Rural Renewable Electrification in Liberia:

Outcomes and Opportunities from a Stakeholder Workshop

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Executive Summary

Rural renewable electrification in Liberia is a key component for the development of the country. The Rural and Renewable Energy Agency has taken leadership in promoting this sector. With support from the Center for Sustainable Systems at the University of Michigan, a stakeholder workshop was hosted in Monrovia in January 2017. Over 60 representatives attended the workshop from government, non-government, charitable, and private organizations. The purpose of the workshop was to catalyze collaboration, identify synergies, and encourage information exchange. The workshop also identified a series of gaps and stakeholder interests, as well as a suggested research agenda, that can be used to increase the effectiveness of rural electrification efforts and continue to catalyze collaborations among stakeholders.

Research presented at the workshop demonstrates that Liberia is poised to have a strong decentralized rural electrification sector. This sector can be competitive with centralized grid programs and can provide co-benefits to electrification such as job creation and local economic stimulation. The opportunity for public, private, and hybrid interventions is large.

Both centralized and decentralized expansion efforts are underway in the country, and discussions with workshop attendees revealed that there are disagreements over whether electrification efforts should start in urban centers and move out to rural areas, or start in the most rural areas and move in to connect with centralized networks. However, there seems to be consensus that particular attention is required for communities that have traditionally been underserved and underrepresented. The paper presents a timeline of policy development since the civil war and a summary of centralized and decentralized efforts for electrification so far.

While many different perspectives and opinions about rural renewable electrification were collected from stakeholders at this workshop, certain repeating themes and opportunities emerged. These can form the basis for identifying priority short-term rural electrification efforts and catalyzing stakeholder synergies. Stakeholders were clear that the leadership RREA is providing in organizing the sector is invaluable but that gaps remain that should be addressed. The themes and opportunities can be split into the following main categories: Information Sharing, Community Engagement, and Data Collection and Research. These categories naturally present some overlap. More detail on each is presented in the paper.

In light of the stakeholders' feedback, several research opportunities were identified. These opportunities could provide a strong agenda for collaboration, synergies, and improvement in the rural electrification sector. Six specific research objectives are recommended for follow up:

1. Understanding Regional Costs of Biomass
2. Developing Tools for Understanding Community Scale Decisions
3. Incorporating West Africa Power Pool Analysis Into Existing Models
4. Hybrid Modeling Of Power and Transportation Infrastructure
5. Modeling Social Network Influence in Technology Dispersion
6. Understanding Maximum Social Impacts Possible Under Budget Constraints.

Finally, there is significant interest from stakeholders to establish a regular communication forum to build upon on the momentum created during this workshop. This forum should be fostered by RREA but led by the stakeholders themselves to ensure sustainability. In the future, it will be important to include delegates representing rural communities at events and priority-setting conversations in order to enhance inclusion and leverage local knowledge. This type of engagement will allow RREA and others to capitalize on available synergies and accelerate rural electrification.

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Abbreviations

CLSG	Côte d'Ivoire, Liberia, Sierra Leone, and Guinea Power System Re-development Project
CSS	Center for Sustainable Systems (University of Michigan)
DG	Decentralized Generation
ECOWAS	Economic Community of West African States
GIZ	German Society for International Cooperation
GoL	Government of Liberia
HFO	heavy fuel oil
LEC	Liberia Electricity Corporation
NEP	National Energy Policy
PV	photovoltaic
RESMP	Rural Energy Strategy and Master Plan (Liberia)
RREA	Rural and Renewable Energy Agency (Liberia)
SREP	Scaling up Renewable Energy Program
USAID	United States Agency for International Development
WAPP	West African Power Pool

1. Introduction

On January 19, 2017, The University of Michigan's Center for Sustainable Systems (CSS) and the Liberian Rural and Renewable Energy Agency (RREA) hosted a workshop in Monrovia, Liberia to encourage information sharing and catalyze action among rural electrification stakeholders. Participants exchanged information and available tools for directing development of rural electricity infrastructure in Liberia. The workshop created a participatory venue for communication among various organizations and attempted to coordinate their work on rural renewable electrification. It also allowed for the identification of knowledge gaps, barriers, and challenges facing renewable development in the country, as well as stakeholder recommendations for better coordination in the future.

