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Perspective

Who is marginalized in energy justice? Amplifying community leader perspectives of energy transitions in Ghana

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ABSTRACT

There is a divide in energy access studies, between technologically-focused modeling papers in engineering and economics, and energy justice frameworks and principles grounded in social sciences. Quantitative computational models are necessary when analyzing energy, and more specifically electricity, systems, as they are technologically-complex systems that can diverge from intuitive patterns. To assure energy justice, these models must be reflective of, and informative to, a wide range of stakeholders, including households and communities alongside utilities, governments, and others. Yet, moving from a qualitative understanding of preferences to quantitative modeling is challenging. In this perspective piece, we pilot the use of the value-focused thinking framework to inform stakeholder engagement. The result is a strategic objective hierarchy that highlights the tradeoffs and the social, economic and technological factors that need to be measured in models. We apply the process in Ghana, using a survey, stakeholder workshops, and follow-up interviews to uncover key tradeoffs and stakeholder-derived objectives. We discuss three key areas that have been rarely, if ever, well-represented in energy models: (1) the relationship between the dynamics of electricity end-use and the technology and economic structure of the system; (2) explicit tradeoffs between electricity access, cost, and reliability as defined by stakeholders; and (3) the definition of new objectives, such as minimizing hazards related to theft. We conclude that this model of engagement provides an opportunity to tie together rigorous qualitative analysis and stakeholder engagement with crucial quantitative models of the electricity system.

1. Introduction

The transition from today's inequitable carbon-intensive energy system to an equitable system based on renewable energy is one of the great challenges – and opportunities – facing humanity. Within the United Nations Sustainable Development Goal 7 (SDG 7), target 7.b is to "expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all developing countries" [1]. Access to electricity leads to enhanced education, business, and healthcare opportunities, and overall improvement in quality of life; yet more than 600 million people in sub-Saharan Africa (SSA) are without electricity [2]. It can be difficult to measure progress towards achieving SDG 7 due to the multi-faceted nature of energy consumption and services, as well as a lack of tangible metrics and benchmarks [3]. However, it is clear that in order to make progress, numerous hurdles must be overcome throughout modern power systems in the developing world, including meeting electricity demand, maintaining reliability, limiting negative environmental impacts, and ensuring that these goals are pursued and achieved in a way that benefits a diversity of stakeholders.

Given the high level of technological complexity in the energy system, scientifically- and technologically-grounded mathematical models are used to inform decision-making in this realm. There exists a wide body of energy models and tools that are commonly used to inform planning and operations of energy systems across a range of temporal and geographic scales. The International Renewable Energy Agency (IRENA) reviews and classifies many of these models and tools with a

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specific focus on their application to understanding the role of renewable energy in emerging economies [4]. Several other studies have provided comprehensive reviews of energy planning models that are widely available and have been applied to systems around the world [5–7]. One such tool is integrated resource planning [8] in which electricity services during the planning period are satisfied using a least-cost combination of supply and end-use efficiency measures. Often these models incorporate concerns such as equity, environmental protection, and reliability.

While we focus on the electricity system, the challenges we discuss are broadly relevant to all energy system models. For example, some models consider the entire energy system in a region, tracking individual resources (e.g. coal, oil, biomass) from extraction to conversion to end use (e.g. electricity, transportation, heat). These models may further consider land-use and agricultural issues as well as a host of other environmental considerations and are typically applied over decades-long planning horizons [9,10]. Widely used examples include MARKAL-TIMES [11,12] GCAM [13–15] LEAP [16] and MESSAGE [17] among many others.

A subset of energy models focus more narrowly on the electricity sector, sacrificing breadth for increased depth of power system representation. Some of these consider the general generation expansion problem (GEP), for example WASP [18] PLEXOS-LT [19] and OptGen [20] while others even more narrowly analyze power system operations without considering potential infrastructure investments or retirements. The so-called production cost models include PROMOD, EnergyPLAN, and GridView [21–23] among many others. Some of the planning models specifically target resource-limited settings such as SWITCH [24] electrification pathways [25,26] Open Source Energy Modeling System (OSeMOSYS) [27] Open Source Spatial Electrification Tool (OnSSET) [28] and Hybrid Optimization Model for Multiple Energy Resources (HOMER) [29].

While these models and tools discussed above collectively establish a diverse range of analytical capabilities that have been applied with success in recent years and decades, one common theme across many traditional energy system models is a general neglect of the important characteristics of developing countries, such as resource constraints, supply shortages, the predominance of informal economies [30] and the preferences of local stakeholders. One study [31] included qualitative results into energy systems modeling. It did not, however, elicit stakeholder preferences on their specific objectives. This misses a direct integration of local stakeholder perspectives about objectives guiding their energy transition.

Another class of models, found primarily in the academic literature on electricity planning in developing countries, addresses some of these issues, through simultaneously optimizing generation and transmission capacity [32–42]. These models address developing countries with less developed transmission infrastructure. They include a very small number of objectives that are typically system-cost based and are rarely, if ever, inclusive of stakeholder preferences.

One approach aimed at including a range of preferences is multi-criteria decision analysis (MCDA; see [43–45]), which highlights tradeoffs between different objectives. These have the potential to better represent stakeholder preferences; but in practice are based on general objectives found in the literature [46]. Thus, a weakness of these models is how they have ignored the political factors that play dominant roles in successful electricity development in SSA [47].

The work presented in this paper is aimed at complementing and informing the energy models that are used to analyze and optimize the operations and planning of country-level electricity systems. Specifically, we focus our stakeholder engagement on planning in the electricity sector. Results from this work are valuable because they can complement quantitative techno-economic analysis, by highlighting how the values of in-country stakeholders have been silenced in the energy transition space. This is necessary and essential to the energy planning space if nations wish to promote energy justice in their planning and work towards serving all communities.

In a largely non-intersecting literature, there is a wide array of papers reviewing energy injustice around the world, which can occur at multiple scales [48] including local, national, and multi-national impacts. Jenkins et al. [49] review three core tenets of energy justice: 1) distributional justice, relating to equal distribution of both the costs and benefits of the energy system; 2), recognition justice, relating to the fair representation of individuals; and 3) procedural justice, providing equal access to decision making processes. Sovacool et al. [48] review macro-scale injustices throughout Africa and suggest that the solution is to "facilitate community involvement and ownership of energy-related facilities." One way to incorporate justice principles into the energy justice space is to incorporate the preferences of stakeholders from emerging economies into electricity planning models [50].

Our contribution to the literature is at the intersection of energy justice, stakeholder engagement, and electricity policy; and it is informed by the context of complex electricity planning models. Our work sheds light on stakeholder preferences related to energy solutions at local and national scales. This work provides a bridge between the *social knowledge* and the *technical knowledge* needed to plan the evolution of the power system.

This paper describes the first step in a process for developing stakeholder-informed modeling and decision frameworks to improve sustainable and equitable electricity access across SSA. In Section 2, we introduce our case study location, and describe our approach to stakeholder engagement through a decision-focused process, including surveys, workshops, and individual interviews. Section 3 details the results of this engagement, including the strategic objective hierarchy. We conclude in Section 4 with a discussion of the importance of stakeholder engagement throughout the process of electricity planning and policy.

2. Methods: increasing inclusivity through stakeholder engagement

Our process consisted of multiple methods with a focus on stakeholder integration into the process [51]. We combine three research methods – surveys, qualitative research, and case study – with the intention of complementing and informing a fourth – quantitative energy modeling. Specifically, our methods include 1) design and deployment of stakeholder surveys, 2) convening of in-person stakeholder workshops to facilitate group discussion, and 3) individual one-on-one semi-structured interviews to solicit candid stakeholder objectives and feedback. The entire process was designed in the context of a shared theoretical approach to achieve transdisciplinary [52]. The approach is grounded in value-focused thinking and consists of eliciting and structuring objectives for eventual use in models and other decision making processes. We start this section by discussing Ghana as the case study, briefly overviewing value-focused thinking, and then describing our three methods of engagement.

