energy communities. This eliminated a further 5 articles, some of which were determined to be too theoretical to make practical suggestions for citizen science projects and others which offered more general reviews of potential renewable energy development in a geographic area. A closer analysis for the 19 articles revealed four general categories which generally describe the content and methods of energy communities, community energy projects, and public participation research: benefits/behaviors, energy practices, intermediaries, and energy citizenship.

The 19 articles retrieved by the PRIMSA methods helped us form the four categories; however, we felt these 19 articles did not offer enough of a holistic view of research on participation and energy communities. Therefore, we completed an additional search stage. We used the following criterion for these additional articles: they must (1) contribute to one of the four categories and (2) represent foundational studies in participation and energy communities. Many of the supporting studies were identified by the first author from previous research on energy infrastructure and public participation [53] and many are also cited as sources in the 19 articles from the filtered list (i.e., "citation chasing"). The supplementary search stage produced an additional 25 results for a total of 44 articles.

Before analyzing the results and the four categories, we note that in addition to a recent review of energy communities and innovation in Europe [40], our desk research stage was guided by a number of arguments for increased and more diverse public engagement in energy policy frameworks and governance models [54,55]. With regard to local energy planning such as the decision to build fossil gas power plants or wind farms, volunteers (including students) with a deep connection to place can be effective at gathering and distributing scientific knowledge. For example, under the banner of citizen science, students in Lansing, Michigan USA organized a forum to educate the public on the city's plans to build a new power plant that would utilize 70% coal and 30% biomass, the science behind the design, and the potential financial and environmental tradeoffs [56]. While such education and outreach events are welcome and necessary, the ultimate goal of this review is to show how previous research on participation in energy communities might be aligned with the practice of citizen science in relation to the SDGs. Therefore, we focused on articles that would help us conceive of how to shape participation in community energy projects into citizen science practice.

Some of the articles included elements of more than one category and, for the purposes of the content review we set them into the category which seemed dominant.

The results of our select literature review (Table 1) and the ensuing categorizations draw from the "ecologies of participation" framework and the view of participation as "the performance of socio-material practices and social science methods" [3] (p. 200). Just as a healthy forest, grassland, or marine ecosystem depends upon more than a single species or a single measurement like temperature or precipitation, public and participation cannot be gauged by single-one off events nor determined by normative evaluations of "good participation." In terms of energy transitions, participation-as-conflict can be expected and can even be a valuable spark for community organization [57]. Still, we strive for participation in energy transitions and citizen energy communities as part of a "maxim of inclusivity" [58]. Furthermore, we believe that the "active participant" approach to citizen science and citizen energy communities are key to overcoming the view of energy users as "passive recipients" [59]. Refining and using this key to unlock sustainability goals includes a shift from "seeing participation as simply about eliciting public views on energy systems in invited events, to seeing it as a challenge of mapping the diversities, relations, and productions of already existing forms of participation across energy systems" [60] (p. 12). As residual impacts of citizen science methods and results extend beyond data-collected or knowledge gained, the performance of participation actively constructs the subjects, objects, and models of participation, each of which "interrelate in wider systems as multiple swarming vitalities" [3] (p. 201). Attempts to harvest and cultivate these vitalities with citizen science are explored the following four sections of qualitative analysis.

Table 1. The 44 articles and the categories used for our analysis. The full results have been published in a document on Zenodo [61].

Authors	Title	Result Categories
Seyfang et al.	A thousand flowers blooming? An examination of community energy in the UK	Benefits and Values
Shirani et al.	'I'm the smart meter': Perceptions of smart technology amongst vulnerable consumers.	Benefits and Values
Islar	'We are not in this to save the polar bears!'–the link between community renewable energy development and ecological citizenship	Benefits and Values
Hicks & Ison	An exploration of the boundaries of 'community' in community renewable energy projects: Navigating between motivations and context	Benefits and Values

Table 1. *Cont.*

Authors	Title	Result Categories
Kythreotis et al.	Citizen social science for more integrative and effective climate action: A science-policy perspective	Benefits and Values
Kalkbrenner	Citizens' willingness to participate in local renewable energy projects: The role of community and trust in Germany	Benefits and Values
Soeiro & Dias	Energy cooperatives in southern European countries: Are they relevant for sustainability targets?	Benefits and Values
Bauwens	Explaining the diversity of motivations behind community renewable energy	Benefits and Values
Süsser et al.	Harvesting energy: Place and local entrepreneurship in community-based renewable energy transition	Benefits and Values
Biresselioglu	Individuals, collectives, and energy transition: Analysing the motivators and barriers of European decarbonisation	Benefits and Values
Corsini et al.	Participatory energy: Research, imaginaries and practices on people' contribute to energy systems in the smart city	Benefits and Values
Smale & Kloppenburg	Platforms in Power: Householder Perspectives on the Social, Environmental and Economic Challenges of Energy Platforms	Benefits and Values
Soeiro & Dias	Renewable energy community and the European energy market: main motivations	Benefits and Values
Hargreaves & Middlemiss	The importance of social relations in shaping energy demand	Benefits and Values
da Silva	The role of local energy initiatives in co-producing sustainable places	Benefits and Values
Kim	A Community Energy Transition Model for Urban Areas: The Energy Self-Reliant Village Program in Seoul, South Korea	Energy Practices
Alvial-Palavicino et al.	A methodology for community engagement in the introduction of renewable based smart microgrid	Energy Practices

Table 1. *Cont.*

Authors	Title	Result Categories
Delina	A rural energy collaboratory: co-production in Thailand's community energy experiments	Energy Practices
Ahlers	A smart city ecosystem enabling open innovation	Energy Practices
Green & Newman	Citizen utilities: The emerging power paradigm	Energy Practices
Pitt & Bassett	Collaborative Planning for Clean Energy Initiatives in Small to Mid-Sized Cities	Energy Practices
Hill & Connelly	Community energies: Exploring the socio-political spatiality of energy transitions through the Clean Energy for Eternity campaign in New South Wales Australia	Energy Practices
van Summeren	Community energy meets smart grids: Reviewing goals, structure, and roles in Virtual Power Plants in Ireland, Belgium and the Netherlands	Energy Practices
Scott et al.	Evaluating the impact of energy interventions: home audits vs. community events	Energy Practices
Costello	Incorporating community governance: Planning sustainable energy security	Energy Practices
Cappa et al.	Nudging and citizen science: The effectiveness of feedback in energy-demand management	Energy Practices
Espe	Prosumer Communities and Relationships in Smart Grids: A Literature Review, Evolution and Future Directions	Energy Practices
Meiklejohn et al.	Shifting practices: How the rise of rooftop solar PV has changed local government community engagement	Energy Practices
Trutnevyte et al.	Supporting energy initiatives in small communities by linking visions with energy scenarios and multi-criteria assessment	Energy Practices
Kloppenburg et al.	Technologies of Engagement: How Battery Storage Technologies Shape Householder Participation in Energy Transitions	Energy Practices

