CLEAN ENERGY SOLUTIONS CENTER
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Scaling Microgrid Deployment in Sub-Saharan Africa: Spotlight on the Role of Batteries

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Webinar Panelists

Eric Lockhart	National Renewable Energy Laboratory
Ayomide Fatunde	PowerGen Renewable Energy
Elisha Chesir	PowerGen Renewable Energy
Matthew Alcock	Standard Microgrid

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Kamyria

Hello, everyone. I am Kamyria Coney. Welcome to today's webinar, which is hosted by the Clean Energy Solutions Center in partnership with the National Renewable Laboratory. Today's webinar is focused on the scaling microgrid deployment in sub-Saharan Africa.

Before we begin, I'll quickly go over some of the webinar features. For audio, you have two options. You may either listen through your computer or over your telephone. If you choose to listen through your computer, please select the mic and speakers option in the audio pane. Doing so will eliminate the possibility of feedback and echo. If you choose to dial in by phone, please select the telephone option. The box on the right side of the [inaudible].

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Finally, one important note of mention before we begin our presentation is that the Clean Energy Solutions Center does not endorse or recommend specific products or services. Information provided in this webinar is featured in the Solutions Center's resource library as one of many best practice resources reviewed and selected by technical experts.

Today's webinar agenda is centered around the presentations from my guest panelists—Erick Lockhart, Ayomide Fatunde, Elisha Chesir and Matthew Alcock—to discuss recent research from around the world batteries and microgrids and case studies from power generated renewable energy in standard microgrids. Before we jump into the presentations, I'll provide a quick overview of the Clean Energy Center. Then, following the panelists' presentations, we will have a question and answer session where the panelists will address questions submitted by the audience. At the end of the webinar, you will be automatically prompted to fill out a brief6 survey as well so thank you in advance for taking a moment to respond.

The Solutions Center was launched in 2011 under the Clean Energy Ministerial. The Clean Energy Ministerial is a high-level global forum to promote policies and programs that advance clean energy technology, to share lessons learned and best practices and to encourage the transition to a global, clean energy economy. 24 countries and the European Commission are members contributing 90% of clean energy investment and responsible for 75% of global greenhouse gas emissions.

This webinar is provided by the Clean Energy Solutions Center, which is an initiative of the Clean Energy Ministerial. The Solutions Center focuses on helping government policymakers design and adopt policies and programs that support the deployment of clean energy technologies. This is accomplished through access to no-cost extra policy assistance and connects to building activities, such as this webinar. The Clean Energy Solutions Center is co-sponsored by the governments of Australia and the United States.

The Solutions Center provides several clean energy programs and services including a team of over 60 experts that can provide remote and interest-specific technical assistance to governments and government-supported institutions, no-cost virtual webinars, trainings on a variety of clean energy topics, partnership building with development agencies in regional and global organizations in delivery of support and an online library containing over 3,500 clean energy policy-related publications, tools, videos and other resources. Our primary audience is made up of energy policymakers and analysts from governments and technical organizations in all countries. But we also start to engage with the private sector, NGOs and civil society.

The Solutions Center is an international network with more than 35 international partners across its sea of different programs. Several of the partners are listed above and include research organizations like IRENA and IEA, programs like SEforALL and really focused entities such as the ECOWAS Center for Renewable Energy and Energy Efficiency.

A marquee feature that the Solutions Center provides is a no-cost extra policy assistance known as Ask an Expert. The Ask an Expert service matches policymakers with one more than 60 global experts selected as authoritative leaders on particular clean energy finance and policy topics. Again, this is provided free of charge and if you have questions for experts, please submit it through our simple, online form at the cleanenergysolutions.org/expert.

We also invite you to spread the word about this service through all of your networks and organizations.

At this time, I want to introduce our panelists. First up today is Erick Lockhart. Eric is currently a project leader at the National Renewable Energy Laboratory based in Golden, Colorado. His current project includes Solar Energy Innovation Network, Microgrids for Energy Access and Distributed Generation Interconnection Collaborative. Eric is also a graduate of Yale College and also holds a graduate degree in global affairs and business from Yale's Jackson Institute and its School of Management, respectively. He has been working at NREL since 2016 and worked in international development and finance prior to his graduate studies.

Next is Ayomide Fatunde. Ayomide also has a business development and engineering associate for PowerGen Renewable Energy where she leads with development of technical strategy for new markets and heavily investigates the economics, design and logistics of microgrid deployment across East and West Africa. She holds a chemical engineering degree at the Massachusetts Institute of Technology and has experience across a vast array of industries with projects completed for Bain & Company, Teva Pharmaceuticals, GE Power and the United States Department of Energy.

Next is Elisha Chesir. He works at the PowerGen Renewable Energy in the engineering division and is also mainly involved in the design and technical analysis stages of mini grids for PowerGen sites in sub-Saharan Africa. He studied electrical and electronic engineering at the University of Nairobi.

And our final speaker today is Matthew Alcock. Matthew is a Chief Technology Officer at Standard Microgrid whose work focuses on research and development and GIS site assessment. After studying for a business science degree from the University of Cape Town, he has undergone various entrepreneurial activities before starting with Standard Microgrid in 2013 as a project manager, overseeing microgrid design and installation.

And with those introductions, I'd like to welcome Eric Lockhart to the webinar.

Eric

Hi, everyone. Just getting my slides up here. Thank you very much for joining us this morning. I'll talk a bit about some research we've been doing at NREL in this space before transitioning to Standard Microgrid and PowerGen. I'll try to be brief so we can get to the, some more interesting on-the-ground work by those two organizations. But I'd like to talk a little bit about the program that this has come out of and sort of how we've been structuring some of this research on microgrids with a focus on batteries in particular.

And so, NREL engagement in the microgrid for energy access space in particular has been part of the Power Africa Beyond the Grid Program and that leaves sort of three main elements of the programming for us. I'll talk about the first and third. And then, the second.

We work with a number of different developers on technical assistance efforts to include sort of more battery-focused work that we're going to discuss today, things like customer agreements between microgrids and the communities they serve, tariff considerations and we serve a suite of different microgrid topics. We also work with government entities that are looking to develop or expand an enabling environment for microgrid deployment in their countries. We're trying to figure out things like how to structure a bidding process or what standards make sense for microgrids in their context, developing a policy and regulatory structures.

Based on our experience with developers on one hand and government entities on the other, we've been identifying areas where some research to support both groups would be useful. This webinar sort of draws on a particular focus that we've had lately on batteries. But we've also sort of identified different areas where we could provide some research that is probably useful for the stakeholder community.

And I'll just—before turning to some more details about the program and the quality insurance framework, I'll mention that this comes out of sort of responding to the estimated 300 million in Africa that don't have, currently don't have access to modern electricity services. And there's of course three ways to get the electricity access out to folks. One being pretty extension on one hand, the other being some of our own systems on the other. And then, this microgrid option sort of fits in between more a power system providing electricity to a community of hundreds of thousands of households. And in this context that we'll be talking about today, what is the off-grid systems better in more rural areas.