2.1. Case study: the electricity system in Ghana

Ghana is located in West Africa with a population of approximately 29 million and a GDP of US$ 66 billion [53]. As of 2018, Ghana had 4,889 megawatts (MW) of installed generation capacity, generating 16 terawatt-hours (TWh) of electricity annually. Electricity demand in Ghana is satisfied by thermal generation (58%), hydroelectric generation (40%), imports (<2%), and solar (<1%) [54]. Ghana has a target of generating at least 10% of its electricity from renewable technologies by 2030, where "renewable" does not include large hydro. To achieve this target, the country has drawn up an ambitious renewable energy master plan that aims to add about 200 MW in small hydro and marine hydrokinetic plants, 741 MW of solar, 327 MW of wind, and 122 MW of biomass [55].

Ghana was selected as the initial location to apply our methodology for two reasons. First, while Ghana still faces a number of challenges related to improving the reliability of its power system and ensuring equitable energy access, it also provides a relative success story in SSA. The electrification rate in Ghana is 90% in urban areas and 65% in rural areas [53] and both are well above the average rates in SSA. However, despite this success in improving electricity access, particularly in recent years, the country also faces a number of challenges that are similar to those present in other SSA countries. In 2014, Ghana faced a severe power crisis, prompting the construction of a 470 MW emergency thermal power plant, using heavy fuel oil, located on a ship. This helped resolve the power crisis, but it was expensive and sacrificed holistic long-term planning objectives to meet urgent short-term needs.

Second, Ghana maintains a stable democracy (ranked fourth among the seven SSA countries classified as free by the 2020 Freedom House report [56] and has more policy continuity than the majority of SSA nations [57]. The government is committed to improving electricity access for its entire population through sustainable means, as evidenced by the renewable generation target. Therefore, the case of Ghana can help in understanding tradeoffs between the views of the population and those of the government with respect to the energy transition, and the analysis provides a logical testbed for our approach before attempting implementation in countries facing more constraints and challenges.

Ghana is fairly typical in the dualism of its socio-economic structure. In the energy space in SSA, there tends to be distinct agencies responsible for urban and rural electrification. Ghana conforms to that model, with one agency serving the urban South while another serves the rural North. Therefore, the policy implications from our study have general application to the agencies promoting electrification in urban and rural areas elsewhere in SSA.

2.2. *Value-focused thinking and strategic objective hierarchies*

Value-focused thinking (Keeney [58]) is a framework that puts a priority on understanding stakeholder preferences as a first step in a decision problem. Objectives are based on *values*, which are defined as the “principles used for evaluation…to evaluate consequences of action or inaction” [58]. For example, values might include social justice or air quality. *Objectives* begin to operationalize values, stating the directional goals, such as “maximize social justice.” Once preferences are clearly represented in the form of specific objectives, they can be used to generate creative alternatives aimed at satisfying preferences. Mathematical models are then designed around these preferences and alternatives, using the best available information to tie the outcomes of alternatives to preferences. While technological constraints are fairly well-represented in electricity planning models, the same is not true for representing preferences [59]. This is similar in concept to what Tarekegne [60] calls the “means-end” distinction. Most electricity planning has focused on “means”, or what we call *alternatives*, such as the type of generation. Tarekegne, echoing Keeney, argues that planning should instead focus on “ends” or what we call values.

In this paper, we pilot the use of value-focused thinking to ensure that equity and energy justice are at the forefront of local and national decisions regarding electricity system design. A key tool in this framework is the Strategic Objective Hierarchy, a visual method for structuring objectives – see Siebert et al. [61] for a recent application of objective hierarchies to terrorism. This method is new to the field of energy justice and electricity access. It has been used in a top-down expert-based analysis of energy efficiency [62]; and, most similar to ours, in a paper on structuring the energy objectives of West Germany [59]. While this latter paper included engagement with representatives from a range of communities, it differs from our work in our focus on energy justice and giving voice to stakeholders in developing countries, as well as our focus on informing complex energy models used to design the electricity system. This method is particularly useful when applied to energy justice, as this is a complex multi-dimensional concept that requires input and voice from affected stakeholders and communities.

In this paper we introduce our model by presenting the results of a pilot project in Ghana. We developed a Strategic Objective Hierarchy that can help inform a wide range of decision problems aimed at improving the electricity system in Ghana, and highlight places where key preferences have not been included in modeling projects. A benefit of this method is that it is a step in the process of translating qualitative findings about preferences into quantitative decision models.

Identifying and structuring strategic objectives provides a foundation for a range of decision problems related to the electricity system. Strategic objectives are structured into a hierarchy, where high-level values – for example, maximizing social justice – are associated with more specific objectives. This enables the derivation of a set of *metrics* that can be implemented into models to measure how well the objective is being achieved. In order to implement a preference into a model, it must be rigorously measurable. Thus, defining a strategic objective hierarchy based on stakeholder engagement is a crucial step in implementing stakeholders’ preferences into the mathematical models that inform the complex decisions in the electricity system.

2.3. *Stakeholder engagement methods*

2.3.1. *Surveys*

The first step in our stakeholder engagement process was the design and implementation of a survey to gather opinions from electricity stakeholders on issues related to electricity access, sustainability, opportunities afforded by electricity access, and preferences regarding quantity and quality of electricity supply. The survey had 18 questions that asked the respondents to prioritize energy transition objectives, and provide opinions on challenges facing the energy system in Ghana (see Appendix A). The survey was first administered in Accra by research assistants from the University of Ghana who assisted the respondents in filling out the forms where necessary, and achieved a 100% response rate, with 71 respondents. The survey was also administered at two in-person workshops (described further in Section 2.3.2) convened in Accra and Tamale with 20 and 18 respondents, respectively. The pre-workshop survey was gender-balanced, (50% female), while the workshop surveys were less so (37% and 18% female in Accra and Tamale). All of the survey respondents had an electricity connection in their home. Table 1 shows the breakdown of stakeholder groups.

2.3.2. *Stakeholder engagement workshops*

The second step was the convening of two stakeholder workshops in two regions of Ghana to capture the differing views of urban and rural dwellers regarding the optimal development pathways for a sustainable electricity system. The first was held on August 13, 2019 in the capital city of Accra in the South, representing an urban population, and the second on August 15, 2019 in the smaller regional hub city of Tamale in the North, representing a rural, community-oriented population.

The aim of the workshops was to engage stakeholders in a process of assessing preferences and values, as well as framing the most pressing

Table 1
Survey Respondent Stakeholder Demographics.

Stakeholder	Pre-Workshop Survey (%)	Accra Workshop Survey (%)	Tamale Workshop Survey (%)
Government	25	44	11
Academics	25	11	28
NGO	8	6	11
Power Generation	10	17	6
Power Utility	10	17	22
Community Stakeholder	4	5	11
Business	11	0	11
Other	7	0	0
Percent Female	50	37	18
Total Observations	71	20	18

and salient issues in the Ghana electricity system. We employed value-focused thinking techniques to explore the range of values held by stakeholders related to electricity transitions. Having a wide range of stakeholders also provided the context of specific energy, economic, cultural, and social systems in Ghana. Fig. 1 outlines the activities undertaken in each workshop.

The Accra workshop was attended by representatives of public agencies, community leaders, industrialists, power producers, and academics. There were 41 participants in total, of which 20 stayed for the entire duration. The Tamale workshop was attended by 18 stakeholders including community representatives, representatives from business, the Northern Electricity Distribution Company (NEDCo), and local chiefs.

2.3.3. One-on-one discussions

The third step involved holding one-on-one semi-structured interviews with a selection of stakeholders to get better context to the results from the previous two steps. Meetings were held in November 2019 with representatives of the organizations displayed in Table 2.