Table 1. *Cont.*

Authors	Title	Result Categories
Lazowski	Towards a smart and sustainable residential energy culture: assessing participant feedback from a long-term smart grid pilot project	Energy Practices
Hargreaves et al.	Grassroots innovations in community energy: The role of intermediaries in niche development Tom	Intermediaries
Van der Waal et al.	How local energy initiatives develop technological innovations: Growing an actor network	Intermediaries
Wallmeier & Thaler	Mayors' leadership roles in direct participation processes-the case of community-owned wind farms	Intermediaries
van der Schoor	Power to the people: Local community initiatives and the transition to sustainable energy	Intermediaries
Warbroek	The role of intermediaries in supporting local low-carbon energy initiatives	Intermediaries
Koirala et al.	Trust, awareness, and independence: Insights from a socio-psychological factor analysis of citizen knowledge and participation in community energy systems	Benefits and Values
Delina	Can Energy Democracy Thrive in a Non-democracy?	Energy Democracy
Pesch	Elusive publics in energy projects: The politics of localness and energy democracy	Energy Democracy
Delina	Energy democracy in a continuum: Remaking public engagement on energy transitions in Thailand	Energy Democracy
Milchram et al.	Energy Justice and Smart Grid Systems: Evidence from the Netherlands and the United Kingdom	Energy Democracy
Miller et al.	Involving occupants in net-zero-energy solar housing retrofits: An Australian sub-tropical case study	Energy Democracy

Table 1. *Cont.*

Authors	Title	Result Categories
Proka et al.	Leading from the Niche: Insights from a strategic dialogue of renewable energy cooperatives in the Netherlands	Energy Democracy
Simcock	Procedural justice and the implementation of community wind energy projects: A case study from South Yorkshire, UK	Energy Democracy

3.1. Benefits and Values of Energy Communities

The benefits and values of participation in renewable energy communities are numerous and heterogenous. They often include social benefits (e.g., stronger community bonds), financial benefits (e.g., lower monthly bills), and environmental benefits (e.g., reduced air pollution related to carbon emissions).

Within the ecologies of the participation framework, the clearest potentials for citizen science to clarify these benefits seems to be via a "residual realist" approach. Chilvers et al. mapped 258 cases of public engagement in energy transition systems that took place between 2010 and 2015 in the UK and found that, in 35% of cases, participation was enacted through "eliciting public views" through opinion surveys, consultations or deliberative processes" [3] p. 204. This normative view of participation can be limiting and reinforce a "knowledge-deficit" understanding of public participation in a more centralized energy infrastructure (e.g., leading surveys or de-escalation forums organized by a utility or energy company). However, collecting qualitative and quantitative data offers opportunities for citizen scientists to offer a baseline of community interests and to demonstrate general willingness to adopt new transition pathways.

In addition to using household surveys for SDG indicators such as 7.1, researchers have used surveys to establish the drivers of participation in community energy projects and local renewable energy initiatives. These surveys suggest that the commonly accepted motivations are (1) social, (2) economic, (3) environmental and (4) political/policy [4,5]. Other qualitative research suggests that community identity, trust, social norms are positively correlated with a willingness to volunteer or invest financial resources in energy communities [10]; however, such correlations, which are not necessarily fixed as members of the same energy cooperatives, may be motivated by different values such as pro-environmental of pro-social [11]. Surveys and interviews imply that in established energy communities, participation seems more fueled by local cohesiveness. While many individuals admit that financial interests may outweigh ecological interests, there remain "linkages between renewable energy and ecological citizenship" [9] (p. 315). Overall, community benefits, lower energy costs, environmental concerns, energy independence, and interaction with the local organizations seem to be stronger motivators than potential profits [62,63]. Citizens-as-scientists should be effective at recognizing and quantifying, the value of place-based development and shared place meanings when designing decentralized, autonomous, and sustainable energy communities [64,65]. With a focus on local development and the understanding and practice of community energy benefits and values, citizen science might contribute in at least two ways.

First, locals who are likely to be impacted and may potentially benefit from an energy community might collaborate in both the design of surveys and collection of data. Lisjak et al. notes a number of data gaps that need to be filled to support EU goals and specifically notes, "voluntary measurement of the exhaust of cars, air quality parameters, or the mapping of the current production of renewable energy in neighborhoods" as ways for citizens to be more engaged [66] (p. 2). Such measurements and mapping might also be helpful with regard to energy use in the home and renewable energy generation. In terms of energy communities, data collected by volunteers could also help to better gauge their neighbors' willingness to participate as well as financial, environmental, and social impacts of existing or potential community energy projects. While existing groups and cooperatives may have the resources and expertise to mount public engagement campaigns, grassroots efforts may be better supported by clear citizen data and analysis. Even for those opposed to a specific energy infrastructure or installation (e.g., fossil gas or wind turbines), citizen science may help them to gather and analyze quantitative data that can give their claims more credibility.

Second, there has been increasing interest in the role of storytelling and narrative modes in citizen science [67,68], and public engagement with specific energy projects and broader energy transitions [69–71]. Ottinger makes a specific connection between storytelling and citizen science, with regard to vulnerable communities supplementing data with stories: "stories of communities on the front lines of energy and petrochemical facilities serve as powerful resources for making sense of citizen science data that would be difficult to interpret—or likely to be misinterpreted—using scientific frameworks alone" [49], (pp. 46–47). Citizen scientists can be trained in the methods of recruiting, recording, and analyzing such stories as they relate to energy uses within their community. Of course, further research is needed to show how involved locals in the collection of data and stories might facilitate the acceptance and growth of energy communities.

3.2. Energy Practices

In terms of an energy community, energy practices often relate to individual actions and can range from the seemingly minor daily practice—flipping a light switch—to more significant lifestyle changes, such as the purchase of electric vehicles, installation of solar panels, and participation in the storage and exchange of electricity on the grid.