The sort of foundational element of all our work in the microgrid space is this Quality Assurance Framework, which I'll just touch on briefly before I get into battery specific discussion. The Quality Assurance Framework was developed by NREL a few years ago with support from the Department of Energy here, in the US to provide a framework for structure and transparency from mini grid to microgrid based on experience with some more traditional utility models. And the idea is to provide sort of a platform to talk about microgrid performance that related to energy access goals and puts microgrid performance and monitoring operation in the context of what the customers are using microgrids for and the level of energy access they're intended to provide. And it maps nicely the multitier frameworks for energy access and things like that.

There's two sorts of primary components to it. One is sort of defining levels of service and here, again, this is what I mentioned of drawing out a bit of a spectrum of different levels of service that might be provided through a microgrid to better communicate across different stakeholder groups what the expectations of the performance of a microgrid might be. Investors can understand how it's performing. Regulators can track performance with respect to a section of different performance levels and microgrid operators can clearly communicate to communities what the exhibition should be for what level of power they should have. Then, I already talked a little bit about this accountability framework. It's a framework for thinking about how to monitor and assess and report a microgrid performance.

I mentioned that through our work with developers and government entities, we've identified a few different places where we thought we could research the broader community and these are just a few of the examples with different publications on a Clean Energy Solutions Center with website under the Quality Assurance Framework. But here, we have the Quality Assurance Framework tariff considerations for microgrids, some research on productive uses of energy, customer agreements, bundling strategies for thinking about how to cluster microgrids from a different financial or operational perspective to try to bring down costs or increase revenue.

And then, on the bottom right there, there's a forthcoming publication on performance modeling of microgrids and that's how to think about what data you'd like to have and how to analyze it. And how that might relate back to understanding performances within the context of the Quality Assurance Framework.

Then, I'll turn to focusing on battery selection and operations and maintenance. And the question that we've been looking into here is which batter and O&M approach leads to lowest lifecycle costs? As I mentioned, there was a number of developers that have been looking at this question of—various questions that relate to batteries, whether it's choosing between lead-acid and lithium-ion batteries, trying to understand how to condition the enclosures that the batteries are in, trying to understand sort of what's being offered in the marketplace and how that might translate to the needs of their business.

I think the audience is many so we focused on developers. It's obviously important for that stakeholder group. The batteries make up a large chunk of the sort of cost pie for microgrids. I think career investors, that's certainly of interest. If it's 20 to 40% say for a ballpark of the lifecycle cost of a system, investors want to understand sort of where that cost is coming from and where there might be risk there.

Sort of similar set of considerations for regulators in understanding what the true costs are of operating the systems and sort of what drives the cost being a level to have policymakers eventually looking to understand how to encourage costs coming down over time. And the researchers trying to contribute to making microgrids a more viable and sustainable business on the continent.

I'll get into the sort of modeling approach and the sort of questions that we looked at within this momentarily. I'll just share a few of the conclusions that I'll talk about first here very briefly. The initial, specific motivation here was to look at comparing with the lithium-ion batteries and lead-acid batteries to get an understanding of in this context which might be the best for managing lifecycle costs. And by and largely, lithium-ion batteries were the lower lifecycle cost option between the two. And I'll add some qualification to that in a moment. That's sort of a high-level takeaway. Higher upfront costs but things that lead to lower lifecycle costs over a 25-year period. Many batteries are shipped in shipping containers are otherwise housed before they get to the site but we still looked at what construction materials might be best for battery lifetime and wood enclosures were most often the best option to manage battery temperatures to approve lifetime. And then, last, the age of the sort of the findings on what type of HVAC system might be best varied by location and battery type so I'll talk about what a bit more.

I'll just go through this very quickly 'cause I want to be sure to save enough time for intermicrotive (sp?) PowerGen but to approach this question of how to select and operate and maintain batteries, we looked at thermal modeling of the building that the battery was housed in, taking into account climate and building materials and things like that. We looked at battery degradation, what the different battery degradation models for each battery chemistry and then all of that analysis sort of flowed into input to the techno-economic analysis to drive towards that overarching output of lifecycle costs for different scenarios.

In order to just get a sufficiently broad sort of picture of what the optimal approach for batteries might be, we looked at a number of different scenarios. We looked at the two batteries I mentioned—lead-acid and lithium-ion. We looked at five different locations across sub-Saharan Africa with the goal of capturing some of the locations where we know microgrids are being developed and then with Niger and then Nakuru and Kenya trying to create a better spectrum for temperature that are radiance here. You can see a sort of representation of the radiance on the bottom right there for the five different locations.

We looked at two different low profiles. We looked at a kind of residential, heavy microgrid setting where almost all the demand is from residences with radios, maybe small refrigerators, lightbulbs and the like. And then, we looked at one that had a bit more commercial activity with a couple of shops and a school. We looked at a few different HVAC configurations and then again at some different construction materials, understanding that there might be constraints there for people who are already using shipping containers.

I'll talk about the battery degradation findings on a couple slides and then the lifecycle costs before turning it over to Matthew with Standard Microgrid. What we're looking at here is the five different locations and the five different configurations for HVAC. And then, there's battery lifetime there on the Y axis. And if we look at say a crowd here, you can see the difference between having no HVAC system at all which is I think, which is fairly common and having an air conditioner managing the temperature in the enclosure year-round. There's little bit more than a year, more battery life that results from switching to air conditioner route. And you can see air conditioners in general are for obvious reasons extending battery lifetimes. But then, this is interesting to note to see that there is not much difference in the setting , having different levels of fans and that having four fans seems to do much of the cooling that can get battery lifetime extended. But they sort of reach a maximum there.

And then, on this next slide here, this is comparing directly lead-acid and lithium-ion batteries across those different HVAC options. And you can see that the lithium-ion batteries that we modeled are consistently lasting longer than the lead-acid batteries. But it's important to think about for both this slide and the prior one that there's tradeoffs associated with these longer battery lifetimes. On the prior slide, for the HVAC options you obviously have the upfront cost of the HVAC, you have the sort of ongoing operations and maintenance of the HVAC, you have to replace them and on the low, the sized microgrids that we're modeling, it's certainly not an insignificant amount of additional load to run an air conditioner to manage the temperature. And if you take a look at the amount of lead-acid, of course, lithium-ion batteries are more expensive so straight off, no front capital cost that goes with this longer lifetime.

We flowed sort of the findings on thermal modeling and battery degradation, as I said, into looking at lifecycle cost analysis. And here's where we capture those various tradeoffs. We have assumptions around the costs of the different HVAC options, sort of we looked at insulation, too, as I mentioned that before. There's a lot of numbers here but I'll focus in on Accra which is the first set of four rows to talk about some of the lifecycle cost outputs.

