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Beyond customer acquisition: A comprehensive review of community participation in mini grid projects

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ABSTRACT

Mini grids are increasingly recognized as a solution for the 840 million people globally without access to electricity and for the additional millions of people poorly served by traditional grid infrastructure. Understanding the role and importance of community participation in mini grid inception, design, build, and operations and maintenance will be essential to sustainably achieving universal access. This review analyzes the literature on community participation in private mini grid projects: how community participation is defined, in which phases of the project it arises, and how it affects the project's sustainability. We find that community participation is almost universally invoked as essential to system sustainability. Community participation most often appears in the operations and maintenance phase, leading to a positive social sustainability. We compile best practices, such as initiating participation early, pursuing wide inclusion, investing in community technical capacity, and creating clear governance models. Finally, we provide a framework and accompanying survey tool to gather information on community participation in mini grid systems to attenuate literature gaps. Community participation in mini grid projects should be leveraged to accelerate universal electricity access and green economic recovery, but it must go beyond surface level customer acquisition.

1. Introduction

Mini grids[1] present a tremendous opportunity to meet Sustainable Development Goal (SDG) 7's call for "access to affordable, reliable, sustainable, and modern energy for all" [1]. Due to cost declines for solar and solar hybrid mini grids, the World Bank's Energy Sector Management Assistance Program (ESMAP) has projected that "mini grids will become the least-cost solution for grid-quality electricity for more than 60% of the unelectrified population in Africa" [2]. To provide for the 840 million who lack access to electricity, there are 4000 mini grid systems under development in Africa, and the Rockefeller Foundation committed to 10,000 more in response to the COVID19 Pandemic [3]. These developments represent an incredible opportunity for pro-community, pro-women, and pro-ethnic minority social justice-centered projects, as energy access is linked to at least 9 of the 17 Sustainable Development Goals (SDGs) [4]. Although these opportunities could also come from grid access, mini grids can provide a vital interim level of service until a reliable grid is available [5].

Despite the opportunity mini grids present, rates of system failure remain high due to technical, economic, political, and social challenges [6,7]. There has been notable work conducted globally on these decentralized energy systems, particularly the technical and economic aspects [2]. The mini grid literature has covered different mechanisms to finance this energy access [8], the cost and benefits of different technologies [9,10], and consumers' willingness and ability to pay [11]. The technical literature on mini grids has addressed improving system efficiency [12], selecting an appropriate technology based on physical contexts and spatial mapping [13–16], and modeling different scenarios [17]. Although previously the least-understood social aspect of a mini

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[1] The World Bank's Energy Sector Management Assistance Program (ESMAP) defines mini grids as "electric power generation and distribution systems that provide electricity to just a few customers in a remote settlement or bring power to hundreds of thousands of customers in a town or city" [2] (pg.3). They note that the vast majority of system sizes "ranged from a few kW to several MW in installed capacity" [2] (pg.3).

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List of abbreviations:

ESMAP	Energy Sector Management Assistance Program
EthOS	e-theses online service (from the British Library)
GNESD	Global Network on Energy for Sustainable Development
NDLTD	Networked Digital Library of Theses and Dissertations
O&M	Operations and Maintenance
PV	Photovoltaic
RMI	Rocky Mountain Institute
SDG	Sustainable Development Goal
SE4ALL	Sustainable Energy for All
UN	United Nations
UNIDO	The United Nations Industrial Development Organization

grid system [18], there has been an emergence of research on the social components of a mini grid [19–21].

Previous reviews have addressed challenges for mini grids in reaching the base of the pyramid market [22], the risks and benefits of PV mini grid systems [23], factors that broadly influence the success of the mini grid system [24], and best practices from seven mini grid case studies [25]. However, there has yet to be a review on the social aspects of mini grid systems and how community members interact with each other regarding the mini grid.

As social challenges have been found to derail mini grid projects, we must understand *if (and if so, how)* community participation, a fundamental social aspect, affects sustainable – and equitable - system performance in the effort towards universal access to electricity. This is particularly salient for private mini grid projects as many do not explicitly have to incorporate the community beyond the grounds of a purely financial relationship, as compared with community owned or hybrid ownership models. The current mini grid industry has seen 259 million dollars of private investment since 2013 and has substantial profit potential for private developers (3.3 billion dollars annually), according to ESMAP [2]. Private projects have clear economic outcomes to meet from private investors, governments, or aid agencies, but lack clear guidance on if and if so, exactly how community participation, a costly component [2], can help meet project goals.

This work investigates the field's current understanding of how community participation affects private mini grid projects. Our aim in this review is to guide researchers and practitioners to better understand the social dimensions of energy delivery models and pursue best practices accordingly. We structured this review to address three underlying questions: (1) How is "community participation" defined or discussed in relation to mini grid projects? (2) What are the principal phases of the mini grid projects where community participation takes place? (3) How does community participation affect the sustainability of the mini grid project? Shedding light on these questions will support the global community in achieving SDG 7.

We grounded our work in a framework developed by the United Nations (UN) and Sustainable Energy for All (SE4ALL) which outlines lifecycle phases and components of sustainability in the context of off-grid energy systems [26].[2] The framework defined four project lifecycle phases: inception, design, build, and operation and maintenance (O&M). They are defined according to the key outcomes in each phase: inception, to "define core goals and approach; " design, to "finalize facility siting, expected needs, and system sizing; "[3] build, to "undertake procurement and execute installation contracts; "[4] and O&M, to "ensure system performance for its expected life." We adapted the UN/SE4ALL framework[5] to categorize references to community participation within three broad categories of sustainability[6] (economic, technical, and social).

This review adds to the literature in three meaningful ways. It is the first article to our knowledge to review and explore community participation employed within energy access discourse and specifically focus on private projects. Secondly, it refines the field's high-level understanding of the impacts of community participation for practitioners to more efficiently operationalize it for expanded access. Thirdly, it raises visibility on the equity and justice concerns at play in the evolving energy access paradigm.

2. Methods

We conducted a comprehensive literature search to answer the outlined questions within the scope of this review between March to July 2020. The primary criteria for eligibility within this study was a quantitative or qualitative article or report of a mini grid program in low- and middle-income countries that discussed community participation between the years of 2000 and 2020. This year range was selected to reflect the current state of the literature on this subject. We searched bibliographic databases including Science Direct, Web of Knowledge, and Google Scholar. Additionally, we incorporated dissertations and masters' theses through Proquest Dissertations & Theses, EthOS, and NDLTD. Additionally, we performed an exhaustive search of the grey literature on community participation with respect to mini grid energy access, querying the databases and resource libraries of multilateral research, finance and development institutions like the World Bank's ESMAP, various divisions of the United Nations, bilateral aid agencies, non-profit think tanks and research institutes, as well as public reports authored by energy access practitioners, trade groups, and relevant market participants. Throughout the studies identified, we conducted hand searches from their references. We consulted experts in the field of decentralized electrification to inform and validate research questions and findings. The terms searched within each database include "mini grid," "off-grid," and "decentralized electricity," with each of these paired with "participation" and "engagement." We excluded studies that only addressed technical or economic aspects of mini grids and those concerned with Common Pool Resource (CPR) structures. While CPR does not dictate a particular governance or management structure, we excluded that literature to focus on private projects and not address the discourse on public goods vs. common resources.

From this initial search, we identified 248 papers through abstract screening based on our primary criteria. We then evaluated those 248 papers in their entirety and identified 78 to be included. We tracked whether the paper was peer-reviewed literature, grey literature, or a

[2] While the framework was developed for sustainability in the context of standalone PV systems for health and educational facilities in emerging markets (not mini grids explicitly), it is a useful framework to think about the longevity and sustainability of any off-grid power system).