The results of our review suggest that almost equal attention has been directed towards the benefits and values of energy communities and the diverse energy practices through which locals generate, distribute, and use energy (Figure 2). Indeed, citizen science can help to further clarify individual and communal energy practices and quantify their outcomes. Research on such activities is already taking place across the globe. For instance, some of our results examine how community energy and microgrids benefit rural areas in Chile [72] and Thailand [73]. Another compared the impact of energy audits and community events in New Zealand [74]. Injecting citizen science methods into research that takes place might help to contribute to various SDGs; however, for the purposes of this study, we focused on how existing citizen energy communities in the EU might further co-produce knowledge in the following areas: smart grids and smart meters, auto-consumption (primarily rooftop solar-thermal and solar PV), and citizen utilities and demand side management.

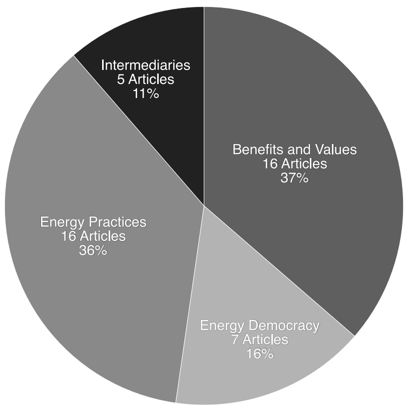

Figure 2. A pie chart showing the percentage of articles from our literature review placed in each category.

Smart grids allow for the real-time, bi-directional flow of energy data between producers and consumers as well as the capacity for program heating, cooling, and other major appliances. Many studies have shown how smart grids and meters can facilitate community networks and microgrids made up of local prosumers [75–77]. Studies of smart tools within the home show how increased information can slightly adjust behaviors, but that broader changes remain elusive. For example, a multi-year study of a smart grid pilot project concluded that although "consumption awareness was gained, there remained a large lack of knowledge on how to make substantial and lasting changes in the home. In particular, households identified that more hands-on help would have been beneficial" [78] (p. 17). Finding ways for trusted, trained volunteers to assist their neighbors with smart devices could be another potential application of citizen science.

Similarly, the practice of altering behavior with time-sensitive messages or reminders, often called "nudging," has been touted for its ability to increase efficiency and lower energy use [79–81]. A specific study of citizen science study of nudging suggests that customized feedback regarding participants' potential cost savings and pollutant-emissions reduced consumption and increased the awareness of environmentally related energy issues and willingness to participate in future citizen science projects [82]. However, the lack of "hands-on" assistance and the view of participants as merely "citizen sensors," reflect a top-down approach between researchers and participants.

Efforts have been made to study the impact of direct engagement in the co-design and material practice of devices [47,83]; yet, again, we find that more collaboration and clearer, more effective behavior may be facilitated by studying smart meter uses with existing and emerging energy communities. Citizen science can facilitate the kind of bottom-up, grassroots solutions that are responsive to community interests and values and have long been identified as drivers of local, sustainable development [84].

Citizen science can clarify the relationships between home energy practices, "prosumers" self-generation (often with solar panels), and broader clean energy infrastructures. For example, using battery storage, homeowners with solar PV can generate "citizen utilities" that allow them to shift consumption or sell surplus directly to the community. Further research has identified how citizen energy communities might operate "community virtual power plants" that challenge the incumbent energy system and allow for more localized energy management and trading [85]. While citizen utilities and community microgrids may not replace the incumbent grid, they can increase efficiency and flexibility and reinforce some of the social bonds and environmental awareness often absent in current energy practices [86]. To achieve this, it is important to understand how the home energy practices and even the energy community activities relate to a broader system, including policy making, market interests, and the design and management of existing grid infrastructure [87]. Combining this broader understanding of local actions and regional, national, and even global interests can be facilitated by intermediaries and pushes towards energy citizenship.

3.3. Intermediaries

In the research on energy transitions and community energy, individual intermediaries and intermediary organizations have been identified as actors positioned between energy providers, energy regulators, and energy users [88]. Intermediaries can facilitate the flow of information, increase community action, clarify policy, and broker the resolution of conflicts [89]. The objectivity of intermediaries can also increase trust during the negotiation process that accompanies new energy projects.

Meanwhile, citizen scientists have been called to act as intermediaries and to act as "public intermediaries and spokespeople within public understanding of science research and practice" [90] (p. 15). Many citizen science projects are led by academic researchers and they act as educators, sponsors, and advocates. While dedicated to the pursuit of scientific objectivity, to increase their impact, these citizen scientists should also position themselves and their research to align with both the niches of grassroots development and the broader institutional networks, which include the local industrial, political, and social interests. For example, in the EU, mayors have been identified as supporting community wind projects by acting as sponsors, champions, facilitators, conveners, or boundary spanners [91]. Many of these roles are shared and it seems citizen science projects might collaborate with the officials to both gather and distribute results to various groups within the community and beyond. Working with energy communities, citizen-science informed intermediaries might create and disseminate tangible proof of alignments and make them visible with case-studies, proof of concept, and reproducibility [92].

The specific role of intermediaries in energy communities has also been well established [93]. Hargreaves et al. explore the "in-betweenness" of intermediaries as organizations or individuals that connect different niches into a broader network. However, they also warn that there is no generic blueprint for an energy community, and that models are not a "substitute for ongoing, context-specific learning that respects and preserves the diversity of local projects infrastructure and to support the development" [94] (p. 874). A review of 13 community energy projects in the Netherlands suggests that many enjoy support from people already employed in the energy sector, who voluntarily engage with the local energy initiatives [95]. Recruiting such individuals with expertise and previous knowledge for a citizen science project can help frame and lend credibility to the findings.

3.4. Energy Citizenship

Energy citizenship is another polysemous term used to explain how emerging energy practices might lead individuals and collectives to gain knowledge about the interrelationships of energy practices, to feel further empowered to demand cleaner energy choices, and to use their political power to shape new energy policies. Energy communities can help build capacity for energy citizenship and, aligned with citizen science, can contribute to SDGs 11, 13, and 17.