If you look at just the first two rows are looking at Accra with a commercial low profile and comparing lead-acid and lithium-ion batteries. And you can see that there's the potential for nearly about 9,000, \$8,000 or \$9,000 in lifecycle costs over 24 years that could be saved by switching from lead-acid to lithium-ion batteries in this case. And it's most interesting that in this setting, the modeling didn't suggest that an HVAC system would be definitively needed although you can see if you look across the three different locations whether or not HVAC was needed very smooth, the point as I started making a few slides ago, that the HVAC needs very meaningfully by location. And lithium-ion batteries, I think folks sort of think of them as being able to manage higher temperatures. And that's true from the perspective of how they're often warrantied and what their specification sheets would indicate. But they're still more comfortable at the temperatures they're designed for, even if they could sustain higher temperatures potentially a little bit better than some of the lead-acid batteries that are out there. At least the ones that we modeled in this analysis.

One thing I'll mention before turning over to Matthew here is that I mentioned we like the two different low profiles and this is something we're going to continue looking at more sort of going forward. If you look on the right side, there's the representation of the two low profiles that we look at and the orange line shows a very heavily residential community and the blue line is the more commercially oriented community profile. And this would be for a community of about 100 households or so. You can see the commercial load has more of a daytime representation here which can more aligned with solar here. You mentioned that outside, we've been looking at solar and battery systems. But PowerGen runs a hybrid system so I will talk about that a bit more. But in the solar and storage case here, what's being shown on the left is the LCOE impact. It's just being some of that load through the daytime hours, through productive uses of electricity like a shop or a school or something like that.

I went quickly there to try to get over to Matthew Alcock quickly. But we have time for Q&A at the end. I'll pass over to you Matthew, to talk about Standard Microgrid's experience. Matthew?

Matthew Just give me a second, I'm just sharing my screen.

Eric And while Matthew's pulling up his slides, I'll go ahead and offer a reminder to type questions into the question pane as you think of them. And we'll get together. And collect as many as we can after we hear from Standard Microgrid and PowerGen. We can see your slides, Matthew.

Matthew Perfect. Cool. Well, thanks so much for having me. The control panel is in the way of my screen. Is it?

Eric No, it's not. We just see the slide.

Matthew My name is Matthew from a company called Standard Microgrid. We're based out of Lusaka and we've got an office in Johannesburg, which is where I spend most of my time doing Smith R&D. And the care maintenance and manufacturing of car systems. All of our sites are in Zambia. And before I start, I just want to say a big thank you to the NREL team—Sam. Eric and Josh and Jimmy and all of you guys—for the huge amount of work that you put into this stuff. Doing the parts of thinking that we can't always afford to do. And this study on battery modeling and temperature modeling and whatnot has come at sort of the perfect time for us while we are getting ready to scale our production, installing a whole bunch of systems and had it not come along, I think we may have maybe made some ill-informed decisions. Just a big thanks to you guys for doing the work that you're doing. I'm going to start off just talking about our company briefly.

We were founded in 2012 with what we believe to be a novel way to hire off-grid communities through judging for energy services for the kilowatt hours is the basic crux of it. We've designed some technology around demand side control, which allows us to sell customers power subscriptions for exactly the appliances our customers have. It may be two lightbulbs for six hours in the evening and 100 watts for a fridge during the daytime hours. And they're only paying for exactly the kilowatt hours that we provision for them for those times.

We offer plans from around $6 a month. That's a basic plan for lightbulbs and cellphone charging. And by strictly controlling what power customers can consume. And when they consume it, we're able to utilize as much of the possible available power per day that our systems can provide. We don't have hybrid systems. We don't have backup generators and we're standardized around a containerized 12-kilowatt peak seller with 30 kilowatt hours of battery backup—lithium, in this case—and then, we install it over the grid to about 150 homes, schools, businesses and institutions.

And we currently have seven grids installed and operational in Zambia with around 900 permanent business connections. Eight of those have, seven of those have—no, six of those have been installed this year so we're ramping up our installations quite quickly. And so, as I mentioned, it's smart meter which enables energy-service-based billing. And then, we're not really utilize I think it's around 90% at least of the potential energy production for each day. We try and as closely as possible fit the demand curve of our customers with the potential supply curve, which is basically the sun turning plus being able to shift demand towards the evening with some battery storage. Also, following standardized system design, we're able to deploy sites very effectively, quickly and not have all the costs associated with designing specific systems for specific sites, changing how the sites work and everything. And it enables us to employ the most recent sites in two-and-a-half weeks to connect 250 households.

And we also utilize local capacity in our project site areas. We've got microgrid managers who are local agency buying power involved from us and resell it. And we've also got regional technicians who typically have helped us install the power system upfront who can do basic maintenance and servicing on our grid so we don't have to drive out each time. That's how we try and standardize our operations and reduce operating expenditure on site. This is just a quick example of one of our examples that's running. That's 12-kilowatt array and neither churches are on it but just connected. And you can see the grid in the background there which connects up about 150 households.

When we are considering what batteries, when we were considering what batteries to go with, we obviously look at price and it's not always easy to pay like for like. But in terms o f usable capacity, we found that lithium actually was quite approaching the cost of lead-acid, even discounting sort of lifetime costs and all of that. Just straight price, we felt that it was almost beneficial to go with them. We obviously look at performance measures and that being proficiency, round-trip proficiency of something like 98.5% for the batteries that we're using. Portability is a big one. The lead-acid batteries that we have used in the past are I think 150 kilograms each. It's almost impossible to lift them whereas the lithium-ion batteries that we're now using, one person can pretty much use them and then you can load them into a car and move them from site to site if need be. Also, the rich data that we're getting from them that we have analyzed quite in-depth yet. The fact that we have built 50 different datapoints lugged by granular each coming from each battery is really useful compared to lead-acid, which you need for the sort of proprietary monitoring systems and it's not as detailed. We like that.

The other thing which I didn't list here is the scalable nature of it. The fact that we can start off, we can start a power system with a reduced amount of battery capacity and as demand grows, we can add in this case 6.5-kilowatt hour increments as we need it. We can either incentivize customers to shift their consumption back in today. We don't need batteries but if we find that there's a size demand for some energy, we can add one or two batteries and grow revenue for a site in that way.

Obviously, we've heard a little bit about the heat tolerance and longevity. It still has yet to be proven from outside. We haven't touched or replaced new batteries so we don't know how long they're going to last. But the indications are that they are lasting b than lead would. And then, the other thing which we spent a lot of time evaluating was the warranty plans that we were being offered. And any company is going to back those warranties. We tried to go for a company that—we use lithium LGQ batteries and we wanted to go for a company that hadn't sprung up in the last five or 10 years and might be gone within five or 10 more so it is quite important for us to have a company that would at least hopefully be around for the sort of 20-year design life of our power systems.

Our engagement with NREL to date was part of a larger engagement around Quality Assurance Framework and customer contracting. The battery portion focused on assisting temperatures on battery degradation using SAM and then thermal modeling to predict temperatures of our power systems. And we use that to inform design decisions around our most recent set of power systems. We looked at temperatures, ambient temperatures from around 20 to 45˚ C. We'd get a little bit cooler at times in Zambia but I mean it's not significant for impacting the battery life, really. We looked at the structures. We obviously standardized our systems around 20-foot shipping containers so we can't—in this case—we can't get away from steel structures.