The interviews focused on four key areas, inspired by results from the Accra and Tamale workshops. First, we discussed the surprising finding that reliability was more pertinent to stakeholders in Northern Ghana while cost was more salient to those in the South. We asked the participants to provide their interpretation of this result. Second, we asked more general questions about the preferences in Ghana regarding the tradeoff between cost and reliability. Third, we asked questions related to preferences for prioritizing electricity consumption for productive revenue-generating activities (i.e., industrial and commercial) compared to providing energy services to end users to directly improve their quality of life, with a specific question on the importance of electricity in schools. Fourth, we asked about their understanding of the plans for financial sustainability of the electricity system in Ghana. We then allowed the discussion to progress following the participants' discretion.

Table 2
Organizations involved in stakeholder one-on-one interviews.

Organization Name	Location	Sector	Description
Africa Centre for Energy Policy (ACEP)	Accra	Non-governmental organization	African energy policy think tank
Energy Commission of Ghana	Accra	Government	Regulation, management, development and utilization of energy resources in Ghana
Electricity Company of Ghana Ltd (ECG)	Accra	Power Utility	Retail service provider
Millennium Development Authority (MiDA)	Accra	Government	Manages Programs related to the Millennium Challenge Corporation
Karpowership Ghana Company Ltd	Accra	Power Company	Independent Power Producer
Unnamed Village (for confidentiality purposes)	Tamale	Community	A community in the Northern Region
NewEnergy NGO	Tamale	NGO	Provides training and services to rural communities in the areas of renewable energy, environmental conservation, micro-credit, water and sanitation
Northern Electricity Distribution Company (NEDCo)	Tamale	Power Utility	Retail service provider

3. 3 Results: lessons from stakeholders in Ghana

3.1. Uncovering strategic objective hierarchy

The goal of this research endeavor was to amplify the voices of local community leaders and other electricity stakeholders in Ghana. This

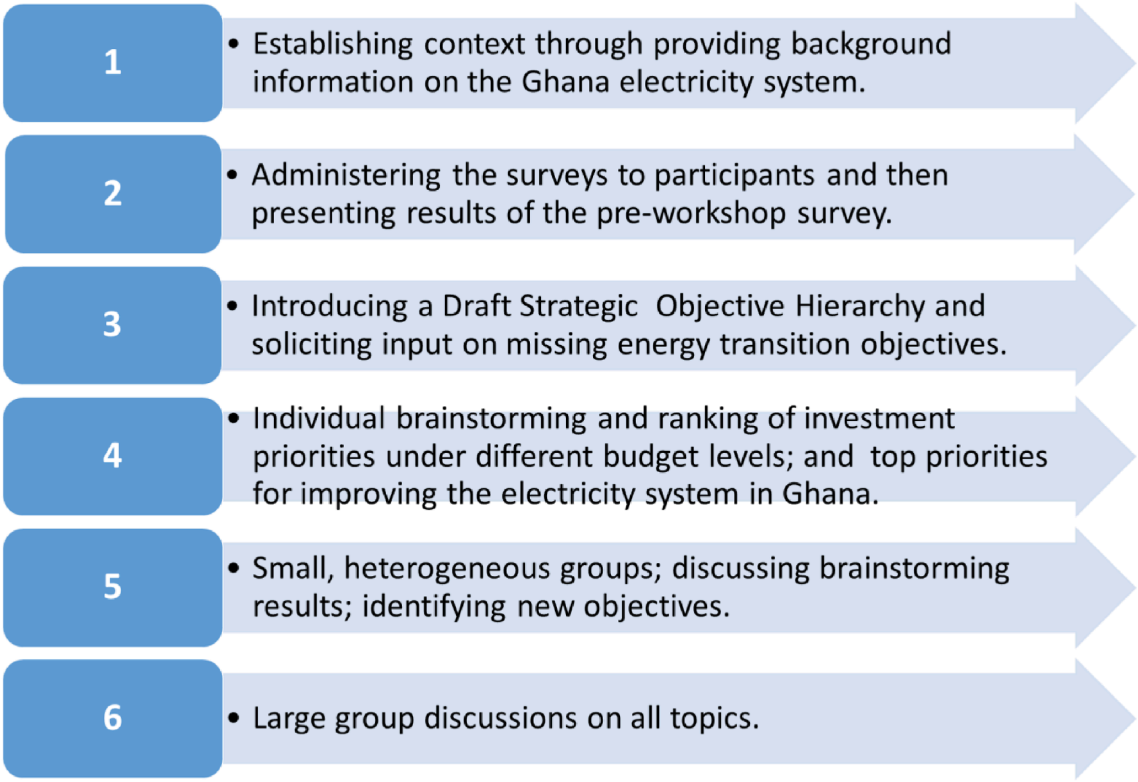

Fig. 1. Activities undertaken in each workshop.

involved eliciting the stakeholder value structure for energy transition objectives. A strategic objective hierarchy is a graphical representation of the underlying objectives of stakeholders. Fig. 2 shows the strategic objective hierarchy that was developed based on stakeholder input during the workshops, highlighting objectives identified through the stakeholder engagement process.

One uncovered objective addressed the definition of reliability, clarifying that increasing outage predictability is as important as reducing outage frequency. Another led to a rethinking of economic priorities. Stakeholders noted that Ghana currently has excess supply of power in the South and therefore suggested shifting objectives away from broadly maximizing generation capacity and towards ensuring productive, revenue-enhancing use of existing resources. Thus, one objective was dropped, and another developed around ensuring that available generation capacity is aligned with peak demand levels. In the South, this implies increasing peak demand, whereas in the North it might imply developing additional generation capacity.

During the workshops a number of social objectives were uncovered, including greater community understanding of the electricity system; thus attention should be paid to increasing education, competences, and capabilities around the energy system [63]. Crimmina et al. [70] provide a recommendation for educating energy managers that might be adapted more broadly for tertiary education. In addition, the safety of individuals was a prominent topic of discussion in the North. In many

