POVERTY ERADICATION THROUGH ENERGY INNOVATION:

A Multi-Layer Design Framework for Social Value Creation

ASU-AE4H JOINT WORKING PAPER

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SUPPORTING INSTITUTIONS

CENTER FOR ENERGY AND SOCIETY
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The **Center for Energy and Society** and the **Grassroots Energy Innovation Laboratory** at Arizona State University support rich networks of social, economic, policy, and environmental researchers working to promote energy innovation, human progress and justice, and transitions to sustainability. The Center and Laboratory strives to make visible the human dimensions of energy systems and energy transitions, as well as the contribution of energy systems to the structures, dynamics, and outcomes of human societies. Their goal is to empower individuals and communities to imagine and create thriving and sustainable futures by improving their ability to envision, analyze, and govern energy systems and energy innovation.

AFFORDABLE ENERGY FOR HUMANITY (AE4H)

The **Affordable Energy for Humanity Initiative (AE4H)** is a global consortium of leading innovators and practitioners from academia, industry and the public sector who are advancing progress on Sustainable Development Goal 7: universal access to modern, clean, reliable and affordable energy. AE4H was founded in 2015 as a joint initiative of the University of Waterloo (Canada) and the Karlsruhe Institute of Technology (Germany). 140+ AE4H members work in over 50 institutions and 20 countries around the world on topics ranging from micro-grid design and ICT for off-grid energy, to policy and finance for energy access, human and environmental dimensions of energy system change, and more. AE4H is managed by the Waterloo Institute for Sustainable Energy at the University of Waterloo.

CONTENTS

INTRODUCTION

The provision of clean energy in regions where modern energy services are not yet available offers a considerable opportunity to advance sustainable development. Directly, the provision of electricity via distributed renewable energy systems has the potential to address three core UN Sustainable Development Goals (SDGs): eradicating poverty, providing clean and affordable energy to all, and taking action to reduce climate change. Indirectly, the availability of modern energy services may also provide infrastructure services that strengthen the ability to tackle several other SDGs, including clean water, decent work and economic opportunities, industry and innovation, reductions in inequalities, quality education, good health, and more.

Simply deploying clean energy technologies does not guarantee success in achieving these broader benefits, however, even if deployment can be accomplished rapidly and at scale. Distributed energy system providers face a significant **socio-technical design challenge**. Designed properly, distributed energy systems and the broader innovation ecosystems that they depend on for success have the potential to create long-term socio-economic benefits that help lift large numbers of the energy poor out of *economic* poverty and build community resilience. Designed improperly, however, these systems and ecosystems may not be sustainable to deploy at the scale required, may perpetuate or even deepen local inequalities, may create significant new forms of risk for individuals or communities, or may create poverty traps that make escaping poverty even more difficult.

We suggest a three-part framework for approaching the socio-technical design challenge of providing clean energy in ways that significantly reduce poverty and enable progress on multiple other SDGs. The three elements of this framework are:

The social value of energy:

Fundamentally, people don't care about access to green electrons or carbon-neutral fuels; they care about what they can do with that energy. If people are able to use the resulting energy to reduce poverty, improve access to health, education, and clean water, reduce inequalities, create good work and new business opportunities, and otherwise accelerate efforts to meet the UN SDGs, then we say that the energy has social value. This means that energy systems need to be designed to deliver energy services in a way and at a price that allows people to pursue social value creation. Just as importantly, energy systems need to be designed in ways that do not create or reinforce diverse forms of social, economic, or environmental risk, inequality, or injustice that degrade social value.

Socio-energy systems & enterprises:

For energy systems to deliver socially valuable and value-creating energy services, they require both the socio-technical systems that deliver energy and energy services in the right ways and to the right places to create social value and also the enterprises that design, install, own, operate, maintain, and expand energy systems over time. Socio-technical systems design requires a user-centered approach that configures systems appropriately to facilitate socially valuable energy use. Socio-energy enterprise design requires attending, in turn, to the forms of work and organization, financial and ownership systems, and governance arrangements necessary to ensure appropriate, long-term systems reliability, adaptation and scaling as community needs grow and diversify, and delivery of socially valuable energy services.