We looked at ventilation and potential for insulation and then, we were making decisions around active and passing cooling. Private systems. We even sold air conditioners and without the _____, we've been looking at with our air conditioners, we'll pay it off in the long run. Those were the sort of criteria that we're looking at.

And here's just, I've actually pulled this slide from NREL's report looking at battery life over 12 months with a static temperature. We can see the blue line. Every 20˚, we lose 4% battery capacity over the year and as the temperatures increase, obviously, that line drops off quite considerably towards 45˚. Our batteries are warrantied up to about 45˚ so we've sort of structured everything around cutting off batteries, putting batteries to sleep as soon as temperatures rise to the levels at which they could become damaging to our warranty or to the battery life. On the right, we've got a matrix that shows usable capacity at various temperatures. I'm sure that this is very familiar to most people who are listening. At 45˚ we've got obviously usable capacity dropping off fairly quickly. And then, this is just showing the temperatures that we expect to experience around Lusaka. One of the sort of captivating data that is meteorological data outside of Lusaka. I think we, our systems generally experience warmer temperatures than we find in Lusaka but this is the best we've got to go off. Hovering around 15 to 20˚ with a few days that are more than 35˚ is what we're sort of basing our modeling off of.

This was with the help of Jimmy and Lars which we modeled our power system and Sketchup. And then, we used, we were modeling the temperatures inside and outside. The blue, you can see the outdoor air, I mean, temperature. The dark red in the graph above is the temperature inside the container and then the battery is the orange, which is overlaid on that. You can see that the temperature inside the container tracks the outdoor ambient temperature fairly well and the battery temperature sort of is a little bit less elastic. More towards the 22˚, 25˚ range which is kind of where we want it.

This just explains the process. We went through, we modeled our structure and the shading in Sketchup. And then, reported the average space temperature throughout the year for various combinations of fans, air conditioners, passive cooling no system as I've already explained. A couple of interesting things to note for Lusaka, none of the fan sizes were able to keep the container below 35˚ C for parts of the year. Fans can't do it all and that makes sense, I guess. If you're sucking in air that is 35˚ and the batteries are generating heat, then they will exceed 35˚.

Interesting to note that the shade has a substantial ability on the fans to keep the container cool. It sort of makes sense but it's good to know the design decision to shade the container is a useful one. And where we sort of landed without thinking was 457 fans would lead to 14 hours of temperatures exceeding 42˚ throughout the year. And in those cases, only—temperatures only exceeded 42˚ by 0.5˚. 45 is really the dangerous cap of temperature for us and this is showing that it's probably only in the middle of it, probably between 12:00 and 2:00 the temperatures will really get high.

We settled on two 350 CFM fans that are dispatchable at various set points. Typically, we have one that runs during the daylight areas. I don't know what temperature it is offhand but it switches on around 7:00 AM, it switches off around 8:99 PM and the other one only switches on when temperatures in the container exceed 30˚. That's from 10:00 AM until 4:00 or 5:00. And that way, we limit the amount of energy that we use for cooling. And in the winter, the fans barely come on at all. But we still manage to evacuate a lot of the hot air that gets reduced. That is the end of my slideshow. I'm happy to take any questions. I believe we're doing questions at the end but thank you all for your time.

Eric Thanks very much, Matthew. Yeah, we'll take questions at the end. Folks, feel free to type them into the questions pane and we'll circulate them. We'll pass it over to Ayomide. I see your screen. If you could just go full screen?

Ayomide Hi, everyone. Did that work?

Kamyria Hit the slideshow button.

Eric There we go.

Kamyria There we go. That's perfect.

Ayomide Hi, everyone. Thanks for having us. Elisha and I are going to be presenting to the case study work we've been doing at PowerGen. I'll probably be going through the first couple of slides. Then, he'll take over in the latter half. We work together in the, on the Adhere team to go evaluate batteries, design better systems for better enclosures, better degradation models for our systems and also working very closely with Eric to figure out what the best path forward was for us and any other ways that we could assist with their evaluations.

Just the short introduction to PowerGen. We're both a mini-grid developer and off-grid power, EPC, which essentially means that we bill-to-service other clients. We can go out to a site and you give us a contract. And we'll bill out your solar panels and your batteries for you and install it. Then, we also have our own specific mini-grid customers where we have people on our meters, paying as you go with sometimes mobile money and we service them. We have call centers that maybe take care of these customers and we collect tariffs from them. And also go out. And install their distribution grid. The mini-grid development side is our bread and butter whereas the—and sort of the core of our business and why we're in this business and why we're passionate. And the off-grid power EPC kind of became an offshoot because we were one of the oldest players in the industry, being founded about eight years ago.

And so, we can, we have the expertise to come in and bill for people who are new to the industry. Over those eight years, we billed about 200 different power systems in seven countries across the region from Somalia to Mozambique. And it really, those are more the EPC markets and now our focus is on the four markets, both in east and west Africa where in Tanzania and Kenya are our oldest markets. We have about 10,000—this very year, 2019—we passed our 10,000th connection. By "connection" here, we mean the household. Imagining that every household has about 4,000 people in it, that's about 40,000 people. It was a very exciting milestone for us and in Tanzania, those are all PowerGen owned sites whereas in Kenya, we have a partnership with—on a tea farm where the workers on the tea farm, we power their homes and the tea farm essentially owns the grid there.

And then, very recently I think since about last year, I think the press release actually just came out this summer—in Sierra Leone, we're developing about 10,000 connections in partnership with the Ministry of Energy there with funding from UNOPS and DFID. It's now the super exciting project for us, basically doubling our connection number in the span of two years what it took us about eight years to do. It's a huge grid and growth for PowerGen. And this huge period of growth is also confounded by all the different things happening technically in the industry with batteries, with converters, with gen sets and all these really fascinating developments that have happened in the past year. That is Sierra Leone and then, also, our sites in Nigeria. We have a local office there as well. In all four of these countries, we have local offices, small teams. Our team is in Nairobi where we're headquartered where Elisha and I used to work. We still work. And in Nigeria, we're basically about to ideally build another 10,000 connections there with subsidization from the World Bank. Let's see.

As I said, we do micro-grid development and the EPC. And so, what that ends up meaning is that we're super vertically integrated. It's the same company that's doing the site surveys of the customers, figuring out what their load demand is going to be, also doing the community engagement, getting the permits and the licensing. And then, sitting down. Doing the complete technical designs, working with supply chain on procurement, figuring out new technologies and then, doubly, working—as I said, we have a call center and we do technical support. We do our own O&M.

We also do appliance financing and we see that there's some customers that they're not using power because they have one lightbulb. But they do want to use power. They do want to increase their energy usage and they have economical reasons for doing that. And so, we'll go over and say, "For sure, we'll sell you a sewing machine. For sure, we'll sell you a toaster. You need fridge for your cold storage business? We'll sell it to you. That sounds great." And this really helps both grow demand at our site.

It's a two-prong benefit, essentially, growing demand at our sites and making sure that customers can have access to the level of energy that they would get if they were in a big C. That's kind of one of our key value propositions. We try to make sure that we can offer 24/7 AC power to all our customers. And so, that's why batteries become such a huge part of that and also why as Eric mentioned we do the hybrid systems.