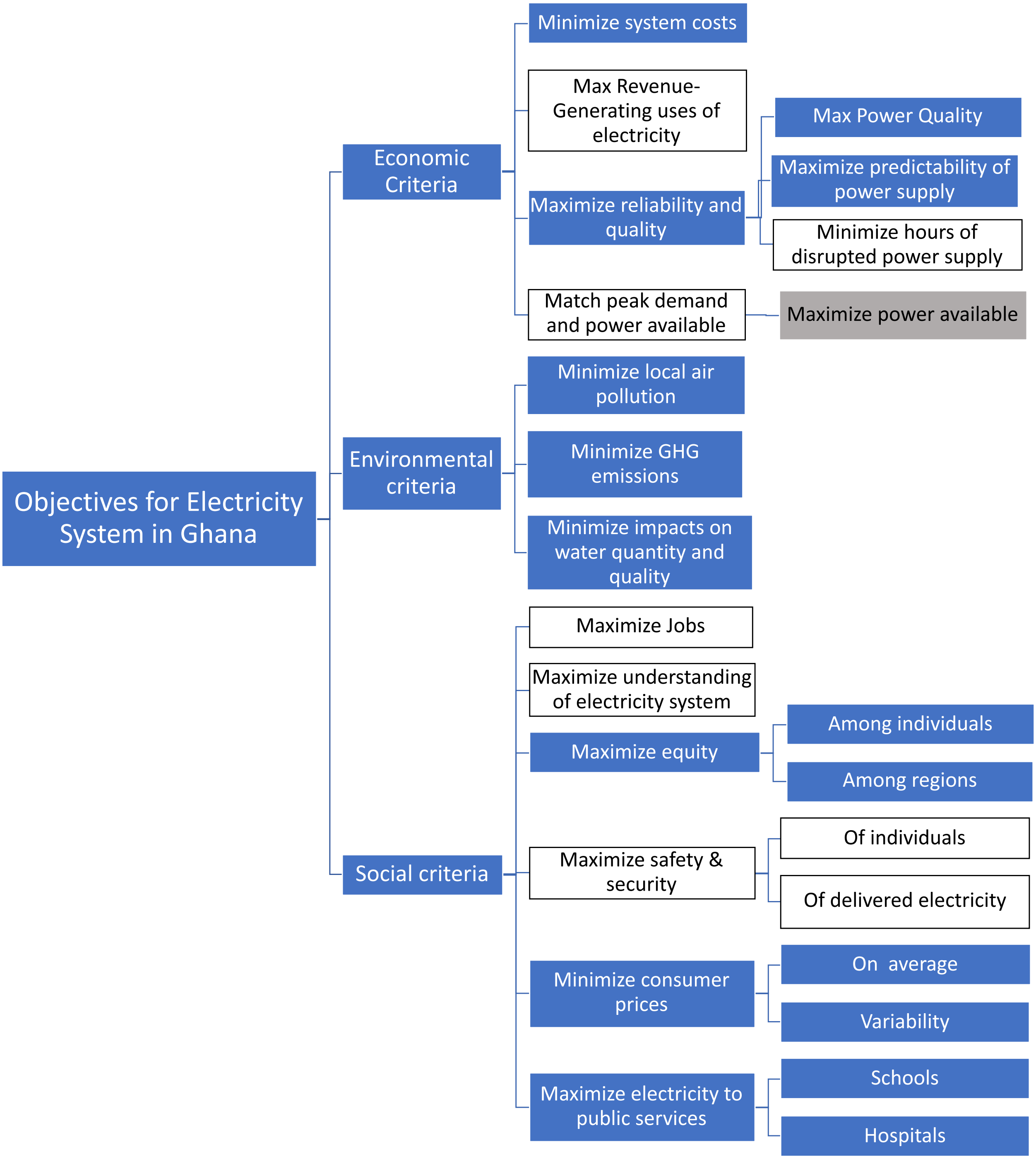

Fig. 2. Strategic Objective Hierarchy for Energy Transitions in Ghana. Blue boxes represent objectives suggested by the research team based on the pre-workshop survey. Clear boxes are objectives identified by participants during the workshops. The grey box was eliminated based on workshop outcomes.

cases, households extend an illegal line from a neighboring household to their own, thereby creating health and safety risks. These cables are often shallowly buried or supported by small sticks. As a result, it is not uncommon for livestock and even people to be killed by electricity transmitted through water that collects on the ground in the rainy season.

Finally, while the stakeholders agreed that the environmental objectives proposed by the research team were reasonable, these objectives did not come up of their own volition in the workshops or follow-on interviews. The environmental objectives appear to be mostly priorities of outsiders and not of high priority to stakeholders within Ghana to whom we spoke (See [64] for another example of this). This is consistent with evidence showing a dearth of renewable energy in Africa, despite Government-stated goals [65]. This opens the possibility of complementarity, where outside stakeholders invest in renewable energy to further their environmental goals (e.g., reducing global emissions), while simultaneously addressing higher priorities for stakeholders within Ghana, such as improving reliability or increasing electricity access.

3.2. *Financial sustainability versus broader sustainability goals*

A major result from the stakeholder engagement process is the unveiled divide between long-term financial sustainability and other social sustainability objectives. This result encompassed two key issues: productive uses of electricity and subsidy challenges.

3.2.1. *Productive uses of electricity versus improved quality of life*

In the Accra workshop, there was a strong emphasis on finding productive uses of electricity that directly generate revenue. This is related to general goals of economic growth, but also to financial sustainability for the electricity system. Participants felt that if consumers were directly generating revenue from electricity, they would be more amenable to unsubsidized tariffs.

In contrast to this discussion theme, survey results indicated that participants considered providing support for education the most important aspect of electricity access, mainly in the form of lighting for schools and households. For example, Fig. 3 shows that all three groups identified students' ability to study at night as the top benefit of low-cost energy access.

While the participants agreed that electricity is of high relevance to education, one of the participants challenged the research team to remember that "electrification needs to be more than just lighting." This speaks to the perspective that lighting is only one of the many possible benefits provided by electricity, and the hope of stakeholders that electricity will also be used as a method to increase economic development and industrialization.

3.2.2. *Challenges of subsidies*

There was a tension in nearly all discussions between wanting to keep tariffs low for industry, high-consumption users, and low-income consumers, versus having tariffs that actually cover the cost of electricity. It was repeatedly claimed that tariffs in surrounding nations were lower, and thus Ghanaian firms are at a competitive disadvantage. Interestingly, the evidence does not fully support this belief, which was widely-held among participants. According to AfDB and ERERA [66] Ghana has the 3rd lowest end-user tariff (including taxes and charges) for all but Medium Voltage end-users in West Africa, including a tariff lower than all neighboring states. Even at Medium Voltage, which provides a good estimate for prices to businesses, Ghana has the 5th lowest tariff in West Africa (taxes and charges included), at 19.7 cents per kWh, slightly higher than the neighboring countries of Cote d'Ivoire and Burkina Faso at 17.3 and 18.8 cents/kWh respectively. Another common concern was that tariffs were high enough to keep some firms out of business, especially small entrepreneurs.

Government officials often pointed to a long-term strategy of running the electricity system at a loss now, with plans to make up the lost revenues through economic growth in the future. This can be seen through the government's aggressive push to connect homes to the national grid. From 1991 to 2002 the number of households connected to the national grid increased from 946,200 (28.5% of the 3.32 million households) to 1,625,000 (43.8% of the 3.71 million households). This

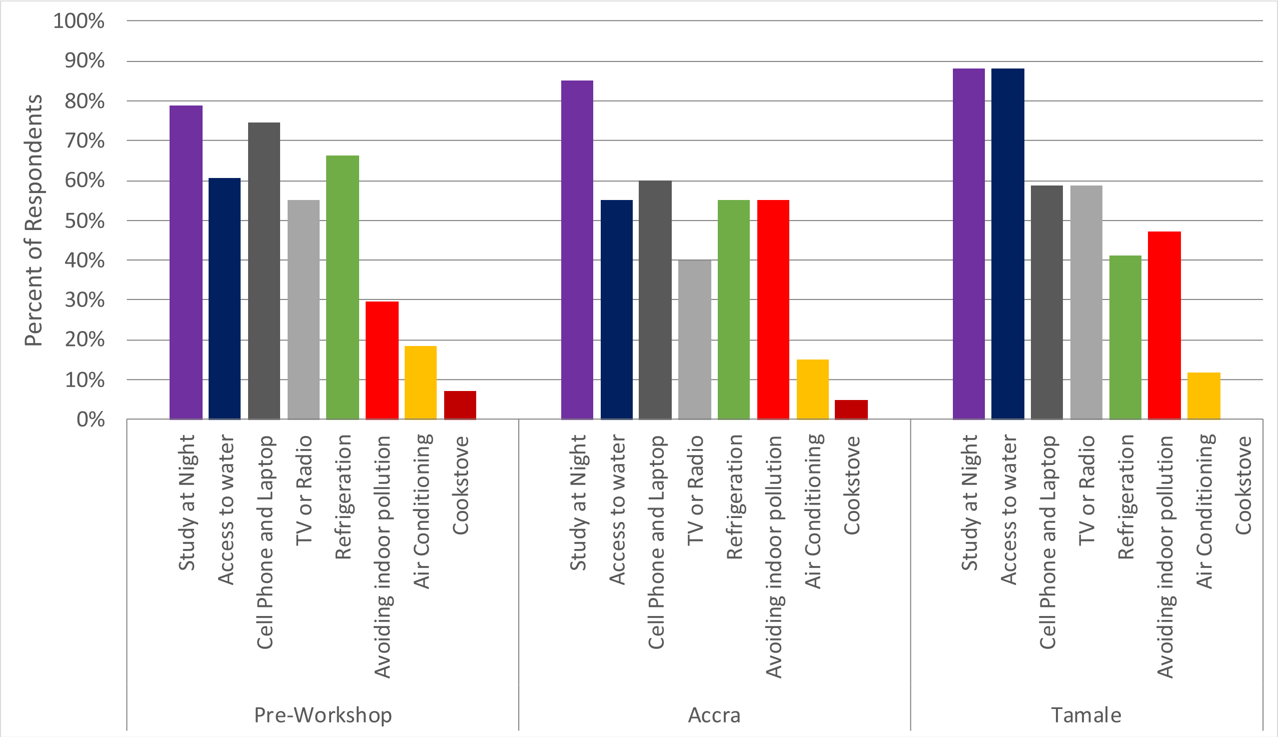

Fig. 3. Benefits from Electricity Access. The bars show the percentage of respondents who chose the response as one of their four choices.

was further increased to 3,595,000 (64.2% of 5.60 million households) connected to the national grid in 2010. In 2018 the household connection rate was 84.3%, which is expected to further increase due to the government's actions supporting its universal connection target for 2020 (Energy Commission of Ghana, 2019c).