Several overarching conclusions can be drawn from the interactions of workshop participants. First, RREA has provided broad and beneficial direction to the sector. RREA has organized knowledge-sharing and other events that have increased the capacity of local institutions to promote rural electrification techniques. These interventions are in-line with the Liberia Rural Energy Strategy and Master Plan (RREA, 2016) which has set targets for electrification of rural settlements and populations and called for electrification through both grid expansion and decentralized generation (DG).

Despite RREA's leadership, there remains a need for additional promotion of rural electrification. There is a great opportunity for bottom-up development strategies to meet the extensive electrification needs in Liberia, especially through demand-driven distributed generation (DG) options such as small-scale biomass, hydro, or solar power. These projects need to be incentivized and organized through a central organizational structure, which has yet to be defined. Bottom-up interventions could be organized and managed by existing organizations (e.g. RREA, Government of Liberia (GoL) and others) to achieve maximum efficiency.

Stakeholders feel that an inclusive and regularly occurring mechanism for information sharing and capacity building would provide a significant benefit to the work in which they engage. It would create transparency and enhance synergies between the diverse set of rural electrification stakeholders in Liberia. It could also serve as a mechanism for establishing institutional knowledge, thereby empowering faster implementation of pilot and larger-scale projects in the future.

Finally, stakeholders voiced the need to include local community leadership in the projects and conversations leading up to those projects. They feel the issue of ownership and governance by local communities has not been fully addressed.

1.1 Stakeholder Representation

Over 60 individual stakeholders were present at the workshop, representing various GoL ministries, intergovernmental aid organizations, research institutions, non-governmental agencies, social organizations, and private companies, which are listed in the Appendix.

1.2 Background

In 2010, Liberia was given the second worst Energy Development Index in the world (after only Ethiopia), with a reported electrification rate of 2% (International Energy Agency, 2012). The World Bank Sustainable Energy for All Global Electrification Database indicates that only 9.8% of the population had electricity access in 2012 (The World Bank Group, 2016).

Over the past decade, the tariff for electricity in Liberia from the centralized power grid has been one of the highest in the world, at over $0.50/kWh. Due to high costs and limited access, over 70% of the urban population and over 90% of the rural population continues to use expensive and inefficient alternatives to electricity and unimproved sources for cooking and heating, including charcoal and wood. Kerosene, candles, and dry cell batteries are the most common lighting options for rural areas (Energising Development, n.d.).

Electricity is a key input to industrialization and human development and improved access is necessary to empower broader economic and social progress throughout the country. The recent United Nations Sustainable Development Goals include "Ensure access to affordable, reliable, sustainable and modern energy for all" as one of 17 Global Goals. But beyond the global recognition of the importance of electrification there are many local drivers. In fact, a recent study shows that energy and employment may be the two most important factors to enabling economic growth in Liberia, and that energy access has a direct causal effect on economic growth (Wesseh and Zoumara, 2012).

1.3 Electrification Events and Policy

Numerous policies, studies and interventions by various organizations have affected the electricity landscape in Liberia. The following chronological overview of these provides an overall understanding of developments in the energy sector--taking into account interruptions caused by the civil war.

Figure 1: Electricity Policy and Events Timeline

1.4 Ongoing Electrification Initiatives

Both centralized and decentralized expansion efforts are underway, and discussions with workshop attendees revealed that there are disagreements over whether electrification efforts should start in urban centers and move out to rural areas, or start in the most rural areas and move in to connect with centralized networks. However, there seems to be consensus that particular attention is required for communities that have traditionally been underserved and underrepresented. Also, during the Rural Energy Strategy and Master Plan stakeholders' consultation held in Gbarnga, Bong County on February 4, 2016, a consensus was reached to adapt an "accelerated electrification through decentralized grids alongside grid extension" (RREA 2016).

1.4.1 Centralized Development Initiatives

Several programs have been established to expand centralized grid access, typically by larger organizations such as The World Bank or the African Development Bank. A non-exhaustive list of these program is presented in Table 1.

Table 1: Programs that have been established to expand centralized grid access in Liberia

Name	**Description**
West African Power Pool (WAPP)	The West African Power Pool (WAPP) is an organizational body that is part of the Economic Community of West African States (ECOWAS). Its objective is to pool power resources in West African countries in order to increase the reliability of the electricity system and create an electricity market throughout the region. The Connection for Cote d'Ivoire, Sierra Leone, Liberia, and Guinea (CSLG) is the transmission expansion plan that is most relevant to development in Liberia. It is currently projected to run northwest from Monrovia to Sierra Leone and northeast from Buchanan to Guinea and Cote d'Ivoire. A potential southeast extension from Buchanan to Tiboto and Cote d'Ivoire is also under study (WAPP, 2011).
Mt. Coffee Hydro Project	Rehabilitation and upgrade of the former hydro plant originally built in the 1960s and damaged during the civil-war. The rehabilitation of this project provides power directly to Monrovia and Paynesville and 66 MW are currently operational. The total upgrade will be 88 MW.