A hybrid system, essentially, is just the fact that it's not just the solar panels and the batteries. We will sometimes incorporate a diesel gen set as well so it's kind of—yes, we are renewable but, essentially, we need to make sure that in a year full of sometimes cloudy days, sometimes rainy days when you can't always have solar power. Then, we're not saying to our customers, "Sorry about that. You can't have any power today. The clouds are out." We try to also generate a diesel gen set to come up for those 8% or 10% of times in the year when solar power can't always cover us.

And this also helps with the sizing because if we were to go fully solar battery, then we would drastically oversize the batteries to make sure that these 10% of days when the sun isn't doing too hot, those 10% of days are covered by the batteries. Having the diesel gens is actually a cost-saving measure for us but it doesn't mean that we don't still spend a lot on batteries. As this slide shows, when you break it down per connection and for all the components going into it, we see that batteries are about 25% of our total CAPEX on generation assets. A year for this one connection would be about $46 of that would go into batteries. And then, full generation assets are about $173. And this is a very loose case.

And it varies drastically depending on the site and depending on where everything is located. Sometimes, logistics ends up being a huge component of the cost but on average, this is kind of what we see and we know that our distribution lines are actually the most expensive part of setting up the mini-grid, which makes sense when you think about the fact that the reason mini-grids are happening is because it's so expensive to extend the main grid from the cities because these poles and these cables, they do come up in what I call spiders at the end of the day if you're building a very large site.

Elisha, do you want to add anything to—I forgot. I've been talking but be sure to jump in at any point. We faced a lot of challenges this past year in terms of storage and figuring out a solution. And it is really great that NREL is able to do this analysis. Sometimes, there's an analysis that we don't necessarily have the time to fully look into but it's super beneficial for us to know. And it came out as part of all the work that was done, we are revamping a lot of our best practices and our techniques. Aside from sites that we built previously, our sites have been all late asset sites and as Eric just said, what we keep an eye on really is the most cost-effective option in terms of the full lifecycle.

And the reason we look at the full lifecycle is because we essentially, you know that your solar panels are going to last 20+ years and so we built out these sites to be 20+ year sites. That's how we sell them to financiers. That's how we make our financial models is we say they're 20+ years. They're going to last 20+ years and we're going to have to replace batteries at some point during that time. We might have to replace our converters at some point during that time and maybe revamp our meters. And things like that. But we tried to scale the lifetime of the site to the longest running component, which is the solar panels.

One more sec. And the main challenges that we were really seeing this past year and previously in terms of making really informed, very solid decisions for storage because we have a wide variance of site conditions. I showed you guys that map earlier where it's we have sites in all the climates essentially that Eric studied in the papers. We have sites in Nigeria where it's pretty hot and then we have sites in Kericho, Kenya where it's actually rather cool.

And then, we have these financial constraints as well with the people that finance our work. They have a say, essentially, in the technology we use and it's all very tied together. And it wasn't until very recently that the price of lithium-ion dropped to a level where these lifecycle savings were actually evident for a very long time. The price of lithium-ion was not paying itself back necessarily even though you had to invest a lot in your initial CAPEX. And then, over the 20 years or so, it would rarely break even. But now, that's really changing and it's really amazing to see that the new research is being done. And the new savings that are happening in the industry.

And the third constraint we really faced was just wading through all, wading through the industry essentially. We had to put a lot of resource into investigating vendors and not to mention how they went with LG Cam because they are a more well-known brand and they are reliable. And it's true. There are so many different vendors right now in this field and it's really hard to understand which one is the best, which one is going to last for more than five years, how do we also manage the cost considerations there? And so, we'll dive into all three of those a little bit. Chesir is going to go into there—Elisha, I always call him by his last name—to how we face some of these challenges. And some of them have solutions. Some of them medium solutions but yeah, it's been a fun year.

Elisha

Thank you, Ayo. It's Elisha. I'll just proceed from where Ayo read. Just to enlighten on some of the challenges we face, it's the operations of climate in different areas. One of it's some police on site because for some, for instance, that might be quite different and then salacious. Then, you come to another that's 18C which is our coolest site. The solutions that you apply in—for instance, what we apply in Kericho and that's where you have to analyze the site and do proper surveying so that they cannot stop you. There's a cooling system that's going to try to lead systems.

Ideally, batteries can operate well at around 25 to 24 electricity nature but achieving this will meant hat you have to invest in cooling systems. But considering some of the sites for instance who have very low consumption of their late of electricity, you may find yourself investing too much on the cooling system for instance than what you're getting from investments. Those are some of the challenges that we face or ideally, it's something that you need to just kind of analyze and come to a compromise that—for your investment. Some of your sites made it where our team launched some connections up to 300 and even in the coming years, we have bigger sites which need more storage. We're starting this. We keep on coming through and we are looking for a true _____ reliable solution.

There's also another site actually pulled from NREL who we've worked with for the past year. And they actually give you how much the load pattern at the site, for instance the introduction of patterns.

Ayomide

It's actually _____ where—and it's in some situations, like the 18-kilowatt hour sites where if you install an AC in that, then basically half of your energy that you're generating is going to go toward cooling your batteries. It doesn't necessarily make sense. You want to install something like two fans that doesn't pull so much energy from your system. But then, in our large sites, we do have the flexibility of saying, "The amount of energy that's going to go into cooling is actually marginal." And so, we try to interplay those two.

And then, here, it's actually pretty crazy with the different commercial loads versus the different residential loads. We do sites that are not just people living their lives in their homes. We also do communities where we're powering the church or powering the farm or the factory or the milling machine or things like that where the loads are much more punctuated. There's way more pull on the system and way more pressure on the system. And so, we see there that it's possible to actually have that increased degradation in some situations.

And then, it's also, it's very interesting here—and Matthew mentioned it earlier as well—that you're going from two fans to three fans is a very marginal difference, doesn't really change much but going from no system to two fans is super important. And then, going from two fans to an AC also has a very large difference as well. And so, playing with those and seeing, "We just set this up. Is the site big enough to handle a really intensive cooling system? Is the site warm enough that it really needs an intense cooling system? Can we just do passive cooling? Can we just do shading? What's going to happen?"

Elisha

Let's proceed to the next slide. Basically, when we started, we were using mainly the lead-acid technology which is the internal free _____ of the operational costs. However, lately, we've been exploring a lot of lithium-ion 'cause the prices have drastically dropped I guess because of economic scale. But more surprised they're not using lithium. The price of lithium dropped and something we're looking at and also considering an independent one, the economics and the benefits definitely outweigh it.

One of the benefits that we may get from that is we can reduce the number of times that we replace our batteries across its lifetime or across the lifetime of the whole project, which we look at maybe from 10 to 25 years. You may save costs of replacing the entire battery set after a number of years. I don't think it is because some of the financiers maybe set your finance assistance as a one time when you proclaim an asset as a one-time investment as opposed to getting these financiers to help you every time you want to upgrade a site or replace the batteries for yourself.