[3] Although not outlined in the UN/SE4All framework, design is also an outcome of budget. In a private project, this could be the balancing of the communities' willingness and ability to pay, rather than their expected needs.

[4] At the end of the build phase, before O&M, there is typically a process of commissioning or onboarding. In private projects, this is customer registration where those obtaining a connection will sign up and receive some level of orientation to activate their account, pre-pay their bill, etc. Although this process did not come up as community participation in any of the papers, we want to acknowledge it.

[5] We note that the UN and SE4ALL framework outlines the sustainability aspects as economic, technical, and organizational [26]; however, we adapted this framework to be economic, technical, and social.

[6] The SE4ALL framework defines sustainability as "the reliable delivery of energy services over time." [26].

thesis, whether the paper covered multiple or just a single mini grid, and whether the paper included the technical specifications of the mini grid (s). We also tracked the technical information from the papers that did include the technical specifications (i.e., details on generation type, peak capacity, batteries, inverters, charge controllers, etc.). We recorded the location of the mini grids within the papers and first and last author affiliations. Finally, we tracked the research methods of each paper.

The selected papers were saved in a shared folder within the reference manger, Mendeley, to be individually read in full. We conducted an in-depth qualitative analysis in which we hand coded the 78 included papers for recurring themes addressing our three core research questions. Following a ground theory approach, we developed the coding criteria as we read the included papers [27].We then organized that thematic analysis within the UN/SE4All's framework for mini grid lifecycle and sustainability. Finally, we recorded if each coded instance of community participation had a positive, negative, or neutral effect on the project.

3. Results

The results section first chronicles the literature included and reports their sources, study locations and technical features. Next, we address definitions of community participation and examples of community participation in the lifecycle phases and sustainability aspects of the mini grid. Within the lifecycle and sustainability analysis, we again evaluated the differences in region, technical aspects, and literary source. This analysis attempted to parse out differentiations in community participation's role in mini grid projects across regions, system types, and types of literature. For example, we investigated if community participation is prioritized differently in Sub-Saharan Africa than in other regions, if generation type or system size impacts participation, and if peer reviewed literature discusses community participation differently than grey reports.

Of the 78 included papers, 40 of the case studies included the technical specificities of the reviewed mini grid installations (i.e., generation capacity, storage capacity); the remaining 38 papers either did not systematically document or only provided a range/average of the technical details of the mini grid systems (e.g., a study that evaluated 65 off-grid solar photovoltaic (PV) projects, but only offered their average peak power [28]) (Fig. 1). Of the 78 case study papers, 37 papers were peer-reviewed literature, 31 were grey literature, and 10 were theses. Thirty-six papers utilized only qualitative methods, such as semi-structured, in depth, and/or expert interviews, focus groups, participant observation, participatory methods, photograph analysis, and document review. Nine studies utilized only quantitative methods typically through survey analysis. However, 33 case studies relied on both qualitative and quantitative methods. In total, the papers included in this review offer the technical specifications of 154 mini grid installations in the developing world. Throughout the analysis, we explicitly refer in figures and text to either papers or specific systems. Papers often covered multiple systems (with different technical specifications), which explains the difference between 78 papers and 154 specific technical systems (Fig. 1).

3.1. Location and technical details of specific systems

The locations of installations for which technical specificities were included are outlined in Fig. 2. From the 154 specific cases, the system sizes ranged from 0.4 kW to 10.7 MW with an average and median capacity of 284 kW and 41.5 kW respectively. Eighteen of the 154 specific systems detailed the battery storage, which ranged from 1.56 kWh to 7776 kWh, with an average and median of 545.5 kWh and 54.72 kWh

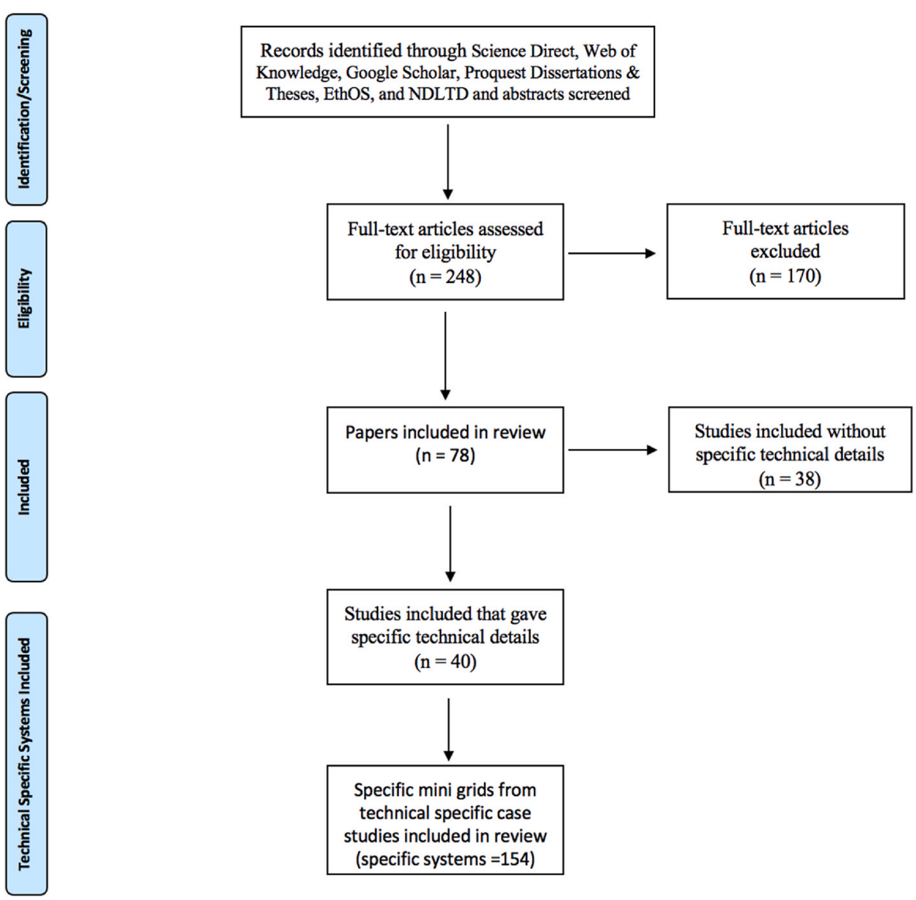

Fig. 1. Literature selection process from identification and screening to the papers included and finally the specific systems. Adapted from Ref. [29].