However, how energy citizenship is cultivated and practiced remains a contentious issue. Studies of public engagement are sometimes studies in appeasement; that is, they are designed not to increase engagement but to better avoid public confrontation. Similarly, research on participation can be focused solely on what attracts potential members or customers. In other words, the primary purpose is to learn best practices for "scaling-up" the numbers of participants. Therefore, extending on Devine-Wright's initial definition of "energy citizenship," Ryghaug et al. [47] critiqued the standard models of publics as passive energy consumers and offered an object-oriented account of energy citizenship. As electric vehicles, smart meters, and rooftop PV become imbricated with everyday life, they offer chances for more direct, material participation in energy transitions. This kind of "mundane energy citizenship" begins with physical, embodied experience, which in turn opens "opportunities for connecting to new issues, new concerns, and through this, new ways of enacting energy citizenship" [47] (p. 29). Solar panels on roofs or electric vehicles in driveways do not define energy citizenship by themselves. Rather, lived experiences with these technologies can co-produce energy citizenship and expand others' opportunities to participate, even in relatively simple ways such as raising awareness of the technologies at our disposal. Meanwhile, porous and complex, relations with family and friends, relations with agencies and communities (e.g., landlords, utilities, schools, etc.) and relations of identity (age, gender, class, race, etc.) shape how we use access, use, and pay for energy [96]. Just as energy citizenship is "co-produced" with a shifting socio-technical system, citizen science inspires the "co-evolution of socio-technical aspects of transitions" [2] (p. 2).

The EU has taken efforts to support energy citizenship as a means for decarbonization. In 2019, along with the designation of citizen energy communities, a call within the work program, "Secure, Clean, and efficient energy" supports social science and humanities research on the "emergence and effectiveness of energy citizenship" [97]. The findings of this call should clarify how factors such as digitalization, social media, social group dynamics, and social justice shape the ways in which energy citizenship is understood and practiced. The specific connections to social justice extend the parameters of energy citizenship. Energy citizenship can shift consumer behavior and raise awareness about clean technologies or energy efficiency; more critically, it should empower individuals to understand and address unequal agency and access to resources and upend the "consumer choice" of the market-driven paradigm. Instead of viewing "energy as a commodity" that is subject to market forces, energy citizenship can shift our view of energy as "ecological resources and a social necessity and subject to collective decision-making" [48] (p. 185). There remains tension between the idea of energy citizenship as civic participation and as ownership. Some argue that "citizen ownership is the highest level of citizen power as it confers the control over the decision-making process and its outcome" [98] (p. 1). However, energy citizenship associates more with stewardship than ownership. It empowers individuals to expand their political power and demand changes to energy policy and industry offerings.

Citizen energy communities and energy citizenship are each underscored by a push to give individual citizens more power over the means of energy production and consumption. When they gain energy citizenship, community groups, non-profits, and other stakeholders are better able to resist centralized energy systems based on fossil fuels, to reclaim the energy sector with more public control and regulatory oversight, and to restructure electric power networks to make them more distributed, diverse, and inclusive [99]. Nevertheless, more empirical studies of energy citizenship and energy democracies are needed to show how these identities and groups are "constructed, co-produced, and with what effect" [60] (p. 9). Citizen science might help clarify these identities, but also find flexible means of supporting their impacts. A common critique of citizen science is that it has been too focused on "observing and collecting data, rather than formulating the citizen science research methods, analyzing and interpreting the data as a means to instigate climate policy action" [100] (p. 8). Citizen energy communities are, understandably, often focused on the financial and policy constraints needed to survive in markets skewed towards massive, for-profit utilities. They often lack the resources to show their members how to exercise energy citizenship in ways that might contribute to global SDG 13 "climate action." Therefore, the ways in which individual energy communities practice energy citizenship needs to be further expanded to show the connections between communities and how their actions relate to broader efforts at energy (and climate) justice [101].

4. Conclusions: Affordances and Constraints of Citizen Science-Energy Community Contributions to SDGs

The results of our literature review suggest that citizen science has not yet formed formal or explicit alliances with energy communities; however, some "participation" in energy communities is often akin to or even copacetic with the methods and practices of citizen science. Therefore, we used participation as a means to read existing literature and identify potential partnerships. These potential alliances relate to four general areas of research: (1) evaluating benefits produced by energy communities, (2) identifying and potentially modifying energy practices, (3) empowering intermediaries, or (4) increasing energy citizenship.

One limitation of our study relates to terminology—energy communities may be engaging activities that qualify as "citizen science" without explicitly using that term. Furthermore, as our review followed a strict methodology involving academic databases, research on the real or potential intersections may have been missed if authors did not select "citizen science," or "energy communities" as keywords. Finally, our results may be limited by the fact that academic publications may not be an integral part of energy communities' activities. Citizen science activities related to energy literacy, community engagement, or data collection and analysis may exist without their results being submitted to peer-reviewed publications.

Nevertheless, our systematic review reveals many potential synergies between citizen science and energy communities. Recognizing the existing lack of alliances, non-profits, community organizations, and policymakers may use our results to lend more financial or institutional support for these initial citizen science actions. Furthermore, academic researchers could use our results to mount specific, reproducible studies on the impact of energy communities by measuring their contributions to SDG 7, 9, 13, and 17. For instance, the data collected in collaboration with energy communities could make supplementary contributions to indicators such as 7.2.1 "Renewable energy share in the total final energy consumption"; 9.4.1 "CO_2 emission per unit of value added"; and 13.3.1 "Extent to which (i) global citizenship education and (ii) education for sustainable development are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment" and 17.17.1 "Amount in United States dollars committed to public-private partnerships for infrastructure" [102].

Putting our results into practice and forging alliances between citizen science projects and citizen energy communities will require resources. Those who manage such projects will also have to overcome significant institutional and, possibly, legal constraints. We anticipate that citizen science-community energy alliances are likely to face barriers related to open data and privacy. Most energy communities are not independent of broader regional or national grid networks, which are often owned and operated by large utilities, which, in many countries, represent oligopolies. Such institutions and the regulatory bodies overseeing their actions have significant responsibilities with regard to grid security and reliability. They are not always amenable to grassroots, open-access actions. For example, Bruce Baer Arnold outlines the challenge that citizen scientists face when attempting to collect, analyze, integrate, and disseminate environmental data from public and private sources. He proposes a kind of "environmental sousveillance" that stresses agency and openness in the collection of smart grid data [103] (p. 376). However, this kind of bottom-up practice could face fierce resistance from the utilities and energy companies who have traditionally collected and owned such data. For instance, the data derived from smart meters or smart photovoltaic inverters can hold private information and it can also have financial value. Real-time knowledge about how much energy is being generated or consumed can inform positions of supply and demand, potentially offering an edge in broader electricity markets, especially as they become more interconnected. Therefore, the sharing of data related to the solar PV panels one buys and installs on their own rooftop can be legally restricted if the user is also connected to a grid owned by a private or public utility.