And other things include logistics because of course the energy density of free demand could be lower than, is actually is lower, way lower than lead-acid. Each of these logistics of shaping would actually be easier working with lithium-ion. I'm not really sure. It could also be replacing these batteries, for instance. When you want to upgrade a system, as we said, some of these lowers customers or—just look at it from a niche or something. The lower experience oversight.

When you build this grid for the first time, the customers may not be consuming so much power. But over time—let's say the first year, like a side note or the third year—the system is actually huge because one thing about electricity, the more you use it, the more you want ore. This expands and we have to keep expanding our system. This does not really work with many sites cause of their using batteries of different participants. Lithium-ion may be a solution that is something there. You can proceed to the next slide, please.

Ayomide

I just want to add basically, we face—as you were talking about the challenge of modularity came up as our sites grew in age. At some of our older sites, we're seeing that demand has doubled sometimes tripled since we installed the system and so, this is really difficult when you think about a lead-acid system because you can't connect—because there's no battery monitoring system. You can't connect the old cells to any new cells. If you want to expand, you have to essentially plop in a new system. You have to plop in new batteries with a new inverter so that they're not connected in series that are a parallel to the old batteries because that would increase the solvation, it would increase the degradation, all these bad things.

And so, what's really, really fascinating about lithium-ion is the fact that there's a BMS in the battery monitoring system that controls overcharging and undercharging. And tries to maintain balance in the system. And tries to console balance. Means that we can connect old and new. And we can sort of work around modularity. And have more flexibility in the way we expand our systems.

But then, there's the side of the challenge where the financiers are more willing to, they're more willing to invest in large sums in the very beginning of the project. And then, they don't want to ask any questions after that. They don't want you messaging them and saying, "Oh, we actually need more money to expand the site by XX amount. All these things have changed now." Blah, blah, blah. They want to make an investment, see what it needs and then proceed from there.

It's even a struggle, the understandings that we got from the NREL analysis are not just technical understandings but also commercial understandings that we passed on, into our financial models when we talk to investors and we say, "Okay, we're going to set up a site with this much worth of usable capacity of batteries and we expect that we're going to replace in XX year, 2020, 2030 with double the capacity because we see this level of growth." And we need to know that all the way now. We need to know that 10 years in advance what we think is going to happen, I think, 20 years from this site. And so, super fun but also just super complicated sometimes.

Elisha

Some of the things when we consider when we're looking at the operations include this B2B of our business, the accuracy of the cycle life because many of us will have different cycle life or different business regulars as well as several _____. Just go the first one says sustainability to business. Some of the things we look at is that is there rain in our operation? Countries in sub-Saharan Africa, for instance. We have to look at the experience of time in sub-Saharan Africa and to see that they really have experience working around the areas that we tend to work in.

Another thing is also the highest operation temperature in which the warrant is still valid. Apparently, sub-Saharan Africa is a bit of a tropical climate which means that the temperatures are much higher than maybe most parts of where some of these batteries are manufactured. Want to know, they warranties aren't cheap, for instance. We don't want to get a warranty of 10 years that we cannot meet its qualifications. That's some of the things that we look at. Other things, also. How sensitive are these units to high-distance rates? It's got to be for long for our sites, for instance. We all want to know how these batteries react to high distance rates and apparently lithium responds very well compared to lead-acid, for instance. Those are some of the factors that we look at as well as how deeply we can stack these units.

Apparently, the lead-acid units, they suffer from deep distance and that's why we do roughly 100% for business to make sure that we achieve the maximum lifetime of this battery life. But for lithium, we may have deeper distance. We may do up to 90% distance without affecting the lifetime or the plan lifetime of dispatching. Some of the things that we look at—and in the summer part, it may be the actual time of the time lifecycle. We find out this is really difficult to get the exact number maybe. But we look at the longevity of the operating unit. The first one is—or the runner—is maybe giving you this offer. You have to look at some experience. How long has this really mattered? How long is it there? All of this information that—it has been maybe installed or deposited. That's some of the product life we have to consider.

And also, apart from that, this also depends on the spiritual detachment of this battery or the different tax rates leads to maybe different length of operation. We have to be ready all the same. Apart from that, we have to also establish a list. The original manufacturers, for instance, or the number. We have to establish really the whole manufacturer of this unless—just to make sure that the battery we get was really the battery that was tested in many conditions. We have to make sure that this lives up to the average.

And the last part is on the ceremony side, it's kind of the best thing when returning systems. This multi-system did actually save a lot in this need because it depends on how you operate it. And now, we can deport any vendors on working with them. Let's make sure that we don't overcharge these batteries, operate them optimally without exceeding the recommended operation practices. These are some of the factors including also the API documentation because apparently, we have to work with different monitoring platforms available for data. This work that's, this is with the manufacturer. We may have to work with other monitoring science platforms which lead to different systems. Some of the past that we look of the API and how well they detected other systems that are not their own systems.

Ayomide

For people not necessarily familiar with APIs, essentially we need our batteries to not only speak to their inverters that are going to send power to their customers but the inverters also need to speak to the metering systems. And then, the metering systems need to speak to our payment systems so that we can actually get the power. And so, we tried. We build PowerGen has a proprietary, large-data warehouse type of thing where we try to pull all these different sources of data. It's like I think every 15 minutes the meter sends us data and then every minute or so, the inverter sends us data.

And so, the BMS is also sending data. I mean, because we've built this huge thing and we'd like to keep using it. We get a little bit finnicky at the thought if a manufacturer tells us that their systems, their BMS is only compatible with certain texts of monitoring software or that their API is unavailable. Essentially, it's the pack weight of the APIs. The pack weight that will help one system communicate with the other system.

And so, some developers will keep that sort of secret because they only communicate with certain types of systems whereas others are super open about it. And say, "Yeah, sure. Build this into your huge data warehouse. Do what you need to do with it." That's been really important to us to figure out, one, first of all, how expensive are these batteries? I feel like that's a whole other question where if they meet all these criteria, then they might be super expensive and we're all dark.

It's really been this really interesting composition of working with our supply chain team for procurement negotiations. Where are these guys selling their batteries from for logistics, necessarily? Are they coming from China? Are they coming from Europe? What are the freight costs associated with that? And you'll find sometimes it's easier to get things from China to West Africa than China to East Africa. It's really strange and all these tiny little things that come in the way that mean that the engineering team cannot work in isolation.

We cannot propose a solution that says, "We want this battery type," and then have supply chain tell us they won't, that one doesn't have any outlets in sub-Saharan Africa. If you ever need to do, if you ever need to get spare parts or if you ever need to get a fix up, you'll have to send all the, everything back to them in China. And there's no way to get any work done here, in sub-Saharan Africa. And so, these tiny little nuances that come into play when you need to build systems across the continent.

And basically, this slide is just covering a lot of the additional industry research that was done outside of NREL that sort of helped us wade through a lot of these vendor offerings. Chesir, I'll let you continue.