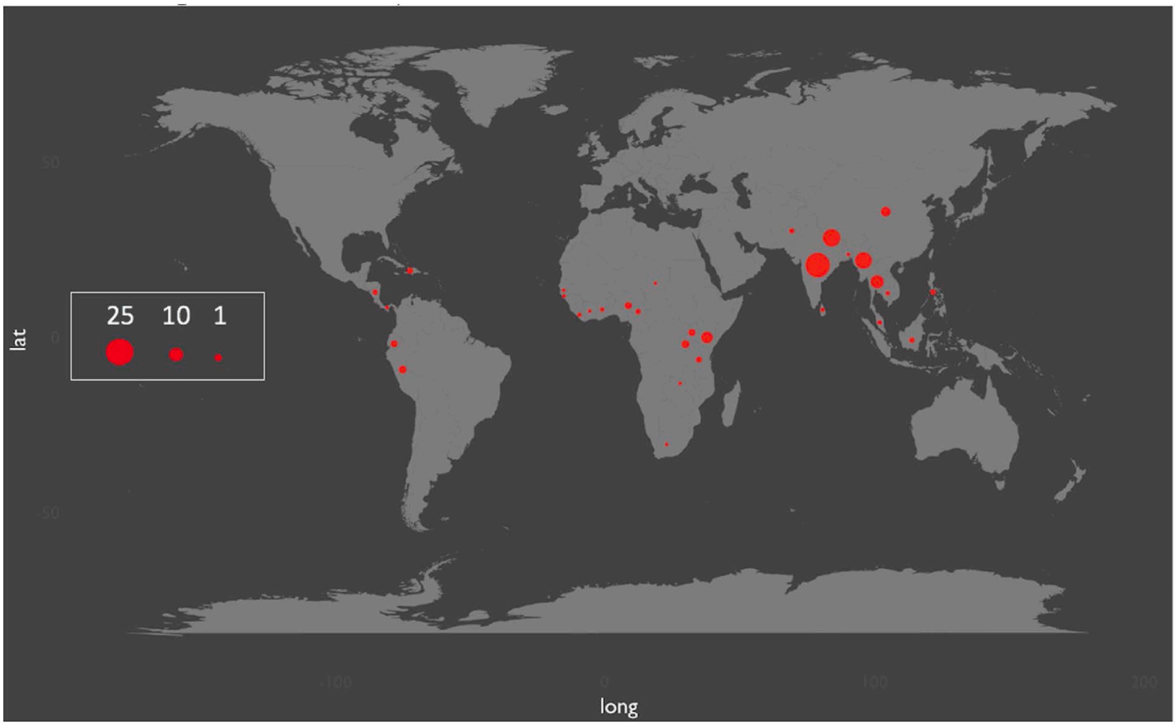

Fig. 2. Locations of the specific mini grid systems included in this review (n = 154) from the 40 papers out of the 78 that provided technical specifications.

respectively. Only four cases mentioned the type of inverter, while three cases indicated the size of the charge controller. We evaluated the type of generation for the technically specific case studies (Fig. 3). Solar photovoltaic and micro-hydro were the most common generation sources (Fig. 3). Appendix A contains extensive details on the specific case studies (e.g., details on generation type, peak capacity, batteries, inverters, charge controllers, etc.).

This review found that the majority of papers discussing community participation originated in Asia, followed by Sub-Saharan Africa (Fig. 2). We also found that PV and hydro were the most common generation sources within the specific systems included, while diesel, biomass, and wind contribute considerably fewer observations (Fig. 3). Within the limitations of our review, this suggested that studies in Asia and projects on PV and hydro may require or prioritize community participation within their projects.

3.2. Discourse and definitions of community participation

A range of definitions have been used in discussing community participation within mini grid projects that explicitly define both terms (community and participation), offer lists of actions, or critique the definitions used in practice. While the term has been used extensively, few papers reviewed explicitly defined community participation. Some of the case studies defined community participation as the dual reality of the residents as individuals benefiting from a project and individuals who also have power over the project [30,31]. Others defined it as a list of tasks that the community is involved in Refs. [19,32] or even as an explicit right [33]. These definitions agree on the necessity of community members' involvement but lack clarity and consensus on the specifics and how much agency communities actually exert.

Grey literature, whose primary audience is either developers or the energy access stakeholder community, seemed to refer to "community participation" interchangeably with "community engagement." However, engagement was often a term used to imply customer acquisition and retention rather than active participation in the project's operation or management. In an evaluation of an off-grid PV project in Chile, Feron critiques community participation in practice stating that "participation is still understood as the provision of information, rather than the engagement of the community from cradle to grave." [34] This peer-reviewed critique suggests that in the grey literature, communities are often seen only as customers, rather than actively engaged in project governance.

Grey literature's use of community engagement to imply customer acquisition and retention can be viewed as a type of community participation but should not be equated with more involved definitions. Although there were some examples of grey literature attempting to outline the importance of community participation, an overarching framework for community participation such as the one presented in this review, will be a useful contribution for both literature and practice.

Discourse within peer-review literature highlighted the differences between disciplines; literature with social science methods emphasized power dynamics [30,34], while policy-focused research tended to define

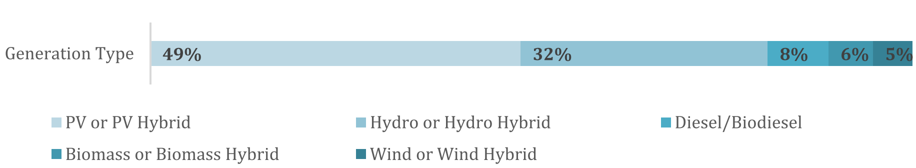

Fig. 3. The frequency of different generation sources for the mini grids with case studies that provided technical details of installed systems (specific systems = 154 from 40/78 papers). We define "hybrid" as any system that had multiple sources of generation. We identify the main generation source for the hybrid from the largest contributing generation type, besides diesel, which is often oversized for back-up generation. For example, a system that has 7.5 kW solar photovoltaic (PV), 1 kW Wind, and 65 kW A diesel would be classified as PV Hybrid [30]. PV and micro-hydro were the most common generation sources between both groups of case studies for this review.

community participation through a list of specific actions [19]. Despite these differences, peer-reviewed and grey literature were equally as likely to discuss equity and gender in relation to community participation, if not explicitly in the definition.

Examination of the literature revealed a range of definitions of community participation and noted a spectrum of involvement [35–38]. Eckert noted that there is a spectrum of community participation based on who runs the project, who is involved, and who has influence over the process, as contrasted with who benefits from the project [39]. The German Corporation for International Cooperation defined community engagement to include “a wide spectrum of activities and tools … the level of engagement ranges from basic information provision and consultation to inclusive, participatory project planning and implementation.” [40] While these papers touched on the complexity involved in community participation, they neglected to categorize them comprehensively or map their effects or interactions.

Despite the lack of a clear definition or the establishment of clean causation, the literature that mentions community participation overwhelmingly attributed a positive role to community participation on the success of off-grid projects, stating that it was “crucial,” “important,” and “a key factor” for the project [31,34,35,41–53]. An evaluation of a project in Mozambique, for example, offered that “an evident requirement for a successful implementation must always be strong individual, community participation, and engagement.” [45] The United Nations Industrial Development Organization (UNIDO) listed community participation as one of five criteria for long term success from evaluating eight of their renewable energy mini grid projects [36].

Despite the spectrum of definitions and consensus that community participation is important, the literature that mentioned it made clear the challenges associated with developing participation; evaluations of wind and micro hydro projects discussed in particular the challenges associated with maintaining community participation over time, noting a decrease since implementation [54,55].

3.3. Lifecycle phases

To comprehensively categorize the ways in which community participation may take place in mini grid projects, we evaluated references to community participation by the UN/SE4ALL’s lifecycle phases (inception, design, build, and operations and maintenance). These lifecycle phases in practice are not strictly mutually exclusive, but for the purposes of analysis, we grouped discussion of community participation in mini grid projects in the literature reviewed along these four phases of the lifecycle in order to systematically interrogate where community participation principally emerges and how it is discussed. Fig. 4 outlines all the specific aspects within each phase. Forty-five out of the 78 papers mentioned community participation in at least one of the lifecycle phases.

3.3.1. Inception

Twenty-three papers of the 78 included predominantly discussed community participation in the context of the inception phase of a mini grid’s lifecycle, focusing on the implications of community participation on initial financing, project initiation, planning, and decision-making processes [38,40,53,56–60] (See Fig. 4).

Some projects required the community to contribute to the capital costs of the project [2,37]. The Global Network on Energy for Sustainable Development (GNESD) offered the suggestion of a 30% contribution [35]. UNIDO suggested that community participation could be leveraged to attract investment, as projects with community participation are often more sustainable [36]. These capital cost contributions involved the community in the project, but often the community’s role extended into the planning of the project.