Energy innovation ecosystems:

Energy access can rarely be accomplished or meaningfully scaled in off-grid contexts without also attending carefully to an array of other elements besides energy users and energy enterprises within what can be defined as an energy innovation ecosystem. Policy makers, researchers, equipment suppliers, media and NGO influencers, and financial investors all play active and important roles, in addition to energy enterprises and users, in setting the contexts for distributed energy projects to develop and operate.

Energy innovation, we suggest, requires coordination across these multiple levels. This requires careful attention to detail in how new energy solutions are deployed, operated, maintained, owned, and scaled by various actors, as well as how different socio-technical energy system designs can be applied in a diverse range of geographies and end-user groups with different cultural, economic and other characteristics.

I. THE ENERGY-POVERTY NEXUS

Energy and poverty are closely linked. While the 1+ billion people who do not currently have access to modern energy services often get the most attention, for the next 2-3 billion who lack reliable, affordable, clean energy, the reality is that the energy systems that serve them can contribute to poverty through numerous pathways.[1] Energy provided to one community can impose costs, burdens, or risks on others, e.g., when power plants to serve urban populations and industry are built in rural communities.[2] The energy sector has historically been an offender with regard to corruption and human rights.[3][4] Aspects of modern energy supply chains, such as coal and uranium mining and petrochemical processing, have created significant health risks for communities working in or living near these industries.[5] Energy doesn't always flow down electricity transmission lines, and diverse factors can drive energy prices beyond the means of the poor.[6] As a result, many poor communities around the world find their economic plights worsened by payments for energy that drain local financial resources, contribute little social or economic value, and create social and psychological strains among indebted individuals, households, or businesses.[7]

Building multi-faceted approaches to tracking and evaluating progress in access to energy is thus an essential starting point to enable progress on the use of energy innovation to help eradicate poverty and meet the SDGs.[8][9] This is a key role that the UN and its partners have played and can continue to play. Headway has been made through the expansion of energy access metrics to go beyond simple have/have-not classifications that typified early efforts to connect energy users to grids. More recent models have focused, for example, on attempts to document the unreliability of grid-based electricity across the developing world and to evaluate the extent to which affordability has limited the impact of electrification.[10] These efforts have informed the development of more nuanced metrics such as the 'tiers of energy access' and notions of 'climbing the energy ladder' that the UN Sustainable Energy for All initiative and other international organizations have popularized.[11] Thus, a key idea that has grown in use in national and international energy system planning processes is the recognition that progress is not measured in the number of connections and kilowatts but rather in the services that energy systems deliver (lighting, device charging, heating, cooling, cooking, etc.) and their quality in relation to meeting the most pressing needs of the end user.[12][13]

From our perspective, the next step is to move beyond service quality to include the broader socio-economic and environmental outcomes of electrification. These outcomes can range widely depending on how energy is delivered and used, as well as the dynamics of local culture and economic conditions. Two communities with identical energy systems can nonetheless find themselves able to use the resulting energy to accomplish very different ends based on their differential opportunities or capacities to exploit energy access for business, educational, or health purposes. Subtle differences in the ownership of energy resources or systems may mean that one community is able to reinvest significant proceeds from energy payments in local and economic development while another finds that energy payments to outsiders drain local financial resources. Differences in the organization of energy enterprises may mean that one community is able to create a long-term, vibrant energy supplier that supports and partners with local institutions, while another is left on its own with a non-functional energy system in only a few months or years. In other words, the ability of energy innovation to reduce poverty and improve other SDGs depends at least as much on the ways energy is delivered and used as it does on the quantity of energy delivered and used.