Liberian Energy Efficiency and Access Project (LEEAP)	A $30 million project by the African Development Bank that started in 2015 and is intended to expand the grid distribution network and improve village-level access to electricity (LEEAP, 2017).
Cross Border Electrification	Several projects along the border with Cote d'Ivoire, part of the ECOWAS Cross Border Electricity Supply Project, wherein 18 communities along the border will be electrified through power generation in Cote d'Ivoire.

1.4.2 Decentralized Development Initiatives

The World Bank Africa Energy Unit has proposed expanding electricity coverage through centralized initiatives such as those mentioned above, however their research shows that even if all these resources are developed, more than 50% of the rural Liberian population would remain unelectrified through 2050 (Africa Energy Unit, 2011). They suggest parallel rural decentralized electrification efforts as a mechanism to improve rural connectivity. Several initiatives and support mechanisms are being offered in this arena through many stakeholders including government and intergovernmental agencies, NGOs, and private organizations. The large number of stakeholders involved and the scale of the different projects provides a situation where coordination and information exchange can be a challenge. These include (but are not limited to):

Table 2: Programs that have been established to support decentralized electrification in Liberia

Organizer	**Description**
NRECA and USAID	The Beyond the Grid Program program seeks to strengthen RREA's capacity. Expected outcomes are annual and five year access expansion plans, project evaluations, oversight and training of rural service providers, management of implementation projects funded by USAID, and building private sector capacity.
The Booker Washington Institute	BWI's Energy Demonstration Lab received 3 biomass gasifiers from All Power Labs, funded by USAID. These are being used to identify opportunities for micro-grid development through research and capacity building at the BWI's Renewable Energy Center. (Booker Washington Institute, 2017).

EnDev	A clean energy development project implemented by the German development agency GIZ, has provided clean cookstoves and solar lamps to rural populations for the past several years.
Sustainable Energy for All	Promoting the expansion of energy access to reach all populations and doubling the share of generation from renewables in Liberia through its Action Agenda (Sandikie, 2015).
RREA	Established to facilitate and accelerate the economic transformation of rural Liberia, by promoting the commercial development and supply of modern energy services to rural areas with an emphasis on locally available renewable energy resources. RREA is leading the development and implementation of the Liberian Rural Energy Strategy and Master Plan (RESMP), and has established projects to introduce renewable DG to communities around the country. These include pilot projects for micro-hydro installations in Yandohun, Dangalahun I, and Dangalahun II as well as programs for solar lanterns and chargers (RREA, 2017).
USAID	Supporting the construction of a 1 MW hydro plant on the Mein River to provide power to about 2,500 residential customers and 150 commercial customers through the Power Africa initiative (USAID brief). Supporting also a micro-grid program in Kwendin that will operate with a gasification system and provide electricity to a community of close to 2000 people (USAID, 2012). As with BWI, the equipment was manufactured by All Power Labs (All Power Labs, 2016).
RREA and World Bank	Piloting decentralized electrification in the town of Yandohun, where a 60kW micro-hydro facility has been reconstructed but given back to the community for operation (Africa Energy Unit, 2011).
World Bank	Supporting several projects in Lofa County to supply power with hydro and thermal diesel generation in the dry and wet seasons, respectively. Studies are currently being conducted on the Kolahun and Kaiha rivers to establish the potential for small hydro generators to minimize diesel usage in microgrids (World Bank, 2017).

Renewable micro-grid options for rural electrification must be integrated into existing electrification plans, following requirements set by the new Electricity Law of 2015. Further challenges are presented by the large number of organizations working in the electricity sector; work by all organizations will need to be aligned and coordinated to achieve maximum impact.