We hope citizen science-energy community alliances may provide a solution. Members/participants may be able to share real-time data related to the energy they generate with their rooftop solar installations and use inside their homes. Together, participants could design and contribute to a database that also supports the Open Power System Data initiative [104]. With aggregated data, the energy community could analyze certain behavior patterns and show the potential impact of new technologies, energy policies, or specific energy sources (e.g., What are the impacts of adding, for instance, 5 megawatts of rooftop solar capacity to community network?).

In the current form, energy communities have the potential to increase energy efficiency, address energy poverty, and to facilitate the uptake of clean technologies and consumption patterns. We believe these potentials can be further charged by citizen science. We anticipate that the recent definition of citizen energy communities will facilitate new projects—and research on their results. Such research will, ideally, also clarify the communication channels, methods, and technologies that can most effectively align the goals of citizen energy communities and citizen science, amplify the impacts of citizens in the energy transition, and to show their direct and supplementary contributions to SDG indicators.

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Appendix A. Booleans Used for the Searches Made in 1 October 2020, with Publish or Perish Software in SCOPUS and WOS Databases (Filtered by Year 2000 to 2020)

Boolean	By Title	By Keywords
"citizen science" AND ("energy communit *" OR "community energ *" OR "energy cooperative")	0	0
"open science" AND ("energy communit *" OR "community energ *" OR "energy cooperative")	0	0
"crowd science" AND ("energy communit *" OR "community energ *" OR "energy cooperative")	0	0
"volunteer monitoring" AND ("energy communit *" OR "community energ *" OR "energy cooperative")	0	0
"amateur science" AND ("energy communit *" OR "community energ *" OR "energy cooperative")	0	0
"public participation *" AND ("energy communit *" OR "community energ *" OR "energy cooperative")	1	14
"communit * engagement" AND ("energy communit *" OR "community energ *" OR "energy cooperative")	0	24
"public engagement" AND ("energy communit *" OR "community energ *" OR "energy cooperative")	0	11

* In Boolean searches the asterisk serves as a truncation operator. Words match if they begin with letters preceding the operator.

References

1. Strasser, B.J.; Baudry, J.; Mahr, D.; Sanchez, G.; Tancoigne, E. "Citizen science"? Rethinking science and public participation. *Sci. Technol. Stud.* **2019**, *32*, 52–76. [CrossRef]
2. Sauermann, H.; Vohland, K.; Antoniou, V.; Balázs, B.; Göbel, C.; Karatzas, K.; Mooney, P.; Perelló, J.; Ponti, M.; Samson, R.; et al. Citizen science and sustainability transitions. *Res. Policy* **2020**, *49*, 103978. [CrossRef]
3. Chilvers, J.; Pallett, H.; Hargreaves, T. Ecologies of participation in socio-technical change: The case of energy system transitions. *Energy Res. Soc. Sci.* **2018**, *42*, 199–210. [CrossRef]
4. Van Veelen, B.; van der Horst, D. What is energy democracy? Connecting social science energy research and political theory. *Energy Res. Soc. Sci.* **2018**, *46*, 19–28. [CrossRef]
5. Capellán-Pérez, I.; Campos-Celador, Á.; Terés-Zubiaga, J. Renewable energy cooperatives as an instrument towards the energy transition in Spain. *Energy Policy* **2018**, *123*, 215–229. [CrossRef]

6. Genus, A.; Iskandarova, M. Transforming the energy system? Technology and organisational legitimacy and the institutionalisation of community renewable energy. *Renew. Sustain. Energy Rev.* **2020**, *125*, 109795. [CrossRef]
7. European Commission Directive (EU). European Commission Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU. *Off. J. Eur. Union* **2019**, *125*, 125–199.
8. Seyfang, G.; Park, J.J.; Smith, A. A thousand flowers blooming? An examination of community energy in the UK. *Energy Policy* **2013**, *61*, 977–989. [CrossRef]
9. Islar, M.; Busch, H. "We are not in this to save the polar bears!"—The link between community renewable energy development and ecological citizenship. *Innovation* **2016**, *29*, 303–319. [CrossRef]
10. Kalkbrenner, B.J.; Roosen, J. Citizens' willingness to participate in local renewable energy projects: The role of community and trust in Germany. *Energy Res. Soc. Sci.* **2016**, *13*, 60–70. [CrossRef]
11. Bauwens, T. Explaining the diversity of motivations behind community renewable energy. *Energy Policy* **2016**, *93*, 278–290. [CrossRef]
12. Hicks, J.; Ison, N. An exploration of the boundaries of 'community' in community renewable energy projects: Navigating between motivations and context. *Energy Policy* **2018**, *113*, 523–534. [CrossRef]
13. Biresselioglu, M.E.; Demir, M.H.; Demirbag Kaplan, M.; Solak, B. Individuals, collectives, and energy transition: Analysing the motivators and barriers of European decarbonisation. *Energy Res. Soc. Sci.* **2020**, *66*, 101493. [CrossRef]
14. Soeiro, S.; Ferreira Dias, M. Renewable energy community and the European energy market: Main motivations. *Heliyon* **2020**, *6*, e04511. [CrossRef]
15. Lang, A.; Edwards, N.; Fleiszer, A. Empty systematic reviews: Hidden perils and lessons learned. *J. Clin. Epidemiol.* **2007**, *60*, 595–597. [CrossRef]
16. Havens, K.; Henderson, S. Citizen science takes root. *Am. Sci.* **2013**, *101*, 378–385. [CrossRef]
17. Eitzel, M.V.; Cappadonna, J.L.; Santos-Lang, C.; Duerr, R.E.; Virapongse, A.; West, S.E.; Kyba, C.C.M.; Bowser, A.; Cooper, C.B.; Sforzi, A.; et al. Citizen Science Terminology Matters: Exploring Key Terms. *Citiz. Sci. Theory Pract.* **2017**, *2*. [CrossRef]
18. Irwin, A. *Citizen Science: A Study of People, Expertise and Sustainable Development*; Routledge: London, UK, 1995; ISBN 0415115485.
19. Brundtland, G.H.; Khalid, M.; Agnelli, S.; Al-Athel, S.; Chidzero, B.J.N.Y. *Report of the World Commission on Environment and Development: Our Common Future*; Oxford University Press: New York, NY, USA, 1987; ISBN 019282080X.
20. Shell, L. Top 18 Projects of 2018. *SciStarter Blog*, 10 June 2019.
21. Bonney, R.; Cooper, C.B.; Dickinson, J.; Kelling, S.; Phillips, T.; Rosenberg, K.V.; Shirk, J. Citizen science: A developing tool for expanding science knowledge and scientific literacy. *Bioscience* **2009**, *59*, 977–984. [CrossRef]
22. Good, B.M.; Su, A.I. Crowdsourcing for bioinformatics. *Bioinformatics* **2013**, *29*, 1925–1933. [CrossRef]
23. Franzoni, C.; Sauermann, H. Crowd science: The organization of scientific research in open collaborative projects. *Res. Policy* **2014**, *43*, 1–20. [CrossRef]
24. Zooniverse: 10 years of people-powered research. *University of Oxford News*, 12 December 2019.
25. Cappa, F.; Rosso, F.; Capaldo, A. Visitor-sensing: Involving the crowd in cultural heritage organizations. *Sustainability* **2020**, *12*, 1445. [CrossRef]
26. Cappa, F.; Laut, J.; Porfiri, M.; Giustiniano, L. Bring them aboard: Rewarding participation in technology-mediated citizen science projects. *Comput. Hum. Behav.* **2018**, *89*, 246–257. [CrossRef]
27. Bremer, S.; Haque, M.M.; Aziz, S.B.; Kvamme, S. 'My new routine': Assessing the impact of citizen science on climate adaptation in Bangladesh. *Environ. Sci. Policy* **2019**, *94*, 245–257. [CrossRef]
28. Phillips, T.B.; Ballard, H.L.; Lewenstein, B.V.; Bonney, R. Engagement in science through citizen science: Moving beyond data collection. *Sci. Educ.* **2019**, *103*, 665–690. [CrossRef]
29. Warin, C.; Delaney, N. *Citizen Science and Citizen Engagement*; Publications Office of the European Union: Luxembourg, 2020; ISBN 9789276179283.
30. European Commission. *Orientations Towards the First Strategic Plan for Horizon Europe*; European Commission: Brussels, Belgium, 2019.