Community participation was frequently invoked in the context of a project’s decision-making process. For instance, a Micro-Hydro Power Project resulted in the creation of seven to 13 member user committees “to manage the process of the project from initiation to continued operation.” [51] In a comparison of case studies in Rwanda and Uganda, one evaluation noted the importance of creating a “forum for decision making that provides equal and fair opportunities for all parties to voice their opinion and to express their preferences and establish a connection between the participatory bodies of decision making and the political implementation level” [54]. Palit explicitly expressed this point, writing, about projects in South Asia, that “in off-grid programs the involvement of rural communities, particularly their participation in decision-making committees, has added value to the planning process.” [20] A hydropower project in Laos created a blueprint which prescribes that the community has to be involved from the very beginning (i.e., attending the first site visit and holding weekly meetings) [61]. They noted the importance of creating an easily understandable plan of action with the community [61]. These studies advocated for clear and early community involvement.

Inclusion of the community in the planning process often took place during meetings [38,59,62–64]. Beyond having key community members as part of the planning and initiation process, these meetings were a way to consult the entire community and bring stakeholders together [33,51]. Meeting frequency and the percentage of participation from the community in these meetings were cited as a metric to gauge engagement and the sustainability of the project [28,55,65]. Project initiation and planning was a key aspect of community participation as it implied that the community was driving the project and thus would support its eventual financial and technical operation.

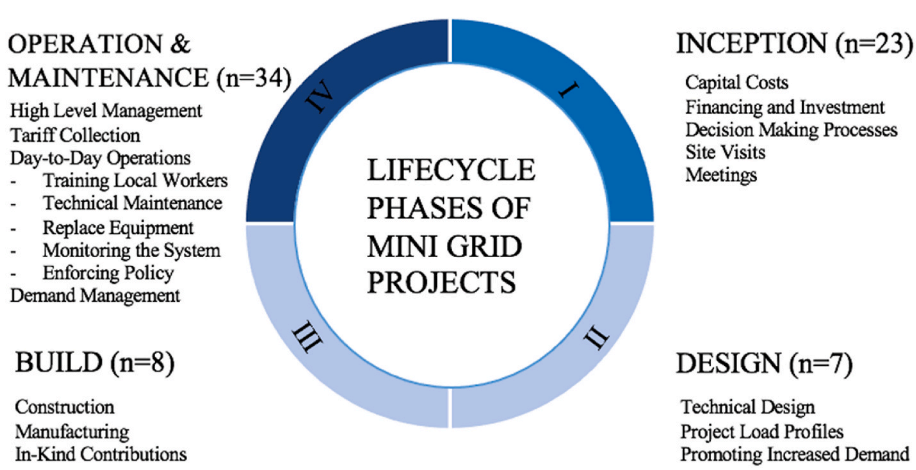

Fig. 4. This figure evaluates the number of papers out of the 78 included that mention community participation in different lifecycle phases of the mini grid project as outlined by the UN and SE4ALL Sustainability Framework. Darker color corresponds to an increasing number of papers. Not every specific system mentioned community participation in a lifecycle phase, while others mentioned multiple. In the case of no mentions, the paper is not represented; however, in the case of multiple mentions, the paper is counted in each respective lifecycle phase. Some papers only mentioned community participation in regard to sustainability aspects (which we address in a later section) but did not comment on which lifecycle phase. Therefore, these papers are not reflected in these numbers. This figure represents 45 unique papers, meaning that 45 out of the 78 included papers mentioned community participation in at least one of the lifecycle phases.

3.3.2. Design

Only seven papers of the 78 included mentioned community inclusion in the design of the system (See Fig. 4). These papers principally considered the role of community participation in system design with respect to estimating local demand, for example in order to produce load profiles around which to design the system as well as project future demand [66,67]. Community input was also observed as a necessary avenue through which to assess willingness-to-pay for these demand estimations [56,57,68]. This willingness to pay was crucial to ensure that the community at large make use of the full potential of the system. Mini grid developers employ various strategies to interact, react to, or influence the community's use of an installed mini grid system (e.g., reducing or increasing consumption or shifting the times of electricity consumption or what it is used for) [69]. We thus note that the Design phase of a mini grid includes not just technical aspects of design, but operational and organizational elements as well. For example, community participation played an important role in promoting the development of 'productive' loads, critical to achieving high system utilization [70].

3.3.3. Build

The Build phase was the third most frequent lifecycle phase in which community participation was mentioned (n = 8 out of 78) (See Fig. 4). Throughout the physical build of the mini grid project, a highly cited aspect of community participation was the involvement of the community in the construction [7] and manufacturing of the system [40,57,62,63,71]. For example, a case study in Pakistan suggested a temporary Project Committee to be responsible for the mini grid only throughout construction [7]. Only one study involved the community in manufacturing, in which local members constructed wind turbines for the mini grid [71]. Participation in this phase could also lead to better financial outcomes as well, which we discuss in a later section.

Another highly discussed aspect of community participation in the Build phase was the provision of in-kind contributions for the implementation of the project [40,57,62,63]. For the build of the mini grid, communities often offer in-kind contributions of land [37], their time and labor [37,59,62], transport to often remote locations [39], and materials. The community could also be involved in local resource assessments [68] and in preparation for the build or the procurement of wooden poles or stones for the construction of the channel and powerhouse [7].

3.3.4. Operation and maintenance

Community participation featured most strongly in the O&M phase (n = 34 out of 78) compared to other lifecycle phases (see Fig. 4) [2,35–37,40,58,60]. Operations and maintenance is a broad phase of each project and activities included high level management, tariff collection, day-to-day operation, and demand management.

Given that projects are often geographically quite far from developers' or funders' headquarters, the community often bears much responsibility for the management and operation of the systems [35,52,57,59,62,63,66,72]. Management was a very ambiguous and varied concept in regard to mini grids and affected every phase of the project. However, management committees were most commonly related to the sustained operation of the mini grid. These management committees had different roles across projects, but typically were responsible for some financial aspect of the program that must be monitored locally. For example, a community micro- and pico-hydro project in Cameroon formed a "Local Project Management committee to operate, maintain and manage the schemes, tariff collection, payment of operators, and repayment of the loan," [73] while Maier writes of an Electric Management Committee that was only responsible for maintenance [7]. Community members were frequently cited as critical to tariff collection [36,37,59,60,74]; Energy 4 Impact found that 44% of developers exclusively use local agents to collect payments from users [75]. The community's management role extended beyond these examples of financial responsibility.

The community was found to also be involved in day-to-day O&M, which included training local workers [76,77], technical maintenance [77,78], the replacement of equipment [55], monitoring the system and enforcing rules [77,79] and verifying activities [80]. Often, these project tasks were coordinated locally through the creation of electricity committees for day-to-day operation [25,81], which were often separate from the overarching management committees. Overall, in some form, the community was involved in either the tariff collection or daily technical maintenance, often in the form of O&M committees.

Beyond traditional O&M, community participation was used to affect the demand for electricity of the mini grid [38,56,58,60,62,66,82,83], which is crucial to the continued operation of the system. In the design phase, there was proactive planning for demand projections, while in the O&M phase, the community actively participated in matching demand to supply. For example, community participation was cited as instrumental in changing patterns of energy consumption [84] and avoiding overuse [25]. Over-consumption was mitigated by the early inclusion of the community [85–87]. This was not an explicit goal set by the operators, but rather an aspect of the mini grid project for which community participation was found to be effective in practice [25,84–87].

3.3.5. Regional and literature type differences in lifecycle phases

We then evaluated if the avenues identified for community participation in each lifecycle phase of mini grid projects differed between regions. There was a similar distribution of examples of community participation across regions and lifecycle phases. We note that there were limited examples from South America in this review. Community participation overwhelmingly emerged in the O&M phase (see Fig. 6 and Figure C.3, Appendix C). Community participation in the design phase was common in the examples with multiple regions or a global focus. Global case reports most frequently cited community participation in the O&M phase, but Asian studies primarily mentioned community participation during Inception phase (see Fig. 6 and Figure C.3, Appendix C). This could be due to cultural, historical, and regional differences as there is no blueprint for community involvement.