Elisha Basically, this is just like industry, part of the research that we do on different industries. How they operate and how other forms like this. Also, looking at this windows spring left us and all those things. Let's make sure that even the memberships that we receive from these windows are actually accurate. And that's how other tech parts also are selling it from their point of a test. Some of them are listed there and this part will be posted. We also check that could be interesting to anyone who wants to check them as well as also any parts.

Ayomide And it's interesting to notice the change in time. LG Chase was the proper market—are they still the market leader, I would say, back in 2015. But I think now, a lot of the other firms are starting to catch up. You'll see here, when you look at just state of health of the battery and quality over time that BYD—which is a Chinese brand or ESS are very neck-and-neck with LG Cam in terms of quality. And L3SS is a much newer company whereas BYD is it's new in terms of that the company has entered into the lithium-ion market. But they're really old in that they used to, they basically make electric cars in China and they're a huge manufacturer there, as well. And so, as Matthew said, take into consideration these guys' staying power. We don't want to buy batteries from someone who's going to go under. And we want to make sure that we're getting the highest quality battery as possible.

Elisha This part is where, the last part of our presentation is that we are enterprise on the research from NREL just to make sure that we're getting the best or the longest life possible on the batteries. How do we respond to temperature sensitivity? As we say before, every temp increase, increase in temperature will have consequences as much according to policy transition now. How do we do to make sure that we don't go beyond the secret or the committed temperature? Some parts, we use arctic cooling and in other parts, we use fans. I guess as we said before, we have to weigh between the temperatures and the different qualities of using fans and basic cooling units.

The last part is, the next part is the cycle sensitivity. We don't do deep distance for batteries. We don't also do high distance threats just to make sure that we don't reduce their lifetime based on how our quality is as much. For outside, soon as—the first thing we do 50% per day and we look at it across between maybe C10 to C10/4. This is it's testing across 10 hours or between four hours as opposed to distancing within now, too. Some of the factors that we have repeated, this oppression over a lifetime.

The last part on this total sensitivity is that dispatch is also—if you put them in or you leave them in storage for a long time, it will soon be clear whether you used them or not. We make sure that we don't procure batteries. We make sure we only procure batteries that we need them in that small, in a small integration. For instance, the difference between six to nine months so that we don't reduce the companies total dispatch here, in storage or even increase their cost of keeping dispatches in storage because we have to keep them, also, in a footing position. At the end of the day, it's not warrantied to keep in storage so just to make sure that we achieve the most or the best from these batteries is to make sure we procure them only when needing them.

And then, the last part is some of the additional practices, also. These are also based on their ways from some of the reports we get from NREL. In some regions, we have also started building brick and mortar houses. We used to use those steel fire boxes but now, we use brick and mortar just to make sure that we get to achieve heating and cooling than maybe using still. This is a struggle because our technicians have to spend more time constructing these as opposed to just checking our already tested power box and putting it on site. Instead, now we have to maybe build it on site just to make sure that we achieve this installment maybe using higher costs in cooling or using air conditioning devices. Also in passive cooling, we are already structured our systems such a way that—hello? Oh, sorry. Am I still on?

>>Kamyria: I can hear you.

Elisha We have structured our distance in such a way that the first panels, the first group of panels will also provide shading for the main powerhouse or power box depending on which one we build. And also, just as an act of cooling which we did IBA is that for bigger sites where we can't rely only on passive cooling, we also have to reduce active cooling quickly so that we can maintain the best temperature.

Ayomide Thank you, everyone. I guess now it's time for questions?

Kamyria Yes. Thank you so much to all of our panelists for all of those amazing presentations. We're just going to jump right into this answer-and-question session and Eric is going to kick us off. Let me take the presentation back from you. Let's see.

Eric I've got a few good questions here. I'll start with one that came in from a couple of different folks, which is one person asked us about if you have any health and safety concerned related with lithium-ion batteries? And another asks what you do to manage those and how you think about any safety considerations for your power houses with these energy-dense batteries in them. Either or both of the organizations could probably answer that question.

Ayomide Chesir, you want to?

Elisha I can answer from—go ahead, Solutions. You can proceed, actually. Sorry. I can't answer the question.

Matthew From our side, we've sort of taken a certain approach to the batteries in terms of we don't mess with them. We don't touch them. We handle them with care. There's less sort of immediate health and safety concerns than lead-acid to jar employees and people who come into contact with the batteries because there's no work to use the force of lead-acid where you have to continue monitoring the batteries and they also off gas. They emit gases. They discharge them. And there's also acid. You've got to be a lot more careful handling them.

In terms of the energy density, they are sealed up in a locked container so nobody can really get to them and I think there's limited risk of spontaneous sort of implosion. From what I understand, the battery chemistry which we're using—which is nickel, metal, cobalt is—is that what they call it or not?—is sort of more inert than the kind that you see in Tesla cars which spontaneously goes into flames or Samsung phones, which do the same.

And then, there's a question of responsibly recycling the batteries when they reach the end of their lives. And that is something that we've yet to encounter. I'm sure we're going to cross that bridge in about five or six years when batteries or reach the end of their lives. And that will be, there will be a need to get the batteries to a recycling center at which there aren't many at this point. There are some additional costs which I think often isn't factored into the lifetime parts of lithium batteries. But the thinking is that there will be more recycling centers, ways that are accessible who can handle the safe disposal of the batteries.

Ayomide I'll just add a quick plug for the battery monitoring systems. A lot of the vendors that do look into that will sell you a system with buyer suppression built into it. Essentially, if anything does catch on fire, the system will shut down and the case will not open. And they'll do a self-contained fire suppression mechanism in there. I'm not fully sure how it works but that's what all the vendors have promised us.

And I think there's also something to be said for the fact that unlike in a cellphone battery where they're overcharging and undercharging are not managed in the lithium-ion cells that we're using, the battery monitoring system is taking extra control and making sure that the situations in which something might explode do not occur. And if they do occur, that you get an alert weeks in advance via the monitoring system. And then, for lead-acid, our systems take intensive leave in the OPCB which is the gel, the gel that acid which are the maintenance free ones. And also, ones in also—they don't have any free liquid floating around. That's been our way of combatting any of the dangers there.

Eric Great. Thanks, both, for that. And Matthew, in the course of his response, that's another question about batteries at the end of their usable lifetimes. Matthew mentioned some of the challenges there. PowerGen team, is there anything you'd like to add to what—your plans for batteries when they reach the end of their usable life?

Ayomide

Yeah, it's actually something that one of our investors was asking s about because they, as always, want to know how much they're going to be spending all the years. And our answer to them was essentially what Matthew said. That ideally by the time that we're doing this in the 10 years that these batteries are ready to be disposed of, that there are more centers for disposal available. Right ow, there are very few which is why it's expensive because the market itself is not ready yet. It's not saturated. But ideally, it will reach a point where it's a little lead-acid where you call a number, they pick up your batteries and they dispose of them, which is what happens with lead-acid.

Eric

Great, thank you. The next question is about something that each organization touched on a bit but I was wondering if you could talk a little bit more about system design across these different climate zones that they're operating in. It game in as the PowerGen team was talking about all the different places you're growing your business. You were talking a little bit about managing all of the different temperature profiles. The question is just a little bit more about how you think about system design in different climates and as a direct follow on the importance of good temperature data. And how you manage temperature data for sort of places that don't have sort of available, reliable data streams.