31. Schleicher, K.; Schmidt, C. Citizen science in Germany as research and sustainability education: Analysis of the main forms and foci and its relation to the sustainable development goals. *Sustainability* **2020**, *12*, 6044. [CrossRef]
32. Fraisl, D.; Campbell, J.; See, L.; Wehn, U.; Wardlaw, J.; Gold, M.; Moorthy, I.; Arias, R.; Piera, J.; Oliver, J.L.; et al. Mapping citizen science contributions to the UN sustainable development goals. *Sustain. Sci.* **2020**. [CrossRef]
33. Castor, J.; Bacha, K.; Fuso Nerini, F. SDGs in action: A novel framework for assessing energy projects against the sustainable development goals. *Energy Res. Soc. Sci.* **2020**, *68*, 101556. [CrossRef]
34. Ottinger, G. Buckets of resistance: Standards and the effectiveness of citizen science. *Sci. Technol. Hum. Values* **2010**, *35*, 244–270. [CrossRef]
35. Fritz, S.; See, L.; Carlson, T.; Haklay, M.; Oliver, J.L.; Fraisl, D.; Mondardini, R.; Brocklehurst, M.; Shanley, L.A.; Schade, S.; et al. Citizen science and the United Nations Sustainable Development Goals. *Nat. Sustain.* **2019**, *2*, 922–930. [CrossRef]
36. EEA Report (European Environment Agency). *Assessing Air Quality through Citizen Science*; European Environment Agency: Luxembourg, 2019; ISBN 9789294802019. [CrossRef]
37. Caramizaru, A.; Uihlein, A. *Energy Communities: An Overview of Energy and Social Innovation*; Publications Office of the European Union: Luxembourg, 2020; ISBN 9789276107132.
38. Devine-Wright, P. Energy Citizenship: Psychological Aspects of Evolution in Sustainable Energy Technologies. In *Governing Technology for Sustainability*; Routledge: London, UK, 2007; pp. 63–86. ISBN 9781849771511.
39. Walker, G.; Devine-Wright, P. Community renewable energy: What should it mean? *Energy Policy* **2008**, *36*, 497–500. [CrossRef]
40. Hewitt, R.J.; Bradley, N.; Baggio Compagnucci, A.; Barlagne, C.; Ceglarz, A.; Cremades, R.; McKeen, M.; Otto, I.M.; Slee, B. Social Innovation in Community Energy in Europe: A Review of the Evidence. *Front. Energy Res.* **2019**, *7*, 1–27. [CrossRef]
41. Brummer, V. Community energy—Benefits and barriers: A comparative literature review of Community Energy in the UK, Germany and the USA, the benefits it provides for society and the barriers it faces. *Renew. Sustain. Energy Rev.* **2018**, *94*, 187–196. [CrossRef]
42. Benevene, P.; Buonomo, I. Green human resource management: An evidence-based systematic literature review. *Sustainability* **2020**, *12*, 5974. [CrossRef]
43. Orellano, A.; Valor, C.; Chuvieco, E. The Influence of Religion on Sustainable Consumption: A Systematic Review and Future Research Agenda. *Sustainability* **2020**, *12*, 7901. [CrossRef]
44. De Filippo, D.; Lascurain, M.L.; Pandiella-Dominique, A.; Sanz-Casado, E. Scientometric analysis of research in energy efficiency and citizen science through projects and publications. *Sustainability* **2020**, *12*, 5175. [CrossRef]
45. Milchram, C.; van de Kaa, G.; Doorn, N.; Künneke, R. Moral values as factors for social acceptance of smart grid technologies. *Sustainability* **2018**, *10*, 2703. [CrossRef]
46. Harzing, A.W. Reflections on Google Scholar. Available online: https://harzing.com/publications/white-papers/google-scholar-a-new-data-source-for-citation-analysis (accessed on 15 October 2020).
47. Ryghaug, M.; Skjølsvold, T.M.; Heidenreich, S. Creating energy citizenship through material participation. *Soc. Stud. Sci.* **2018**, *48*, 283–303. [CrossRef]
48. Lennon, B.; Dunphy, N.; Gaffney, C.; Revez, A.; Mullally, G.; O'Connor, P. Citizen or consumer? Reconsidering energy citizenship. *J. Environ. Policy Plan.* **2020**, *22*, 184–197. [CrossRef]
49. Ottinger, G. Making sense of citizen science: Stories as a hermeneutic resource. *Energy Res. Soc. Sci.* **2017**, *31*, 41–49. [CrossRef]
50. Pettibone, L.; Blättel-Mink, B.; Balázs, B.; Di Giulio, A.; Göbel, C.; Heubach, K.; Hummel, D.; Lundershausen, J.; Lux, A.; Potthast, T.; et al. Transdisciplinary sustainability research and citizen science: Options for mutual learning. *GAIA* **2018**, *27*, 222–225. [CrossRef]
51. Tauginienė, L.; Butkevičienė, E.; Vohland, K.; Heinisch, B.; Daskolia, M.; Suškevičs, M.; Portela, M.; Balázs, B.; Prūse, B. Citizen science in the social sciences and humanities: The power of interdisciplinarity. *Palgrave Commun.* **2020**, *6*, 1–11. [CrossRef]
52. Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G.; Altman, D.; Antes, G.; Atkins, D.; Barbour, V.; Barrowman, N.; Berlin, J.A.; et al. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Med.* **2009**, *7*. [CrossRef]