Central to navigating this challenge is understanding the diverse feedback loops and trade-offs that can occur in socio-energy systems. Replacing kerosene lamps with solar lanterns is popular in many communities suffering from extreme poverty precisely because of a positive feedback on poverty reduction and social value creation: improving health and quality of life, safety for children and animals, reductions in economic drain caused by kerosene purchases, support for small businesses through evening labor, for community activities, and for children's education--not to mention the business opportunities to be found in building, selling, and repairing the lanterns. Trade-offs can also occur. For example, energy used for productive economic purposes such as providing power for small-scale manufacturing and post-harvest agricultural processing may create measurable local economic benefits, however these may not be equally shared and drive consequential phenomena such as urban-rural migration in counterintuitive ways. A study in Honduras identified a counterintuitive reduction in educational attainment by children following an increase in electrification, posited to result from increased job market opportunities which both reduced children's ability to go to school when their parents gained employment outside of the home and, in some cases, also resulted in children leaving school to enter the workforce themselves.[14] Trade-offs between employment and educational attainment as in the example cited above may not occur frequently and should not be generalized without nuanced analysis. The key point is that complex socio-economic outcomes do arise from electrification and have the potential to enhance or detract from the achievement of a wide range of development targets beyond simple access to energy and energy services.

With electrification efforts ramping up across diverse geographies as a result of falling system costs, increasingly supportive policies and the development of new business models, a plethora of new cases which can shine a light on these dynamics will emerge and deserve close attention from policymakers and researchers. This analysis should be both *participatory:* involving local community members as both subjects and research collaborators that help scope key questions in alignment with their interests. Similarly, it should be *place-based*: tailored to local conditions and not assumed to uncover the same dynamics everywhere.

The 21st century is a key moment in the history of global energy innovation. Humanity must decarbonize its energy systems. For that effort to achieve more than green energy, however, it must also be designed to promote broader sustainable development goals and objectives. That means understanding and acting upon the knowledge we increasingly have about how energy links to poverty, health, education, inequality, and more.

II. THE SOCIAL VALUE OF ENERGY

The centerpiece of our model is *the social value of energy*. [15] The social value of energy can be understood to be the net benefit or value that an individual, household, business, community, or society derives from energy they are able to create and/or use. The social value of energy incorporates both economic and non-economic benefit or value, the latter including such considerations as health, education, wellbeing, etc. The social value of energy also accounts for costs, burdens, risks, and other negative outcomes or externalities associated with the generation, transmission, or consumption of energy. It can be expressed, mathematically, using the equation:

Social Value of Energy = ∑(Economic benefits + other non-economic benefits) – ∑(costs + burdens + risks) – ∑(externalities)

The social value of energy thus provides a direct measure of the causal link and direction of influence between the availability of energy (and/or access to it) and the potential for improving measures for community wellbeing on any of several SDGs, including poverty, health, education, food security, sustainability, etc. For individuals, households, or communities that experience a rise in energy access that is accompanied by a significantly positive social value of energy, the SDG indicators are likely also to rise. By contrast, if rising energy access is not accompanied by increasing social value of energy, then something problematic is occurring: perhaps the costs of energy are too high, something is preventing the individual, household, or community from using energy to create social value, or the environmental or health risks or burdens created by energy generation or use are outweighing the otherwise positive benefits. Put simply, increasing the social value of energy is critical for reducing and ultimately eliminating poverty, and meeting the SDGs.

The social value of energy also offers a valuable tool for comparing energy provision technologies, either when considering replacing one energy technology with another, when considering competing technology options for a new energy project or initiative, or when considering options for energy systems design once a technology has been chosen. One of the central lessons of distributed energy development projects over the past several decades has been that technology choice (e.g., between diesel generator-based microgrids or kerosene lanterns and renewable alternatives) and technology design (e.g., between cookstoves) matter enormously in terms of the sustained usability, benefits, and costs that communities are able to derive from energy technologies.[16] By measuring the value proposition for specific designs or technologies for specific individuals, households, or communities, the social value calculus offers a tool for assessing these choices in terms of the outcomes that matter to the users.