Finally, the existence of separate utilities in the North and South is causing financial challenges and appears to be at odds with the goal of universal energy access. In particular, electricity tariffs in Ghana are cross-subsidized with the intention that the higher-consumption consumers subsidize the low-consumption consumers. For example, residential customers are charged an energy rate of GHp 16.31/kWh for monthly consumption up to 50 kWh; and increasingly higher rates for higher blocks of energy [67]. Participants believed that an unintended consequence of the pricing structure is that it implicitly discourages consumers from increasing their use of electricity. Most pressing, in the North, there are simply not enough high-consumption consumers to cover the subsidies. Thus, the northern utility runs at chronic losses.

3.3. Reliability versus costs

A surprising result was that participants in the North, a much poorer region, placed a higher priority on reliability than participants in the South, a region with higher income and higher concentration of industries. On the other hand, cost was a higher priority in the South. Fig. 4 details the energy transition priorities for the various survey respondents. In the South, considering the combined pre-workshop survey and the Accra workshop survey, roughly twice as many respondents (65 vs. 32) ranked cost as most important compared to reliability. In the North this is reversed, with almost three times as many (16 vs. 6) ranking reliability as most important compared to cost.

Fig. 5 further illustrates these concerns over cost and reliability. In Accra, tariffs and fuel prices were mentioned often, whereas in Tamale, reliability was a more prevalent theme. These concerns were mirrored in the workshop discussions, particularly in the South, where cost and competitiveness were prominent topics of conversation.

Follow-up interviews shed some light on the cost-reliability tradeoff. All interviewed stakeholders were concerned about both reliability and cost. However, since 2015, following the contract for electricity from Karpowership, electricity in the South has been much more reliable, but more expensive.

In the North, on the other hand, the majority of the consumers fall within the subsidized 0–50 kWh bracket, and therefore cost may not be as pressing of an issue to these consumers despite their generally lower income. This leads, however, to the electricity system operating at a sustained loss due to the high costs of connecting sparsely populated communities and a customer base of predominantly low-income customers. A primary component of the government's effort to achieve universal connection by 2020 has been investment in north–south transmission lines. However, the combination of low maintenance budgets and long lines lead to frequent outages. For example, in Accra 58% of respondents reported fewer than two electricity disruptions per week, while in Tamale 72% reported two or more. Thus, in our workshops and interviews, reliability concerns in the North were more salient. Such differing views on the cost-reliability tradeoff was a primary theme of these workshops.

Thus, it may be the case that the South has come to take reliability for granted and would like to reduce costs, while the North has come to take low cost for granted and would like to improve reliability. This could indicate a more general behavioral trend where stakeholders tend to prioritize actions that improve perceived negative aspects of the status

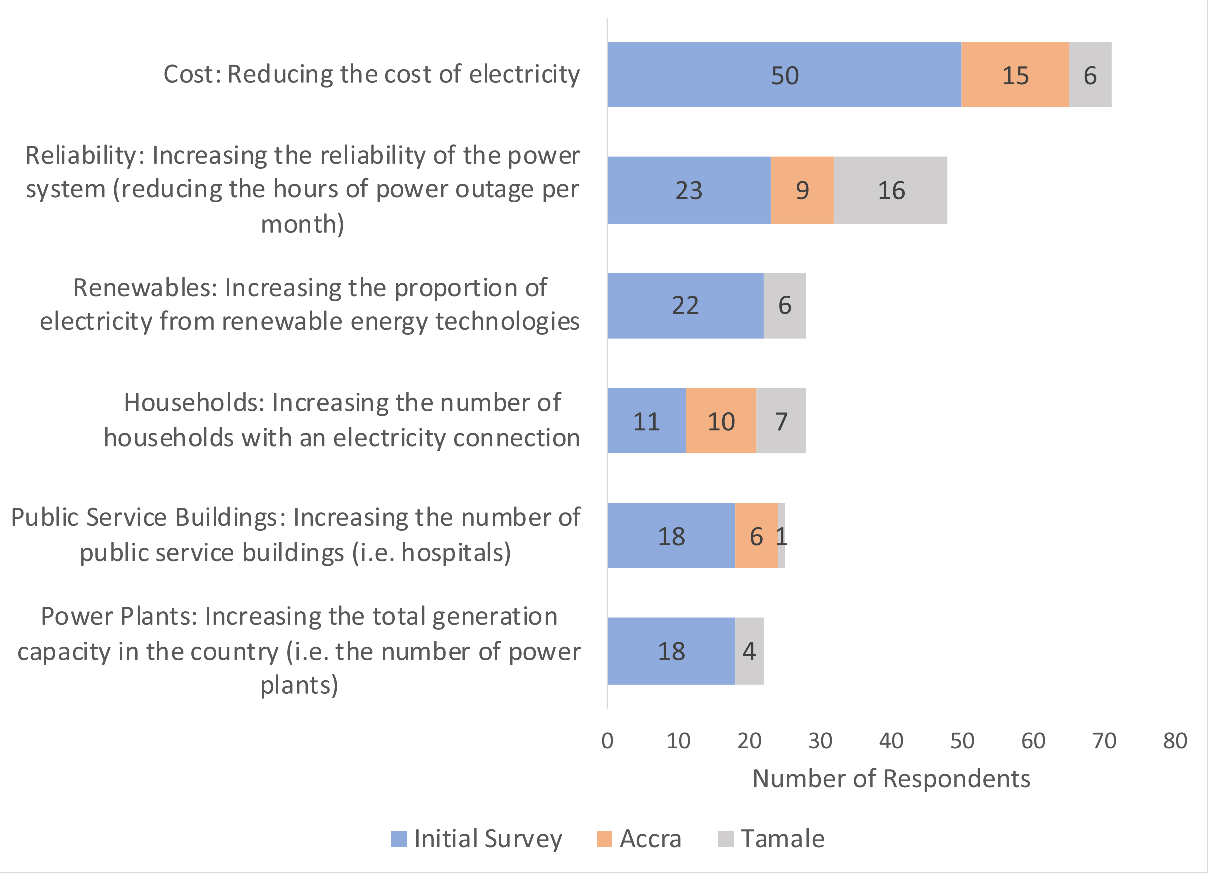

Fig. 4. Priorities for improving the quality of life for the people of Ghana through improvements in the electricity system. Bars show the number of people who ranked the priority as most important.

(Accra)

(Tamale)

Fig. 5. Stakeholder responses to an open ended question on "challenges facing the Ghana electricity system" from the Accra and Tamale Surveys.

quo, rather than actions that maintain perceived positive aspects of it.

3.4. Clear communication

The workshop in the North focused strongly on consumer confusion over the tariffs. This confusion was particularly pronounced under a previous tariff system, which offered a subsidized rate for the first 50 kWh of monthly consumption; but if consumption exceeded 50 kWh, an unsubsidized rate was retroactively charged for the first 50 kWh as well as any additional consumption. This caused one of the chiefs at the Tamale meeting to exclaim "we feel cheated!". The one-on-one meetings confirmed that this tariff system has now been changed to a more standard system without retroactive charges. Nevertheless, our engagement indicates that great distrust still exists between consumers and the utilities [68]. Additionally, people were generally displeased with increases in tariffs or fees for electricity-consuming services, such as grinding corn at mills. The challenges of electricity education and communication with the public are exacerbated by the high illiteracy rate in the North (76%).