2. CSS Research Findings

Research conducted by CSS and other institutions was presented to stimulate stakeholder discussion. The main research findings suggest that there is sufficient mini-hydro, small biomass, and solar potential in Liberia to supply expected rural demand. The Liberian suppressed rural electricity demand is expected to be as high as 310 - 325 GWh/yr (Alfaro and Miller, 2014, Africa Energy Unit, 2011). Biomass potential alone has been estimated at over 5121 GWh/yr, with solar PV potential at 457 GWh/yr and small hydro at 231 GWh/yr (Alfaro and Miller, 2014).

Small decentralized units and renewable micro-grids can be quickly implemented and would increase rural electricity access while minimizing transmission losses. Many DG options would also result in ancillary benefits, such as new jobs, economic inflows, and human capacity building. CSS has developed a scenario exploration tool named *BABSTER*, which allows stakeholders to explore situations where these benefits are being sought as part of decision strategies. A case study was shared during the workshop, which allowed for visualization of the scenarios in a geographically explicit format.

Babster case study results show that complete rural electrification is possible through de-centralized grid efforts at competitive rates, while utilizing only the renewable resources available to Liberia. The model provides the option to explicitly consider various co-benefits of electrification, such as economic development and job creation. Depending on the different co-benefits sought, a range of network structures can be considered - from a fully centralized model to a highly decentralized model of 124 independent generators. The lowest electricity costs obtained by the model were $0.20 and $0.24 per kWh, with 85% and 45% of generation capacity provided by decentralized resources respectively. These electrification plans are largely based on biomass resources with small shares of solar and micro-hydro. The large gap in decentralization in the lower cost scenarios is due to different main objectives. In the case of 85% decentralized generation the main objective is to minimize the cost of electricity, while in the 45% decentralized generation the main objective is creating economic flows. The model shows potential for creating a minimum of 665 jobs and up to $5.83 million per year of economic inflows within rural communities. These scenarios were used to illustrate possibilities but other technological options are also feasible, economic, and provide significant co-benefits (Alfaro et al, 2017).

CSS also presented ongoing research on waste to energy opportunities and willingness-to-pay (WTP) for electricity attributes which could be useful for future work in Liberia.

3. Themes and Opportunities for Future Work

While many different perspectives and opinions about rural renewable electrification were collected from stakeholders at this workshop, certain repeating concerns emerged. These can form the basis for identifying priority short-term rural electrification efforts and catalyzing stakeholder synergies. The themes and opportunities can be split into the following main categories: Information Sharing, Community Engagement, and Data Collection and Research. These categories naturally present some overlap.

3.1 Information Sharing

The theme of information sharing was prevalent throughout the workshop. Initial efforts are under way. RREA has developed and disseminated the RESMP while EnDev is developing an internet based tool to share the location and basic data of renewable energy projects in Liberia. Despite this leadership, stakeholders felt that there were many more efforts that could be undertaken.

<u>Stakeholder Forum</u>

While this workshop provided opportunities for stakeholders to engage, the general agreement was that a more consistent forum would be helpful for the stakeholders. A monthly or bimonthly meeting led by RREA could provide a venue where information is shared both formally and informally amongst the members.

Collaboration among stakeholders, especially on the national level, should be encouraged for its ability to improve the productivity of all projects. Meaningful partnerships need to be formed, especially between stakeholders present at the workshop, private sector players, academic institutions, NGOs, and the Liberia Electricity Corporation (LEC). Institutions and institutional structures to manage these relationships should be identified and engaged. Increased collaboration could be facilitated through additional workshops that focus on the electrification of specific communities and regular (monthly or biweekly) meetings for stakeholders should be held to continue the conversation and explore the potential for additional collaboration.

Some stakeholder feedback was not about electrification in itself, but rather about how to improve workshops or meetings such as the one held in January. It became clear that many individuals would have benefitted from practical examples as opposed to abstract or theoretical discussions. In addition, in order to sustain some of the ideas shared at this workshop, a communication platform or system would help to maintain engagement.

In terms of community engagement, better communication could help some stakeholders to better understand local politics and interest groups, which in turn would improve project implementation. On the other hand, community leaders should be made aware of the benefits of various technologies so that they can make more informed decisions.

Pilot Project Status Dissemination

Experience from previous DG efforts and small-scale demonstration plants can inform any efforts moving forward. Pilot projects, such as the EnDev facilities in Nimba County, have included a variety of technologies and business models. The experience gained from these projects can provide feedback to help identify best-practices for achieving the national plans. All of the work conducted in this field will be much more effective if organizations can consult each other and organize their efforts. Existing knowledge must also be shared among stakeholders, so that other concerns like environmental degradation can be minimized.