The social value of energy is thus similar in concept to, reinforces, and synergizes with other innovative approaches to human development. For example, Sen's approach to development as freedom is grounded in the idea that food security is not simply about the availability of food but rather also about the social, economic, and political affordances that enable people to secure food for their own consumption.[17] Indeed, as recent research on food-energy-water nexus problems has shown, for many communities, energy services may function as critical affordances for food security (e.g., fuel for snowmobiles for hunting in winter in isolated northern communities; animal or fuel energy to enable tilling of land; fuel or electricity for cooking; energy to pump irrigation water) or water security (e.g., pumping groundwater for drinking).[18]

As described in greater detail below, the social value of energy also depends on the abilities of individuals, households, and communities to convert energy access into productive uses of energy to create positive change, including the necessary forms of knowledge, skill, and organization.

III. A MULTI-LAYER DESIGN FRAMEWORK FOR SOCIAL VALUE CREATION

We propose, here, to embed social value creation within a multi-layer design framework that can guide the design of projects and initiatives. This framework is captured in Figures 1 and 2.

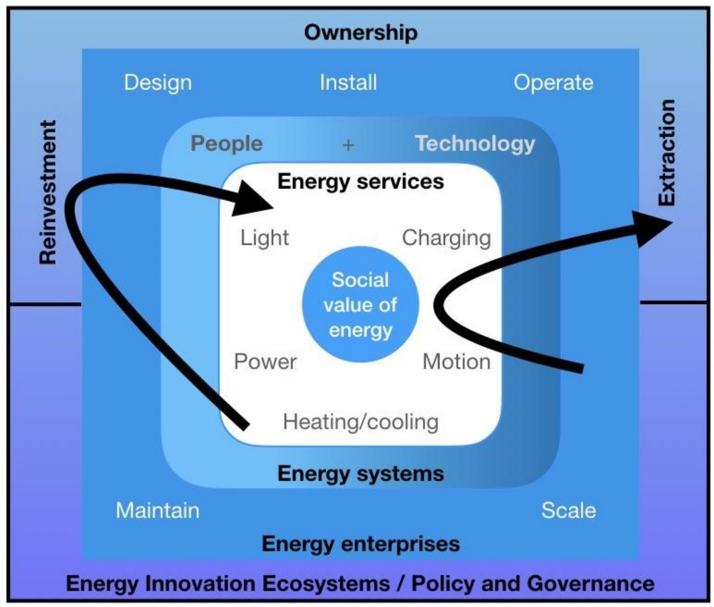

Figure 1. The Multi-Layer Design Framework

Layer 1 - Social Value of Energy

Although the social value of energy can be captured loosely by the equation above, in reality, a threefold process can be used for mapping, anticipating, and achieving high-social-value energy systems. The first task is to map and evaluate the existing social value of energy within the individual's, household's, or community's ordinary patterns of social and economic activities. These maps will provide essential information for identifying critical energy services that may be lost, if not appropriately accounted (and potentially substituted) for during the transition to new energy systems. They also serve as a starting point for the second task, which involves engaging individuals, households, and communities in anticipating and prioritizing potential opportunities to enhance social value creation, either by improving the effectiveness or efficiency of existing processes or introducing new ones to the socio-energy system. Finally, the third task involves the pursuit of high-social-value energy service delivery that achieves effective integration of social and technical elements through user-centered design. Once such a system is up and running, remapping of the social value of energy offers a strategy for outcome assessment for energy systems, based on economic and noneconomic benefits, and its reduction due to costs and externalities.

Layer 2 - Socially Valuable Energy Services

Social value is not created by energy but by energy services: the things that energy enables individuals, households, and communities to do, such as providing light, heat, cooling, work, device charging, etc. A crucial element in mapping the social value of energy is, therefore, mapping the energy services that communities either currently use or could potentially use in future scenarios to create social value. In most cases, households and businesses will need multiple, overlapping energy services.[20] Education may require, for example, lighted and heated or cooled classrooms, power for computers and wi-fi systems, charging for electronic devices, lighting and heating for studying at night, transport for teachers and children to school, and more. Failing to provide one or more of these services may significantly undermine educational outcomes.