53. Wuebben, D. From wire evil to power line poetics: The ethics and aesthetics of renewable transmission. *Energy Res. Soc. Sci.* **2017**, *30*, 53–60. [CrossRef]
54. Hess, D.J. Energy democracy and social movements: A multi-coalition perspective on the politics of sustainability transitions. *Energy Res. Soc. Sci.* **2018**, *40*, 177–189. [CrossRef]
55. Feldpausch-Parker, A.M.; Endres, D.; Peterson, T.R. Editorial: A Research Agenda for Energy Democracy. *Front. Commun.* **2019**, *4*, 1–8. [CrossRef]
56. Calabrese-Barton, A.M. Citizen(s') Science. *Democr. Educ.* **2012**, *20*, 1–4.
57. Cuppen, E. The value of social conflicts. Critiquing invited participation in energy projects. *Energy Res. Soc. Sci.* **2018**, *38*, 28–32. [CrossRef]
58. Sovacool, B.K.; Brown, M.A. Deconstructing facts and frames in energy research: Maxims for evaluating contentious problems. *Energy Policy* **2015**, *86*, 36–42. [CrossRef]
59. Lacey-Barnacle, M. Proximities of energy justice: Contesting community energy and austerity in England. *Energy Res. Soc. Sci.* **2020**, *69*, 101713. [CrossRef]
60. Chilvers, J.; Pallett, H. Energy Democracies and Publics in the Making: A Relational Agenda for Research and Practice. *Front. Commun.* **2018**, *3*, 1–16. [CrossRef]
61. Wuebben, D.; Romero-Luis, J.; Gertrudix, M. Sample Records. Citizen Science and Citizen Energy Communities: A Systematic Review of Potential Alliances for SDGs. Available online: https://zenodo.org/record/4122068 (accessed on 1 November 2020).
62. Koirala, B.P.; Koliou, E.; Friege, J.; Hakvoort, R.A.; Herder, P.M. Energetic communities for community energy: A review of key issues and trends shaping integrated community energy systems. *Renew. Sustain. Energy Rev.* **2016**, *56*, 722–744. [CrossRef]
63. Soeiro, S.; Ferreira Dias, M. Energy cooperatives in southern European countries: Are they relevant for sustainability targets? In Proceedings of the International Conference on Energy and Environment Research, Aveiro, Portugal, 22–25 July 2019; Volume 6, pp. 448–453.
64. Süsser, D.; Döring, M.; Ratter, B.M.W. Harvesting energy: Place and local entrepreneurship in community-based renewable energy transition. *Energy Policy* **2017**, *101*, 332–341. [CrossRef]
65. Soares da Silva, D.; Horlings, L.G. The role of local energy initiatives in co-producing sustainable places. *Sustain. Sci.* **2020**, *15*, 363–377. [CrossRef]
66. Lisjak, J.; Schade, S.; Kotsev, A. Closing data gaps with citizen science? Findings from the Danube Region. *ISPRS Int. J. Geo-Inf.* **2017**, *6*, 277. [CrossRef]
67. Constant, N.; Roberts, L. Narratives as a mode of research evaluation in citizen science: Understanding broader science communication impacts. *J. Sci. Commun.* **2017**, *16*, 1–18. [CrossRef]
68. Richter, A.; Sieber, A.; Siebert, J.; Miczajka-Rußmann, V.L.; Zabel, J.; Ziegler, D.; Hecker, S.; Frigerio, D. Storytelling for narrative approaches in citizen science: Towards a generalized model. *J. Sci. Commun.* **2019**, *18*, 1–24. [CrossRef]
69. Malone, E.; Hultman, N.E.; Anderson, K.L.; Romeiro, V. Stories about ourselves: How national narratives influence the diffusion of large-scale energy technologies. *Energy Res. Soc. Sci.* **2017**, *31*, 70–76. [CrossRef]
70. Moezzi, M.; Janda, K.B.; Rotmann, S. Using stories, narratives, and storytelling in energy and climate change research. *Energy Res. Soc. Sci.* **2017**, *31*, 1–10. [CrossRef]
71. Komendantova, N.; Neumueller, S. Discourses about energy transition in Austrian climate and energy model regions: Turning awareness into action. *Energy Environ.* **2020**, *31*, 1473–1497. [CrossRef]
72. Alvial-Palavicino, C.; Garrido-Echeverría, N.; Jiménez-Estévez, G.; Reyes, L.; Palma-Behnke, R. A methodology for community engagement in the introduction of renewable based smart microgrid. *Energy Sustain. Dev.* **2011**, *15*, 314–323. [CrossRef]
73. Delina, L.L. A rural energy collaboratory: Co-production in Thailand's community energy experiments. *J. Environ. Stud. Sci.* **2020**, *10*, 83–90. [CrossRef]
74. Scott, M.G.; McCarthy, A.; Ford, R.; Stephenson, J.; Gorrie, S. Evaluating the impact of energy interventions: Home audits vs. community events. *Energy Effic.* **2016**, *9*, 1221–1240. [CrossRef]
75. Dinusha Rathnayaka, A.J.; Potdar, V.M.; Dillon, T.S.; Kuruppu, S. Formation of virtual community groups to manage prosumers in smart grids. *Int. J. Grid Util. Comput.* **2015**, *6*, 47–56. [CrossRef]
76. Cai, Y.; Huang, T.; Bompard, E.; Cao, Y.; Li, Y. Self-sustainable community of electricity prosumers in the emerging distribution system. *IEEE Trans. Smart Grid* **2017**, *8*, 2207–2216. [CrossRef]