Besides region, there were differences between the grey and peer-reviewed literature. The grey literature included more references to community participation across all four lifecycle phases (see Figure C.2, Appendix C). However, both grey literature and peer-review had the most examples of community participation in O&M (see Figure C.2, Appendix C). Seven grey literature pieces noted community participation in the Build of the mini grid, compared to only one in peer-reviewed literature. Examples of community participation were mostly drawn from studies after 2010, regardless of region or literature type. The timeline reveals that the past ten years have witnessed a significant growth of evaluation and work on community participation in mini grid projects.

3.3.6. Technical system differences in lifecycle phases

We investigated the types of generation and size of systems associated with the case studies that mentioned community participation in the four lifecycle phases of the project. Thirty-six out of the 40 papers that provided technical specifications mentioned community participation in a lifecycle phase (Fig. 5). Community participation in PV projects was most commonly associated with project inception, while participation in the build of the system was most common in wind projects. Community participation in Hydro and PV projects was most frequently cited for O&M (Fig. 5). The results in the upper panel of Fig. 5 indicate that community participation is relevant in each phase of the project regardless of generation source (full details in Table B.1, Appendix B); however, the literature is particularly attuned to the need for community participation in the O&M phase of PV/PV Hybrid Projects. The results suggest that wind may require more local coordination to build, while hydro and PV may need more resident maintenance. We

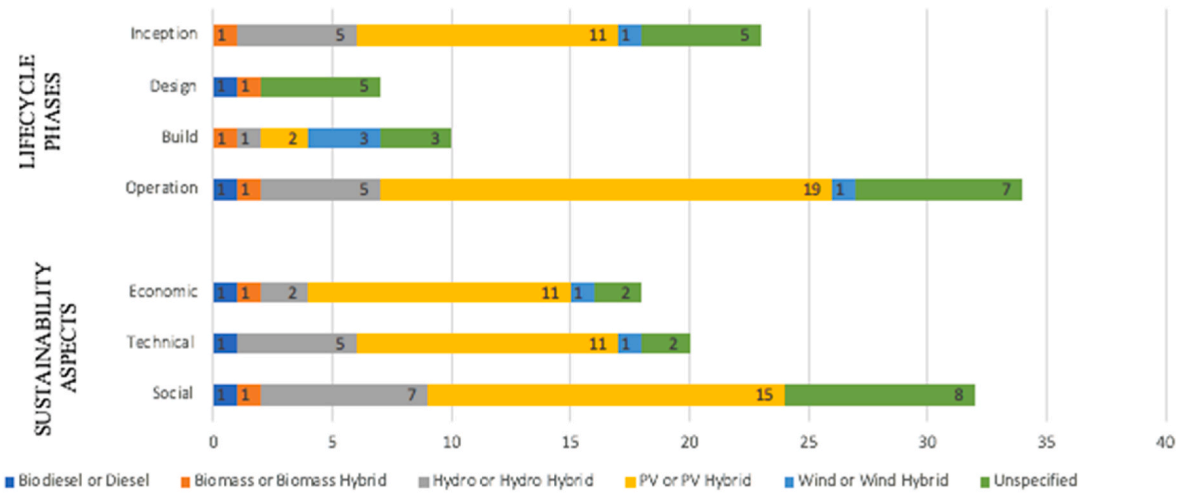

Fig. 5. This figure depicts the number of specific mini grid systems (out of 154) from the 40 papers that provided technical details and mentioned examples of community participation within a phase of the lifecycle (inception, design, build, and operation) or a sustainability aspect (economic, technical, and social) broken down by generation type. Not every specific system mentioned community participation in a lifecycle phase or a sustainability aspect, while others mentioned multiple. In the case of no mentions, the specific system is not represented; however, in the case of multiple mentions, the system is counted in each respective lifecycle phase or sustainability aspect. We define "hybrid" as any system that had multiple sources of generation. We identify the main generation source for the hybrid from the largest contributing generation type, besides diesel, which is often oversized for back-up generation. For example, a system that has 7.5 kW solar photovoltaic (PV), 1 kW Wind, and 65 kW A diesel would be classified as PV Hybrid [50]. The lifecycle phase section of the figure represents 36 unique papers, meaning that 36 out of the 40 papers that provided technical specifications mentioned community participation in at least one lifecycle phase. The sustainability aspect section of the figure represents 29 unique papers, meaning that 29 out of the 40 papers that provided technical specifications mentioned community participation affecting at least one aspect of sustainability.

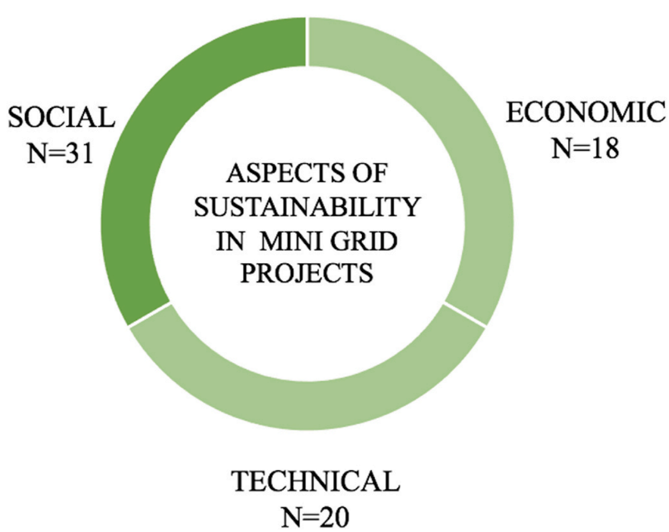

Fig. 6. This figure summarizes the number of papers out of the 78 included that mention community participation affecting aspects of the mini grid project as adapted from the UN and SE4ALL Sustainability Framework. The depth of color corresponds to an increasing number of papers. Not every specific system mentioned community participation in a sustainability aspect, while others mentioned multiple. In the case of no mentions, the paper is not represented; however, in the case of multiple mentions, the paper is counted in each respective aspect. If a paper mentioned both a technical and social outcome, then it would be double counted in this figure. Some papers only mentioned community participation in regard to lifecycle phases but did not comment on sustainability aspects. Therefore, these papers are not reflected in these numbers. This figure represents 55 unique papers, meaning that 55 out of the 78 included mentioned community participation affecting at least one of the sustainability aspects.

conducted the same analysis for system size (Table B.3. Appendix B), which revealed that there was no specific range of system size associated with community participation and a specific lifecycle phase.

3.4. Sustainability effects

We next address how community participation affects the sustainability of the system (economic, technical and social). Sustainability was rarely defined explicitly in these studies, but rather seemed to be equated with longevity of the technical system. The categories of economic, technical, and social are not mutually exclusive and have significant overlap and feedback loops; however, we identified which principal dimension of sustainability a document spoke to when referencing the ultimate outcome. The documents included in this section either explicitly or implicitly spoke to an effect of community participation on the mini grid system. Fifty-five out of the 78 included papers mentioned community participation affecting at least one of the sustainability aspects.

3.4.1. Economic sustainability

First, we address how community participation affected the economic aspect of the mini grid, which was the least cited out of our three lenses (n = 18 out of 78) (see Fig. 6). From a project development perspective, community participation was often cited as a main factor in reducing costs and time surrounding the projects [2,36,37,58]. The literature found that local monitoring, rule enforcement, labor, technicians, and maintenance can save projects money [31,39,70,88,89]. The Rocky Mountain Institute (RMI) found that improving 'customer engagement' could reduce the total system cost by 16.6% [72].˙UNIDO found that their "project in Sri Lanka shows that without community support and involvement, the project will experience delays, and insufficient understanding of sustainable operations of the mini grid may lead to inadequate tariffs to cover necessary maintenance costs." [36].