Pilot project experiences can be one of the critical formal information sharing points in the agenda on the periodical stakeholder forums.

3.2 Community Engagement

Workshop participants expressed a strong sentiment that local Liberian communities should be more involved with electrification efforts, especially in project identification and operation. Community members should be involved in needs assessments prior to project implementation, project selection, and continuing evaluation processes. Further involvement could be facilitated through trainings and increased communication to integrate local communities into work done by NGOs and implementing partners. Further, capacity building at the local level would improve the ability to include knowledgeable community members at the planning stages of a project. Capacity building could occur through educational institutions, and is especially needed to provide more Liberian technicians and engineers. Stakeholders are also interested in more information regarding the potential for economic growth and additional community economic flows through participation in upstream and downstream renewable project activities. Overall, especially given the number of ongoing electrification projects, investment in skills of local Liberians should be prioritized through entrepreneurial, technical, and managerial training.

Communication between stakeholders and communities is of the utmost importance. Communities need to feel *more* ownership over the systems that are being developed for them, and they need to understand both the benefits and pitfalls. Improved communication with communities can help to identify where systems are most needed and desired. This communication can also facilitate the prioritization of interventions so that development efforts become demand-driven instead of donor-driven, as is now the case.

The particular communities involved in an electrification effort are an essential and often decisive component of the project's success or failure. Community engagement includes resolving concerns of ownership, improving education and involvement, and ranking electricity access among other community priorities. These efforts should be conducted through conversation and participatory methods and not based on pre-existing assumptions.

Experience highlights that a strong sense of community ownership will increase the sustainability of a project, as opposed to the perception that "outsiders" own and profit from the revenue. First and foremost, interventions should be demand-driven and not introduced from a top-down mechanism-- one way to accomplish this is to begin with projects in urban centers, where demand already exists. Communities should be involved with project development from the start and not brought into the picture after decisions have already been made. Network analysis can be used to identify individuals who serve as "super-hubs"--exerting influence and maximizing connections in a community--and these individuals can be asked to help generate sufficient support for a project.

It is important that community-level electrification efforts are not undertaken until it is established that the community needs, wants, and is willing to pay for electricity in the form that is being offered. The specific context of each community is highly important, and the entry process to each community should be carefully planned. Developers should improve practices to build trust in communities that have had bad experiences in the past; trust and increased engagement to community-level institutions and organizations such as women's and youth groups can also help to address the social barriers to renewable electrification.

Community empowerment and ownership of projects is also very important for success. This can take the form of ownership over infrastructure and generated electricity, provision of labor and maintenance supply chains, and in-kind contributions to build responsibility. Awareness and education about how to involve communities could assist developers with their community engagement processes. For example, a liaison or early adopter who is involved with a pilot project could take up education and outreach within communities. Again, this would be time-intensive in the early stages, but it would create more sustainable projects in the long run.

3.3 Data Collection and Research

The success of DG development plans also depends on consumers' willingness-to-pay (WTP), which describes how much people are willing to pay for, and therefore how much they value, that good or service.

Data Collection

Liberians want their own, accurate information to reflect their communities--granulated, site specific data are not available for most renewable resources, which makes it difficult for investors and communities to assess site suitability. Technical data, resource mapping, and other assessments require resources and capacity, as well as a process for sharing those relevant data among interested organizations. A compilation of all electrification efforts in Liberia would enable knowledge sharing between practitioners and also allow for data collection regarding a particular type of project before its implementation in another area. At the moment, all data are not publicly hosted or shared, so efforts are sometimes duplicated on projects for which relevant data could have been obtained from existing databases. This barrier could easily be addressed

through a platform (perhaps owned by RREA) to share data and resources in the country. A platform for data sharing could also include visual information, geographic information, and/or maps to allow a quick comparison of differences in resource availability and electricity access over space and time.

In addition to quantitative resource data, it would also be helpful to share data on project success or potential. Lessons can be learned from ongoing DG projects, such as the difficulties faced by various projects, the progress experienced with the biomass mini-grid in Kwendin, and the success of EnDev with solar lamps in various regions. Stakeholders requested the release of 2-3 case studies per county, which would allow for an easy comparison of these projects, highlighting both successes and challenges. This type of information would help to establish the local context, which varies widely from region to region. Sharing basic information about each different community and what types of projects have or have not been successful would help to bridge knowledge gaps; even lessons from other sectors (for instance, water distribution interventions) can be studied. Individual Liberian communities have diverse characteristics and different intervention styles may be more or less successful in different locations. These characteristics must be identified, with the results shared so that developers can replicate the best possible practices for each specific community.