One stakeholder suggested the adoption of utility-led community meetings designed to educate the local people on electricity and pricing structures. One chief gave an example of a community meeting where grinding mill proprietors explained how their fees were affected by rising electricity prices, and patrons explained how the increased fees were causing hardships. In the end a compromise was reached. Consistent with the chief's ideas, there is evidence in the literature that there would be greater community support and understanding if the utility company met with communities to discuss tariff structures and payment processes [69,70]. Studies have shown that community engagement with stakeholders in the energy industry can result in widespread acceptance of energy technology and better understanding of energy policy in the community [71–74]. It is plausible that this could in turn lead to greater consumption, more timely bill payment, and increased utility revenues to support infrastructure maintenance and investment.

4. Conclusions

In global electricity transitions, there is a grand opportunity to design systems that are equitable and promote social and economic development for all segments of society. We present the outcomes from an engagement process designed to elicit and represent the electrification objectives of key stakeholders in the public and private sector in Ghana.

The overarching conclusion is the need for stakeholder engagement throughout the planning, policy and implementation process. We focus on how the results of these engagements can inform what planners and policymakers measure and model. We have highlighted a number of important tradeoffs that are not typically seen in electricity planning models or even in the MCDA models that explicitly incorporate multiple criteria.

First, we found that stakeholders did not bring up environmental objectives on their own. Stakeholders agreed, when probed, that environmental concerns are important. However, the lack of initiation of this topic highlights the priorities of communities in rural areas: environmental issues are secondary to reliable electrification. There is a dissonance between local in-country stakeholder objectives, and objectives laid out by the international community, such as SDG7 with its strong environmental connotations.

Second, related to this, when uncovering local stakeholder objectives we also saw the emergence of new objectives that are rarely – perhaps never – implemented in either optimization or MCDA electricity planning models; most specifically the objectives of maximizing safety and minimizing electricity theft. Kumar et al. [46] present a detailed list of criteria used in top-down energy-related MCDA models. Of 30 studies, only 3 of 145 criteria listed involve safety, and none were related to theft. It is challenging for empirical researchers to collect relevant data at the intersection of technological, social, and economic understanding, and for modelers to represent these objectives in quantitative models. For example, it is important to understand the relationship between tariff structures, the physical infrastructure, and incentive and opportunity for theft, and how likely different combinations are to lead to life-threatening outcomes.

Third, we found a strong interest in developing business or planning models related to productive, revenue-generating uses of electricity. However, stakeholders perceived an important tradeoff between utilizing electricity to provide direct consumer benefits – such as residential lighting – and the dynamic economic benefits of productive, revenue-generating consumption. Explicitly recognizing this tradeoff will impact all levels of electricity system development, from initial generation, distribution and transmission planning to market and tariff design, and other policies' implementation. A related tradeoff exists between stimulating near-term economic activity with low costs while also ensuring the long-term financial sustainability of the system. Very few electricity planning models account for the dynamic economic impacts of prioritizing revenue-generating uses of electricity through policies and/or targeted tariff design. This is at least partly because the empirical basis for understanding these dynamics is weak [75]. Thus, future work is needed to expand this empirical basis and to develop models accordingly.

Fourth, we identified a common interest in the tradeoff between cost, reliability, and access. This is tightly tied to questions about tariff structures and subsidies. Subsidies make electricity more affordable to low-income residents, but reduce revenues that can support reliability, thereby challenging long-term financial sustainability [76]. This tradeoff is important as it relates to prioritizing infrastructure investments, particularly when resources are limited. Countries must prioritize among possible capital investments – e.g. household connections, transmission lines, transformers, generation capacity in various regions, maintenance, environmentally sustainable technologies, and others. While these aspects are often included in some fashion in planning models, it is most typically through cost-minimization combined with reliability and access constraints. However, such an approach may be insufficient in developing countries where load curtailment occurs regularly – and inequitably – throughout the power system, and where energy access rates are well below 100%. Furthermore, traditional planning models often assume static system maintenance costs, without considering the possibility that increased maintenance may improve system reliability and reduce replacement costs over the long run. Our results indicate that these tradeoffs and other specific stakeholder preferences should be incorporated into planning models.

Finally, the identified need for better communication between communities and utility companies underlies the need for stakeholder and community engagement at all levels, from two-way communication in developing solutions, continuing through engaging communication strategies throughout the process.

Beyond the implications for modeling and empirical research, some policy implications were identified. First, policies that support large scale investments in agricultural electrification in rural communities could generate revenues through increasing agricultural output [77–79]. If successful, this would provide the backbone infrastructure needed to support residential and commercial electrification efforts. Second, complementarities exist where coordinated investments in off-grid renewable generation might achieve the parallel objectives of both developing countries like Ghana (access, cost, reliability) and external stakeholders (reducing global emissions); Gujba et al [80] for example, review a number of climate-oriented international funders who have invested in energy access. Finally, stakeholders universally identified the importance of electricity in education, indicating that school electrification should be prioritized, especially in the rural area, to reduce urban–rural education gaps [81].

This first application of this framework has some caveats and need for future research. The stakeholders were largely limited to a sample of convenience; in particular there was more representation of communities in the rural north than in the more developed urbanized south. Electricity planning is part of a larger whole; yet in order to get actionable information, values, and objectives, it is necessary to limit the scope. Thus, some important interactions with other systems, such as oil and gas or transportation, may have been missed.

The study uses a sample too limited to be nationally representative. Care has been taken to be cautious in the interpretation of results. However, given that the sample covers representatives from a broad spectrum of sectors, we believe the results and interpretations are plausible. It is left for further research using large samples to confirm the robustness of our findings ahead of actual policy action by the authorities.

There is a grand opportunity for government, academia and industry to work with consumers to design power systems that are environmentally and economically sustainable, while also providing services equitably to all segments of the population.

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

Supplementary data (Survey Questions Provided to Stakeholders Before and During the Electricity Workshop) to this article can be found online at https://doi.org/10.1016/j.erss.2021.101933.

References

[1] United Nations, United Nations Sustainable Development SDG 7, United Nations Sustainable Development, <https://www.un.org/sustainabledevelopment/energy/> n.d. (accessed September 10, 2020).
[2] B. Sovacool, I. Vera, Electricity and education: the benefits, barriers, and recommendations for achieving the electrification of primary and secondary schools, Energy Educ. J. (2014) 1–36.
[3] C.G. Monyei, K.O. Akpeji, Repurposing electricity access research for the global south: a tale of many disconnects, Joule 4 (2) (2020) 278–281, https://doi.org/10.1016/j.joule.2019.11.013.
[4] IRENA, Planning for the renewable future: long-term modelling and tools to expand variable renewable power in emerging economies, 2017.
[5] D. Connolly, H. Lund, B.V. Mathiesen, M. Leahy, A review of computer tools for analysing the integration of renewable energy into various energy systems, Appl. Energy 87 (4) (2010) 1059–1082, https://doi.org/10.1016/j.apenergy.2009.09.026.
[6] H.-K. Ringkjøb, P.M. Haugan, I.M. Solbrekke, A review of modelling tools for energy and electricity systems with large shares of variable renewables, Renew. Sustain. Energy Rev. 96 (2018) 440–459, https://doi.org/10.1016/j.rser.2018.08.002.
[7] M. Bissiri, P. Moura, N.C. Figueiredo, P.P. Silva, Towards a renewables-based future for West African States: a review of power systems planning approaches, Renew. Sustain. Energy Rev. 134 (2020) 110019, https://doi.org/10.1016/j.rser.2020.110019.
[8] A. D`Sa, Integrated resource planning (IRP) and power sector reform in developing countries, Energy Policy 33 (10) (2005) 1271–1285.
[9] J.F. DeCarolis, P. Jaramillo, J.X. Johnson, D.L. McCollum, E. Trutnevyte, D. C. Daniels, G. Akın-Olçum, J. Bergerson, S. Cho, J.-H. Choi, leveraging open-source tools for collaborative macro-energy system modeling efforts, Joule (2020).
[10] J.-P. Sasse, E. Trutnevyte, Regional impacts of electricity system transition in Central Europe until 2035, Nat. Commun. 11 (1) (2020).
[11] R. Loulou, G. Goldstein, K. Noble, Documentation for the MARKAL family of models, Energy Technol. Syst. Anal. Program. (2004) 65–73.