Community participation was linked to improved financial performance of the mini grid, which often led to a virtuous cycle (or without it, a vicious cycle) [57]. Local input could help plan appropriate generation costs and tariffs that the customers can and will pay [77,90]. This better financial performance led to a virtuous or healthy cycle of customers paying for electricity and operators maintaining the grid [25,72]. This was in contrast to a vicious cycle in which customers cannot or do not pay and operators cannot maintain the system. Case studies from Nigeria and Sierra Leone found that "community engagement facilitates rapid customer sign-ups, increased demand for energy, and willingness to pay for services" all of which improve the financial performance of the system [40]. RMI found in their mini grid projects in Nigeria that community engagement was crucial for demand pull and the ultimate scaling of these projects due to reduced costs at scale [38]. They explained that "continuous community engagement improves acquisition and retention of customers, maintains willingness to pay for power, and ensures the economic viability of the mini grid." [62] These examples from papers that mentioned community participation suggest that it was necessary beyond initial connections.

Despite the beneficial economic aspects from community participation, there are some concerns raised in the literature. Case studies from the South Pacific found that a third party (not the community) should be in charge of fee collection [91]. Despite the positive aspects of community participation within projects in India, "most stakeholders also agreed that genuine engagement with the community is difficult and costly to achieve." [37] Overall, despite program difficulties, community participation within the studies that mentioned it was found to have positive economic effects.

3.4.2. Technical sustainability

Only twenty out of 78 case studies mentioned community participation affecting the technical aspects of the system (see Fig. 6). Community participation was found to lead to the longevity of the technical system, both through proper maintenance and lack of theft, while a lack of training was identified as detrimental. Community participation was attributed to preventing failure and ensuring the sustainability or longevity of the project [2,36,72,92,93]. Studies noted that community participation prevented premature technical failure and the longevity of the system [25,28,31,77]. Finally, the Batti Ghar Foundation found that there was a high failure rate when a community was not involved [67]. These evaluations from studies that mentioned community participation were often vague in the exact causation yet suggested that community participation contributed to program success.

The theft, safety, and security of the physical system were mentioned in relation to community involvement [36,62]. Community participation lessened the risk of theft if it was incorporated early in the project [86,87] as it promoted accountability [33]. In case studies in Nepal, Kenya, and Peru, a lack of theft was attributed to the fact that the individuals participating in the project convinced the larger public that theft was detrimental to the entire community [94]. In a comparison of strong and weak community participation, strong local management led to the continued functioning of the system and minimal maintenance, while weak local involvement led to theft [31]. In the literature that mentioned community participation, an installed system was more secure when the community was involved.

Specifically, this subset of the literature stressed the need to couple training and community participation, as often there is insufficient local technical knowledge to allow community participation to be effective. For example, lack of technological knowledge among the community members who are participating can lead to dirty solar panels, reduced output, reduced reliability, and poor performance [25]. Proper training is necessary because technical aspects may initially be beyond the abilities of community members [95]. This training would need to address both performing the technical activity and recognizing technical issues. Without proper training or baseline technical knowledge, a local intermediary or civil society organization may be necessary [46] because without it the technical system is left as a liability for the community [96]. Thus, the studies that mentioned community participation found that it must be intentionally implemented and coupled with proper training and social infrastructure [20], which we address next.

3.4.3. Social sustainability

Finally, the social aspect was the most cited effect within the papers that mentioned community participation ($n = 31$ out of 78) (See Fig. 6). There is a wide body of literature on the ability of community participation to resolve conflicts and provide a space for formal complaints to be addressed [69]. A common misconception is that all local participants have the same view or opinion of the mini grid project. Community participation can manage varied interests, provide a pathway for feedback, and avoid anger and frustration within the community [97].

Within this subset of the literature, community involvement instills a sense of ownership or commitment to the project [52,56,57,60,63,66]. Studies noted that community engagement led to informal ownership and vested interest [98,99] without which the project had poor sustainability [65]. These examples did not reflect explicit ownership; however, even a sense of ownership or power over the project led to a greater level of commitment towards sustaining the system.

Community participation allowed for the effective dissemination of information and education for the entire community about the project [2,100]. Community participation was notably linked to the adoption and acceptance of the technology and participation in the project [36,69]. Both peer-reviewed and grey literature noted that community participation was critical to the diffusion of technology [36,74,101].

Some evaluations, such as renewable energy projects in Central America, noted that private models faced issues integrating the technology in the society [102]. Acceptance of the system was crucial for the project to continue, let alone thrive, and thus community participation was deemed necessary.

Papers that mentioned community participation found that it led to larger equity within the community. Community participation was found to allow the project to reach "Bottom of the Pyramid" customers [103] and involve the poor who are traditionally left out of the electrification process [93]. Thus, community participation was necessary to ensure equity within the communities that the energy access projects serve but must be monitored if certain elites or groups take control.

Many studies in the subset of the literature that mentioned community particpation specifically noted the importance of including women in community participation activities [40,56,57,59,93]. Women were largely ignored in energy projects [104]. There was a large value to including women as literature noted that they can often be more trustworthy, have bookkeeping experience, have a deeper understanding of the benefits of the project (specifically for their children) and care deeply that the project is maintained [61]. Involving women was not always easy as social norms led women to be surprised that they were included in the project. They were hesitant to add their voices to the decision-making process [35]. The results from this subset of the literature suggests that mitigating elite capture (e.g., wealthier households controlling the project) and involving female voices are vital aspects to ensuring community participation, and ultimately equity.

In the papers included, the community's involvement allowed the project to adjust to the context of the local setting [58,82]. A framework for policy design of mini grids stressed that "the role of community in all stages of mini grid development and operation is critical for taking local context into account and ensuring that community members' needs are met." [80] In a report on mini grids in Southeast Asia, engagement allowed stakeholders to assess contextual knowledge to maximize the benefits of the project [99]. Papers that mentioned community participation found that it allows a project to respond to unforeseen or extraordinary situations that may cause project failure without such support.

This subset of the literature notes that a sense of trust was necessary to achieve these positive effects of community participation [59]. In Latin America, Southeast Asia, and Sub-Saharan Africa, studies noted that engaging locals built trust simultaneously [78], because outsiders are often not trusted [105]. Projects will fail in the long run without genuine trust in the community and considerable training and investment to bolster community participation [25]. The need for trust speaks to the fact that there must be a high quality of community participation, and ineffective community participation is possible and unfortunately common.

Despite these positive effects of community participation, there were some instances in which community participation was not beneficial for social aspects of the project. For example, some of the local individuals in charge of the operation or tariff collection took advantage of their positions for their own monetary or political gain [25]. A review of seven mini grid projects found that "community dynamics were the biggest factor in determining the longevity and performance of a microgrid," indicating that community participation is necessary, but it is not sufficient. The quality of that participation was the key factor leading to the project's success [25]. Community decisions that were not always respected [73] and illiterate populations in the planning process posed challenges [54]. These examples reveal that not all community participation leads to positive social outcomes, but with strong community dynamics, it can be beneficial.

3.4.4. *Regional and literature type differences in sustainability*

Within the economic, technical, and social sustainability of mini grid projects, there were some regional differences. Community participation affecting social outcomes was most frequently cited in Asian or global case studies (Figure C.1 and C.4, Appendix C). African case studies represented a majority of the examples of community participation linked to social sustainability but had relatively equal numbers of economic and technical sustainability. Community participation examples related to economic sustainability were evenly distributed by region, while those related to technical sustainability were primarily from Asian or Global cases (see Figure C.1 and C.4, Appendix C). Global studies had the most examples for social sustainability. These results suggest that conventions in the discourses and narratives of community participation differ by region; however, these differences could be due to specific community dynamics. Therefore, these results can only provide preliminary guidance for where community participation may work best, given a proposed site location.