Research

Research institutions can offer assistance and/or guidance with several issues that were highlighted in this workshop. There are three general research output requirements that need to be prioritized: 1) development of new knowledge, 2) synthesis and sharing of existing knowledge through improved stakeholder collaboration, and 3) development of pilot projects.

Support for new data collection is possible in several areas. First, additional data have been requested on renewable resource availability and site suitability for different types of rural renewable electrification projects. There is also room for additional collection and synthesis of data emerging from other pilot projects or similar electrification projects worldwide; institutions can find a role in researching and comparison of best global practices. On the social side, there is a lot of interest in understanding the WTP of rural consumers. For example, a social objective function could be defined to establish the relative priority of electricity consumption compared to other goods and services - such information would be crucial to project success. Finally, there is opportunity to explore the role of social networks in the deployment of renewables projects; and this could build upon data from existing and planned projects.

Finally, there is space for establishing more pilot projects on renewable technologies to complement ongoing knowledge gathering efforts. Pilot projects can help to test and validate theoretical knowledge (e.g. resource availability, demand projections, cost estimates) on an experimental platform. It will be important to identify the optimal technologies and practices for

implementing a system in a real-world setting, as well as ways to support community engagement. Renewable electricity pilot projects in Liberia will also reduce future social barriers to technology adoption by providing operational facilities where Liberians can see generation occurring and learn more about the pros and cons of different technologies.

4. Recommendations for Future Research Focus

Given the feedback gathered during the stakeholder meeting and in an attempt to catalyze future collaborations, CSS and RREA have identified a series of future research opportunities. We provide these opportunities as recommendations that can guide the research agenda and incentivize collaboration among different stakeholder organizations while significantly addressing the feedback from the wider stakeholder group.

4.1 Understanding Regional Cost of Biomass for Electricity Generation

Liberia has significant biomass resources that could be used as a fuel for generating electricity. Many studies have been conducted throughout Africa to estimate the annual sustainable energy potential from biomass (IRENA 2013, World Bank 2011). However, many of these studies make macro-scale assumptions to arrive at cost and supply estimates for entire countries or multi-country regions. In reality, there are a number of highly localized factors that may influence the cost and availability of biomass fuel stock, particularly when used in smaller, decentralized biomass generators. For example, the poor road infrastructure in rural Liberia may prevent transport of crop waste during much of the year. Additionally, while it is possible to develop theoretical supply curves based on economic parameters, the reality on the ground may be quite different. Local farmers may be resistant to deviate from their current practices, and additional incentives may therefore be required.

Proposed research would collect additional field data to enhance understanding of the localized factors that can influence the cost and availability of biomass for electricity generation in rural areas. Qualitative and quantitative data will be obtained through interviews with farmers and other stakeholders, administering of 'willingness-to-sell' surveys to, and developing models of biomass supply chain logistics on the sub-national level.

4.2 Developing Tools for Understanding Community Scale Decision

While there have been a number of efforts to develop optimal long-term electrification plans at the national level in Liberia, many decisions are actually made at the local level by town leaders, businesses, and individual households. Centralized modeling can provide a broad development blueprint and inform policymakers on the optimal means of providing support for various development plans.

However, more tools are needed to consider the specific geographic, economic, social and cultural factors that may influence decision making at the local level, and provide support for decision makers. This opens a wide area of research that can include WTP surveys,

entrepreneurship programs, cooperative development schemes, and market based dissemination of technologies. All of those approaches would benefit from research engagement that can then be communicated back to national level planning to create more effective programs on the ground .

4.3 Incorporating WAPP Analysis in Existing Models

Previous CSS research has focused on identifying optimal electrification strategies under a range of different development objectives in Liberia (Alfaro and Miller, 2014). These modeling efforts assumed current conditions in Liberia, where transmission and distribution infrastructure are essentially non-existent outside of Monrovia. However, the planned CLSG connection will provide Liberia with access to electricity from the West African Power Pool (WAPP) in the near future. This has potential to dramatically alter the power sector landscape in Liberia. Yet, there are concerns associated with Liberia becoming overly reliant on importing electricity from across country borders. Future work can focus on understanding the role of the WAPP in future infrastructure development plans and quantifying the tradeoffs between imports that may be lower-cost in the short term, as opposed to making investments in internal generation and distribution capacity that may provide higher pay-offs in the long term.