77. Zafar, R.; Mahmood, A.; Razzaq, S.; Ali, W.; Naeem, U.; Shehzad, K. Prosumer based energy management and sharing in smart grid. *Renew. Sustain. Energy Rev.* **2018**, *82*, 1675–1684. [CrossRef]
78. Lazowski, B.; Parker, P.; Rowlands, I.H. Towards a smart and sustainable residential energy culture: Assessing participant feedback from a long-term smart grid pilot project. *Energy. Sustain. Soc.* **2018**, *8*, 1–21. [CrossRef]
79. Costa, D.L.; Kahn, M.E. Energy conservation "nudges" and environmentalist ideology: Evidence from a randomized residential electricity field experiment. *J. Eur. Econ. Assoc.* **2013**, *11*, 680–702. [CrossRef]
80. Momsen, K.; Stoerk, T. From intention to action: Can nudges help consumers to choose renewable energy? *Energy Policy* **2014**, *74*, 376–382. [CrossRef]
81. Sudarshan, A. Nudges in the marketplace: The response of household electricity consumption to information and monetary incentives. *J. Econ. Behav. Organ.* **2017**, *134*, 320–335. [CrossRef]
82. Cappa, F.; Rosso, F.; Giustiniano, L.; Porfiri, M. Nudging and citizen science: The effectiveness of feedback in energy-demand management. *J. Environ. Manag.* **2020**, *269*, 1–13. [CrossRef]
83. Forshaw, S.; Newman, P.; Ferrario, M.A.; Simm, W.; Friday, A.; Coulton, P. Stimulating a dialogue on renewable energy through making. In Proceedings of the 2014 Companion Publication on Designing Interactive Systems, New York, NY, USA, 17–20 June 2014; Association for Computing Machinery: New York, NY, USA, 2014; pp. 17–20. [CrossRef]
84. Seyfang, G.; Smith, A. Grassroots innovations for sustainable development: Towards a new research and policy agenda. *Environ. Polit.* **2007**, *16*, 584–603. [CrossRef]
85. Van Summeren, L.F.M.; Wieczorek, A.J.; Bombaerts, G.J.T.; Verbong, G.P.J. Community energy meets smart grids: Reviewing goals, structure, and roles in Virtual Power Plants in Ireland, Belgium and the Netherlands. *Energy Res. Soc. Sci.* **2020**, *63*, 1–14. [CrossRef]
86. Green, J.; Newman, P. Citizen utilities: The emerging power paradigm. *Energy Policy* **2017**, *105*, 283–293. [CrossRef]
87. Verkade, N.; Höffken, J. Collective energy practices: A practice-based approach to civic energy communities and the energy system. *Sustainability* **2019**, *11*, 3230. [CrossRef]
88. Moss, T. Intermediaries and the governance of sociotechnical networks in transition. *Environ. Plan. A Econ. Sp.* **2009**, *41*, 1480–1495. [CrossRef]
89. Bird, C.; Barnes, J. Scaling up community activism: The role of intermediaries in collective approaches to community energy. *People Place Policy Online* **2014**, *8*, 208–221. [CrossRef]
90. Irwin, A. Constructing the scientific citizen: Science and democracy in the biosciences. *Public Underst. Sci.* **2001**, *10*, 1–18. [CrossRef]
91. Wallmeier, F.; Thaler, J. Mayors' leadership roles in direct participation processes—The case of community-owned wind farms. *Int. J. Public Sect. Manag.* **2018**. [CrossRef]
92. Van der Waal, E.C.; van der Windt, H.J.; van Oost, E.C.J. How local energy initiatives develop technological innovations: Growing an actor network. *Sustainability* **2018**, *10*, 4577. [CrossRef]
93. Warbroek, B.; Hoppe, T.; Coenen, F.; Bressers, H. The role of intermediaries in supporting local low-carbon energy initiatives. *Sustainability* **2018**, *10*, 2450. [CrossRef]
94. Hargreaves, T.; Hielscher, S.; Seyfang, G.; Smith, A. Grassroots innovations in community energy: The role of intermediaries in niche development. *Glob. Environ. Chang.* **2013**, *23*, 868–880. [CrossRef]
95. Van Der Schoor, T.; Scholtens, B. Power to the people: Local community initiatives and the transition to sustainable energy. *Renew. Sustain. Energy Rev.* **2015**, *43*, 666–675. [CrossRef]
96. Hargreaves, T.; Middlemiss, L. The importance of social relations in shaping energy demand. *Nat. Energy* **2020**, *5*, 195–201. [CrossRef]
97. European Commission. *Horizon 2020 Green Deal Work Program (2018–2020) 10. Secure, Clean and Efficient Energy Call: BUILDING a Low-Carbon, Climate Resiliant Future*; European Commission: Brussels, Belgium, 2020; ISBN 1620182019202.
98. Gorroño-Albizu, L.; Sperling, K.; Djørup, S. The past, present and uncertain future of community energy in Denmark: Critically reviewing and conceptualising citizen ownership. *Energy Res. Soc. Sci.* **2019**, *57*, 101231. [CrossRef]
99. Allen, E.; Lyons, H.; Stephens, J.C. Women's leadership in renewable transformation, energy justice and energy democracy: Redistributing power. *Energy Res. Soc. Sci.* **2019**, *57*, 101233. [CrossRef]

100. Kythreotis, A.P.; Mantyka-Pringle, C.; Mercer, T.G.; Whitmarsh, L.E.; Corner, A.; Paavola, J.; Chambers, C.; Miller, B.A.; Castree, N. Citizen social science for more integrative and effective climate action: A science-policy perspective. *Front. Environ. Sci.* **2019**, *7*. [CrossRef]
101. Creamer, E.; Taylor Aiken, G.; van Veelen, B.; Walker, G.; Devine-Wright, P. Community renewable energy: What does it do? Walker and Devine-Wright (2008) ten years on. *Energy Res. Soc. Sci.* **2019**, *57*, 101223. [CrossRef]
102. UN Statistical Commission. *Global Indicator Framework for the Sustainable Development Goals and Targets of the 2030 Agenda for Sustainable Development*; UN Statistical Commission: New York, NY, USA, 2020.
103. Arnold, B.B. Environmental Sousveillance, Citizen Science and Smart Grids. In *Intellectual Property and Clean Energy: The Paris Agreement and Climate Justice*; Springer: Singapore, 2018; pp. 375–398. ISBN 9789811321559.
104. Wiese, F.; Schlecht, I.; Bunke, W.D.; Gerbaulet, C.; Hirth, L.; Jahn, M.; Kunz, F.; Lorenz, C.; Mühlenpfordt, J.; Reimann, J.; et al. Open Power System Data—Frictionless data for electricity system modelling. *Appl. Energy* **2019**, *236*, 401–409. [CrossRef]