The different types of literature played a role in which sustainability aspect community participation affected. The grey literature again offered more evidence linking community participation with aspects of the mini grid's sustainability; however, for technical affect, we found a similar number of examples in grey and peer-review literature (see Figure C.2, Appendix C). Every region had only one example from before 2010, again indicating the emerging literature in the past ten years.

3.4.5. *Technical system differences in sustainability*

We evaluated the types of generation and size of systems associated with the case studies that mentioned community participation in economic, technical, and social sustainability. Twenty-nine out of the 40 papers that provided technical specifications mentioned community participation affecting an aspect of sustainability (Fig. 5). Community participation in PV projects was most commonly associated with social aspects, while participation in Hydro and PV projects was most frequently cited for technical sustainability (Fig. 5, full details in Table B.2, Appendix B). PV and Hydro were the most frequent generation types in general. The results in Fig. 5 indicate that community participation affects economic, social, and technical aspects of the project regardless of generation source. We conducted the same analysis for system size (Table B.4. Appendix B), which revealed that there was no specific range of system size associated with community participation's effect on sustainability.

3.5. *Negative effects of community participation*

Finally, we evaluated whether each example of community participation had a positive, negative, or neutral effect on the project. While community participation is typically thought to have a positive impact, our results revealed that community participation had a negative impact in nine cases out of the 78 papers. Four of the negative cases involved the operation and maintenance phase, when a lack of training of the participating local community led to a negative technical effect on the project. However, the reports did not provide detailed examples, but rather indicated that lack of technical knowledge led to dirty solar panels, reduced output, reduced reliability, poor performance [25,52,95,96]. One case of community participation in the operation and maintenance phase led to a negative economic effect (low rates of fee collection). Finally, community participation in the inception phase of the project resulted in two cases of negative economic effect and one case of negative social effect. These results from a subset of the literature suggest that community participation is beneficial for the mini grid, as long as all parties are respected, proper training is provided and there is clear communication around tariff collection.

4. Discussion

This review has identified a multitude of definitions and a spectrum of involvement for community participation in mini grid literature. Across the four lifecycle phases of a mini grid projects studied, community participation featured most prominently in the O&M stage, though almost just as often in the Inception stage in the form of system planning and meetings. Among the subset of the mini grid literature that mentioned community participation, it was linked most frequently to positive social outcomes, increasing a sense of ownership, equity, the ability to adjust to a given local context, and ultimately to the longevity of the technical system. Examples of community participation with negative outcomes demonstrated a lack of proper training that affected the technical aspects of the mini grid project.

We now discuss unifying definitions of community participation, an integrated framework to structure community participation, best and worst practices, areas for future research, and the implications for the private sector.

4.1. *Unifying definitions and discourses of community participation*

Despite nearly universal acknowledgment of the importance of community participation in mini grid projects within this subset of the literature, community participation as a concept still lacks a clear, unifying definition. A defining framework would allow practitioners to explicitly outline the nature of the project and the power dynamics between the developer, any intermediaries, and the community. Given the spectrum of models of community participation, any definition should acknowledge and articulate the many varied types. Finally, this definition should clarify the difference between community engagement and community participation in the lifecycle phases of the mini grid project. Community engagement usually refers to customer acquisition, rather than individual involvement in aspects of the inception, build, design, or operation. These inclusions will have significant implications for harmonizing the discourse between peer-review and grey literature.

Clarity and harmonization will help both researchers and implementers share and follow best practices, or at least, more accurately characterize the involvement structures by which community participation may take place. Community participation is not a box to check off in a mini grid project, but rather an ongoing and dynamic element that will adjust and respond to the local context.

In this subset of the literature, we observed more examples of community participation linked to social sustainability, rather than economic and technical sustainability. Developers, community stakeholders, and energy access practitioners would benefit from employing a more structured approach to mapping community engagement opportunities both across the project lifecycle phases *as well as* the aspects of sustainability. Doing so could illuminate site or context specific opportunities or risks. Given this context, it may be useful for further work to review systems that have failed as well as systems that were successful in the long run.

To structure the spectrum of definitions and discussion on community participation, we constructed an integrated framework from the results of our extensive review (see Fig. 7). The goal of this framework is not to standardize community participation, but rather provide common language for researchers, practitioners, developers, and the community. This framework describes community participation in terms of its' ***breadth*** across lifecycle phases, the level of ***depth*** of each community participation activity, and the level of ***equity*** the project provides within the community it serves. Breadth provides insight into which lifecycle phases community participation may arise. Depth refers to when the community is initially involved, the duration of their involvement, and the level of power they have in their involvement. Finally, equity refers to the degree to which all members of the community have fair access to project involvement. Guided by those three aspects, this framework has the potential to clearly outline the spectrum of community participation within mini grid projects.

4.2. Best practices

Below we have compiled a set of best practices from the case studies examined. Community participation should be initiated during the system's inception (e.g., by the initial site visit) to build trust and gain context for the project. Trust is a key driver of later project success. Operators or representatives from the mini grid developers should participate in additional community activities not related to the mini grid to build that relationship. Explaining the benefits of the project to the community and agreeing on community contributions can yield greater interest and investment. Projects should equally mobilize community participation in the design and build of the system. Early and regular meetings and discussion forums between developers, locally respected figures and community members early in the project will increase sense of community buy-in and lower project costs of labor, maintenance, monitoring and rule enforcement. These meetings cannot be only with village leaders as this increases the risk of elite capture. Developers should use community input for assessing the needs and values of the customers such as willingness to pay, energy demand and load profiles.

Issues of equity should be addressed at the forefront of community discussions. Women, poorer customers, and individuals across

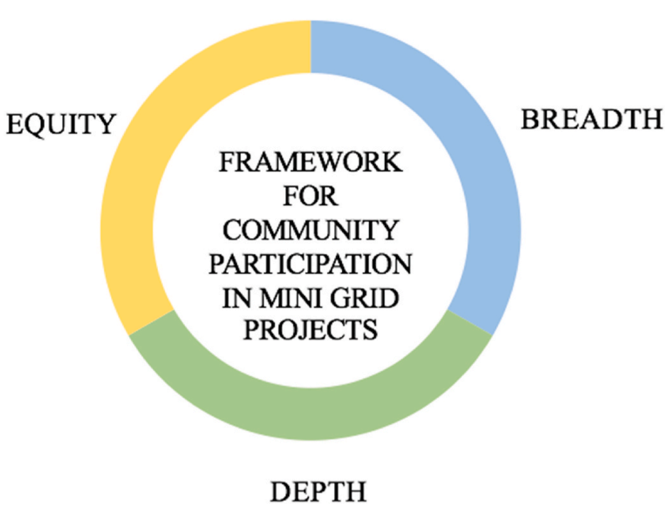

Fig. 7. We developed this framework for community participation in mini grid projects from our literature review to structure the varying definitions and discussions within the literature. The three pillars are breadth, depth, and equity. Breadth provides insight into which lifecycle phases community participation may arise. Depth refers to when the community is involved, how long their involvement is, and the level of power and involvement they have. Finally, equity refers to the level in which all members of the community have fair access to project involvement.

marginalized social strata should be encouraged to participate and provide feedback in order to prevent elite takeover and subjugation. Women should be prominent and hold positions in committees and community discussions. Circumventing potential cultural norms that prevent women from positions of influence may pose a challenge for developers, but it is necessary to spur equity and develop a greater understanding of community needs.