4.4 Hybrid Modeling of Power and Transportation Infrastructure

Traditional energy models generally do not account for the vulnerability of fuel and maintenance supply chains to disruptions in transportation infrastructure. In many rural regions of Liberia, roads are largely unusable during much of the rainy season. This strongly limits fuel supply. Similarly, a relatively minor maintenance issue at a rural generation unit may lead to a disproportionately long outage if maintenance staff and replacement parts are not able to reach the site. A hybrid model is needed to better understand and quantify the interdependencies between these two infrastructures and channel investments appropriately. For example, it may be the case that the energy system would benefit more from targeted road or bridge upgrades than from certain investments in electrification infrastructure that might be more commonly considered as the solution.

4.5 Modeling Social Network Influence in Technology Dispersion

In rural regions of Liberia there are often a small number of local leaders that have a strong influence on the rest of the population. Understanding the impact of these leaders, and other socially respected individuals, on the adoption and dispersion of renewable energy technology can improve project planning and efficiency. By carrying out social mapping, it may be possible to determine whether providing these ‘super hubs’ with trial systems could speed technology adoption in the broader community. This could be made more relevant by analyzing regional data, obtained through past experiences of technology deployment.

4.6 Understanding Maximum Social Impacts Under Budget Constraints

The Liberia Rural Energy Strategy and Master Plan sets clear electrification target of 35% for rural regions by 2030. It reviews a number of technical options that can be implemented to achieve these goals, including a mix of both grid expansion and distributed approaches. However, The Master Plan also identifies a funding gap of approximately $750 million that will be needed to meet these objectives.

It is important to understand how the socially optimal development plan might evolve in the case that this full funding requirement is not obtained. Rather than identifying the least-cost means of reaching an electrification target, this research would identify priority strategies and locations for electrification that maximize social utility subject to budget constraints.

This work would also examine the time-value of electrification through social utility optimization. For example, weighing the benefits of immediate provision of limited off-grid electricity access against a delayed, but more robust, connection to the national grid. This would further help to quantify the value of a hybrid rural microgrid system that provides short term service but can also be easily integrated with the national grid in the future.

5. Conclusions

The stakeholder engagement workshop provided by RREA and CSS in January gathered critical feedback that enhanced understanding of the present state of collaboration in the rural electrification sector, shed light on knowledge gaps, and can guide a research and improvement agenda to facilitate broader participation while focusing on possible synergies. Stakeholders were clear that the leadership RREA is providing in organizing the sector is invaluable but that gaps remain that should be addressed. The most important gaps identified by the stakeholders were information sharing, grassroots community engagement, and more focused data collection and research.

Research presented at the workshop demonstrates that Liberia is poised to have a strong decentralized rural electrification sector. This sector can be competitive with centralized grid programs and can provide co-benefits to electrification such as job creation and local economic stimulation. The opportunity for public, private, and hybrid interventions is large.

In light of the stakeholder feedback several research opportunities were identified. These opportunities could provide a strong agenda for collaboration, synergies, and improvement in the rural electrification sector. Six specific research objectives are recommended for follow up:

1. Understanding Regional Costs of Biomass
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There is significant interest from stakeholders to establish a regular communication forum to build upon on the momentum created during this workshop. This workshop should be fostered by RREA but led by the stakeholders themselves to ensure sustainability. In the future, it will be important to include delegates representing rural communities at events and priority-setting conversations in order to enhance inclusion and leverage local knowledge. This type of engagement will allow RREA and others to capitalize on available synergies and accelerate rural electrification.

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Appendix

Organizations in attendance

Africa Lonestar Power Corp.

Beyond the Grid Program, USAID

Booker Washington Institute

Delegation of the European Union to Liberia

EnDev

Forestry Development Authority, Wheintown, Liberia

Liberian Energy Network

Liberian Environmental Protection Agency

Liberia Institute for Statistics and Geo-Information Services

Ministry of Lands, Mines and Energy

Ministry of Public Works (Donor Office)

Plan International, Liberia

Rural Renewable Energy Agency (RREA)

Swedish Embassy

University of Liberia

United States Agency for International Development

Center for Sustainable Energy Technology

Fosera Solarsystem GmbH & Co

Center for Sustainable Systems (University of Michigan)