[12] R. Loulou, U. Remme, A. Kanudia, A. Lehtila, G. Goldstein, Documentation for the times model part ii, Energy Technol. Syst. Anal. Program. (2005).

[13] J.A. Edmonds, J.M. Reilly, Future global energy and carbon dioxide emissions, atmospheric carbon dioxide and the global carbon, Cycle (1985) 215–246.

[14] J. Edmonds, J. Clarke, J. Dooley, S.H. Kim, S.J. Smith, Stabilization of CO2 in a B2 world: insights on the roles of carbon capture and disposal, hydrogen, and transportation technologies, Energy Econ. 26 (4) (2004) 517–537, https://doi.org/10.1016/j.eneco.2004.04.025.

[15] S.H. Kim, J. Edmonds, J. Lurz, S.J. Smith, M. Wise, The objECTS framework for integrated assessment: hybrid modeling of transportation, Energy J. (2006).

[16] LEAP, <https://leap.sei.org/> n.d. (accessed September 10, 2020).

[17] L. Schrattenholzer, The energy supply model MESSAGE, 1981.

[18] W. Version IV, Wien Automatic System Planning (WASP) Package, 2001.

[19] PLEXOS Market Simulation Software, Energy Exemplar, <https://energyexemplar.com/solutions/plexos/> n.d. (accessed September 10, 2020).

[20] PSR | OptGen — Model for generation expansion planning and regional interconnections, PSR | OptGen — Model for Generation Expansion Planning and Regional Interconnections. <https://www.psr-inc.com/softwares-en/?current=p4040> n.d. (accessed September 10, 2020).

[21] PROMOD, <https://www.hitachiabb-powergrids.com/offering/product-and-system/enterprise/energy-portfolio-management/market-analysis/promod> 2020 (accessed September 10, 2020).

[22] H. Lund, H. Lund, Chapter 4–Tool: the EnergyPLAN energy system analysis model, Renew. Energy Syst. (2014) 53–78.

[23] GridView, <https://www.hitachiabb-powergrids.com/offering/product-and-system/enterprise/energy-portfolio-management/market-analysis/gridview> n.d. (accessed September 10, 2020).

[24] M. Fripp, Switch: A planning tool for power systems with large shares of intermittent renewable energy, Environ. Sci. Technol. 46 (11) (2012) 6371–6378, https://doi.org/10.1021/es204645c.

[25] N. Moksnes, A. Korkovelos, D. Mentis, M. Howells, Electrification pathways for Kenya–linking spatial electrification analysis and medium to long term energy planning, Environ. Res. Lett. 12 (2017), 095008.

[26] Electrification Paths for Nigeria, Tanzania and Zambia, <http://electrification.energydata.info/presentation/> n.d. (accessed September 10, 2020).

[27] M. Howells, H. Rogner, N. Strachan, C. Heaps, H. Huntington, S. Kypreos, A. Hughes, S. Silveira, J. DeCarolis, M. Bazillian, OSeMOSYS: the open source energy modeling system: an introduction to its ethos, structure and development, Energy Policy 39 (2011) 5850–5870.

[28] A. Korkovelos, B. Khavari, A. Sahlberg, M. Howells, C. Arderne, The role of open access data in geospatial electrification planning and the achievement of SDG7. An OnSSET-based case study for Malawi, Energies 12 (2019) 1395.

[29] HOMER - Hybrid Renewable and Distributed Generation System Design Software, <https://www.homerenergy.com/> n.d. (accessed September 10, 2020).

[30] F. Urban, R.M.J. Benders, H.C. Moll, Modelling energy systems for developing countries, Energy Policy 35 (6) (2007) 3473–3482, https://doi.org/10.1016/j.enpol.2006.12.025.

[31] C. Senkpiel, A. Dobbins, C. Kockel, J. Steinbach, U. Fahl, F. Wille, J. Globisch, S. Wassermann, B. Droste-Franke, W. Hauser, Integrating methods and empirical findings from social and behavioural sciences into energy system models—motivation and possible approaches, Energies 13 (2020) 4951.

[32] D. Nock, T. Levin, E. Baker, Changing the policy paradigm: a benefit maximization approach to electricity planning in developing countries, Appl. Energy 264 (2020), https://doi.org/10.1016/j.apenergy.2020.114583.

[33] J.-P. Carvallo, B.J. Shaw, N.I. Avila, D.M. Kammen, Sustainable low-carbon expansion for the power sector of an emerging economy: the case of Kenya, Environ. Sci. Technol. 51 (17) (2017) 10232–10242, https://doi.org/10.1021/acs.est.7b00345.

[34] T. Levin, V.M. Thomas, A mixed-integer optimization model for electricity infrastructure development, Energy Syst. 4 (1) (2013) 79–98, https://doi.org/10.1007/s12667-012-0067-8.

[35] F. Kemausuor, E. Adkins, I. Adu-Poku, A. Brew-Hammond, V. Modi, Electrification planning using Network Planner tool: the case of Ghana, Energy Sustainable Dev. 19 (2014) 92–101, https://doi.org/10.1016/j.esd.2013.12.009.

[36] A. Sanoh, L. Parshall, O.F. Sarr, S. Kum, V. Modi, Local and national electricity planning in Senegal: scenarios and policies, Energy Sustainable Dev. 16 (1) (2012) 13–25, https://doi.org/10.1016/j.esd.2011.12.005.

[37] D. Pozo, E.E. Sauma, J. Contreras, A three-level static MILP model for generation and transmission expansion planning, IEEE Trans. Power Syst. 28 (1) (2013) 202–210, https://doi.org/10.1109/TPWRS.2012.2204073.

[38] V. Modi, E. Adkins, J. Carbajal, S. Sherpa, Liberia Power Sector Capacity Building and Energy Master Planning Final Report, Phase 4: National Electrification Master Plan, Modi Research Group, 2013.

[39] J. Hlouskova, S. Kossmeier, M. Obersteiner, A. Schnabl, Real options and the value of generation capacity in the German electricity market, Rev. Fin. Econ. 14 (3-4) (2005) 297–310.

[40] A. Afful-Dadzie, E. Afful-Dadzie, I. Awudu, J.K. Banuro, Power generation capacity planning under budget constraint in developing countries, Appl. Energy 188 (2017) 71–82, https://doi.org/10.1016/j.apenergy.2016.11.090.

[41] M.D. Rodgers, D.W. Coit, F.A. Felder, A. Carlton, Generation expansion planning considering health and societal damages – a simulation-based optimization approach, Energy 164 (2018) 951–963, https://doi.org/10.1016/j.energy.2018.09.004.

[42] O. Ogunrinde, E. Shittu, M. Bello, I.E. Davidson, Exploring the demand-supply gap of electricity in Nigeria: locational evaluation for capacity expansions, in: 2019 IEEE PES/IAS Power Africa, IEEE, 2019, pp. 587–592.

[43] D. Nock, E. Baker, Holistic multi-criteria decision analysis evaluation of sustainable electric generation portfolios: New England case study, Appl. Energy 242 (2019) 655–673, https://doi.org/10.1016/j.apenergy.2019.03.019.

[44] P.A. Trotter, N.J. Cooper, P.R. Wilson, A multi-criteria, long-term energy planning optimisation model with integrated on-grid and off-grid electrification – the case of Uganda, Appl. Energy 243 (2019) 288–312, https://doi.org/10.1016/j.apenergy.2019.03.178.

[45] S.J.W. Klein, S. Whalley, Comparing the sustainability of U.S. electricity options through multi-criteria decision analysis, Energy Policy 79 (2015) 127–149, https://doi.org/10.1016/j.enpol.2015.01.007.