Layer 3 - Effective and Efficient Socio-Technical Systems Integration

Socio-technical systems can be defined as systems that contain both technical and social elements working together to accomplish system goals and objectives.[21] Often technical design takes priority, but social design can be just as important.[22,23] Energy systems are technical in that they require a suite of technical systems that deliver energy, in an effective and efficient way, e.g., by collecting the sun's energy, transforming it into electrons, transporting those electrons to the location where they are needed for social value creation, and making them available to people in a way that can be harnessed for the necessary purposes.[24] At the same time, energy systems are social in that they require a suite of interlocking knowledges, skills, and behaviors that enable people to safely and effectively access and make use of the energy services provided by the technical systems to create social value.

Moreover, these social and technical systems must be tightly integrated so that they work together on multiple levels, e.g., at the level of individual users, so that they can use energy effectively to create social value, as well as at higher levels of organization, such as the utility-level, so that payments for energy are sufficient to pay for energy generation, operations, and distributions (or are supplemented by other appropriate funds). Failure modes are easy to envision, in which social and technical integration falls short. Systems that break and are not repairable by people present in the locality will not create social value until arrangements can be made to fix or replace them.

Layer 4 - Energy Enterprises

The socio-technical systems that underpin socially valuable energy service delivery are complex arrangements that require careful and thoughtful design, installation, operation, maintenance, and, ideally, expansion and scaling. Historically, electrical utilities have undertaken this work, employed and trained the necessary workforces to undertake energy systems work, created and maintained accounting systems, etc. In the world of distributed energy, however, utilities are increasingly being supplemented by more locally and community focused micro-utilities or enterprises that can provide these activities.[25,26] For distributed energy systems, local enterprises make sense (whether private, public, or nonprofit in design) for at least two significant reasons. First, such organizations have the potential to be more effectively engaged with individuals, households, businesses, and communities, e.g., in a continuous process of user-center design and redesign that allows for ongoing upgrading of energy systems to meet new opportunities for social value creation and to address problems and challenges. Second, as we will suggest in the next layer, such organizations have the potential to be locally owned and operated and thus contribute more significant ongoing reinvestment to the community. Beyond social value creation, local ownership and reinvestment is the most significant avenue through which energy systems can contribute to poverty alleviation.

Layer 5 - Ownership and Financial Reinvestment

One of the most challenging facets of distributed energy system development is understanding how and the extent to which the energy system creates wealth on behalf of and reinvests in local communities. Ownership arrangements are thus essential. While a great deal of attention has been properly focused in recent years on unlocking the capital necessary to finance new energy systems construction, this attention has inappropriately distracted attention from the ownership models [27,28] used (and, especially, the extent to which community-based ownership [29,30,31] has a legitimate place in the energy sector), the extent to which the ownership models employed enable, take advantage of, or in fact distort or decline to take advantage of diverse potential pathways by which energy systems can reinvest in local social and economic development, and the overall level of wealth creation (or, unfortunately in some cases, wealth destruction) that attends the introduction of new energy systems.

These concerns are especially significant as investor interest in remote energy systems ramps up. If the goal is not merely to run electricity wires but to effectively catalyze and support local social and economic development and other advancement toward other SDGs, then attention to ownership practices and reinvestment pathways is crucial. Pathways can include a variety of strategies from, e.g., creating local jobs that are filled via local hiring to local purchasing of materials to investing in local businesses that can benefit from energy provision, to providing opportunities for ownership and profit-retention in local communities. Aligned against this are the pathways via which energy systems extract financial and other resources from communities in ways that detract from their ability to advance development, e.g., by providing outside investors with annual returns on investment that derive from community income, creating or reinforcing corrupt ownership or governance regimes, etc.