Ayomide

I think we found that typically, well, one because we have the team on the ground in many of the countries that we move to, when the data is unreliable, we just go out and try to collect it. We'll just install some sensors. And then, a lot of times, I think Homer has actually been very helpful in getting the historical—Homer and TGIS have been our biggest resources for getting locational data about the temperature of the place, the solar radiance of the place and even things to the level of where are the roads? And you can see on TGIS where the latest grid lines are. That's been super, super helpful for us.

And in terms of design—maybe Elisha can talk more about this but—it has been pretty crazy for us 'cause as we go to the new markets, we see such different patterns of consumption. If you compare a community in Nigeria to a community in Tanzania, the community in Nigeria has for many years now been working on generated power. They already have appliances. They just don't have access to the main grid so they don't have access to reliable power. And they spend a lot of money on it. It's very different from the community in Tanzania where we're sort of the first instants of power that they've seen. We're selling them lightbulbs and we're selling them power sockets and things like that whereas in Nigeria where it may be sometimes where we're outfitting their existing internal wiring and we don't see the same huge jump in demand once we connect them 'cause they've already been using appliances.

And so, we have to accommodate our—we have to make different assumptions about the load growth of those sites. And that informs how we size the sites. And so, we typically have been basically sizing our Nigerian sites to start off much larger whereas—and I think this is also just a learning that we got form Tanzania was that we didn't size them large enough in the beginning. And the, they grew tremendously whereas these ones, you might be sizing them really large in the beginning. And they might not grow that much because they already have power. I can't even give you a fully definitive answer because we're still in the middle of sorting out how differently we're going to treat each site. But we are trying to standardize around certain things, around certain ratios. If you have a residential customer, they typically want this level of PD to battery ratio versus a commercial customer who has operations during the day. They need less battery power. And so, starting from that baseline and saying, "Well, they turned on their appliances at this time." And really just doing very intense site surveys to understand the customer as best as we can.

Eric

Thank you. And Matthew, anything there from your side on sort of data and system design for different environments?

Matthew

I guess I've been fortunate in only being in one region as opposed to very many. But we also use TGIS extensively to find out as much as we can before areas before we go there. We also target probably a more machinist type of site. Typically variable, same sort of size, often quite a similar demographic from one system to another. We've opted for a standardized model so that it sort of simplifies the design and fabrication and installation of our systems. And we allow for some levels of upgrade and expansion to each site. But we assume to try to find better products that look kind of the same so we don't have to do too much ad hoc. We design them.

And as Ayomide just mentioned, we see demand growth and expand batteries the distance to go along with that. And in most cases, it's the same in that we go in and sell people their first lightbulb. In that, they throw away their candles and torch batteries and buy their first lightbulb from us. We sort of get to write the rules a little bit on how people relate to power and relate to purchasing it. But in terms of region to region, our customers are seen at the moment to be fairly similar.

Eric

Great, thank you. I'll pause from the questions about standard microgrids and reply to a question about Power Africa in Uganda. One of the attendees was asking us if there was a program doing any work in Uganda. And not battery related, but we have been working just on the regulatory side in Uganda for what their enabling environment might look like. I'll connect you with that person for more detail.

And I think we've sort of got time for just one more question here. And I might just do a somewhat open-ended one. Each organization has talked about sort of some of the outstanding questions as it relates to batteries and system design. I'm wondering if you could kind of each just sort of mention a few priority research and development requirements in this area as you see them. And maybe, we'll start with Matthew.

Matthew

I think that this sort of industry is going to be one or less on operations maintenance because these systems do carry a significant price tag when you have to go back and replace something that's either broken or worn out. It will be interesting to see and I think it might be too early to have all the data required to know this for sure. What does it look like after 10 years? How do operations maintenance costs scale with number of sites? And how can clustering sites help mitigate that? That's s ort of one of the more interesting things that has come out of where we are now and we get to figure out that sort of how valuable is it to have two sites that are within 50 kilometers to each other? And how do we think about investing our resources to maintain those sites that are local rather than sort of centralized or running maintenance teams. That's sort of where I think further research is going to be really useful for the industry, looking at those costs and how they scale.

Ayomide

For me, I've found—and Chesir, please correct me if you don't agree but—I've found that predicting demand has just been one of the hardest things for our industry and what I'd really like to see us move towards is basically pooling all the data that we get. We take all these site surveys. We ask them questions like, "What's your income?" We ask them what their primary task at home is. We ask them what appliances they already have and all these things. And I'd really like to see across all microgrid developers kind of taking that data, saying, "How can we extrapolate this and develop models and simulations of what this type of customer will look like in year zero, in year five, in year 10 and in year 29?"

And I think that is a long ways for now. We're kind of working with what we've got but ideally, one day we do have a much more robust understanding of the customer and we can make very data-driven approaches to sizing our systems and predicting their demand. And be actually correct about all that. And I think right now, we get lucky a lot of the time.

Elisha

Yeah, I think that's what I would say. We have to understand how the site will grow over time so you have to start from the point of extrapolation. What do you need to know when you want to know how this site will grow in the next three years to five years to 20 years? You have to monitor how all those partners that facilitate the _____ and maybe including this be a channel on the market. Some of them are really self-sufficient. You just have to know the current activity of these people. That means large scale farming or just small-scale farming or just a community. We have to understand the people and then, after understanding the people, you can estimate the logical.

But if you cannot estimate the logical for instance, then you have to work on a system. How can I make a system? I record the challenges that I may not expect, for instance. Let's say you expected this lot to be too whatever speak percentage and now, he's conducting 100%. How do we now tackle the systems from that particular point of view? And that's why you look at maybe this year in generation or other factors that can support you to explain the system, to affect the quality or also costing on—cost issues or cost of the system. You have to analyze both areas from a particular point of view and also from the customer point of view. Prediction and action.

Kamyria

Perfect. Thank you guys all for that informative Q&A session. And for the questions that we didn't have time to get to today, we will connect with you offline after the webinar and we're just going to go ahead and close up this webinar. On behalf of the Clean Energy Solutions Center, I'd like to extend a thank you to all of our extra panelists and to our attendees for participating in today's webinar. We very much appreciate your time and hope in return that there were some valuable insights that you can take back to your ministry, departments or organizations. We also invite you to inform your colleagues and those in your networks about Solutions Center resources and services including no-cost policy support through our Ask an Expert service.

I invite you to check the Solutions Center website if you would like to view the slides and listen to the recording of today's presentation as well as previously held webinars. Additionally, you will find information on upcoming webinars and other training events. We are also now posting webinar recordings to the Clean Energy Solutions Center's YouTube channel. Please allow for about one week for the audio recording to be posted.

And finally, I would finally like to ask you to take a quick moment to complete the survey that will appear when we conclude the webinar. Please enjoy the rest of your day and we hope to see you again at a future Clean Energy Solutions Center event. This concludes the webinar.