[46] A. Kumar, B. Sah, A.R. Singh, Y. Deng, X. He, P. Kumar, R.C. Bansal, A review of multi criteria decision making (MCDM) towards sustainable renewable energy development, Renew. Sustain. Energy Rev. 69 (2017) 596–609, https://doi.org/10.1016/j.rser.2016.11.191.

[47] B. Tarekegne, M. Rouleau, An energy justice based approach for electrification planning - an agent-based model, in: 2019 IEEE Global Humanitarian Technology Conference, GHTC 2019, 2019, pp. 1–4, https://doi.org/10.1109/GHTC46095.2019.9033126.

[48] B.K. Sovacool, A. Hook, M. Martiskainen, L. Baker, The whole systems energy injustice of four European low-carbon transitions, Global Environ. Change 58 (2019) 101958, https://doi.org/10.1016/j.gloenvcha.2019.101958.

[49] K. Jenkins, D. McCauley, R. Heffron, H. Stephan, R. Rehner, Energy justice: a conceptual review, Energy Res. Social Sci. 11 (2016) 174–182, https://doi.org/10.1016/j.erss.2015.10.004.

[50] K. Running, Towards climate justice: how do the most vulnerable weigh environment–economy trade-offs? Soc. Sci. Res. 50 (2015) 217–228, https://doi.org/10.1016/j.ssresearch.2014.11.018.

[51] P. Scherhaufer, S. Höltinger, B. Salak, T. Schauppenlehner, J. Schmidt, A participatory integrated assessment of the social acceptance of wind energy, Energy Res. Social Sci. 45 (2018) 164–172, https://doi.org/10.1016/j.erss.2018.06.022.

[52] E. Heaslip, F. Fahy, Developing transdisciplinary approaches to community energy transitions: an island case study, Energy Res. Social Sci. 45 (2018) 153–163.

[53] Ghana | Data, <https://data.worldbank.org/country/ghana?view=chart> n.d. (accessed September 10, 2020).

[54] ECG, The 2019 Electricity Supply Plan for the Ghana Power System. The Energy Commission, Ghana, <http://www.energycom.gov.gh/files/2019%20Electricity%20Supply%20Plan.pdf> 2019.

[55] ECG, Ghana Renewable Energy Master Plan. The Energy Commission. <http://www.energycom.gov.gh/files/Renewable-Energy-Masterplan-February-2019.pdf> n.d. (accessed April 27, 2019).

[56] Freedom house, Freedom in the World 2020: Countries and Territories, Freedom House. <https://freedomhouse.org/countries/freedom-world/scores> 2020 (accessed September 10, 2020).

[57] Fitch Solutions, Broad Political Stability In Ghana Ahead Of 2020 Elections, <http://www.fitchsolutions.com/country-risk-sovereigns/broad-political-stability-ghana-ahead-2020-elections-22-11-2019> 2019 (accessed September 10, 2020).

[58] R.L. Keeney, Value-focused Thinking, Harvard University Press, 1996.

[59] R.L. Keeney, O. Renn, D. von Winterfeldt, Structuring West Germany's energy objectives, Energy Policy 15 (4) (1987) 352–362, https://doi.org/10.1016/0301-4215(87)90025-5.

[60] B. Tarekegne, Just electrification: imagining the justice dimensions of energy access and addressing energy poverty, Energy Res. Social Sci. 70 (2020), 101639.

[61] J.U. Siebert, D. von Winterfeldt, Comparative analysis of terrorists' objectives hierarchies, Decis. Anal. 17 (2) (2020) 97–114.

[62] G. Haydt, V. Leal, L. Dias, Uncovering the multiple objectives behind national energy efficiency planning, Energy Policy 54 (2013) 230–239, https://doi.org/10.1016/j.enpol.2012.11.027.

[63] E. Colombo, F. Romeo, L. Mattarolo, J. Barbieri, M. Morazzo, An impact evaluation framework based on sustainable livelihoods for energy development projects: an application to Ethiopia, Energy Res. Social Sci. 39 (2018) 78–92.

[64] G. Siciliano, F. Urban, M. Tan-Mullins, G. Mohan, Large dams, energy justice and the divergence between international, national and local developmental needs and priorities in the global South, Energy Res. Social Sci. 41 (2018) 199–209.

[65] A. Afful-Dadzie, A. Mallett, E. Afful-Dadzie, The challenge of energy transition in the Global South: The case of electricity generation planning in Ghana, Renew. Sustain. Energy Rev. 126 (2020), https://doi.org/10.1016/j.rser.2020.109830.

[66] AFDB and ERERA, Comparative Analysis of Electricity Tariffs in Ecowas Member Countries, African Development Bank, <https://africa-energy-portal.org/sites/default/files/2019-12/Electricity%20Tariffs%20Study%202019.pdf> 2019.

[67] Electricity Company of Ghana Limited, Electricity Company of Ghana Limited, (2020), Current Tariff, <http://www.ecgonline.info/index.php/customer-service/services/current-tariff> 2020.

[68] F. Boamah, E. Rothfuß, 'Practical recognition'as a suitable pathway for researching just energy futures: seeing like a 'modern'electricity user in Ghana, Energy Res. Social Sci. 60 (2020), 101324.

[69] V.N. Mathur, A.D.F. Price, S. Austin, Conceptualizing stakeholder engagement in the context of sustainability and its assessment, Constr. Manage. Econ. 26 (6) (2008) 601–609, https://doi.org/10.1080/01446190802061233.

[70] J. Sagebiel, J.R. Müller, J. Rommel, Are consumers willing to pay more for electricity from cooperatives? Results from an online Choice Experiment in Germany, Energy Res. Social Sci. 2 (2014) 90–101.

[71] P. Velasco-Herrejon, T. Bauwens, Energy justice from the bottom up: a capability approach to community acceptance of wind energy in Mexico, Energy Res. Social Sci. 70 (2020), 101711.

[72] O. Mont, A. Neuvonen, S. Lähteenoja, Sustainable lifestyles 2050: stakeholder visions, emerging practices and future research, J. Cleaner Prod. 63 (2014) 24–32.

[73] S. Hanger, N. Komendantova, B. Schinke, D. Zejli, A. Ihlal, A. Patt, Community acceptance of large-scale solar energy installations in developing countries: evidence from Morocco, Energy Res. Social Sci. 14 (2016) 80–89.

[74] J. Morrissey, E. Schwaller, D. Dickson, S. Axon, Affordability, security, sustainability? Grassroots community energy visions from Liverpool, United Kingdom, Energy Res. Soc. Sci. 70 (2020), 101698.

[75] K. Lee, E. Miguel, C. Wolfram, Does household electrification supercharge economic development? J. Econ. Perspect. 34 (1) (2020) 122–144.

[76] R. Burgess, M. Greenstone, N. Ryan, A. Sudarshan, The consequences of treating electricity as a right, J. Econ. Perspect. 34 (1) (2020) 145–169.

[77] S. Amuakwa-Mensah, The impact of rural electrification and institutional quality on agricultural output, SLU, Dept. of Economics, <http://stud.epsilon.slu.se> 2019.

[78] C. Kitchens, P. Fishback, Flip the switch: the impact of the rural electrification administration 1935–1940, J. Econ. Hist. 75 (2015) 1161.

[79] J. Lewis, E. Severnini, Short-and long-run impacts of rural electrification: evidence from the historical rollout of the US power grid, J. Dev. Econ. 143 (2020), 102412.

[80] H. Gujba, S. Thorne, Y. Mulugetta, K. Rai, Y. Sokona, Financing low carbon energy access in Africa, Energy Policy 47 (2012) 71–78, https://doi.org/10.1016/j.enpol.2012.03.071.

[81] A. Mejdalani, M. Hallack, R. Costa, D. Lopez, A brighter future: The impact of rural school electrification programs on the dropout rate in primary education in Brazil Energy Division Infrastructure and Energy Sector, Inter-American Development Bank, Energy Division Infrastructure and Energy Sector. Working Paper 974, December. 2018.