Layer 6 - Energy Innovation Ecosystems

Clean energy is already being supplied to many previously underserved regions through ecosystems of semi-coordinated actors (see Figure 2). Through their interactions these actors develop policy, technology, financial and other innovations which act to remove barriers historically facing the sustainable provision of energy to economically, politically and geographically isolated end users. These innovations include for example:

A. *Financial innovations* including those in the area of micro-finance that enhance end users ability to pay for energy services;

B. *Technology innovations* including the integration of ICT with energy systems to allow for remote monitoring and maintenance of technology that is highly dispersed;

C. *Business model innovations* including partnerships between enterprises and local organizations in the marketing and sales of clean energy products within communities that are skeptical of new technologies;

D. *Policy innovations* including the introduction of quality standards and certifications that provide a leg up for trusted suppliers of high quality clean energy products.

Actor groups include direct suppliers and users of energy systems and technologies, as well as the supporting organizations that enable suppliers and users to interact efficiently. Flows of equipment, data, money, influence and expertise connect these actors to one another. Understanding the connections between actors, how innovations are developed within the ecosystem and the barriers and challenges facing increased co-operation (flows of value) between actors can aid high-level decision-makers in designing interventions (policies and programs) that will function to remove additional barriers. While Figure 2 provides a high-level view of the ecosystem, the development of ecosystem models for specific geographies may yield results that clarify the weaknesses of particular markets and ecosystems and how they might be improved, better adapted to local contexts, and focused to ensure high levels of social value creation throughout the full array of ecosystem participants that effectively lead to improved social outcomes for end-users.