Greater allocation of up-front capital investment for training and information dissemination programs can be initially costly, but when done effectively and appropriately can lead to longevity of the project. Informing community members about the project with community demonstrations and planning discussions will lead to greater investment and increased trust with developers. Developers should engage key individuals in the community to disseminate information and education. When local manufacturing does not sacrifice the quality of technical implementation, projects should consider local manufacturing to create local jobs and integrate community members in the project through technical training programs [71]. The preponderance of community participation in O&M, PV projects specifically, could have implications for local jobs. Operators should train local workers for the labor, technical, and maintenance aspects of systems. This will increase the chances that their system will have a virtuous cycle, while also building community capacity. The decentralized renewable energy sector has been shown to drive substantial job creation [106]; community participation in mini grids can continue to support that effort.

Establishing a clear local governance structure or adapting an existing one (e.g., committees with bylaws, specific meeting times, etc.) that caters to the community being served and provides an accountability model for successful operation will lead to longevity of the system. Governance structures that are representative of the community are most conducive to successful project operation. Instead of large committees, a widely representative group of community members should serve as a link between developers and customers in the community. Local project management committees of respected and trusted community members, as well as those who are typically marginalized, should be responsible for tariff collection, operator payments, repayment of loans, and maintenance. If transparency in tariff collection cannot be locally enforced, a third party should collect the tariffs. Inclusive, segmented, local committees created to manage local worker training, technical maintenance, and rules/policy enforcement can lead to system longevity. Project failure is more likely to occur in the O&M phase, and thus community participation could keep all stakeholders accountable.

4.3. Gaps for further research

These case studies provide a wealth of information; however, gaps in the literature remain. The results of this review outline best practices, but these results are often narratives from evaluations rather than explicit studies focused on isolating the effects of community participation; there is a need to identify the isolated effect of community participation in mini grids.

This review supports the emerging work that investigates how to incorporate community input into decision making for or even co-design of development projects (despite illiteracy and unfamiliarity with energy systems) [107–112]. We call for further work to understand how that process affects how the system is built and communities are served.

We argue for a more qualitative lens for understanding community participation. As noted above, community participation should not be a box to simply check off. It is fluid and varies across projects. Therefore, there needs to be a more fundamental understanding of the quality of community participation across the different lifecycle phases. Further research is needed to investigate "appropriate" community participation.

The community is not a monolith, in which all individuals agree or have equal voices and power within the community. Therefore, further work should investigate community participation dynamics, paying particular attention to intra-household dynamics and different income levels, social groups, and strata of society. This is particularly important with the rise of interest in productive or incoming generating loads, as these loads may disproportionately affect individuals within the community.

Finally, projects exist within regulatory or legislative frameworks that inform community involvement [57], but further research could refine or justify these regulations. As national grids expand, there is a potential for interconnection with these mini grids [113]; however, project sustainability may be jeopardized if interconnection issues are not adequately considered. Therefore, the benefits of community participation need to be explicitly outlined and leveraged to meet emerging challenges.

All of these gaps call for an increased focus on community participation in mini grid projects. Therefore, this review motivates the need for a widely accessible aggregated database of mini grid projects, which explicitly reports on aspects and metrics of community participation. This would allow for great specificity in understanding community participation and understanding commonalities at a more granular level (e.g., type, scale, and reach of community participation in different regions, urban/rural environments, and different technical systems). This data should be segmented by the size and scope of the mini grid project and the community participation. For example, a mini grid serving a 2000-person community will have different participation needs than a 50,000-person site. The literature insufficiently accounts for the range of systems sizes (e.g., 0.4 kW to 10.7 MW) and the population of people served. We call for a better categorization for rural/urban settings, acknowledging that urbanization is a process, not a static state. We include in this review a survey tool for mini grid projects and operators to collect information on community participation in their mini grid projects, along the framework of breadth, depth, and equity, and begin the work to fill these gaps in the literature (Appendix D).

4.4. Implications for the private sector

This review of a subset of the mini grid literature found that community participation was linked to positive social outcomes, a sense of ownership, equity, the ability to adjust to a given local context, and ultimately to the longevity of the technical system. These results imply that there is a role for community participation to improve private sector outcomes. However, meeting SDG7 will require extensive mini grid deployment over a relatively short period of time, and community participation requires time and resources. This could suggest an inherent tension between the scale and speed necessary to meet SDG7 and the time and effort needed from private developers to incorporate community participation beyond customer acquisition. The best practices we identified can streamline the role of community participation in private projects to balance the time, effort, and speed needed for the provision of electricity. None of the best practices demand any community ownership, but rather present a pathway for community participation within private projects.

With flagging grid extension momentum and generally weak regulatory structures for off-grid energy provision in the geographies surveyed, the ethical dimensions of how intentionally power dynamics are considered when designing and implementing energy access projects is of primordial importance to avoid perpetuating or even deepening preexisting distributional inequities. Although private projects do not explicitly have an incentive to work against elite capture or inequities within their system as long as bills are paid, this review reveals that injustices surrounding community participation are often linked to unsustainable systems.

Finally, the challenge of designing locally appropriate technologies that serve energy needs to off-grid populations requires the marriage of economic, technical, and social analysis in designing and deploying solutions that serve their intended purpose. This design intersection is evolving rapidly in particular thanks to technological innovations that enable new modalities for community engagement and participation across the lifecycle of a given project. Rapid proliferation of mobile communication technology, for example increased accessibility to smartphones and mobile money systems, can create new mechanisms by which community members can engage with the project, for example through peer-to-peer trading platforms for units of energy. Such technologies offer energy access practitioners new opportunities to address the principal social, technical and economic challenges uncovered in this review with an eye towards both improving the inclusivity of energy access interventions and harnessing their potential for broader development objectives.

4.5. Limitations

While significant, our sample size does not represent all mini grid projects currently deployed or being implemented in the developing world. Much of the literature addressed only the technical components and did not mention community participation. This limits our review in that we were only able to evaluate a subset of papers on mini grid projects, and thus we are not fully able to comment fully on the role of community participation. In contrast, in the papers that did cover the social components of community participation, there was a lack of technical data. It is worth noting that technical papers were excluded from this review because they contained no information on community participation. Therefore, there is a wealth of technical data that has not yet been connected to social questions. This limitation of our review calls for further interdisciplinary work to understand sustainability more holistically.

Additionally, no case study within the review utilized methods with causal implications, and thus our results must be cautiously considered. Our review could be biased from the tendency to only publish work based on successful mini grid programs. We advocate for the research community to support pre-analysis plans in mini grid evaluations to limit this bias and publish work on both unsuccessful and successful projects.

Our review has the limitation of reviewing only English language papers. We acknowledge that this review produced few systems from north and southern Africa. This could be due to the English language limitation or that system reports and studies from those regions did not speak to community participation. Southeast Asia has had a much longer history with community mini grids, which limits the conclusions we can draw from our regional analysis [2].

Another limitation is that there may be a bias in the literature to evaluate certain technologies more than others, and thus the results may be biased towards one technology or one lifecycle phase based on that technology. The operation and maintenance phase is the longest temporally, and thus the results are biased to have more papers addressing that phase of the lifecycle. Finally, the lifecycle phase lens fails to account for the longitudinal progress of the system after it is operating and excludes the possibility of an iterative process. Further research should explore community participation's role in the growth and adaption of mini grids. Data needs are ongoing and must be dynamic in response to the project.

5. Conclusions

This review interrogates the ways in which community participation is discussed in literature addressing access to energy challenges through privately funded mini grid projects in developing world contexts. Categorizing the avenues of impact through which community participation emerges in reviews of such projects, as well as their observed impacts on various dimensions of a project's longevity, offers a more granular and nuanced understanding of where further research into this key pillar of sustainability is needed.

Community participation is important in the rapidly evolving and emerging off grid energy service providers and models. This review and survey tool can offer lessons for these new technologies and the communities they serve.

In making more visible where, when, how, and why community participation matters to the success of mini grids, this review can further orient researchers, practitioners, and funders in grappling with such considerations of equity to meet the goal of 'universal electrification for all.'

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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