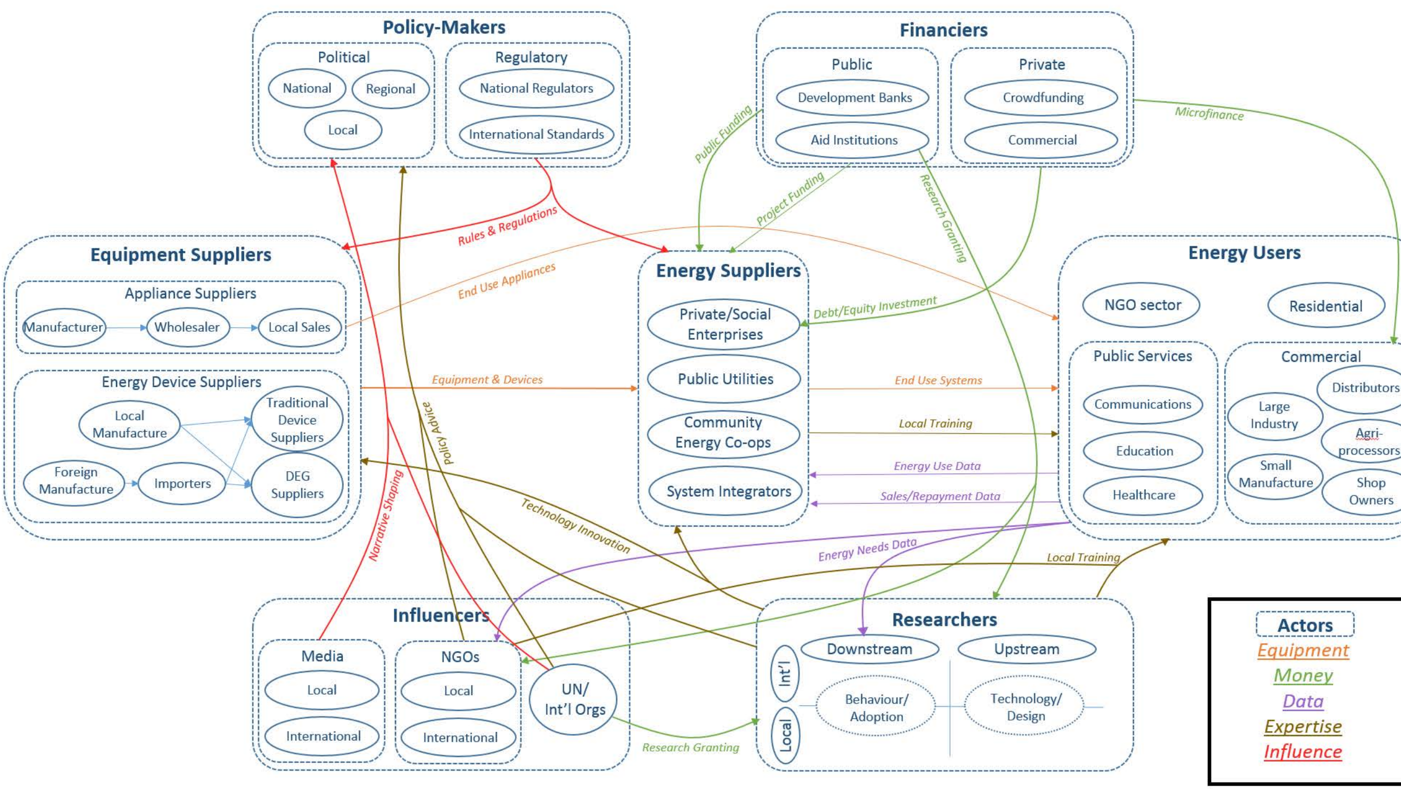

Figure 2: Energy Access Innovation Ecosystem

Layer 7 - Policy and Governance

The final facet of the model are the broader policy and governance arrangements that both support (or impede) the development of effective, distributed socio-energy systems that catalyze and advance local social and economic development.[20] Policy and governance must incorporate both appropriate incentives (or avoiding of costly disincentives) to encourage energy development as well as appropriate regulatory frameworks and institutions that ensure performance abides by proper norms and rules. Policy and governance need to facilitate anticipatory capacities and processes to envision sustainable, socially valuable energy systems;[31][32] to design or contract for them; to enable appropriate local input into decision-making processes; to support ownership models [33] that allow for local reinvestment of profits, local sourcing of parts, local employment of energy workforces, investments in growing energy-consuming businesses, or other strategies for enhancing the local economic benefits derived of energy systems; and to hold energy enterprises and energy innovation ecosystems accountable for both practices and outcomes.

IV. NEXT STEPS

The conversation about energy access has advanced considerably in recent years, with regard to understanding both the need to go further than simple measures of the availability of energy and the complexity of user-centered design processes. Building on this, we argue that a social value approach can provide the conceptual and practical foundations for pursuing energy innovations that significantly advance a wide range of SDG goals for individuals and communities. Next steps involve beginning to answer a series of questions about how to translate these ideas into practice in on-the-ground energy innovation initiatives and to create technology, planning, and policy frameworks to support this approach. Relevant questions include:

What are good examples of the diverse ways that communities can use off-grid energy innovation to create high levels of social value? How can these examples be synthesized to create a framework that helps communities and energy enterprises identify the best opportunities for local social value creation through energy innovation in a given setting?

What kinds of ecosystems, policies, and governance arrangements are necessary to support social value approaches to energy innovation and the work of organizations and communities to implement it?

Conversely, what are ways that energy projects detract from social value, and how can these be minimized in off-grid energy innovation? How can energy innovation ensure net positive investment into communities?

Can a social value approach help justify greater investments in energy development, especially in higher cost developments, that might not be affordable based solely on measures of the financial returns from energy sales? [34,35] What kinds of metrics of social value creation and policy innovation would be necessary to support such efforts? [20,36]

How can organizations focused on energy innovation (whether social or business enterprises) best support communities in adopting and implementing a social-value-based approach to energy development? What do these organizations need to be successful? What does their spectrum of work entail?

Can a social value approach shift the focus of energy projects from narrow concerns with domestic energy consumption to wider concerns of small business development, community health and education, and other development objectives? Can it also help encourage a more ambitious sustainable development agenda and highlight the deep and broad significance of the opportunities presented by energy projects and initiatives within that agenda? If so, how?

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